A STUDY OF THE EFFECTS OF DIFFERENT FREQUENCIES OF DEFOLIATION ON THE RECOVERY GROWTH OF TWO VARIETIES OF LUCERNE (*Medicago sativa* L.)

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THIS THESIS IS DEDICATED TO MY

TWO SONS,

JOHN AND ROY.

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Symbols and abbreviations used.

Treatment abbreviations are as in table 3.1.

C Chanticleer variety

W Wairau variety

RTCR root plus crown

TNC total non-structural carbohydrates

TN total nitrogen

LSD Least significant difference

ANOVA analysis of variance

P = 0.01 the percentage significance

F the F-ratio value

r correlation coefficient

R^2 coefficient of multiple determination

CHAPTER 1.

INTRODUCTION

In recent years there has been increasing interest in the use of lucerne in the farming systems in localities other than those which have "traditionally" grown lucerne. Much of the North Island, including the Manawatu is involved with this developing interest. To contribute to the information needed to support this, a field experiment studying the effects of different frequencies of grazing lucerne was established in 1965 at Massey University. Pure sowings of two varieties were used. These were New Zealand certified Chanticleer and New Zealand certified Wairau, with treatments ranging from continuous grazing through to hay stage defoliation. This experiment is discussed in more detail in appendix 1A.

By the spring of 1969 at the commencement of the author's study, treatment differences were apparent. The author's study continued selected treatments and measured their differences of spring growth. The initial interest was in the treatment yield differences, volunteer species ingress, lucerne persistence and the associated interaction, if any, between the defoliation treatments and the spring climatic parameters.

Further more detailed work considered the lucerne plants' response to these treatments; the differences of their size, growth form, growth efficiency and organic reserve content. During the last half-decade, several intensive studies have been made of the nature of lucerne regrowth (Leach, 1968a, 1969a; Keoghan, 1970) and the physiology of lucerne regrowth (Hodgkinson, 1967 ; Smith and Silva, 1969; Keoghan, l.c.; Smith and Marten, 1970) after defoliation. Verification of some of these results was attempted in the field environment, at the same time using this information to explain other observations made.

Along with all these aspects, the responses of the two varieties were compared.

While there is considerable information on the agronomic aspects of lucerne and the lucerne sward's productive response to defoliation frequency, there is little information on the nature of the individual lucerne plant's response in the sward environment. The recently increased knowledge of the nature and physiology of the lucerne plant's regrowth is increasingly in need of verification in the more rigorous and competative sward environment. This information needs to be further extended to circumstances of continued treatment application. This study considers some aspects of these requirements.

CHAPTER 2

REVIEW OF LITERATURE

As well as considering lucerne defoliation this thesis includes a lucerne variety comparision and measurements in a late winter/spring growth period. To satisfy these latter aspects, this review initially considers the origin and the morphological variation between lucerne varieties and the seasonal growth of lucerne. The bulk of the review dconsiders the response of lucerne to different defoliation frequencies, supported by a review of the physiological, morphological and some selected environmental factors involved in lucerne growth after defoliation . Concluding the review is a consideration of the variatal influence on the response of lucerne to defoliation.

Several reviews associated with this thesis topic have been recently compiled and were available as theses. Defoliation of pure lucerne (Keoghan, 1967), lucerne growth after defoliation (Keoghan, 1970),the physiology of lucerne regeneration (Hodgkinson,1967) and others of an older and more general nature (Willard, 1951; May,1960). Where pertinant, reference will be made to studies on species other than lucerne.

2.1. The Types and Morphological Variation of Lucerne.

Iversen and Meijer (1967) reviewed the known types of lucerne identifying two main species; 1.*Medicago sativa.* native of a temperate climate; 2.*M. falcata.* originating in the colder climate of Siberia. Hybridisation between *M. falcata* and *M. sativa* species has resulted in the *M. media* species of rather variable type. Brief descriptions of each group have been compiled from their observations and those of Bolton (1962).

M. sativa is a plant native to an arid mainly low land environment, where it has developed an erect growth habit, few thick stems, large long leaves and a deep almost unbranched tap root. It is highly productive , with early growth,rapid post defoliation recovery and a variable degree of winter hardiness based on dormancy. Diseases are few so that little resistance has developed. Flowers are purple.

M. falcata is a plant of colder, more humid upland environments where it has been subjected to much more competition and diseases with resultant disease resistance. It has developed a prostrate growth habit, fine branched stems, small darker leaves, a much branched root system and a deep set crown giving good cold resistance. Productivity is low with late spring growth and slow recovery. Flowers are yellow.

M. media - Cultivated varieties tend to have stems which are fine numerous and branched, leaves small and numerous, and a high proportion of fasiculated roots; considerable resistance to disease and frost; flowers are a mixture of variegated, purple, green, white and yellow.

In the western world, M. sativa and M. media are the only species to be cultivated, while strains of M. falcata are used in Siberia and China. M. media varieties show considerable variation in growth form, its development probably being an interaction of natural selection and varying amounts of introgression with M. falcata (Palmer,1967). Iversen and Meijer (1967, p.79), suggested a classification of lucerne varieties based on the dominance of M. falcata genes as indicated by agronomic and botanical characteristics. They considered this to be more complete than several previous classifications.

Studies of varietal growth form differences have supported the classification of Iversen and Meijer (1967).

2.1.1. Shoot Growth.

Larson and Smith (1963) compared ten lucerne varieties and showed a strong correlation between increasing M. falcata content and decreasing autumn growth measured as height, increasingly prostrate growth habit, and a lack of winter injury. The prostrate growth was largely associated with the basal portions of the shoot stems. Using individual plants of Ranger lucerne, Kehr and Gardner (1960) showed that even within a single variety, such shoot growth variability can be quite extensive. They further noted the positive correlation between recovery growth rate and more erect growth.

Leach (1969a) using Totana, Hunter River and Rhizoma lucernes (erect, semi-erect and semi-prostrate respectively), demonstrated the differences of shoot numbers. After twenty-eight days regrowth from a 5cm stubble length, these varieties had 23, 34, and 44 stems respec-

tively per plant, while individual shoot sizes and growth rates showed the reverse sequence. Such differences of stem density persist with high plant population densities (Palmer, 1967). Leaf/stem ratios increase with M. falcata content (Davies, 1960b; Rogers 1961), although Zaleski and Dent (1960) found the reverse. Sheridan et al. (1968) observed that lucerne varieties expressing increasing amounts of M. sativa content were significantly associated with fewer but longer internodes. Between shoot types Keoghan (1970) observed with Wairau lucerne, that stubble shoots had greater leaf/stem ratios than basal shoots, the difference being due to differences of internode length rather than differences of leaf length. There does not appear to have been any study to determine whether the relative importance of each shoot type differs between varieties.

2.1.2. Crown Growth.

From the study of the crown development of eight lucerne varieties, Smith (1955) demonstrated the positive correlation between the M. falcata content with 1.dry weight of rhizomes; 2. their average number; 3. average crown width. Associated shoot number differences (Leach, 1969a) are due in part, at least, to the increase of potential stem sites on the crown and/or stubble. Major varietal differences of crown positions relative to the soil surface are indicated in Iversen and Meijer's (1967) classification.

Lucerne rhizomes grow as short horizontal extensions of the crown below ground level. In some instances this growth property has been intensified by breeding to provide more persistent varieties under grazing (Heinrichs, 1963).

2.1.3. Root Growth.

Four root systems for lucerne are described, (Bolton,1962; Heinrichs, 1963).

a.Tap root system - characteristic of M. sativa lucernes, having a vertical tap root with side laterals. Lateral spread is by limited crown expansion.

b. Branched rooted system - characteristic of M. media lucernes,

having more than one primary root from the crown, with or without a tap root and able to develop adventitious shoots from the roots. Lateral spread is by more extensive crown expansion.

c.Rhizomatous system - as described (section 2.1.2.).

d.Creeping rooted system - characterised by the horizontal growth of lateral roots four to eight inches below the soil surface. Varieties have been isolated by breeding to provide persistence under grazing in dry land conditions (Heinrichs, 1963; Kilcher et al. 1966; Daday, 1968).

Smith (1951) demonstrated a large variation in root branching among the range of varieties studied, this being in accordance with the above classification. He postulated that these differences were likely to affect the adaptability and capacity of lucerne to survive drought, resist winter heaving and to absorb nutrients. Busch et al. (1968), related heaving resistence to greater root branching. The other aspects do not appear to have been investigated in detail. Carlson (1925) observed that soil structural differences could cause lucerne to adopt considerable variation in root form.

2.1.4.Correlation of Growth Characteristics.

It appears that some of the associations of morphological and growth characteristics in lucerne which have been observed in the past, are probably based more on natural selection that genetic origin (Palmer, 1967). Supporting this statement are the demonstrations that the creeping rooted character can be combined with the earlier, quicker growing and higher yielding M. sativa varieties (Daday, 1962; Heinrichs, 1963). Similarly, Busbice and Wilsie (1969) and Davis and Baker (1966) have shown that it should be possible to combine these M. sativa growth characteristics with winter hardiness as their genetic linkage with poor winter hardiness is not strong. Although the types and morphological variations of lucerne varieties are quite extensive, very few studies have been made of the relationship of these growth form differences to yield. Further, growth form comparisions can only be made satisfactorily when similar management conditions exist. Recent work suggests good breeding potential exists for yield increase by combining some of the growth characteristics which until recently were thought to be genetically opposed.

2.2. The Seasonal Growth Pattern of Lucerne:

Lucerne is grown under a wide range of environments. These range from no winter growth due to excessively low temperatures in the higher latitudes through to continuous winter growth in the warmer lower latitudes, although this pattern may be modified by altitude. Summer temperatures are not "normally" excessively growth restrictive except for some regions where they are high - greater than 25 C (Feltner and Massengale, 1965), lack of moisture usually being more growth restrictive (Leach 1970)). The seasonal growth patterns are considerably controlled by the local environment. (Leach, 1968a).

2.2.1. Plant Growth

The seasonal pattern of lucerne growth has been described for cool temperate environments by Sonneveld (1962) in the Netherlands and by Nelson and Smith (1968a,b) in Wisconsin,U.S.A. In the Autumn, shoot growth rate steadily declines as temperatures and day length decrease, till the winter months during which there is little or no herbage growth. They and Grandfield (1943), and Feltner and Massengale (1965) found that crown buds enlarged and numbers increased in the late autumn and overwintered to provide the shoots for spring growth, which reached a maximum growth rate in late spring. In environments with milder winters, growth of lucerne continues through the winter (Stanhill, 1962; Leach, 1970c). Lower summer growth rates associated with limited moisture availability are often observed where irrigation is not used (Nelson and Smith, 1968b; Leach, 1970c). The latter author found summer growth was more restricted than winter growth in Adelaide, Australia.

The seasonal growth of lucerne underground organs has recieved limited attention. In a pot experiment (all roots) (Heipko, 1959), and field experiments sampling the top 9" of tap root (Baker and Garward,1959) and the top 6" (Smith 1962; Nelson and Smith,1968a), root dry weight showed a slow steady decline over the winter, becoming faster at the start of spring reaching an early spring weight minimum. Nelson and Smith (1968a) found root dry weight to have an increasing trend from this spring minimum through to relatively high values the following autumn if associated with an infrequent defoliation system.

They also observed that while root dry weight changed thus, crown dry weight was relatively constant throughout the season. These observations were made in cool temperate environments. The responses in warmer winter environments have not been specifically reported.

Floral initiation and development occurs throughout much of the growing season. The time for the appearance of floral primordia has been shown to be negatively related to the mean air temperature prevailing (Dobrenz et al. 1965; Dermine et al. 1967; Smith, 1969a), positively with shoot node number (Dobrenz et al. 1965),all leading to lower yields at maturity with higher temperatures (Smith, 1969a). The effect of moisture and/or its interaction with temperature on the time to floral appearance does not appear to have been investigated for lucerne.

The major environmental factor(s) controlling seasonal growth depends on the season and region considered. Lucerne growth has an approximate temperature optimum of 15 C for established plants, (Steinke, 1963; Feltner and Massengale, 1965; Robison,1966; Smith, 1969a) while seedlings have a higher temperature optimum of 15 - 20 C (Gist and Mott, 1957). Mitchell (1955, 1956) observed the same optimal temperature occurance for the growth of temperate and subtropical grass and clover species. Temperature is likely to be the major growth controlling factor during the winter and early spring when soil moisture is usually adequate. Feltner and Massengale (1965) observed reduced lucerne top growth and root dry weights during very high summer temperatures (greater than 25C) while using irrigated Moapa lucerne in Arizona. Soil temperatures also strongly influence top and root growth (Neilson et al. 1960; Levesque et al. 1963; Heinrichs, 1966). Early spring growth may thus be more limited by soil temperatures which tend to be slower rising than by air temperatures.

The light intensity at the canopy surface of a lucerne sward required for maximum photosynthesis was calculated by Thomas and Hill (1949) to be about 3,500 foot candles. Both Matches et al. (1962) and Cowett and Sprague (1962) found that a reduction from full sunlight to an approximately similar level had no measureable effect on top dry weight. Lower light levels tend to be associated with lower seasonal temperatures and so may not have an important effect on growth per se, while light temperature interactions may well be of greater

importance, especially for higher temperatures (Langar, 1967). Cowett and Sprague (1962) showed the benificial effect on lucerne growth of increasing day length from 10 to 16 hours.

Soil moisture with dryland lucerne is generally a limiting factor for summer/autumn growth (Kilcher et al. 1966; Lobb,1967; Leach,1970c). This effect may be direct, or indirect due to lack of root growth and hence induced nutrient deficiency (Mitchell 1957).

These several environmental factors, individually or in combination are some major determinents of lucerne production during different seasons, those operating at any one season being dependant on the locality under consideration.

2.2.2. Chemical Composition of Roots

Seasonal changes and the chemical composition of lucerne roots and crowns are mainly of interest during the autumn, winter and early spring. At other times of the year, management, especially defoliation, modifies natural trends. Hodgkinson (1967) has reviewed the subject.

The carbohydrate reserves of plants represent the reserve energy stored in the vegetative organs of plants. The total of these carbohydrate reserves have been termed total available carbohydrates (TAC) and total non-structural carbohydrates (TNC). In accordance with the reasoning of Smith (1969b) the term (TNC) will be used in this thesis.

Several studies have shown that the percentage and/or weight of total non-structural carbohydrates (TNC), starch,and the weight of total nitrogen (TN) steadily increase in the autumn and early winter if growth is undisturbed (Graber et al.,1927; Grandfield, 1943; Bula and Smith, 1954; Jung and Smith, 1961); the combined effect is presumed to result from the hydrolysis of starch to sugars and the latters use as respiratory substrates. Except for any small early winter peak, reducing sugars represent only a minor component of the TNC over the Autumn /winter/early spring period (Bula and Smith, 1954; Jung and Smith, 1961). The concentration of the various fractions varies considerably between reports, this being determined by different extraction methods used and the growth conditions pertaining.

The above authors do not offer physiological explanation for the autumn increase of organic reserves. Sonneveld (1962) suggests that the

carbohydrate increase may result from the decreasing autumn temperatures reducing the growth processes, either directly on such functions as cell division or indirectly on functions such as ion uptake, while the photosynthetic process is less restricted. Brown and Blaser (1965, 1970) provide supporting evidence with grasses, demonstrating an increase of carbohydrate compounds under conditions of positive energy balance . Murata et al. (1965) showed that with lucerne, apparant photosynthesis was still relatively high between 0-10 C. With temperature decrease, respiration rate might be expected to decrease and contribute to the carbohydrate accumulation. In practise this may be of limited importance, as Marata et al. (1965) found little change in lucerne respiration rate over this lower temperature range. Day and Dart (1969) reported that the nitrogenase activity of lucerne root nodules was still substantial at temperatures of 3 and 5 C. This suggests that the autumn/early winter increase of TN concentration could result from a similar excess of supply over demand.

Unlike TNC, TN weight is relatively constant through the winter period (Jung and Smith, 1961). The slow fall of TAC weight indicates a slow use for maintenance respiration while the constancy of TN weight indicates little or no such use for nitrogenous compounds. These observations apply in circumstances of very little or no winter growth. In winter growing regions these fluctuations are more likely to resemble those of a normal growth period.

With the rise of spring temperatures, and associated increase or commencement of shoot growth, the concentration of TNC and its component fractions show a rapid decline (Graber, 1927; Willard, 1951; Bula and Smith, 1954; Jung and Smith, 1961; Smith, 1962; Nelson and Smith, 1968b), as does the TN concentration (Bula and Smith, 1954) and TN weight (Jung and Smith, 1961). As growth increases, organic reserves reach minimum levels and then start to increase as the supply of assimilates exceeds the growth and respiratory demands. It has been generally assumed that these spring concentration reductions result from the translocation of organic compounds from the roots and crown to the apices of newly growing shoots (Jung and Smith, 1961; Sonneveld, 1962). This is true in part, but of equal consideration is the use of these compounds in respiration and in new root growth during this period. Studies such as those of Hodkinson (1967), Smith and Silva (1969), Silva (1968),

and Smith and Marten (1970) who considered this same problem following defoliation,are needed to elucidate the situation during early spring growth.

Changes in the organic chemical composition of lucerne underground organs during the active growing season are generally dominated by those effects resulting from defoliation. Smith (1962) demonstrated a general increasing trend for TNC concentration in uncut lucerne during this period.

This may not be so apparent in regions where lucerne grows actively in the winter. Excessive summer temperatures (greater than 25 C) with associated high respiratory use of TNC can result in a decrease in their concentration (Feltner and Massengale, 1965). Small TNC decreases may be associated with floral and seed development (Dobrenz and Massengale, 1966). Moisture stress may cause TNC levels to increase (Brown and Blaser, 1970).

As Hodgkinson (1967) notes, all studies associated with the autumn/winter/spring seasons have been conducted with lucerne growing in cool temperate regions having milder winter climates. Further consideration of the subject of organic reserves will be made during the review of the effects of defoliation.

2.3. The Effects of Defoliation Frequency on Lucerne.

The following aspects are considered.

1. The effects of defoliation frequency on lucerne yield both on an area and plant basis.

2.The effects on botanical composition and persistence.

3.The growth form response and associated growth rates under different defoliation frequencies.

4. Where pertinent, the effects of defoliation height and its interaction with defoliation frequency.

2.3.1. The Effects of Defoliation Frequency on the Yield and Chemical Composition of Lucerne.

2.3.1.1. The Yield of Shoots.

Keoghan (1967) reviewed this subject fully and was freely referred to during the composition of this review. In "general terms",

from the earliest workers through to those of today, defoliation frequency has been shown to be an important determanent of lucerne yield, this increasing with decreased frequency. The end result is dependant on a number of factors such as the actual frequency in terms of time and/or stage of growth, associated climatic conditions and previous management. Keoghan (1967) has reviewed the early work, mostly in North America, which demonstrated the yield advantage of infrequent defoliation. Nelson (1925) found marked yield differences when defoliating lucerne at full bloom, early bud and a succulent growth stage. These were 3.8, 2.1, and 0.7 tons per year respectively - the average of three varieties and two years growth. Graber et al. (1927) at Wisconsin, observed an initial advantage in shoot yield with frequent defoliation, which in time was surpassed by the infrequent defoliation treatments. Dennis et al. (1959) and Tsuma (1968) observed a similar effect.

Keoghan (1967) observed that lucerne managements trials, many including the effects of defoliation frequency, have been conducted throughout the world in a wide range of climatic and edaphic conditions. He divides these climates into humid and dry regions. Although the effect of defoliation frequency is similar in each region, the quantative response varies considerably between them. Weir et al. (1960) using irrigated Californian Common lucerne in the warm temperature, high light intensity and long growing season conditions of California, found shoot yield to increase from 14,700 lb/ac to 23,551 lb/ac between the extremes of frequent pre-bud through to infrequent half-bloom defoliation. In the fourth year, defoliation of all previous treatments at one tenth bloom showed no significant yield differences between them. In a similar environment, Jackobs (1950) and Jackobs and Oldmeyer (1955) demonstrated a similar yield response with defoliation frequencies ranging between 25 and 41 days. In each case, little reduction in plant vigour occurred with frequent defoliation under these conditions. Others have also shown similar results (see Willard, 1951; Keoghan, 1967). In these circumstances it is probable that inefficient light utilisation with frequent defoliation is a major determanent of the lower yields.

In the more rigirous conditions of Wisconsin, Kust and Smith (1961), using Vernal lucerne, obtained a yield of 1.14 tons/ac from 6 cuts/year increasing to 4.29 tons/ac from 3 cuts/year. Also at Wis-

consin, Smith and Nelson (1967) had similar results. The growing season in this region is considerably shorter and without the same extended high light intensities. Under English conditions, the results of Davies (1960b) using Du Puits and Grimm lucernes,indicated that while in most years three cuts will give best yields, in particularly wet and cloudy years, this frequency will be too severe. This is more apparent in the following years growth, which is restricted by low plant vigour and possibly death. Whitear (1959) made similar observations.

In the milder conditions of South Australia,using an irrigated three year stand of Hunter River lucerne, Judd and Radcliffe (1970) recorded 4,830, 9,890, 12,030, and 14,750 lb. D.M. for 3, 4, 5, and 6 week defoliation frequencies.

Keoghan (1967) discusses the reasons for the interactions of environmental conditions with defoliation frequency. The recorded yields are dependant on the vigour of the lucerne plant which in turn has been correlated with root reserve levels (Graber et al.,1927; Hildebrand and Harrison, 1939; Weinman, 1948; Neilsen et al.,1957; Weir et al.,1960; Kust and Smith,1961; Sonneveld, 1962; Feltner and Massengale, 1965; Nelson and Smith, 1967; and others), and proportional to root weight (Dotzenko and Ahlgren, 1950; Nielsen et al.,1956; Weir et al.,1960; Langille et al.,1965; Langer and Steinke, 1965; Smith and Nelson,1967; Caulsey, 1968; Ueno and Smith, 1970). Willard (1951) indicates that it is well known that plants in humid regions have higher shoot/root ratios than those growing in drier regions. Keoghan (1967) reasonably argues that the greater plant vigour in the drier climates is associated with the maintenance of a higher root reserve level and with time, a sustained root weight and growth. In these conditions, the evidence of Brown Blaser (1965, 1970) would indicate the positive energy balance existing, resulting in the higher organic reserve levels observed.

Iversen (1967) demonstrated the influence of edaphic factors. Using four lucerne varieties, he showed that lenient grazing was more productive <u>per se</u>, and more so on a heavier soil type,while severe grazing was more productive on a lighter soil. With severe grazing on the heavier soil, having a greater soil moisture content than lighter soil, there is more competition from other species. These take advantage of this soil moisture benefit to the weakened lucerne plants dis-

advantage. This defoliation frequency/soil moisture interaction is likely to be found between the range of soil types on which lucerne is grown.

Many other workers from similar and intermediary climatic regions have demonstrated the advantage of defoliating infrequently. Some of these defoliated at fixed time intervals or number of cuts per year (Hildebrand and Harrison, 1939; Nielsen et al.,1954; Davies and Davies, 1956; Dennis et al.,1959; Steinke, 1963; Bryant and Blaser, 1965; Langer and Steinke, 1965; Smith,1965; Monson, 1966; Smith and Nelson, 1967; O'Connor,1967; Tsuma, 1968), while many others have done so at different stages of growth (Burlison et al., 1930; Dent, 1955; Dexter, 1964; Feltner and Massengale, 1965; Langille et al., 1965; Keoghan, 1966; Lobb, 1967; Robison et al., 1968). Keoghan (1967) lists others in each group. Generally, with frequent defoliation, the reduction of plant vigour is cumulative over sequential years.

An important aspect of defoliation frequency is the cutting criterion selected. Those used have been, either set time intervals or dates and for stages of growth, height of shoots, presence of basal buds or shoots, height of basal shoots, presence of flower buds and stage of flowering. Keoghan (1967) points out that cutting according to stage of growth is superior,although practically a more difficult operation because of the difficulty of estimation. Growth rates vary with environmental conditions, so that set time intervals can result in variable yield quality as well as risking plant vigour and stand persistance by defoliation at too immature growth stages. Also, consistent hay quality requires harvesting to be at a relatively consistent stage of growth (Meyer and Jones, 1962). Crowder et al. (1960) obtained greatest yields and best quality when defoliating with 2" high crown shoots present, compared with a wide range of fixed time intervals. Tysdal and Kiesselbach (1939) observed the apparent benefits of such a criterion when comparing defoliation frequencies between different varieties. Crown shoot appearance can commence both before and during flowering (Willard, 1951; Keoghan, 1967), indicating their lack of correlation as defoliation criteria. Recently, Nelson and Smith (1968a) and Leach, (1969a) have suggested that this criterion takes advantage of the lucerne plants physiological readiness for defoliation (section 2.4.2.1.).

In practise, especially with mechanical harvesting, management and quality considerations may necessitate a combination of criteria be used.

In contrast to the effect of frequent defoliation, too infrequent defoliation can also result in reduced annual yields (Nelson, 1925; Willard, 1951; Crowder et al., 1960; Kust and Smith, 1961; Smith, 1962, 1965; O'Connor,1967), or in little further yields increase (Davies, 1960a). Such results infer reduced growth rates at mature stages of growth. In favourable conditions however, lucerne crop growth rates may be sustained at maximum or near maximum levels for some time (Keoghan, 1966), as the lucerne shoot is not determanent in growth, producing floral and vegetative growth simultaneously. On the other hand plant growth is definately reduced with excessively infrequent defoliation. More usually crop growth rates will decrease, or, as Willard (1951) concluded, even become negative at mature growth stages due to death and loss of lower leaves, small branches and the attacks of forage feeding insects. Other factors such as lodging of heavy crops, and the associated death and decomposition of mature stems and also new basal shoots will reduce yields (Keoghan,1966). Attacks by fungal diseases can cause serious leaf drop in mature lucerne (Keoghan, 1967).Fuess and Tesar (1968) studied the reasons for Kust and Smith (1968) and Smith (1965) obtaining greater yields from 3 (one-tenth bloom) compared to 2 (full bloom) defoliations each year in Wisconsin. Over 2 years, two-thirds of a 17% yield advantage for the 3 defoliations was due to net leaf loss, the remainder appearing to be due to higher net photosynthetic rates of the physiologically younger plants defoliated 3 times. The results of Brown et al.(1966a)and Pearce et al. (1968) demonstrating reduced lucerne leaf photosynthetic efficiency with age lends support to this latter conclusion.

The ultimate yield requirements for lucerne are in most cases a combination of dry weight yield and quality. The digestibility optimum for lucerne occurs at an earlier stage of growth than the maximum dry weight yield (Coop, 1967), while Griffith and Ramsay (1932) found little change in nutritive quality up to bud stage. Bailey et al. (1970) found a relatively steady decrease in feed quality during regrowth to early flower. Generally, some quality must be sacrificed with more infrequent defoliation so as to maintain sward productivity, vigour and

purity, except maybe, in drier regions using irrigation (Meyer and Jones, 1962). In Ontario, Canada, Winch et al. (1970) found that defoliation at the 50% visible bud stage of growth gave the best combination of all these requirements.

There is evidence to suggest that in many situations a single immature defoliation will not have particularly harmful residual effects. Yields will probably be reduced in the year of cutting, but the distribution of yield may have advantages for management (Keoghan, 1967). A very early spring defoliation generally results in decreased annual yield, but with little if any adverse residual effect (Jackobs, 1950; Jackobs and Oldemeyer, 1955; Dent, 1955; Langille et al., 1965). In a high light, low rainfall region, Jackobs (1950) defoliated with first spring growth at 4", 7", 12" and no defoliation, finding little yield difference and no residual treatment effect. In a less favourable climate, yield reduction was apparent (Langille et al., 1965). The timing of any late autumn defoliation is critical, especially in cooler temperate regions with overwintering problems. The last defoliation must be early enough before growth ceases to allow for the accumulation of sufficient organic reserves needed for the establishment of winter hardiness and to meet the requirements of early spring growth (Smith, 1964). In milder winter growing regions, the autumn accumulation of organic reserves is not likely to be of great concern, other than to maintain reserve levels in accordance with normally recommended defoliation practises.

2.3.1.2. Root Growth.

There are three aspects involved: root dry weight differences between treatments, immediate post-defoliation root dry weight changes and new root growth. In most circumstances, under sward conditions, the cummlative effect of more frequent defoliation on the lucerne tap root is to reduce its dry weight (Graber et al., 1927; Dotzenko and Ahlgren, 1950; Baker and Garwood, 1959; Dennis et al., 1959; Langille et al., 1965; Bryant and Blaser, 1965; Smith and Nelson, 1967). This is in keeping with the loss of plant vigour generally observed with frequent defoliation. With pot experiments sampling the whole root system (Hildebrand and Harrison, 1939; Langer and Steinke, 1965; Leach, 1968a)

observed similar results at the end of their experiments.

Changes of root dry weight (mostly the top 6-8" of tap root and often including the crown) during the post-defoliation regrowth show initial decrease to a minimum at 2-4 weeks and then increase through to shoot growth maturity (Graber et al.,1927; Willard, 1951; Nielsen et al.,1957; Sonneveld, 1962; Smith and Silva, 1969). This decrease is expected to be considerably less when there is a substantial residual leaf area left. A large portion of the observed weight changes are due to similar changes in organic reserve levels (section 2.3.1.3).

With relatively infrequently defoliation, recent fine root growth can make a significant contribution to total root dry weight at the time of defoliation. Fine root growth (root tip extension) is markedly reduced or stops soon after relatively close defoliation; to start regrowing significantly some time later. Investigations show that this varies from 15 days (Hodgkinson, 1967; Ueno and Smith, 1970), to 10 days (Ginzburg, 1958) and 7 days (Smith and Silva, 1969). Hodgkinson (1967) observed that partial defoliation resulted in less restriction of root growth. Mitchell and Denne (1967) presents results which show a 50% loss of fine feeding roots 6 days after defoliation to 1 inch. Zykov (1969) reported that up to 55-60% of fine lucerne roots may die after each defoliation, being mineralised within 25-30 days. Further evidence is required to verify fine root death of such proportions. Mitchell and Denne (1967) stressed that the importance of this fine root growth reduction(and death) was in the associated reduction of the active nutrient absorbing capacity of the root system.

Decreasing defoliation frequencies of reasonable intensities will enable an increase of the rate and amount of fine root recovery between harvests. With more frequent defoliations the significance of this fine root loss is the probability of induced nutrient deficiency and the resultant loss of plant vigour (section 2.4.1.2). Although removing the supply of carbohydrates by defoliation is expected to limit the growth of lateral roots, Hodgkinson (1967) concluded from his own experimental results and the reports from others, that primarily "..... the growth of lateral roots following herbage removal is limited by the supply of essential growth substances which are synthesised by the leaves".

The depression of root dry weights following defoliation has been observed with other species; grasses (Jacques and Edmonds, 1952; Alberda, 1957), clover (Tesar and Ahlgren, 1950; Butler et al., 1959; Chu, 1971); and the reduction or cessation of root growth; grasses (Oswalt et al., 1959; Davidson and Milthorpe, 1966b).

In a cool winter region, Rather and Dorrance (1938) observed the drop in lucerne root dry weight after defoliating too late during the autumn growth period.

2.3.1.3. Chemical Composition.

Compared to root growth, more attention has been given to the concentration changes of organic reserves following defoliation. Total non-structural carbohydrate (TNC) reserve changes are closely correlated with root dry weight changes, decreasing to a minimum at about 3 weeks and then increasing to a maximum at full bloom (Nielsen et al., 1956; Sonneveld, 1962 for others; Smith, 1962; Reynolds and Smith, 1962; Cooper and Watson, 1968; Smith and Silva, 1969; and others). Levels of starch in particular and sugars, change in a similar pattern to the TNC changes after defoliation (Nelson and Smith, 1968). As for root dry weight dry weight, partial defoliation reduces the fluctuations of these reserve levels. Nielsen et al., (1956) found the percentage of hemicelluloses in tap roots also declined after defoliation, while Hodgkinson (1967) observed that the levels of some polysaccharides declined following complete defoliation. With cocksfoot, (Milthorpe and Davidson, 1966b) observed that non-carbohydrate compounds declined after defoliation in circumstances of low initial reserve levels. With lucerne, it is possible that more complex compounds will be broken down and used for respiration and/or new growth following severe defoliation and/or with plants of low organic reserve levels.

Many reports show that increasing defoliation frequency results in reductions of the amount and often the concentrations of TNC reserves at the end of the experimental period (Nelson, 1925; Graber et al., 1927; Willard, 1930; Hildebrand and Harrison, 1939; Weinmann, 1948; Nielsen et al., 1956; Weir et al., 1960; Smith, 1962; Feltner and

Massengale, 1965; Langille et al., 1965; Smith and Nelson, 1967).

Concentrations and amounts of organic nitrogen reserves, usually recorded as total nitrogen (TN), are affected in a similar manner by defoliation frequency as are TNC reserves, except that immediately following defoliation a small concentration increase has sometimes been observed. This is considered to be due to the greater relative drop of the TNC concentration (Jansen, 1929; Graber et al., 1927; Grandfield, 1935; Nielsen et al., 1956; Smith and Silva, 1969). The levels of TN concentrations, amounts and associated fluctuations are considerably less than those for TNC reserves.

The TNC reserve fluctuations are in response to the net effect of new growth, respiration demands and assimilate supply (section 2.4.1.), which may be modified by the effect of environmental conditions on the net energy balance within the plant (Brown and Blaser, 1965, 1970). Lucerne is largely dependant on rhizobial activity in root nodules for its nitrogen supply. In sward conditions, defoliation and reduction of light intensity has been demonstrated to depress root nodule activity and numbers (Thornton and Nicol, 1934). Both treatments reduced photosynthetic activity and provide evidence suggesting that continued nodule activity is dependant on an adequate carbohydrate supply (Pritchett and Nelson, 1951). Butler et al. (1959) demonstrated similar responses with Trifolium and Lotus species. These studies demonstrated the need for plant nitrogen for regrowth following more severe defoliation and hence the observed TN fluctuations.

Nelson and Smith (1968a) showed that crown dry weight was considerably less than the top 6" of root, while Jung and Smith (1961) showed lower concentrations of carbohydrate reserves and less seasonal fluctuation for crowns. Ueno and Smith (1970) provide supporting evidence for the relative importance of roots, but showed further, that tap root wood stored more total non-structural carbohydrate (TNC) reserves than the tap root bark (separated by the cambium layer). TNC concentration and amount were both distributed in proportions of 25% (crown), 55% (tap root wood) and 20% (tap root bark). Following defoliation, the depletion and replenishment of TNC was in the same proportions, suggesting equal availability to storage sites for respiration and growth requirements.

Comparing changes in the level of TNC during regrowth between small, medium and large sized plants, Ueno and Smith (1.c.) showed minimal TNC weights per pot and TNC% on days 7, 14 and 14-21 respectively; the total amount of TNC utilised was proportional to initial plant size. The respective utilisation efficiencies were 1.50, 0.75 and 0.58 g of TNC used to produce 1g of shoot dry matter; it was not known why larger plants were more efficient. TN was not considered

Lukezic et al. (1969) using gnotobiotic greenhouse conditions showed that the carbohydrate reserve decrease with frequent defoliation is a true plant response and not influenced by micro-organisms.

The effects of defoliation on the levels of mineral reserves in lucerne has not been investigated, but from the effect on fine root growth, especially with more frequent defoliation, it would appear that mineral reserves may be of some importance (Mitchell and Denne, 1967; Hodgkinson, 1967; sections 2.4.1.1., 2.4.1.2.)

The actual role and significance of these reserves during regrowth is discussed later (section 2.4.1.1.)

2.3.1.4. Defoliation Height.

Height of defoliation when infrequent tends to be unimportant, especially in practical circumstances, the wastage from residual stubble often being greater than new shoot growth gains. Higher cutting is only likely to be of importance with frequent defoliation when the residual leaf area may give a significant contribution to the plants assimilate supply. This interaction has been demonstrated by Kust and Smith, (1961), Langar and Steinke (1965), and Smith and Nelson (1967), and is likely to be most apparent in a low energy environment (Langar and Steinke, 1.c).

2.3.1.5. Defoliation by Cutting and Grazing.

There are several distinct differences between these two processes. Cutting is simple and direct. In comparision, grazing can be selective both for lucerne leaf (Arnold, 1960) and new shoots (Peart, 1968). Even when moderate, such grazing will depress lucerne's ability to compete with grasses and weeds (Iversen (1967).

Animal treading reduces pasture yields (Edmonds,1966), while nutrient recirculation via animal excreta boosts growth, having greater effect under conditions of adequate soil moisture and generally, giving non-legumes an increased competitive growth advantage due to an enhanced nitrogen availability (Watkin, 1954; Cuykendall and Marten, 1968). The determination of an optimum grazing frequency is dependant on yield, quality and persistency considerations, and further, on the growth stage effect on palatibility and the associated utilisation efficiency. Residual mature stems are basically wasteful (Dann, 1968). In general, although absolute yields vary between cutting and grazing, relative yields are similar and Matches (1968) considers the latter parameter more important for evaluating swards.

2.3.2. Effects of Defoliation Frequency on Lucerne Persistence.

The reduction of yields with frequent defoliation can be due to reduced plant numbers (stand reduction), reduced plant vigour or size and associated reduction of shoot numbers per plant. This latter is not loss of persistence per se, but rather an expression of it. Gross et al., (1958) observed that frequently cut lucerne plants were considerably smaller, but their numbers had not been decreased. Willard (1931) observed a similar situation in that he found a low correlation between shoot yield and stand density. Feltner and Massengale (1965) observed the same effect for several treatments. There have been many reports however, showing a decrease in plant numbers with frequent defoliation. For instance Nelson (1925) found 2, 3 and 4 cuts per year reduced plant numbers to 12, 3 and 0 plants per square foot over 2 years. Representing a milder environment, Judd and Radcliffe (1970) observed 4.1, 5.5, and 6.4 crowns per square foot after 3 years defoliating at 3, 4, 5 and 6 weekly intervals. Similar relationships between defoliation frequency and plant numbers were obtained by Jackobs and Oldmeyer (1955), Davies (1957), Dennis et al. (1959), Rixhon (1966), Cullen (1967), Smith and Nelson (1967), Peart(1968), Leach (1970).

Reduced plant vigour, virtually a basic component of reduced persistence, results largely from the effects of environmental conditions and the individual or the combined effect of frequency and seasonal timing of defoliation (sections 2.3.1.1.; 2.3.1.2.; 2.3.1.3.). Further,

reduced plant vigour is often aggravated by a concomitant increase of weeds and grasses which provide direct environmental competition (Nelson 1925; Petersen et al., 1953; Nielsen et al., 1954; Dennis et al., 1959; Weir et al., 1960; Iversen 1967; Judd and Radcliffe, 1970; Leach, 1970c). With moderate defoliation frequencies, it has been suggested that an initial reduction of plant numbers will decrease plant competition, enabling remaining plants to grow larger and thus maintain yield (Grandfield, 1934; Kust and Smith, 1961). It is possible that after the initial defoliations, a more infrequent treatment may be needed to establish this effect.

Some more specific aspects depressing lucerne persistence have been demonstrated. In cool winter regions, considerable winter death of plants can result from an ill-timed autumn defoliation (Smith, 1965). In drier regions or seasons, lucerne is more persistent with more frequent defoliation if not irrigated. Ward et al. (1966) demonstrated this with a lucerne cocksfoot sward; the deeper lucerne root system giving it a competitive advantage for soil moisture, in spite of reduced vogour. With infrequent defoliation, the lucerne plants vigour is such that it can succesfully compete with grasses and weeds, even under irrigation. Van Riper and Owen (1964), Iversen (1967), and Lobb (1967) also noted better dry land persistence. Feltner and Massengale (1965) found that the reduction of lucerne stands under frequent defoliation was aggravated by excessively high summer temperatures of greater than 25 C. It has been observed that lucerne is more persistent in conditions of high fertility, especially for potassium (Graber and Sprague, 1938; Markus, 1966; Smith, 1969a). Lobb (1967) found that on the soils used, selective withholding of phosphorous fertilisation gave lucerne a competitive advantage over grasses and weeds which have a greater phosphorus requirement , and hence, for lucerne, improved persistence. It should be noted, that this management may be at the expense of maximum potential lucerne yields on phosphate deficient soils (Stephen, 1970). Differences in lucerne persistence associated with varietal growth form differences have been demonstrated by Kehr et al., (1962) Leach (1969b). Smith and Graber, (1941) suggested that management techniques detrimental to lucerne production and survival, may also increase susceptibility to diseases

and amplify differences in disease tolerance between varieties. Thus, lucerne persistence is very dependant on the defoliation frequency used, but may well be further modified by any of the other considered aspects.

2.3.3. The Growth Form Response of Lucerne to Different Defoliation Frequencies.

The effect of increased defoliation frequency reducing plant size, as evidenced by smaller roots has often been demonstrated (section 2.3.1.2). This has been shown to be associated with the death or size reduction of crown stems (Nielsen et al.,1954; Gross et al., 1927; Peltier and Tysdale, 1935; Grandfield, 1945) and stems per plant (Peltier and Tysdale, l.c.; Cowett and Sprague,1962; Rumbaugh, 1963; Leach, 1968a, 1970c) are also reduced. This would be expected with the fewer crown and stubble sites present on the smaller plants. The combined effect of these factors is expressed in the lower yields obtained.

At the single shoot level, the results of Leach,(1968a, 1969a) indicated that the individual shoot length at harvest depends on when it resumes extension growth and is largely independant of stage of maturity at defoliation or the intensity of cutting. With defoliation at an earlier growth stage, Leach (1968a) observed fewer shoots, while Keoghan (1970) found little difference in shoot numbers, but both observed reduced initial shoot growth due to the delayed commencement of shoot elongation. Keoghan (l.c.) suggests that shoot numbers will only be reduced with prolonged immature defoliation when the crown size is reduced. This is supported by another of his observations that lucerne has "a tremendous reserve of buds for future regrowth". Thus with more frequent defoliation average shoot length is likely to be less, (e.g. Tsuma, 1968) and more immature at a given harvest time. Comparing his results with those of Leach (l.c.), Keoghan (l.c.) suggests that inter-plant competition within his simulated sward compared to Leach's (l.c.) spaced plants, may well explain their differences of shoot numbers.

The later stage of growth at defoliation, the higher the stem/leaf ratio is likely to be. This is because of increasing lower leaf loss (Fuess and Tesar, 1968) and increasing dry matter accumulation in

the stems (Meyer and Jones, 1962). The residual growth results of Tsuma (1968), showed a lower stem/leaf ratio for previously more frequently defoliated treatments. This correlates with the slower initial shoot growth and longer time to maturity of more frequently defoliated lucerne. Hodgkinson (1967) found that population density did not affect the stem/leaf dry weight ratio of shoots at the same stage of growth.

Both Leach (1968a, 1970 a,b). and Keoghan (1970) consider the relative importance of stubble and basal shoots as components of yield. Keoghan's (l.c.) classification defined stubble shoots as arising on upper stubble nodes with inter-node length greater than 0.6 - 0.7 cm, while basal shoots arise from the crown and lower nodes not exceeding 0.5 cm in length. For discussion, Leach's (1970a) classification for shoots arising on the 0-2 cm and 2-10 cm stubble segments are similar. Both authors found that the contribution of basal shoots to yield was much more important at all stages of defoliation. This was represented in terms of numbers and earlier extension growth. Stubble shoots probably only approach important proportions with high level, very immature defoliation (Keoghan, l.c.). Under field conditions, Keoghan (l.c.) noted even greater basal shoot dominance with all stages of defoliation. Both authors also observed indications of intershoot competition. With very intensive defoliation resulting in smaller shoot numbers (all basal shoots), individual shoot size was slightly larger than with less intensive defoliation when some stubble shoots were present as well (more shoots). Hodgkinson (1967) demonstrated a similar result in an experiment in which shoot numbers were experimentally controlled (section 2. 4. 2. 3.).

As the height of defoliation is raised, with immature stubble, a greater residual leaf area is left. However, there is negligable residual leaf area with mature stubble regardless of defoliation height, although this latter can be increased by a significant leaf area contribution of newly elongating basal shoots (Keoghan, 1967). Such leaf area is capable of significantly contributing to the lucerne plant's initial post defoliation carbohydrate assimilation, particularly with immature stubble (Hodgkinson, 1967; Keoghan, 1970; section

2. 4. 1. 3.).The interaction of defoliation frequency with defoliation height is implicit.

2.3.4. The Effect of Defoliation Frequency on Lucerne Growth Rates.

The lower yields with more frequent defoliation represents an overall lower crop growth rate (CGR). For given growth periods,comparisions of lucerne growth rates between treatments of different defoliation frequencies, appear to have been confined to studies at Lincoln, Canterbury (Steinke 1963; Langer and Steinke, 1965; Keoghan, 1966, 1970). The majority of studies have considered only total annual yields. Steinke (1963) showed that frequent defoliation, reducing plant weight, was associated with lower relative growth rates (RGR), indicating less efficient growth from the smaller plants. He also obtained initially negative root RGR for closely defoliated plants. In some cases this could also apply to whole plant growth, when this below-ground weight loss is faster than the rate of new growth. Implicit in the lower yields at each harvest of more frequently defoliated lucerne are lower CGR's.

Most of the work on lucerne growth analysis has bee concerned with the relationship between CGR or rate of photosynthesis and leaf area index (LAI) (Steinke, 1963; Keoghan, 1966, 1970; King and Evans, 1967; Wifong Brown and Blaser, 1967). This work, as in other crops (Watson, 1958; Ludwig et al., 1965 - cotton; Shibles and Weber, 1965 - soy beans; Williams et al., 1965 - maize; and others) was aimed at determining whether an optimum LAI would be attained and if so, the nature of it; i.e. narrow, broad, or plateau. Keoghan (1970) considers the subject and its explanations fully. Steinke (1963), with a lucerne field experimant, demonstrated a narrow LAI optimum, thought to be due to soil moisture limiting the more mature growth. King and Evans (1967), Wilfong et al., (1967) and Keoghan (1970) obtained broad optimum LAI, while in 1966 and in other experiments in 1970, Keoghan obtained plateau LAI relationships. These varied results indicate the complexity of factors controlling this relationship. Among these factors are the efficiency of light inter-

ception related to changes of the light extinction coefficient (Keoghan, 1970); differences of leaf photosysthetic capacity between species (Brown, Blaser and Duntun, 1966) and possibly varieties (Dornhoff and Shibles,1970); reduced leaf respiration rate of older and more shaded leaves in the canopy, probably explained by an associated increase of specific leaf area (Wilfong et al., 1967; Williams et al., 1965; Shibles and Weber, 1965); and the effects of other environmental variables, especially moisture (Keoghan, 1970).

The influence of different defoliation frequencies has not been reported. With more prolonged treatments resulting in differences of sward morphology (e.g. stem density), light interception will be varied which nay well influence the form of the CGR/LAI relationship. Postulated changes for the more physiological factors are less obvious, although Keoghan (1970) found a denser lucerne sward had a greater average specific leaf area than a less dense sward.

2.4. Factors Controlling the Yield and Regrowth Rate of Lucerne.

These factors are grouped as a physiological, morphological and environmental classification, and are considered as they contribute to the explanation of the various aspects of yield and regrowth discussed in the previous sections. Of necessity, the controll of regrowth *per se*, will tend to precede the situation in respect to different defoliation frequencies.

2.4.1. Physiological Factors.

2.4.1.1. The Role of Reserves.

There are three types of reserves to consider: non-structural carbohydrates, nitrogen and mineral reserves. The effect of different defoliation frequencies on subsequent shoot growth and root weight, organic reserves and plant vigour has been discussed. The carbohydrate reserves have recieved far more attention in the past, in particular, for their contribution to new shoot growth. A relatively consistent line of thought has developed over the last forty-five years in respect to this role of carbohydrate reserves, but in the last decade its

validity has been questioned, and during the last few years the question has been elucidated considerably.

In 1927, Graber et al. postulated that "..... New top growths especially in the earlier stages, are initiated and developed largely at the expense of previously accumulated organic reserves." This postulation was generally accepted over subsequent years, supported by repeated demonstrations of good correlations between plant yield and/or vigour with carbohydrate reserve levels (Harrison, 1939; Sprague and Graber, 1938; Weinman, 1948; Weir et al., 1960; Feltner and Massengale,1965; Langille et al., 1965; Smith and Nelson, 1967; and others) and that growth after defoliation is generally associated with a decrease in the level of carbohydrate reserves (Graber et al., 1927; Grandfield, 1935; Brown and Munsell, 1942; Reynolds and Smith, 1962; Smith, 1962; Nelson and Smith, 1968b) which follows the general cyclic pattern described (section 2.3.1.3.). Doubt as to the soundness of this postulation was expressed notably from two sources. May and Davidson (1958) suggested that the post-defoliation use of carbohydrate reserves for respiration could be of greater importance. Soon after, May (1960) questioned the acceptance of the hypothesis of accumulated carbohydrated reserves having a specific role in initiating regrowth since "..... the paucity of knowledge of mobilising hormones, mechanisms of translocation and utilisation of carbohydrate reserves at meristems precluded a critical evaluation of the part played by reserves in determining regrowth." Smith (1962) still contended that carbohydrate reserves in part contribute to new foliar regrowth of lucerne after defoliation, and recent work has supported this view.

In response to these reconsiderations, much work has been done to elucidate this aspect of regrowth, this being particularly successful with lucerne (Hodgkinson, 1967, 1968, 1969; Silva, 1968; Smith and Silva, 1969; Smith and Marten, 1970), and other species (Davidson and Milthorpe, 1965, 1966a, 1966b; Carlson, 1966a 1966b; Alberda, 1966; Mitchell and Denne, 1967). Earlier work was done with grasses showing grass shoot stubble to be the main source of carbohydrate reserve, rather than the roots, and that these reserves were used

for both respiration and new growth (Davidson and Milthorpe, 1966a; Alberda, 1966). Marshall and Sagar (1965), using ^{14}C tracer, showed a grass inter-tiller photosynthate interdependance following partial defoliation, while Ehara et al. (1967), using Paspalum notatum demonstrated that new leaf tissue used in part at least, ^{14}C labelled compounds from the stubble and roots. With severe defoliation and low initial reserve levels, Davidson and Milthorpe (1966b) and Alberda (1966) found that substances other than non-structural carbohydrates were used to suppliment their reserve supply. Nitrogenous compounds were suggested, but also plant parts may be sacrificed to provide a source of substance for regrowth and/or respiration (Alberda, 1966), and Hodgkinson (1968) stated that even structural compounds could be broken down and retranslocated.

Particularly good progress has been made in resolving the role of organic reserves in lucerne regrowth by studying their re-distribution after being ^{14}C labelled. By this method, Hodgkinson (1967), Silva (1968) and Smith and Marten (1970) have all conclusively demonstrated that organic reserves are used in part, for the formation of new lucerne shoot growth. In more intensive studies, Hodgkinson (l.c.) followed this redistribution over 30 days regrowth, while Smith and Marten (l.c.) did so by harvesting at 5 regrowth stages - 15 and 30cm height, bud, first bloom and 50% bloom. Their results showed several similarities. Notably, the greater proportion of ^{14}C-labelled compounds was used as respiratory substrates, although during the early regrowth period, respiratory and new shoot growth use was approximately equal. Also, the percentage content of ^{14}C-labelled compounds in the total new shoot growth was initially high, decreasing with time as current photosynthate increasingly contributed. Thus the intensity of shoot labelling was inversely proportional to the length of the post-defoliation period.

In marked contrast, Smith and Silva (1969) in a quantative study and Silva (1968) using ^{14}C-labelling, found at 21 and 26 days respectively, that much greater proportions of the origionally stored organic compounds in the roots and crowns were used in new shoot and root growth; that used as a respiratory substrate being relatively small.

In agreement however, was the high initial use of organic compounds stored in the roots and crowns for new shoot growth, followed by the rapidly increasing contribution from current photosynthate. Both groups observed the continued use of labelled organic compounds throughout the vegatative growth stage. All except Hodgkinson (1967), found that they had a high utilisation of labelled compounds (70-80%). Hodgkinson (l.c.) observed a 50% utilisation by 20 days regrowth, after which there was little change.

Smith and Marten (1970) found that much of the initially labelled non-structural carbohydrates later located in new shoot growth occurred as translocated non-structural carbohydrates; that incorporated in shoot structural tissue being relatively low, fluctuating between 4 and 9% of the initial reserve level. Hodgkinson (1967) did not distinguish between these fractions.

More complex organic compounds may be depleted during regrowth (section 2.3.1.3.). Nielsen et al. (1956) reported hemi-cellulose mobilisation during lucerne regrowth. Hodgkinson (1967) had evidence suggesting this may occur, but also quoted Whistler and Young (1960), and Porter (1962) as providing evidence suggesting that hemicellulose and cellulose are stable end products of metabolism. Nitrogenous compounds located in storage organs are necessarily translocated for new shoot growth,but if necessary, as Steward et al., (1958) have shown,they can be utilised as respiratory substrates. This evidence supports other reports that other non-structural carbohydrate reserves can be utilised during pasture regrowth, as respiratory substrates at least (Davidson and Milthorpe, 1965, 1966b, Alberda, 1966; Humphreys and Robinson, 1966), particularly if defoliation is reasonably severe and reserve levels are low. More detailed investigation to determine the relative importance and use of these compounds during regrowth, and under what conditions are required.

This has been done to some extent with quantative studies of the importance of nitrogenous compounds in plant regrowth. Such studies are few, even though Graber et al., (1967) included organic nitrogen compounds in his definitions of reserves. Using grass species, Bommer (1966) obtained considerably greater yields from plots recieve-

ing heavier applications of nitrogen fertiliser, with an associated greater reduction of carbohydrate reserves, suggesting greater use of the latter. More directly, both Dilz (1966) and Sheard (1968b, 1970) found a high correlation between plant nitrogen content at defoliation and weight of regrowth, while that between regrowth and turf carbohydrate content was low, (Dilz, 1966) and negative with fructose concentration in the tertiary shoot of timothy (Sheard, 1968b, 1970), the vegetative organ most influencing the spring growth of timothy (Sheard, 1968a). Dilz (1966) demonstrated a considerably grater shoot yield per a unit weight of protein compared to a unit weight of carbohydrate. This efficiency of proteinaceous compounds suggested that they were at least as important for herbage regrowth as non-structural carbohydrates. Sheard (1968b, 1970) found that a high internal N supply provided a ready supply of organic N for new shoot growth. If in low supply, though, it may well be growth limiting, even though the carbohydrate reserve level is adequate to meet the energy demands of growth and respiration from these non-nitrogenous substrates. He concludes "........a balance of carbohydrate for energy and a readily available source of protein for the synthesis of new protoplasm within the plant is superior to a high carbohydrate-low protein relationship."

This work with grasses has not been extended to legumes and in particular, to lucerne. The effect of severe defoliation restricting lucerne root nodule nitrogen fixation (section 2.3.1.3.) and restricting root growth (section 2.3.1.2.), means that initially, protein precursors required for new shoot growth, must largely be provided from reserve sources. Using the nodulated legume, Pisum sativum during vegetative growth, Pate (1956) showed the direct export of fixed nitrogen from the root nodules to the shoots as amides (observed in other symbiotic associations; see Pate et al., 1965). Sugars translocated from the leaves provide essential carbon skeletons for amide synthesis in the roots (Pate et al., l.c.). It is reasonable to expect a similar occurrence in lucerne, and as such, it is most probable that some of the ^{14}C labelled organic compounds in the lucerne roots in the experiments of Hodgkinson (1967) and Smith and Marten (1970)

were amides or other nitrogenous compounds. In lucerne this is yet to be experimentally verified. In turn, a proportion of the translocated material used in new lucerne shoot growth was most probably these ^{14}C-labelled nitrogenous compounds. With a number of species it has been shown that these translocated amides and amino acids are transaminated in the leaves to form different amino acids and proteins (Pate, 1966; Joy, 1967).

Hodgkinson (1967) found that ^{14}C-activity was located throughout the shoot after 20 days regrowth, although more intense in the earlier formed tissue. This indicates a continued acropetal movement of ^{14}C-labelled material into the shoot during this period. At the same time he found new shoots started to export assimilates to the roots by the 6th day after complete defoliation. Although a bi-directional movement of carbohydrate has been questioned (Hodgkinson, 1967), a continued acropetal movement of ^{14}C-labelled amides and amino acids to be incorporated in the growing leaves and apical region tissue of the shoot could well explain the continued labelling of the shoot over this period. Normally, this process would be expected to last until such time as root nodule activity and/or soil nitrogen absorption return to a level satisfying shoot growth requirements. Pate and Wallace (1964) showed that the field pea shoot receives much nitrogen in organic form through the xylem, as well as some in the phloem. Lucerne,may have a similar method of acropetal nitrogen distribution. Recent work suggests the possibility of bidirectional movement in the phloem should not be ruled out (Crafts, 1967; Trip and Gorham, 1968; Ho and Peel, 1969). More probable is a bidirectional movement of photosynthate basipetally and nitrogenous compounds acropetally. The directional distribution of these compounds is probably largely controlled by the influence of the various plant parts as sites of demand (sinks), their relative importance varying in relation to their individual intensities of demand for each compound. Wardlaw (1965) demonstrated this principal with wheat, and Hale and Weaver (1962) with Vicia.

It is suggested that the role of nitrogenous reserves in lucerne and other species regrowth probably warrants study of a similar nature to that already performed with carbohydrate reserves. Their

importance in shoot regrowth may well be relative to the level of carbohydrate reserves, as concluded by Sheard (1968b). The greater role of lucerne organic reserves as respiratory substrates has been reasonably established, although at the same time as Hodgkinson (1970) concluded, the hypothesis of Graber et al., (1927) has been confirmed, but "..... it still remains to be shown that the availability and quality of these compounds (nitrogenous and carbohydrate) regulate the rate of shoot regeneration." Environmental factors aside, it may be that the relative levels of nitrogenous and carbohydrate from residual leaf area and/or new shoot leaf will soon confound the relationship.

The influence of defoliaion frequency on the role of organic reserves is through its control over the levels and amounts of reserves available in the storage organs at defoliation; possibly the relative levels of available nitrogencus and carbohydrate reserves; its influence on root nodule activity; the extent of residual leaf area left, and its activity; and whether or not more complex compounds are broken down. Further work, is needed to elucidate the relationship of these aspects with different frequencies of defoliation.

The role of mineral reserves does not appear to have been investigated, except that Hodgkinson (1967) regrew lucerne in both phosphorous containing and phosphorous-free media, and obtained no yield differences for the single regrowth period studied. This indicated a high level of surplus phosphorous within the root and crown, and that with reasonable nutrient availability mineral reserves may not be a problem in the short term. In the longer term, with repeated frequent defoliation, they may be growth limiting (see section 2.4.1.2.).

In the preceding discussions and some of those to follow, the use of work on grasses to provide support or indicators for the same situation in lucerne, should be considered with some reservation. Being monocotyledons and dicotyledons respectively,their leaf morphology and development is very different. Davidson and Milthorpe (1966a) concluded from their studies with Dactylis glomerata, that photosynthate export from the leaves did not occur until they were close to full expansion. In contrast Hodgkinson (1967) observed export from new lucerne shoots on the 6th day of growth, and with the field pea, individual leaves commence significant assimilate

export when only one quarter their final area (Pate, 1968). These differences result from their differences of leaf anatomical development (Esau, 1960; Fahn, 1967). The other major consideration is their different modes of nitrogen nutrition. However, providing these differences are recognised and kept in mind, hypothetical extrapolations may be useful.

2.4.1.2. The Role of Lateral Roots.

Finer lateral root growth slows considerably or even ceases after defoliation, dependant on its severity (section 2.3.1.2.). Evidence from grasses (Mitchell and Denne, 1967), indicates that this reduction of root (tip) growth, if prolonged, may soon be followed by root hair death, and hence a reduction of the active nutrient absorbing area. This will recover only by renewed root tip growth as Hodgkinson (1967) observed with lucerne lateral roots, which became brown along their length, and suberised in the exodermal cells. There is little absorption of ions through the walls of suberised roots (Kramer, 1956), and ion uptake is an active process (Brouwer, 1965) requiring a supply of assimilates. Thus severe defoliation will sharply or completely reduce the assimilate supply to the lateral roots, reduce root growth, and also reduce ion uptake. With grasses Oswalt et al.,(1959), and Davidson and Milthorpe (1966b) have demonstrated a marked reduction of ^{32}P uptake following defoliation. It is probable that the same occurs with lucerne, for a time period largely dependant on the potential energy supply of the plant. In this latter context Hodgkinson (1967) found that ^{14}C-labelled assimilates were translocated equally into the tap root and lateral roots for the first 20 days' regrowth but there-after a higher proportion was translocated into the lateral roots, this being coincident with the renewed lateral root growth and activity after 15 days, these providing a stronger sink.

In the short term, with plants of reasonable vigour, this root growth reduction may not be excessively important in restricting the plants' nutrient supply as shown by Hodgkinson (1967; section 2.4.1.1.). With less vigourous plants, lower internal available nutrient levels may exist, resulting in the root growth reduction being more significant. This potential deficiency will be countered in part

by the nutrient remobilisation (including nitrogen) that occurs within the plant, from older, and especially senescing organs to active growing regions (Hopkinson, 1964; Leopold, 1964). With other non-nodulated species, a resultant induced nitrogen shortage may be be significant at an earlier regrowth stage. With lucerne, reduced nodule activity may create a similar nitrogen effect.

In the longer term, a continuation of frequent defoliation will aggravate the situation in that nutrient and nitrogen levels in the roots will not be adequately replenished, because of the limited root growth. These deficiencies will certainly start to limit shoot growth. In these circumstances, Mitchell and Denne (1967) suggested that these factors may be the major determanents of the yield reductions generally recorded. They emphasise that where there is a decrease of the effective nutrient absorbing surface and nodule activity, the decreased root efficiency will probably be considerably greater than a reduction in the weight of the total root system would indicate. Ueno and Tsuchiya (1968) observed this with lucerne, top growth,having a greater dependance on lateral root growth, compared with tap root growth.

A further root factor limiting shoot growth, may be a reduced root production of growth substances. Waring et al., (1968) performed experiments which suggested that root-synthesised cytokinins may be needed for protein synthesis in shoots. These are likely to be produced in the lateral root tips, and consequently production would be curtailed in association with reduced root activity following defoliation. Although initial root supplies may result in a temporary excess above demand following defoliation (section 2.4.1.3.),they may be limiting to shoot growth a few days later, when defoliation is severe. In complete contrast, Hodgkinson (1967) concluded from his own results, and the work of others, that following defoliation, shoot produced growth substances (auxins-Torrey (1950) and Pilet (1965); vitamin B compounds-Robins (1951)) are more restrictive than the supply of carbohydrates to the growth of lateral roots. The most important conclusion from this, is that growth substances are probably an important controlling factor during the regrowth of shoots and associated root growth.

2.4.1.3. The Role of Residual Leaves.

In the past, the area of residual leaf following defoliation has largely been considered as it is affected by the defoliation height. At a given height, though, the stage of maturity at defoliation (frequency) can also influence the area and efficiency of residual leaf. Thus the inter-relation of its photosynthetic vontribution with organic reserve levels in promoting shoot regrowth must be considered. Further, the several reports showing that a leafy stubble can alleviate the adverse effects of frequent defoliation on yield (section 2.3.1.4.) are directly pertinent.

Both Hodgkinson (1967) and Keoghan (1970) studied the physiology of the subject.

The primary requirement is that any yield advantage must out weigh the disadvantage of incomplete herbage utilisation. Further, more mature defoliation is usually associated with a low residual leaf area giving little if any regrowth benefit (Ridgman, 1960; Van Riper and Owen, 1964; Keoghan, 1966; Hodgkinson, 1967). A further problem in field conditions is the high rate of stubble death observed by Ridgman (1960), and Keoghan (1966, 1970), especially if the stubble is relatively mature.

Keoghan (1970), lists several factors that will determine the effectivness of residual leaves:

1. The area of leaves on the stubble and their light intercepting properties.

2. The photosynthetic efficiency of these leaves including their adaption to the marked change in environment caused by defoliation.

3. The longevity of these leaves during regrowth.

The basal leaf area of reasonably dense lucerne swards decreases as shoot growth ages (Keoghan, 1966; Fuess and Tesar, 1968), to very low levels with maturity; e.g. 0.14 LAI for 34 days growth (Keoghan, l.c.). Pearce et al. (1968) and Keoghan (1970) showed that this residual basal leaf life is of limited duration relative to natural leaf longevity. This is still shorter in the field. This suggests that a leafy stubble can be attained only by relatively immature defoliation. There is the exception, in that with mature swards, new basal shoot leaf area can be significant, providing defoliation

is high enough to retain these shoots. Keoghan (1966) measured a basal shoot LAI of 0.41. In the only reported case, Keoghan (1970) found a 10cm leafy stubble to have a considerable light interception capacity.

Several workers have demonstrated that the photosynthetic efficiency of lucerne leaves decreases with age (Pearce et al., 1965; Brown et al., 1966a,b; Hodgkinson, 1967; Fuess and Tesar, 1968; Keoghan, 1970; and others with other species). From this evidence Brown et al. (1966b) thought that stubble residual leaves, the older leaves, were probably not very efficient. However Hodgkinson (l.c.) found that the apparent photosynthetic rates of residual leaves increased considerably following defoliation, irrespective of age. Keoghan (l.c.) showed a similar response, this adaption to the increased light environment being complete within 24 hours, causing him to conclude that in good light conditions a leafy stubble could provide a significant assimilate contribution, reducing the stress of frequent defoliation on the root system. There is some uncertainity as to how comparable the residual leaf improved photosysthetic rate and that of newly produced leaves are. Hodgkinson (l.c.) found little difference at 10 days in a glasshouse study. In contrast Keoghan (l.c.) found new leaves appeared to be more active in an out-door experiment, which is possibly the more likely situation in the field in view of the greater leaf senescence rate. observed in field conditions (Keoghan, l.c.). In turn though, there must be a leaf age limit to this adaption. Any improvements of basal leaf photosynthetic efficiency will be more beneficial following immature defoliation, as Brown et al. (1966b) showed that younger residual leaves survived longer.

Both Hodgkinson (1967) and Keoghan (1970) demonstrated the beneficial effects on shoot growth of residual leaves, using 15cm and 10cm high stubble respectively. Total plant weight decreased to a minimum for the first 7-10 days with no residual leaf, but showed no decrease with residual leaf area. After this minimum weight point, Keogham (l.c.) observed that the whole plant and shoot growth rates were very similar. The yield results of Hodgkinson's (l.c.) experiment show a similar effect. The commencement growth stages of this common growth rate, appears to correlate with the stage of a critical leaf area observed by Silva (1968). He considered that the attainment of this growth stage during regrowth is associated with shoot growth becoming largely independant for (presumably) carbohydrate supply, this coming from photosynthesis. Yields of shoots were greater,

the sooner this point was attained. Leach (1970a) also observed that retaining residual leaf area increased total yield by enabling the earlier resumption of shoot growth, the effect being independant of stage of maturity at defoliation. Davidson and Milthorpe (1966a) after examining the results of Ward and Blaser (1961) demonstrated that they had obtained the same effect with cocksfoot. This correlates with the conclusions of Leach(1969a) for each of three lucerne varieties, that regrowth yield depends on the number of shoots and particularly, the time when each shoot resumes growth. Keoghan (1970), also found that the shoots elongating earliest contributed most to the final yield.

2.4.1.4. The Inter-relationship of the Physiological Factors.

The evidence indicates that carbohydrate reserves largely influence lucerne regrowth indirectly. They are used to a greater extent as a respiratory substrate in the roots and crowns; to a lesser extent as carbon skeletons for the formation of amides and amino acids in the roots, and for translocation as carbohydrates into the new shoots. This latter occurs for each shoot until the attainment of a critical leaf area enabling the new shoot growth to be relatively self sufficient for respiratory and growth carbohydrate requirements. Continued root to shoot organic translocation occurs (Hodgkinson, 1967) probably largely as nitrogenous compounds needed for leaf and apical growth in particular. The pattern of translocation and the importance of nitrogenous compounds in regrowth and respiration requires further study. It is feasible that an organic reserve combination of low nitrogen and high carbohydrate levels may limit growth, although this may be more likely in non-leguminous species which generally have a lower nitrogen content. For lucerne to attain a high carbohydrate reserve level, the growth conditions will be such that nitrogen fixation activity is likely to increase giving a higher nitrogen reserve level unless there are specific factors limiting fixation. In most instances, high carbohydrate reserves will be associated with improved nitrogen levels, and probably enhanced top growth.

Residual leaf area makes an important positive contribution of assimialte in regrowth conditions of low carbohydrate reserves. This

is directed to new growth and for respiration, but also in an indirect manner by easing the withdrawal on root and crown carbohydrate reserves by the shoots, leaving more for root respiration and potentially for root growth; this, providing that defoliation is high enough and at an early enough growth stage to ensure there is sufficient residual leaf area obtained. The benefit from residual leaf area is particularly apparent in these latter circumstances, in view of the increased photosynthetic activity of residual leaves after defoliation (section 2.4.1.3.) and that these conditions are typical of frequent defoliation. In practise, in the field, residual leaf area is probably of limited importance, as the density of a reasonable stand coupled with the more usual defoliation at later stages of growth, will result in considerable senescence of basal leaf (section 2.4.2.2.). Hence very little residual leaf will be left even with higher defoliation.

These regrowth aspects, largely related to the plant's carbohydrate balance, tend to be of more importance in the short term after each defoliation.

With prolonged sequential frequent defoliation, it is suggested that depletion of nutrient and nitrogen levels in the plant may be more influential in causing the reduced plant vigor and size so often observed.

In this context, there is the importance of the reduced lateral root growth and the associated reduction of nutrient uptake. For Hodgkinson (1967) this probably lasted for 15-20 days, as new root growth was not significant till the 15th day. During the latter stages of this period of reduced root activity, a nutrient shortage may develop, even though shoots are probably relatively independant for assimilates. The availability of carbohydrates at the root tips is possibly an important factor restricting this root growth. However, Hodgkinson (l.c.) presented evidence which indicated that a supply of essential growth substances which are synthesised in the leaves may be the primary restricting factor (section 2.4.1.2.). With lucerne, many of these aspects of root growth, activity, and their control are likely to be equally applicable to the reduced root nodule activity and hence nitrogen availability, following defoliation.

From these responses, it may be postulated that with continued close and frequent defoliation, the short regrowth interval will initially result in the depletion of carbohydrate, nitrogen and nutrient root reserves with only a limited replenishment by the next harvest. Root growth is

restricted for longer periods than shoot growth, which would result in nutrient reserves (probably including nitrogen) staying relatively depleted, in turn resulting in more restricted shoot growth, so further restricting the supply of carbohydrates and possibly necessary growth substances for root growth. The plant would become progressively weaker, with root death and overall reduction in weight and size as has been frequently demonstrated. These various growth restrictive factors will be more marked in plants of low vigour and probably more so if small. Also, competition with larger lucerne plants and/or other species will be increasingly evident accentuating the defoliation effect. Needless to say, the above discussion assumes that the various environmental factors necessary for growth are not limiting.

If appears as though shoot regrowth may basically be restricted firstly, by the time taken to attain a leaf area permitting the shoots to be self-sufficient for carbohydrate, and secondly, through a limited availability of nitrogenous compounds and nutrients restricting the rate of the subsequent regrowth, or even the first regrowth.

2.4.2. Morphological Factors.

2.4.2.1. Basal shoot status in mature lucerne.

It has been established that greatest annual yields are often obtained if the presence of new basal shoots is used as a defoliation criterion (section 2.3.1.1.). Mitchell and Denne (1967) suggested that defoliation before either flowering or the start of new basal shoot growth would mean the lucerne plant has to re-establish active meristems from the crown at a time when the plant is not physiologically ready for this. This re-establishment period will involve an initial growth delay, even in conditions of large residual leaf area as can be the case with immature defoliation. Nelson and Smith (1968a) concluded similarly from their studies of lucerne morphological development.

The advantage of the basal shoot presence criterion, presupposes that defoliation height is such as to leave any developed basal shoots intact. If cut, Meyer and Jones (1962) found that there was a time delay while new shoots developed. Keoghan (1970) demonstrated a significant yield advantage when these shoots are left intact. The photo-

synthetic capacity of basal shoot leaves has not been investigated. It is probable that they have lower light saturating intensities typical of leaves that have developed in the shade (Leopold, 1964). It is not known if these leaves photosynthetically adapt to the higher light intensities following defoliation, as observed for mature residual leaves (Hodgkinson, 1967; Keoghan, 1970). If they do not adapt, growth delay may occur while the shoots develop their first sun leaves. Keoghan (l.c.), presents evidence suggesting that even if these leaves do adapt, they are less photosynthetically active than newly produced leaves.

2.4.2.2. Senescence.

Keoghan (1970) stated; "....The extent to which a measure of viable plant material underestimates productivity depends on the rate of loss of dry matter produced during regrowth." Fuess and Tesar (1968) demonstrated the large loss of leaf and hence yield if lucerne is allowed to become fully mature. With time, this loss is progressive from the bottom of the shoot following the leaf age gradient. From the studies on leaf longevity in outdoor grown lucerne, Keoghan (l.c.) found little leaf loss up to 30 days regrowth, but progressive older leaf death after this. Pearce et al. (1968) found significantly less leaf senescence in thinned plots. It is probable that improved light conditions in the thinned sward largely contributed to this extra longevity. This has been demonstrated for other species (Brougham 1962, Hopkinson 1966). It is probable that as lower lucerne leaves become excessively shaded, photosynthesis of these leaves will be very low and senescence initiated or accelerated, resulting in the lifting of the leaf canopy as shoot growth approaches maturity. Leaf canopy depth and leaf area may be increased during growth because of a decrease of the mean light extinction coefficient due to changes of leaf arrangement, permitting better light penetration (Keoghan 1970) The rate of lower leaf senescence would probably be reduced.

Defoliation frequencies may affect leaf senescence by the rate of leaf area production and hence the time before basal leaves are in excessive shade and thus encouraged to senesce. Differences in stem density under different defoliations frequencies (section 2.3.3.) may alter the light environment of the sward although changes of leaf angle and arrangement may also influence this result.

On a larger scale, Keoghan (1970) observed that whole shoots sen-

esced and died; this probably being more applicable for the last shoots elongating as they would be subjected to strong light competition from the earlier elongating and hence larger shoots.

These losses from senescence have been discussed in the productive agronomic sense. It should be remembered that the physiological loss is smaller as a large proportion of the nutrient content (including nitrogen) of the senescent organs are retranslocated to actively growing organs. This is important in helping to maintain growth when the source of these nutrients may be limited (Benson et al., 1961; Leopold, 1964; Greenway et al., 1968).

Other environmental factors influence leaf longevity; moisture stress and high temperatures generally accelerate the onset and rate of senescence (Leopold, 1964). Disease attacks can also reduce leaf life (Keoghan, 1966).

A further requirement is the maintenance of adequate root growth to provide new centres for cytokinin synthesis, adequate levels of which are required for the normal leaf longevity in the conditions prevailing. (Leopold, 1964; Waring, et al., 1968).

2.4.2.3. Shoot Numbers and Plant Intershoot Competition.

Leach (1968a, 1969a) concluded that regrowth yield is dependant primarily on the number of shoots and time each starts elongating. This latter factor is largely controlled by the physiological factors discussed. The number of shoots are partly controlled by crown and stubble morphology and modified by varietal differences. Leach (1969a) obtained significantly greater shoot numbers and a resultant yield from a lenient defoliation compared to a severe defoliation, but with varietal differences evident only with the lenient defoliation. These results "tended" to reflect differences in the number of potential shoot sites, although some of the varietal influence was obviously genetic. Keoghan (1970) did not find this yield advantage of greater shoot numbers, considering this was explained by intra-plant competition, but was also likely to be in part due to inter-plant aerial competition as he used potted plants arranged in a simulated sward. Leach (1968a, 1969a) used spaced plants as did Cowett and Sprague (1962) who obtained a similar yield advantage for shoot numbers per plant. Rumbaugh (1963) demon-

strated that increased lucerne plant density reduced stem number and size due to interplant competition. As Keoghan (1970) concluded, and Leach (1968a) recognised, extrapolation from spaced plants to sward conditions may lead to variences such as this.

The evidence for, or suggestion of , plant intershoot competition has been presented severally (Hodgkinson, 1967; Leach,1968a, 1970a; Keoghan, 1970). Leach (1970a) noted a competative advantage for shoots elongating earliest which Keoghan (1970) confirmed from his experiments. Keoghan (l.c.) considered from his observations that this arose from the very heterogeneous nature of the lucerne shoot population which varied widely in time of elongation and thus size and stage of maturity. The competitive effect was such in one experiment, that some complete shoots senesced.

Hodgkinson (1967) using single plants on which only 4,8 or 12 shoots were permitted to grow, observed an extreme plasticity of shoot growth. Weight per shoot changed inversely with shoot numbers per plant, thus retaining a relatively constant yield. He suggested the evidence indicated, that providing the environment was non-limiting for growth it was not the number of shoots per plant that limited regrowth yield, but the rate of supply of organic and inorganic compounds from the roots to the new shoots. Leach (1968a) also observed evidence for inter-shoot competition; shoot size and number present showing an inverse relationship.

This would suggest that the time of shoot elongation is more important as a determinant of yield, than the number of shoots . Further Keoghan (1970) noted that lucerne has a tremendous reserve of buds for future regrowth, of which only a small proprrtion elongate after each defoliation. These buds are largely located on the crowns and stem bases. This is in accordance with the greater relative importance of basal shoots compared to stubble shoots (Cowett and Sprague 1962; Hodgkinson, 1967; Leach, 1970a; Keoghan, 1970). This dominance of basal shoots is accentuated in the field (Keoghan, l.c.).

2.4.3. Environmental Factors.

2.4.3.1. Light tramsmission and interception in the lucerne canopy.

This is considered in association with the lucerne's physiol-

ogy. Langer (1967) and more recently Keoghan (1970) reviewed this subject. Lucerne is a potentially high yielding species, this being partly due to the good light interception properties of its canopy.

The amount of light intercepted is dependant on the stage of growth and stem density as major variables. Cowett and Sprague (1963) demonstrated a decrease in the amount of light intercepted as plant density was decreased, this effect possibly being initially countered in sward conditions by increases of stem numbers per plant due to the reduced interplant competition (Smith, 1962). Stanhill (1962) demonstrated that a decrease of defoliation frequency from 31 to 48 days resulted in an increase of the proportion of light intercepted during the season with an associated yield increase. This is expected with lucerne, where the induction of a more prostrate growth form due to frequent defoliation is not generally apparent as compared to such induction for some other species (Brougham, 1959). Normally a more prostate growth form has a greater residual light interception capacity.

For several species, a range of light transmission patterns have been recorded; from an abrupt light decrease for white clover (Mitchell and Calder, 1958; Stern and Donald, 1962), Less so for red clover (Mitchell and Calder, l.c.), to a relatively uniform decrease for grasses and grass/clover mixtures (Mitchel and Calder, l.c., Stern and Donald, l.c.). Of the several studies for lucerne (Steinke, 1963; Warren Wilson, 1965; Keoghan, 1966, 1970; Tsuma, 1968) it has been shown that the percentage light decrease is relatively sharp in the top third of the canopy, below which there is a more gradual decrease. The transmission curves tend to be similar to that of red clover. Keoghan (1966, 1970) observed that previous management (different defoliation heights) can modify the transmission pattern, presumably resulting from changes of sward structure. He also demonstrated differences between establishing and established stands, these differing in the pattern of stem arrangement and stem density. Tsuma (1968) used previous defoliation freqencies of 2,3,4 and 6 weeks, and found, a little unexpectedly, that there was little difference between the transmission patterns in the upper canopy layers of the first common residual regrowth. Heights of regrowth were significantly different. Stem densities were different, especially between the 6 weeks treatment and

and each of the other treatments collectively, thus implying that leaf arrangement must vary to account for the lack of transmission differences. Further, LAI was significantly different between all treatments. His results imply that the sward's leaf arrangement and presentation adapted in each case to give a relatively similar light extinction coefficient in the in the leaf layers of the canopy.

Stratified leaf sampling has been performed with lucerne (Steinke, 1963; Keoghan, 1966, 1970) and with point quadrat (Warren Wilson, 1965) for comparision with light transmission values. These reports have shown a larger proportion of leaf in the top 20-30 cm of the canopy. The combination of basal leaf senescence and stem growth, results in the leaf canopy lifting off the ground in the later stages of growth. At the same time, there is an increasing stem weight distribution with depth in the canopy . This basic similarity occured both for spaced plants (Steink, 1963) and swards (Keoghan, 1966, 1970). Keoghan (1970 observed that the canopy light transmission pattern was not closely related to the leaf distribution pattern. This was in part due to the light extinction coefficient values differing between canopy levels and in turn not correlating well with the associated leaf area values. This indicated differences of leaf orientation and distribution with canopy height, which may also change with maturity. Warren Wilson (1965) and Scott and Wells (1969) have both shown changes of leaf angle with canopy height.

Lucerne light interception varies with stage of growth, between canopy layers and between different canopies resulting from different agronomic management treatments, and probably between varieties. This varience largely originates from associated differences of canopy structure, evidenced by the variation of the light extinction coefficient (Keoghan, 1970). It seems to be increasingly evident, that lucerne canopy srructure is quite plastic. Possibly, this has an important indirect compensatory role in maintaining good light interception.
A main effect of frequent defoliation is the greater post-defoliation light wastage, hence the need for management to provide for rapid recovery growth to reduce this. A further requirement is to keep the canopy at maximal light interception as long as possible, consistent with continued near maximal crop growth rates, plant quality requirements and other pertinent management considerations.

2.4.3.2. The effect of temperature on lucerne growth.

In general, the work reported for air temperatures indicates that 15C is an approximate optimum for the shoot growth of established lucerne (Steinke, 1963; Langer, 1967; Iversen and Meijer, 1967; Smith, 1969a; Nelson and Smith, 1969; Stock, 1969). Seedlings favour higher temperatures (Gist and Mott, 1957; Garza et al., 1965; Trevine, 1966). With temperature increase above the apparent optimum, yields of both tops and roots decrease, as also do the levels of carbohydrate reserves (Smith, 1969a; Nelson and Smith, 1969). Also noted was an advanced maturity, first flowering occuring considerably sooner in warmer temperatures. Temperatures used were warm (32/24C day/night) and cool (18/10C). Nelson and Smith (l.c.) found that the advantage of the cool regime was partly due to the longer growth period to maturity, development of a larger leaf area, and a higher net assimilation rate. With somewhat higher summer temperatures of 37.5 to 42.5C, Feltner and Massengale (1965) and Robison (1966) also showed yield decreases, but more particularly, large decreases of carbohydrate reserves.

The root yield decrease at higher temperatures also applies to higher night temperatures alone, particularly if associated with lower light conditions (Steinke, 1963). These results are consistent with an increasing depletion of available substrates for night respiration. Support comes from Murata et al. (1965), who showed that lucerne had a broad optimum temperature range for photosynthesis (10-25C), while respiration rate increased steadily with temperature increase, particularly beyond 30C.

Iversen and Meijer (1967) clearly demonstrated shoot growth increase over the lower temperature range to an optimum of 65/50 F (an approximate mean of 15C). At the lower temperatures, root growth (probably weight increase more than root extension) and carbohydrate reserve levels appear to benefit, as evidenced by their increase in the autumn and their importance for overwintering in cool winter environments (Smith, 1964). Murata et al. (1965) also showed that lucerne photosynthesis was maintained at quite high levels with temperatures approaching 0C. Actual shoot growth limitations at these lower temperatures does not appear to have been investigated.

Langer (1967) reviewed the strong interaction between light and temperature levels which can occur with lucerne. The adverse affects

of higher temperatures on growth are particularly evident with low light conditions e.g. 1000 f.c. Strong light can reduce and in some cases reverse the effect of higher temperatures (Gist and Mott, 1957; Steinke, 1963; Garza et al., 1965), since the assimilation rate increases while respiration rate is little changed (Murata et al., 1965; Nelson and Smith, 1969). Seedlings are likely to be more responsive with their higher optimum growth temperature. Further, longer photoperiods will tend to compensate for lower light intensities (Rhykerd et al., 1960).

A defoliation interaction exists with temperature, lucerne growth having a higher temperature optimum when not cut (Steinke, 1963). This probably results from higher temperatures causing greater respiratory use of organic reserves in defoliated plants, so aggravating an already depleted reserve level (section 2.3.1.3.). This would suggest that the lucerne growth temperature optimum may tend to decrease with more frequent defoliation.

There is much less information on the effect of soil temperatures on lucerne growth, and what there is has been confined to seedlings and very young plants. Lucerne root growth has an optimum soil temperature but with reports ranging from 12C (Heinrich et al., 1966) to 19.4C (Neilsen et al., 1960), while shoot growth showed a linear response up to the highest reported soil temperature of 26C (Levesque et al., 1963). Further work is needed to clarify the situation. Ueno et al. (1968) found a significantly higher correlation between lateral root growth and shoot growth, than that with tap root growth, over a soil temperature rangs of 10-25 C. This is logical, since both active root tip growth, and nutrient uptake - an active process (Brouwer, 1965), probably respond positively to soil temperature increase over this range. In support, Neilsen et al. (1960), Levesque et al. (1963) and Heinrich et al. (1966) found that shoot nitrogen and phosphorus content increased with temperature increase and the same in the roots (Neilsen et al., l.c.). The nitrogen increase indicates the active response of the root nodules, although this is probably in part an indirect benefit due to an enhanced carbohydrate supply to the nodule systems, as lucerne nodule nitrogenase activity is still substantial at 3 and 5C (Day and Dart, 1970).

In the whole plant, these temperature effects will be operating on any one organ in two ways. Firstly, the direct effect of temperature on the growth of that organ, and secondly, an indirect effect of temperature on the activity of other organs which supply compounds required else where in the plant. A notable example, is not only temperature reducing root growth directly, but also indirectly, through a reduced supply of growth factors from the shoots.

The adverse effect of freezing or near freezing temperatures during the winter on lucerne overwintering is important in the relavant regions, having dependance on adequate energy reserves, with varietal differences involved (Smith 1964; Langer, 1967). A problem of persistence also exists in climates of very high summer temperatures (Feltner and Massengale, 1965).

Although temperature has definite influences on lucerne growth, between temperature extremes, in field conditions, it's effect is likely to be dominated by its interaction with light intensities. Its main influence on lucerne yield during seasons of active growth may be in modifying the time to flowering, although in good growth conditions this may be countered to some extent by the non-determinant nature of lucerne growth (Keoghan, 1967).

2.5. Lucerne Varietal Comparisions for defoliation and Growth.

Early reports concluded that different cutting schedules resulted in little difference between adapted varieties (Willard, 1951). On the other hand, the large morphological variation that exists between lucerne varieties (section 2.1.), suggests that varietal response differences to defoliation are likely to exist, probably in interaction with various other management and environmental factors. Keoghan (1967) concluded similarly.

With relatively infrequent defoliations the *M. sativa* type lucernes are more productive than the *M. falcata* types. Davies (1970) compared eight varieties of differing *falcata* content, using 2,3 and 4 defoliations per year. Early varieties (*sativa* type) yielded well over this defoliation range, while late varieties (*falcata* type) only yielded well with infrequent defoliation. It was thought this result was associated with a slower growth rate and later spring growth

for the falcata types. Using three reasonably genetically diverse varieties as spaced plants, Leach (1969a) observed this growth rate advantage for the sativa variety (Totana), but also its earlier maturity, expressed by an earlier commencement of active shoot elongation following defoliation. For optimum yields, this maturity difference may mean that sativa types can be defoliated more frequently by comparision with falcata types, within an overall system of relatively infrequent defoliation. With 4 varieties, Tysdal and Kiesselbach (1939) found a similar growth maturity response related to falcata content. With a large range of varieties, Kehr et al., (1963) confirmed the greater productivity of sativa lucernes with defoliation at one tenth bloom, while in a milder climate using the same defoliation frequency, Leach (1970b) confirmed this. With frequent defoliation of 5 varieties, Gross et al., (1958) found the yield of all varieties was depressed, but found that of sativa type lucernes, was more severely affected. Both Feltner and Massengale (1965) in warm temperature summer conditions and Iversen (1967) observed the same effect with frequent defoliation.

The effect of frequent defoliation between varieties, is also expressed in differences of persistence. With frequent defoliation it is generally accepted that sativa type lucernes are less persistent than falcata types. This has been demonstrated severally (Iversen, 1967; Daday, 1968; Bray, 1967; Leach 1970c.). Daday's (1968) study included a comparision with creeping lucernes, these being the most persistent. With the same varieties, Leach (1969b) found the order of persistence to be reversed. He concluded that the creeping habit alone, does not necessarily confer better persistence under grazing. This possibly has to be conbined with active growth (Leach l.c.) and lighter textured soils permitting the development of the creeping habit (Heinrich, 1963; Rogers 1967; Leach, l.c.). The effect of regional climatic conditions on lucerne persistence has been stressed (section 3.2.). With the more extreme environmental conditions and a common defoliation treatment, there seems to be little difference between the response of the sativa and falcata lucernes. Jackobs and Oldmeyer (1955) in a dry high light climate, with 4 genetically varied varieties, found no loss of persistence with 4 to 7 week defoliation frequency treatments. In contrast, in a humid, very low light year in Ireland, Farragher (1968), found all of 8 varieties had a high mortality rate with early bud defoliation, although an earlier than recommended stage of defoliation for this climate

(Dent, 1955). In more intermediary climatic conditions, the varietal interaction between defoliation frequency and persistence will tend to be dominant. Kehr et al.(1963), confirmed this to some extent, finding that broad crowned varieties (falcata type) had greater persistence than narrow crowned varieties (sativa type) over a wide range of management conditions.

The reasons for better falcata persistence and production with frequent defoliation are not clear. With relatively infrequent defoliation in the field, residual leaf area is,probably of limited importance for lucerne regrowth (section 2.4.1.3.). This may not be so with frequent defoliation or continuous grazing. With this management falcata persistence has been associated with their more prostrate growth form (Keoghan, 1967) which later may be intensified by the effect of frequent defoliation (Brougham, 1959). Leach (1970c) observed the extreme of some slow growing very prostrate Spanish varieties having excellent persistence under continuous grazing. It is generally thought that this response is associated with a greater residual leaf area. With lucerne, this situation has yet to be verified.

Another aspect relates to some earlier work indicating that rapidly growing sativa varieties reduced their root reserves at a greater rate and to lower levels following immature defoliation and were consequently more harmed (Keoghan, 1967). Leach (1969a) demonstrated this, as indicated by root weight changes, between Totana, Hunter River and Rhizoma lucernes, these having increasing falcata content respectively. Whether the growth and activity of fine lateral roots are similarly affected between types is not known. In turn, the influence of the associated differences of root form is another unknown, although it may be that the more fasiculated root system of the falcata types (Iversen and Meijer 1967, section 2.1.3.) provides them with a more lasting potentially active root absorption system. With these lucerne types under frequent defoliation, this may in part be achieved by the assimilate and possibly growth substance contribution of the residual leaf area (section 2.3.1.2.), providing this is significant.

The nature of lucerne shoot growth shows considerable variation between varieties of different types (Leach, 1969a; section 2.1.1.), but with this variation there are compensatory morphological differences operating. Differences of shoot numbers being countered by reciprocal leaf size and shoot weight differences, leading to a "relative" equality of plant leaf area and yield; actual values for each variety being dependant to a considerable extent on how soon shoots commence elongating after defoliation (Leach, l.c.). A similar canopy compensatory effect was suggested in respect to light transmission (section,2.4.3.1.). The observations of Leach (l.c.) were with spaced plants. In sward conditions competition influences modify plant morphology (section 2.4.2.3.), althoughtthe extent to which varietal differences are maintained with different plant densities and management treatment is again largely unknown. Palmer (1967) did observe that stem densities typical of each lucerne type tended to persist over a range of plant densities. The complexity of the situation is indicated by the observations of Chisci (1968), that due to interplant competitiveness, the relative yields of the same varieties differed when grown as spaced plants and in swards. One shoot growth factor which appears to be common to most varieties is the dominance of basal shoots in contributing to yield, although with higher defoliation stubble shoots may be of more importance, albeit still smaller, with the more falcata type varieties.

Iversen and Meijer (1967) studied the response of a genetically representative range of lucerne varieties to photoperiod and temperature. With 8 and 12 hour photoperiods, African (sativa type) was more productive, while with 16 hours both sativa and falcata hybrids had similar production. With 20 hours all had reduced production. A common temperature of 65/50 F (day/night) was used. They suggested, that in regions with milder winters and earlier springs temperature rises, sativa types may be more productive. Using a 12 hour day they found a sativa type to be more responsive at lower temperatures of 60/40 F, enhancing the early spring photoperiod advantage. Schonhurst et al. (1975) also obtained a significant divergence of response to photoperiod and temperature between 10 varieties, the varietal response was similar.

Over the range of lucerne types being used, there are some significantly different responses to defoliation and environment. There is

also a considerable paucity and future need for information to explain these varietal differences, particularly defoliation responses. The shoot growth study of Leach (1969a) has been a start. In practise, the choice of variety for a given environment is obviously important for best yield and persistence under the subsequent anticipated management. For the future, it may be that this choice can be significantly aided by the availability of improved varieties bred for each region. This breeding potential appears to be available (Heinrich, 1963; Davis and Baker, 1963; section 2.1.4.). Further, Leach (1970a) noted the inverse relationship between shoot number and shoot size in the range of cultivars he used and suggested; "..... genetic recombination may be necessary to produce plants with large numbers of rapidly growing shoots."

CHAPTER 3.

The Experiment and Basic Methods.

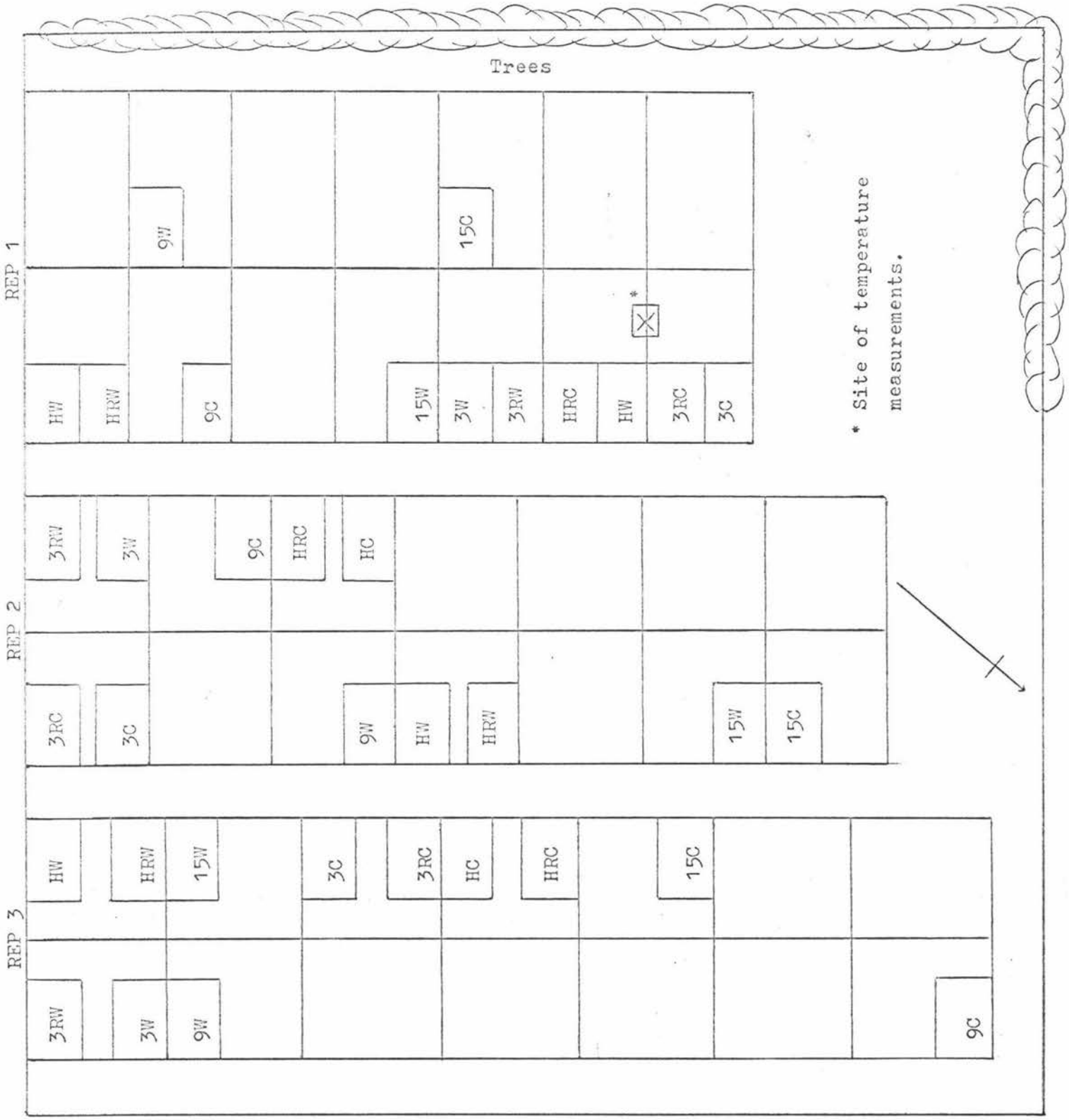
3.1. The Aims and Treatments:

The thesis experiment was conducted on selected portions of the larger established experiment previously introduced (chapter 1.) and discussed in appendix 1A. The basic aim of the thesis experiment was to provide some explanation of the factors contributing to the treatment differences already observed in the original experiment which had been established 4 years earlier. To do so, the main defoliation treatments were continued. These were defoliating at 3", 9"and 15" mean shoot height and at a hay stage of one-tenth bloom during the spring of 1969 (i.e. from the 7th of August through to the 12th of November). This period ensured a greater likelihood of reasonable soil moisture levels as well as providing the further interest of an early spring growth study. In previous years, all treatments were spelled with two hay stage defoliations during the spring. Two additional defoliation treatments were applied. A portion of each original 3" and hay stage plot was cut at the hay stage and 3" height growth stage respectively (i.e. reversed treatments). This was intended to provide an indication of their respective recovery capacity and vigour decline; this being determined from a short three week regrowth study after the termination of the main part of the experiment. With all treatments, two lucerne varieties were used. These were New Zealand Certified Chanticleer lucerne (having a growth form tending to the *sativa* type) and N.Z. Certified Wairau (by comparison, having a growth form tending more toward the *falcata* type). The varietal descriptions and differences are discussed fully in section 10.2 . All treatments are summarised in table 3.1.

3.2. Experimental Layout:

The original experiment had a completely randomised factorial design with three replications. The selections of eight plots (large plots) per replication represented the combination of the four basic treatments continued with the two varieties. Within each large plot an approximately

Fig. 3.1. The experimental layout of the original experiment with the thesis experiment plots superimposed as indicated and described in the text.



quarter corner (small plot) was randomly identified along the access side of the large plot.

Where a reversal treatment was involved there were two small plots identified within each large plot. The overall layout is illustrated in Fig. 3.1.

The small plots (36' x 24') were in turn divided into 54 permanent sub-plots of approximately 8' x 2', separated into three rows by four equally spaced tapes strung the length of the small plots. The sub-plots were located by markers spaced at 2 ft intervals along the tapes, enabling their identification. Individual sub-plots were selected for each sampling from a randomised table of the 54 subplots, thus enabling the identification of destructively sampled areas so that they could be avoided for future sampling.

Table 3.1. Treatments Used and Their Identification

Main Experiment.

DEFOLIATION TREATMENT	VARIETY		PREVIOUS TREATMENT
	C*	W*	
3" Mean shoot height	3C	3W	Same
9" " " "	9C	9W	"
15" " " "	15C	15W	"
Hay, one tenth bloom	HC	HW	"
3" Mean shoot height	3RC**	3RW	Hay stage
Hay, one tenth bloom	HRC	HRW	3" height

Reversal Experiment.

3C, HC, 3RC, HRC. 3W, HW, 3RW, HRW.	Regrown for two weeks after the completion of the main experiment.

* C, Chanticleer. W, Wairau. ** R, a reversal treatment.

3.3. The Experimental Site:

The site of 5 acres at Massey University, Palmerston North, was very slightly terraced with good northerly aspect, except for a portion of replication 1. This was partly shaded in the late afternoon by a row of trees on the western and north-western boundaries. To minimise any related adverse effects, the closest small plots were located away from the trees in their large plots (Fig. 3.1.).

In a previous experiment, Tsuma (1968) described the soil type of the site after Pollok (1967). "The soil is an Ashhurst shallow silt loam, formed on the Intermediate Terrace. The top soil is a 3" to 5" deep free draining silt loam. The sub-soil is a gravelly loam extending to a depth of about 16", below which occurs ferruginous loamy coarse gravel to a depth of 60" or more. The drainage of the last group is slightly imperfect due to compaction in this zone." There was some soil variability, mostly in respect to the depth of top soil. Any influence this may have had on the experiment was assumed to have been accounted for by the replications.

3.4. Measurements and Methods:

These are introduced at this stage as a summary; individually they receive full consideration in the subsequent relevant chapters.

1. Measurement of sward production, composition and persistence for each treatment using quadrat sampling, botanical analysis, point analysis and plant number counts.

2. The amount and composition of the first regrowth on an individual plant basis, obtained from the disection of randomly dug plants sampled at each of the relevant cardinal growth stages. Growth analysis of the shoot growth. The numbers and length growth of individually identified shoots measured weekly in the field.

3. The rates and amounts of whole shoot senescence on the dissection and field identified plants. The leaf canopy dimensions during growth and associated leaf senescence rates. Measurements of sward physiognomy from stratified leaf area estimations were compared with the associated light transmission profiles.

4. The organic reserves of total non-structural carbohydrates and total nitrogen were measured in the crowns and top 15 cm. of the tap root. This was done at weekly intervals for selected treatments during the first spring growth, and in association with some secondary studies.

5. Short interval temperature recordings ($\frac{1}{2}$ hr) made during the first 6 weeks were related to the associated shoot growth.

6. The reversal experiment shoot growth was measured with three weekly quadrat samplings and associated with measurements of the lucerne shoot growth composition and organic reserve levels.

7. A combined discussion of the relevant varietal differences

and similarities.

3.5. Statistical Analysis:

Conventional analyses of variance (ANOVA) and regression were calculated as required using a computor program made available by Professor R.E. Munford using Massey University's IBM 1620 computor facilities. For the ANOVA, a fixed effects model was used (3F.1.), the replication (a) interactions being incorporated into the error term (Snedecor and Cochran, 1968).

$$X_{ijk} = u - a_i + b_j + c_k + (bc)_{jk} + e_{ijk} \qquad (3F.1.)$$

With some data, square root or logarithmic transformations were used to normalise it before ANOVA. An indication of which to use was obtained from frequency distributions of the data in each form, determined by using a program written for this purpose (appendix 5A.4.). Percentage data was transformed to the arcsin form.

Missing observations were determined using the least squares method (Snedecor and Cochran, l.c.).

When the ANOVA was significant at the 5% lower level, the treatment means were compared using the method of Least Significant Difference (LSD) (Snedecor and Cochrane, l.c.), with the formula 3F.2.

$$L\ S\ D = \sqrt{\frac{2(EMS)}{n}} \cdot (t_{0.05} \text{ or } t_{0.01}) \qquad (3F.2.)$$

where:

EMS = ANOVA error mean square

n = number of observations contributing to each compared mean

t = studentised t-value at the 5% or 1% level.

Significant data means are presented with the level of ANOVA significance, the LSD values at 5% and 1% levels, and with significant LSD differences between means being indicated by different letters. The variability of each ANOVA is indicated by its within group standard error (SE) (i.e. for the replication values), and the associated ANOVA coefficient of variation, CV% (3F.3).

$$CV\% = \frac{\text{within group SE}}{\text{General Mean}} \qquad (3F.3)$$

For certain relationships, Multiple Regression analyses were performed to describe them. The individual plant growth data was analysed by comparing sets of such fitted curves (section 5.1.2.), which were fitted using a modified Multiple Linear Regression analysis program provided by the Massey University compuţor unit (appendix 5A. 2.).

3.6. Climatic conditions During the Experiment:

The daily mean temperatures (max + min/2) were obtained from the Grasslands Division Meteorological Station, D.S.I.R., located approximately one mile away. Daily rainfall records were taken from the Massey University Meterological Station located about 400 yards from the site. Daily levels of incident solar radiation were obtained from the records of the plant Physiology Division, D.S.I.R., also located approximately one mile away These records are illustrated in Fig. 3.2, the data being tabulated in appendix 2A.

Temperatures during the period were characterised by a slow increase within the fluctuating range of 10 - 13°C until a significant rise to 15 - 17°C in early November. There was a notable cold period in the last week of August (mean of 8°C).

Rainfall tended to be sparce throughout the experiment with no heavy falls being recorded. Drier spells occurred between the 17/9 and the 6/10 (29 days with 17 points) and after three weeks with 144 points, between the 27/10 and the 22/11 (26 days with 05 points).

There was a trend of increasing daily solar radiation levels throughout the experimental period. The mean November level was 2½ times that for August.

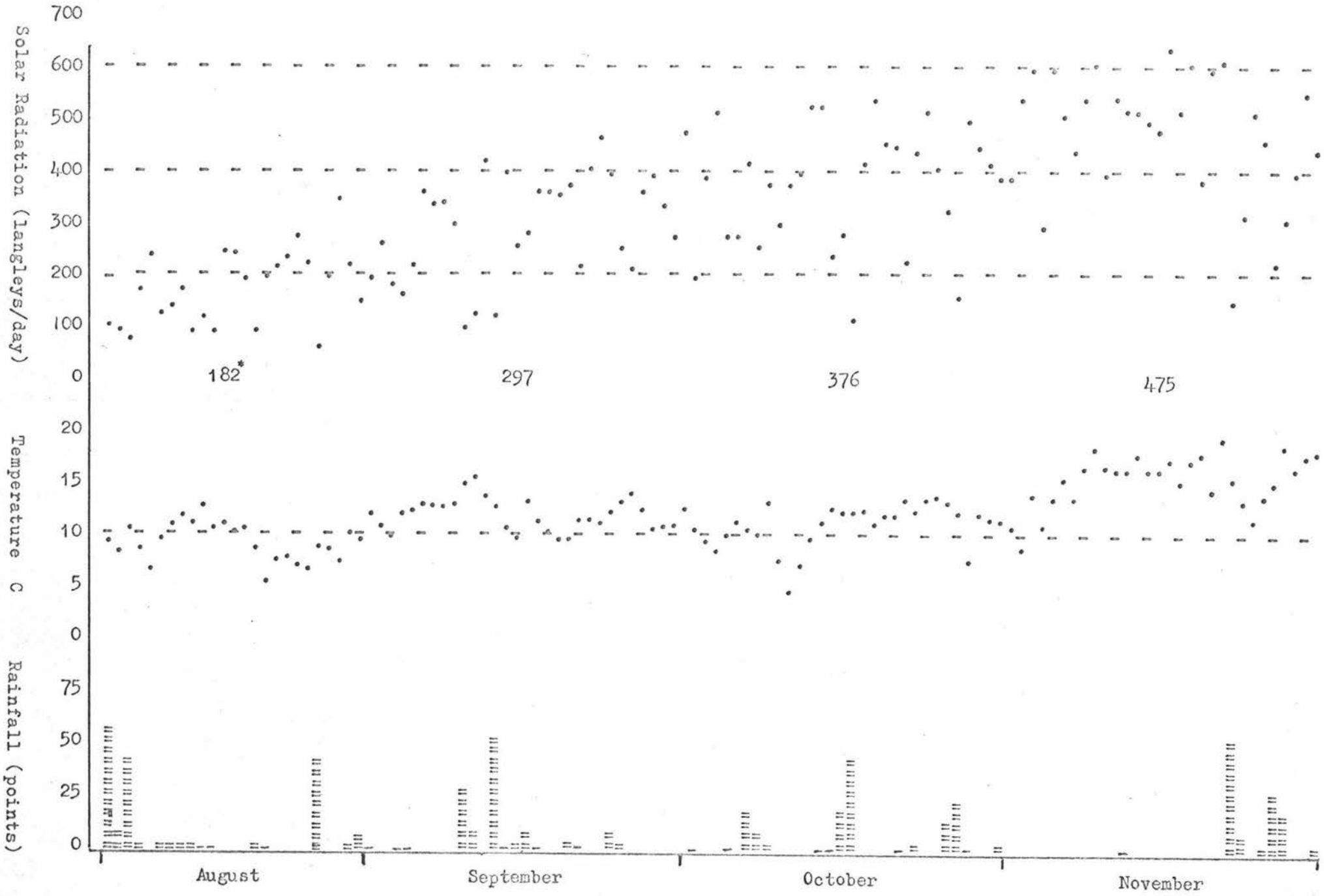


Fig. 3.2. Daily Climatic Parameters

* Monthly means.

CHAPTER 4

CROP PRODUCTION, COMPOSITION AND PERSISTENCE.

The spring shoot production of the selected treatments was measured for a three month period from August through to early November in 1969.

4.1. Method.

On the 7th. of August all plots were pre-trimmed to a common height of 4-6cm "intended" to provide a common basis for growth comparison (section 5.2.1.). A Gravely reciprocating mower was used for this purpose and all subsequent treatment defoliations. Each plot was cut twice, the second cut opposing that of the first to give a more uniform stubble. The plots were cleared of cut material by raking.

Production samples for each small plot were taken from three quadrats, each 2'x1' individually located on a randomly selected sub-plot. Production was measured as the top growth cut to ground level at time (2) less that cut to ground level at time (1); the latter cut immediately followed the pre-trimming or later treatment production cuts. To obtain these samples, electric sheep shears were used, enabling rapid ground level defoliation.

The three samples for each of the residual or production cuts were grouped, the total sample being dried in a forced draught oven at 80 C for 24 hours, after taking a representative sample for botanical analysis. This analysis involved separating the sub-sample into lucerne, other species, dead matter and soil, and then drying as above. Total dry weights of the various fractions were subsequently calculated. Work pressure sometimes required that these botanical sub-samples be held in a refrigerator for up to 7 days; no noticeable deterioration was observed.

The production cut times for each treatment were as outlined in table 4.1.

Some difficulty was experienced in estimating when a treatment was at the desired growth height for sampling or making production cuts (section 5.3.6.). Because of the time involved with regular measurements of a random sample of stems, and also because of a great variation of individual stem heights in each plot also noted by Keoghan (1970), an arbitrary height criterion was used, viz, when approximately 50% of the stems in front of a 20" wide stand of the prescribed height were judged to be equal to or higher than this height (plate 4.1.). At each time of measurement six readings were taken on each small plot, the replication estimates being the average of the six readings

Plate 4.1. The method and stand used for estimating the mean shoot height of the lucerne crop. The lower cross piece was moved vertically to provide the required height.

Table 4.1. Production Cut Schedule.

Chanticleer						Wairau					
3	3R	9	15	H	HR	3	3R	9	15	H	HR
Pre-trimmed 7/8						Pre-trimmed 7/8					
					21/8* (14)						2/9 (26)
4/9 (28)						8/9 (32)					
		14/9 (38)						20/9 (44)			
					20/9 (12)	2/10 (24)					2/10 (16)
24/9 (20)									5/10 (59)		
			29/9 (53)								20/10 (18)
					5/10 (15)	23/10 (21)					
17/10 (23)								29/10 (39)			
					20/10 (15)						5/11 (16)
		23/10 (39)								7/11 (92)	
29/10 (12)						10/11 (18)					
					29/10 (9)		11/11 (96)	11/11 (13)	11/11 (37)		
				5/11 (90)							
10/11 (12)	10/11 (95)				10/11 (12)						
		11/11 (19)	11/11 (43)								
5**	1	2½	2	1	7	4	1	2⅓	2	1	5

*21/8 - the date of harvest.

(14) - the days of growth.

** The number of harvests.

per small plot, which were in turn averaged over the three replications.

Because of the lateness of flowering in the hay crops, the H treatments were cut at first flower instead of one-tenth flower. As the 3R treatments were later flowering, it was decided to cut these four days after the H treatments. Final production cuts were made at the same time for all the other treatments so as to complete this part of the experiment.

The botanical composition results were supplemented by a point analysis study of the initial stubble on the 11th. of August, taking 60 points per plot. Hits of lucerne, bare ground, weeds, clover and grass were recorded. A three point vertically orientated instrument was used.

On the 8th. of August, plant population counts were made for each treatment. To do this, it was necessary to dig the plants up until their tap roots were visible as their crowns were often unidentifiably intermingled. Six 1'x1' quadrats were sampled for each replication. On the 14th. of November the counts were repeated for the 3", 3R, HR and H treatments.

It should be noted that up until the first 3" treatment cuts were made for the 3 and HR treatments, the 3 and 3R and the H and HR treatments were respectively identical.

The analysis of yields was confined to the cumulative production of each treatment for the length of the experiment. Individual harvest yields and crop growth rates (CGR)* within treatments were used where pertinant to help explain the cumulative results. Statistical analysis of this, point analysis and plant population data was by standard ANOVA (section 3.5.). Point analysis data was analysed using the raw figures, as all plots had the same total of 60 points measured. The more usual use of Relative Frequency, was in this case considered to provide little further advantage.

4.2. Results.

4.2.1. Cumulative production.

The different defoliation frequencies had little effect on the cumulative total production. Treatment differences were not significant (table 4.2., fig. 4.1.). As varietal differences were not significant, treatment effects are considered as the combined varietal response.**

In contrast, the cumulative production of both the lucerne and other species resulted in significant treatment differences ($P = 0.01$), but again with no significant difference between varieties (tables 4.3., 4.4.). The yields of lucerne and other species showed a strong reciprocal relationship within each treatment and less completely between treatments, as can be

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* $CGR = \frac{W_2 - W_1}{t_2 - t_1}$ W_2 and W_1 are the growth at times t_2 and t_1 respectively.

** Where applicable, this approach has been followed in other analyses.

readily seen from figs. 4.2. and 4.3.

Table 4.2. Cumulative Total Production. (gm/6 sq ft)

	C + W	Statistics
3	280.53	Varieties NS
3R	254.96	Treatments NS
9	267.72	
15	325.58	SE. 64.22
H	225.35	CV% 24.00
HR	250.71	

Appendices: Data 3A.4.2. Statistics 4A.4.1.

Table 4.3. Cumulative Other Species Production. (gm/6 sq ft)

	C + W	Statistics
3	211.78 a*	Varieties NS
3R	197.73 a	Treatments 1%
9	112.34 b	
15	75.04 bc	SE. 55.24
H	37.17 c	CV% 44.70
HR	107.14 b	

LSD for treatments 60.25 (5%) and 81.88 (1%).

* Means are compared at the 5% level.

Appendices: Data 3A.4.2. Statistics 4A.4.1.

This relationship is largely responsible for the similarity of the total yields between treatments. Within the reciprocating relationship, the expected significant treatment groupings arose (tables 4.3., 4.4.; section 2.3.1.1.). Generally, the more frequent the pre-experiment and current defoliation, the lower the lucerne yield and inversely the greater the yield of the other species. The exception to this was the significantly greater lucerne yield of the 15" compared to the H treatment, while the other species yield was in the same treatment sequence.

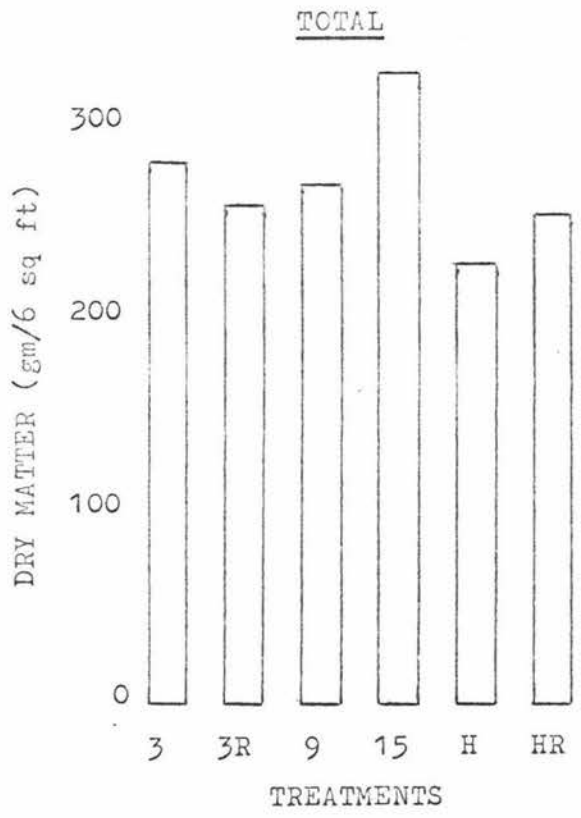
Treatment comparisons of cumulative yields with varieties combined.

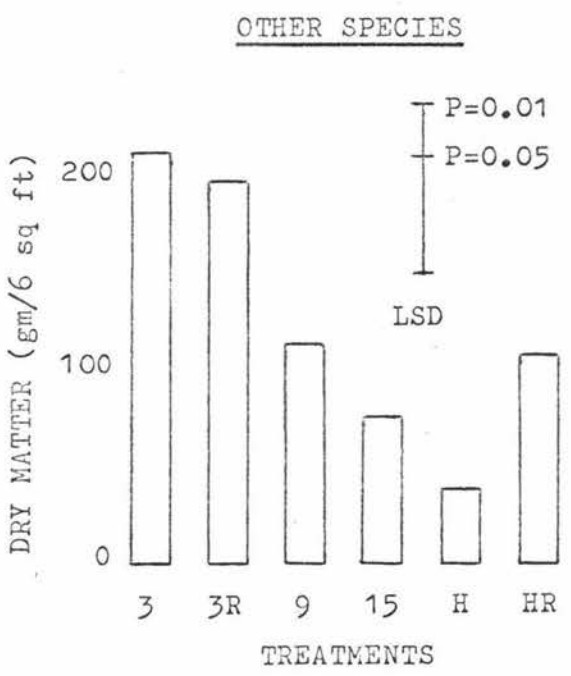
Figure 4.1. Total yield. (top left)

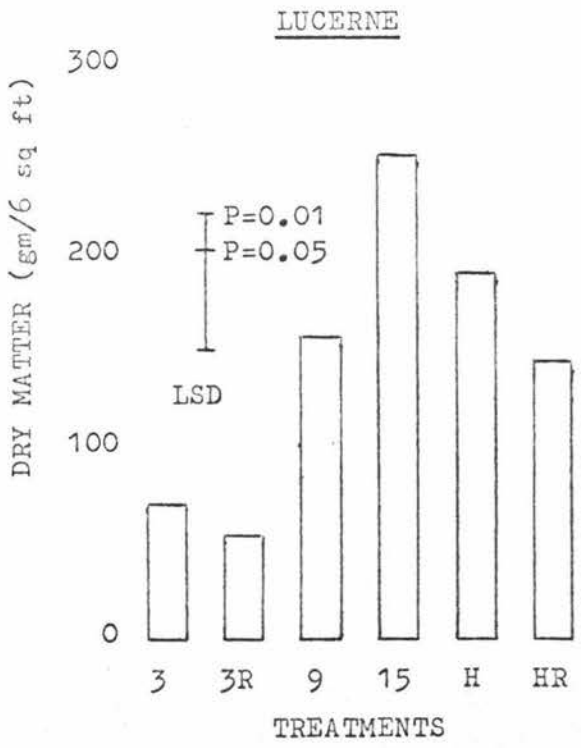
Figure 4.2. Other species yield. (top right)

Figure 4.3. Lucerne yield. (bottom left)

Figure 4.4. Percentage of lucerne. (bottom right)


TOTAL
DRY MATTER (gm/6 sq ft)
300
200
100
0
3
3R
9
15
H
HR
TREATMENTS


OTHER SPECIES
DRY MATTER (gm/6 sq ft)
P=0.01
P=0.05
LSD
200
100
0
3
3R
9
15
H
HR
TREATMENTS


LUCERNE
DRY MATTER (gm/6 sq ft)
300
200
100
0
P=0.01
P=0.05
LSD
3
3R
9
15
H
HR
TREATMENTS

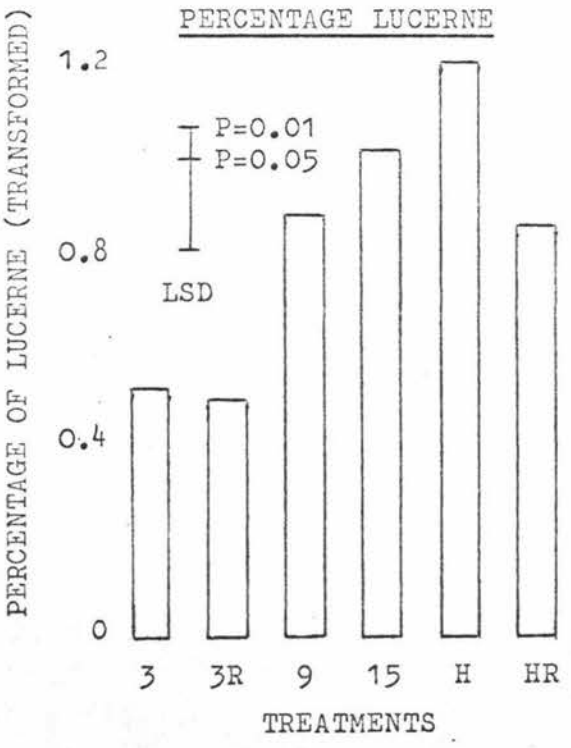

PERCENTAGE LUCERNE
PERCENTAGE OF LUCERNE (TRANSFORMED)
1.2
0.8
0.4
0
P=0.01
P=0.05
LSD
3
3R
9
15
H
HR
TREATMENTS

Table 4.4. Cumulative Lucerne Production.(gm/6 sq ft)

	C + W	Statistics
3	68.75 a*	Varieties NS
3R	57.22 a	Treatments 1%
9	155.37 b	
15	250.53 c	SE. 47.18
H	188.18 b	CV% 32.80
HR	143.12 b	

LSD for treatments 52.07 (5%) and 70.77 (1%).

* Means are compared at the 5% level.

Appendices: Data 3A.4.2. Statistics 4A.4.2.

On a relative basis though, the percentage of lucerne in the cumulative totals followed a regular and significant pattern between treatments, increasing with decreasing defoliation frequency (table 4.5., fig. 4.4.).

Table 4.5. Cumulative Lucerne Percentage.

	C	W	C + W	Statistics
3	0.449** (19.40)***	0.571 (29.80)	0.510 A*(24.50)	Varieties NS
3R	0.384 (16.40)	0.593 (30.80)	0.488 A (22.45)	Treatments 1%
9	0.943 (65.75)	0.805 (51.30)	0.874 B (58.10)	
15	0.970 (74.00)	1.108 (78.20)	1.039 BC(77.00)	SE. 0.165
H	1.305 (90.60)	1.084 (77.00)	1.194 C (83.60)	CV% 20.00
HR	0.752 (47.00)	0.947 (65.50)	0.849 B (57.20)	

LSD for treatments 0.189 (5%) and 0.257 (1%).

* Means are compared at the 1% level.

Arcsin transformed. * Natural.

Appendices: Data 3A.4.2. Statistics 4A.4.2.

The results of the reversal treatments, 3R and HR, are considered and discussed in chapter 9 where this aspect is considered in full.

4.2.2. Botanical composition.

The general reciprocal relationship between the yield of lucerne and that of the other species has been shown in section 4.2.1. This relationship is supported by the significant (P = 0.01) point analysis results recorded in the first week of the thesis experiment (tables 4.6., 4.7., fig. 4.5.). These latter results indicate the residual effect of the pre-experiment treatments and also support the production responses of these continued treatments during the thesis experiment.

Table 4.6. Point Analysis Record of Lucerne.

	C	W	C + W	Statistics
3	6.33	7.00	6.66 aA*	Varieties 1%
9	9.33	13.00	11.16 bAB	Treatments 1%
15	11.33	20.66	16.00 cBC	
H	16.00	22.66	19.33 cC	SE. 1.338
Av.	10.75 M	15.83 N		CV% 10.05

LSD for varieties 3.05 (5%) and 4.24 (1%).
LSD for treatments 4.32 (5%) and 5.99 (1%).
* Means are compared at the (a) 5% and (A) 1% levels.
Appendices: Data 3A.4.3. Statistics 4A.4.3.

Table 4.7. Point Analysis Record of Other Species**

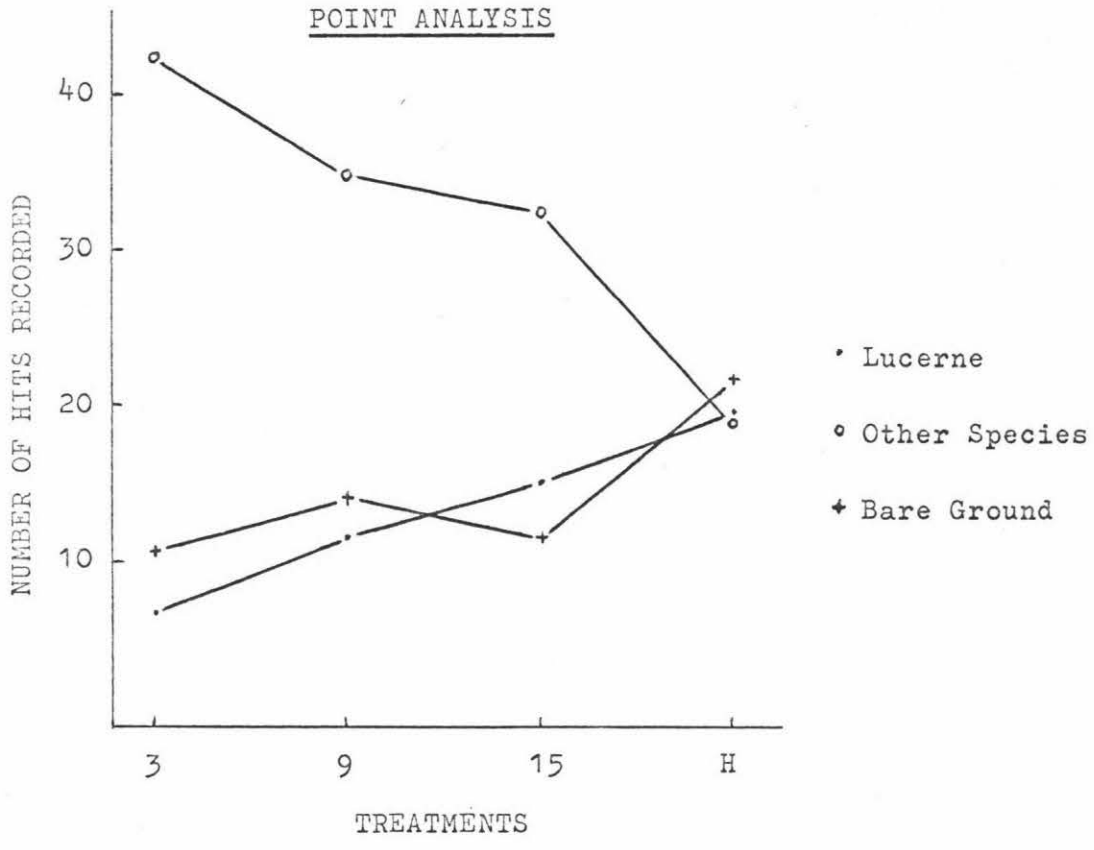
	C + W	Statistics
3	42.50 a*	Varieties NS
9	34.66 b	Treatments 1%
15	32.16 b	SE. 3.910
H	18.83 c	CV% 12.20

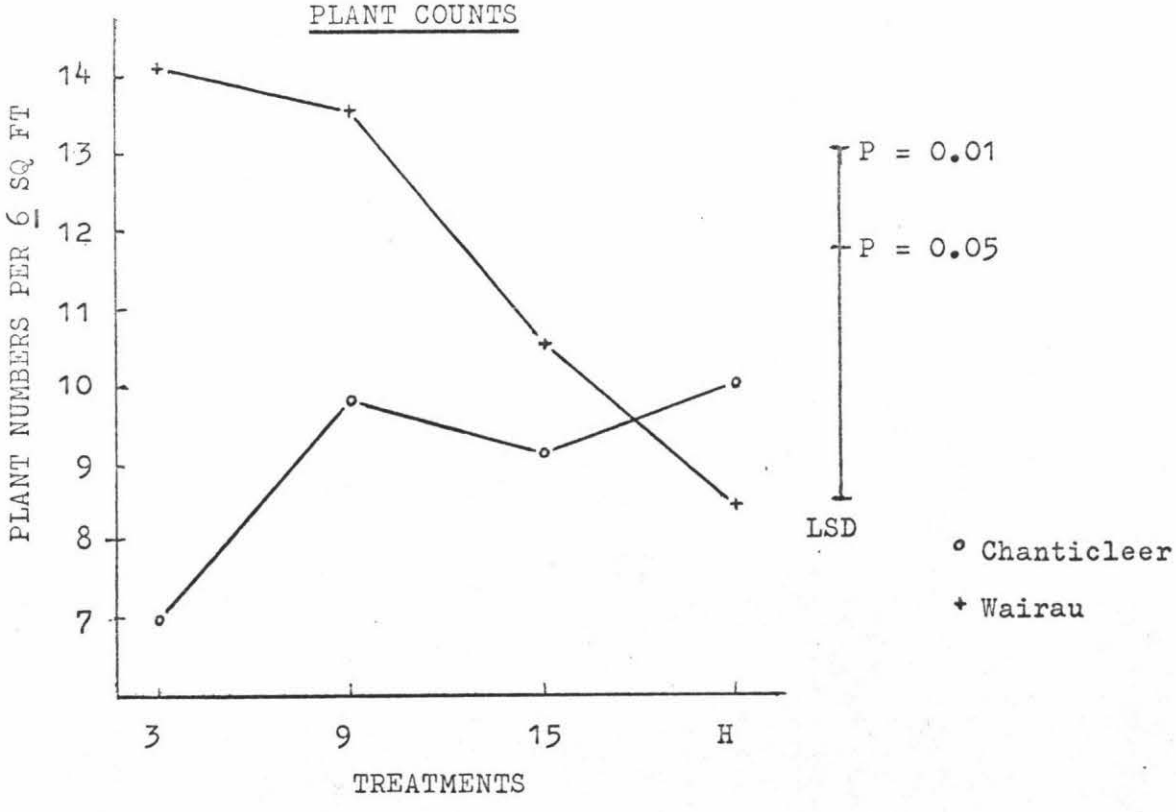
LSD for treatments 7.56 (5%) and 10.50 (1%).
* Means are compared at the 5% level.
Appendices: Data 3A.4.3. Statistics 4A.4.3.

** The point analysis record of other species is the added records of the grasses,clovers and other weeds.

Figure 4.5. A treatment comparison of the point analysis record for lucerne, other species and bare ground. Varieties were combined.

Figure 4.6. The interaction of varieties with treatments for the plant counts made at the commencement of the experiment.


POINT ANALYSIS
NUMBER OF HITS RECORDED
40
30
20
10
3
9
15
H
TREATMENTS
Lucerne
Other Species
Bare Ground


PLANT COUNTS
PLANT NUMBERS PER 6 SQ FT
14
13
12
11
10
9
8
7
3
9
15
H
TREATMENTS
P = 0.01
P = 0.05
LSD
Chanticleer
Wairau

Apart from the H treatment, the amount of bare ground recorded was similar for all treatments; the H treatment being significantly greater (P = 0.05) (table 4.8.), particularly for the Chanticleer variety. This had a significantly greater (P = 0.05) value. The greater H treatment value arose from a lower other species record associated with little lucerne increase (fig. 4.5.).

Table 4.8. Point Analysis Record of Bare Ground.

	C	W	C + W	Statistics
3	11.33	9.66	10.50 a*	Varieties 1%
9	15.66	12.33	14.00 a	Treatments 1%
15	13.33	10.00	11.66 a	
H	28.33	15.33	21.83 b	SE. 3.86
Av.	17.16 m	11.83 n		CV% 26.60

LSD for varieties 3.64 (5%) and 5.06 (1%).
LSD for treatments 5.16 (5%) and 7.16 (1%).
* Means are compared at the 5% level.
Appendices: Data 3A.4.3. Statistics 4A.4.3.

Between the other species, the grass records (table 4.9.) were significantly different between treatments (P = 0.01), this being the main factor responsible for the other species response (table 4.7.). Clover records showed a similar trend, having significant differences (P = 0.05) between treatments (table 4.10.), while in contrast, the other weeds had no significant treatment differences (table 4.11.).

Table 4.9. Point Analysis Record of Grass.

	C + W	Statistics
3	21.00 a*	Varieties NS
9	16.16 ab	Treatments 1%
15	10.83 b	SE. 5.844
H	0.83 c	CV% 47.80

LSD for treatments 7.27 (5%) and 10.09 (1%).

* Means are compared at the 5% level.

Appendices: Data 3A.4.3. Statistics 4A.4.4.

Table 4.10. Point Analysis Record of Clovers.

	C + W	Statistics
3	6.50 a*	Varieties NS
9	4.00 ab	Treatments 5%
15	3.00 ab	SE. 3.77
H	0.16 b	CV% 110.00

LSD for treatments 4.34 (5%) and 6.03 (1%).

* Means are compared at the 5% level.

Appendices: Data 3A.4.3. Statistics 4A.4.4.

Table 4.11. Point Analysis Record of Other Weeds.

	C + W	Statistics
3	15.00	Varieties NS
9	14.50	Treatments NS
15	18.33	SE. 6.60
H	17.83	CV% 40.70

Appendices: Data 3A.4.3. Statistics 4A.4.4.

4.2.3. Lucerne Persistence.

The point analysis records for lucerne as a measure of persistence represent a combined measure of plant size (as indicated by crown size) and plant numbers. The results (P = 0.01) showed that at the start of the thesis

experiment more lucerne was present in those plots less frequently defoliated (table 4.8., fig. 4.5.).

Lucerne plant population counts taken at the beginning of the experiment showed no treatment effect for the combined varieties, but did show a very significant variety x treatment interaction (table 4.12.) which is illustrated in fig. 4.6. With a significance of 5% there were three treatment groupings; the 3W and 9W and the 3C treatments being at the high and low extremes respectively with the balance of the treatments being grouped between. In association, the varietal differences and the variety x treatment interaction were highly significant (P = 0.01).

Table 4.12. First Plant Number Count. (No./1 sq ft)

	C	W	C + W	Statistics
3	7.02 a*	14.19 c	10.61	Varieties 1%
9	9.81 ab	13.59 bc	11.70	Treatments NS
15	9.12 ab	10.53 b	9.82	Var x Treat 1%
H	10.05 ab	8.45 ab	9.52	SE. 1.50
Av.	9.00 M	11.70 N		CV% 14.50

LSD for varieties 1.62 (5%) and 2.25 (1%).
LSD for var x treat 3.24 (5%) and 4.51 (1%).
* Means are compared at the (a) 5% and (A) 1% levels.
Appendices: Data 3A.4.3. Statistics 4A.4.5.

In contrast, lucerne plant weights (root and crown) measured at the start of the thesis experiment (table 4.13.) were greater with decreasing defoliation frequency. This was significant at the 2% level, largely due to the greater H treatment weights.

Small reductions of plant numbers for the 3C, HC and HW treatments and a large (45%) reduction for the 3W treatment were revealed in the final counts. The overall difference between plant population counts was highly significant (P = 0.01) (table 4.14.). The significant variety x treatment interaction originated mostly from the 3W treatment decrease.

Table 4.13. Initial Root + Crown Weight. (gm/plant)

	C + W	Statistics
3	2.99 A*	Varieties NS
9	3.29 A	Treatments 1%
15	3.63 A	SE. 1.30
H	6.76 B	CV% 31.20

LSD for treatments 1.85 (5%) and 2.80 (1%).

* Means are compared at the 1% level.

Appendices: Data 3A.5.2. Statistics 4A.4.5.

Table 4.14. Comparison of the First and Second Plant Population Counts. (no./1 sq. ft.)

	C	W	C + W	Statistics
1*3	7.02	14.19	9.93 A**	Counts 1%
1 H	10.05	8.45		Varieties NS
2 3	6.00	7.55	7.24 B	Treatments NS
2 H	8.33	7.10		Var x Treat 1%
				SE. 2.034
				CV% 23.00

LSD for counts 1.61 (5%) and 2.24 (1%).

* 1 and 2 are the first and second plant counts respectively.

** Means are compared at the 1% level.

Appendices: Data 3A.4.3. Statistics 4A.4.6.
3A.9.3.

4.3. Discussion.

4.3.1. Production.

In the interpretation of many of the results of this chapter and some of those of later chapters, account must be taken of the two following effects:

1. the results represent the residual response to the previous treatments (appendix 1A.).

2. the results are representative of responses to the treatments applied during the thesis experiment.

Naturally these two aspects are closely related.

Within the confines of each aspect, two other factors provide some limitation to the interpretation of the measured cumulative production. Firstly, the pre-treatment defoliation was the cause of a direct loss from the removal of what winter growth there had been up to the 7th of August, and indirectly from the growing time lost during the re-establishment of active re-growth. The maximum height of lucerne growth at cutting ranged from 15-20 cm for the H treatments through to 4-8 cm for the 3" treatments. Although it would have been preferable to have measured and included this growth in the total lucerne production, it is probable that its omission was not statistically important, as it would have extended the established significant yield differences between treatments, except for that between the 15" and H treatments, which may have been slightly reduced (fig. 4.3.). The second factor is that the changing climatic parameters during the thesis experiment (section 3.6.) probably had a differential effect on the growth rates of the different species, dependent on the times of defoliation.

The increase of cumulative lucerne production with decreasing defoliation frequency, is completely in agreement with many other reports (section 2.3.1.1.) as also is the reciprocal decrease of other species growth (section 2.3.2.). In contrast, the general equality of the total cumulative production between treatments as diverse as those used, is unusual, and particularly in this case where the other species are all volunteer ones. This combination of total, lucerne and other species yields was very similar to the results for the first harvest of the previous year taken from the same treatments (appendix 1A., tables 1A. 1., 1A 2., 1A. 3.), as common growth period silage crops. These results may largely be explained by the growth of lucerne being restricted in the early spring by lower temperatures (see section 3.6.), associated with the more responsive growth of the grasses

and other volunteer species over this same period, giving them an initial competitive growth advantage (O'Connor 1967). This temperature restriction of lucerne growth was probably relatively proportional between treatments. In terms of total yield it would have been more so with decreasing defoliation frequencies because of the correlated increasing lucerne content. With the more frequently defoliated treatments and particularly the 3" and 3R treatments, the large other species content would have been expressing its competitive advantage.

The initially greater restriction of lucerne growth is exemplified by the individual harvest results of the 15" treatments. Both had lower C.G.R.'s and reasonably high percentages of other species in the first harvest, compared with much higher C.G.R.'s and a very low other species percentages in the second harvest (table 4.15.).

Table 4.15. The 15" Treatments' Crop Growth Rates and Yield Composition

	C	W
	Crop Growth Rates**	
HARVEST 1	1.333	2.353
" 2	3.345	3.990
	Percentage of Other Species	
HARVEST 1	48.7	35.0
" 2	5.6	2.6

** gm/6 sq ft/day

The much higher C.G.R.'s of the second harvest suggest a greater growth response to the warmer late spring temperatures (section 3.6.) with an associated strong competitive growth advantage over the other species. This effect would have been considerably enhanced by the higher October-November levels of solar radiation (section 6.3.). The high growth rates of the 15" treatments' second harvest explains their significantly greater cumulative lucerne yield over that of the H treatments (table 4.3., fig 4.3.); the C.G.R. of the latter treatment for the length of the experiment (one harvest), (table 4.16.) was of a similar order to that of the first harvest of the 15" treatments. The slower overall H treatment growth rates were also partly due to senescence losses during more advanced growth stages.

Defoliating earlier, using the appearance of new basal shoots as the defoliation criterion, would have limited these losses and led to closer equality of lucerne yield between the 15" and H treatments (section 5.3.6., 6.2.).

Although direct comparison of residual growth between all treatments could not be made because of the treatment design, that between the extreme treatments of 3R and H, having similar growth periods, were compared (table 4.16.). The CGR of the H treatment was significantly (P = 0.01) 3-4 times greater.

Table 4.16. Lucerne Crop Growth Rates** of the 3R and H Treatments

	C + W	Statistics
3R	0.598 A*	Treatments 1%
H	2.069 B	SE. 0.854
		CV% 64.00

LSD for treatments 0.811 (5%) and 1.229 (1%).
* Means are compared at the 1% level. ** (gm/6 sq ft/day)
Appendices; Data 3A.4.1. Statistics 4A.4.5.

If the thesis experiment had been continued for the full growing season it is expected thet the equality of yield between treatments would have changed to the usually reported situation of total yields increasing with decreasing defoliation frequency. With later harvests, warmer temperatures pemit faster overall and immediate post-defoliation growth rates as evidenced by the faster 15" second harvest crop growth rates. The resultant improved competitive ability of lucerne against other species results in the latters production being increasingly curtailed with decreases of defoliation frequency. The second crop of the previous year, also with a common growth period for all treatments, showed just this effect (tables 1A.4., 1A.5., 1A.6.). If drier conditions developed, this would, so long as not extreme, further favour the lucerne's summer dominance (section 2.2.). With sown grass species in association with lucerne the same seasonal response has generally recorded (O'Connor 1967).

It is concluded that the similarity of total production over a range of defoliation frequencies is a normal first spring growth response for well established lucerne stands growing in environments similar to that of Palmerston Norht.

4.3.2. Botanical Composition.

The restricting influence of decreasing defoliation frequency on the establishment of other species is clearly shown with the point analysis results (tables 4.7.-4.11., fig 4.5.): these being a record of the responses to the treatments of the previous year. The treatment gradient of the more permanent members of the other species, the grasses and clovers (tables 4.10., and 4.11.), probably largely resulted from their competition with lucerne for light. This would be initiated in the immediate post-defoliation period when the more frequently defoliated less vigorous lucerne plants have slower growth rates (Silva, 1968; Leach, 1968a; 1969a; Keoghan 1970; section 9.2.2.).

The balance of other species, the other weeds of table 4.12. were largely annual weeds, with a large compliment of winter growing species. Although having no significant treatment effect, these showed a slight interaction with the grass and clover results (tables 4.9., 4.10., 4.11.), indicating some inter-species competition and explaining the similarity of the other species results for the 9" and 15" treatments (table 4.7.). A combined effect of seasonal growth limitation and lucerne dominance of these other weeds in later harvests is probably an important reason for the reduced total growth of the other species growth recorded in these later harvests. Some replacement probably occurred with summer growing annuals, although these species changes were not confirmed experimentally.

The significantly greater competitiveness of the H treatment lucerne was expressed in the negligeable grass and clover content, and the resultant greater amount of bare ground (tables 4.10., 4.11., 4.9.). It is likely that later in the growing season a trend of increasing amounts of bare ground with decreasing defoliation frequency would develop as the other weeds were reduced as suggested above. Tsuma (1968) observed this end result in his experiment conducted during the summer months.

It is interesting that these results suggests the different grass populations between treatments (table 4.9.) probably represent the basic and most permanent other species response to the treatments used. This is probably being augmented in the warmer summer months by the clovers (table 4.10.), while the bare ground and other weeds probably tend to vary reciprocally. This may be typical of the species organization in lucerne stands established for some time, in this case 4 years, and is supported by similar results from a spring point analysis study of the same treatments the previous year (appendix 1A.; table 1A. 7.).

4.3.3. Lucerne Persistence.

It will have been observed that the measurements of lucerne residual persistence varied depending on what measurements were made (section 4.2.3.). Logically, measurements of plant size, in this case as weight, and plant numbers are most meaningful.

The trend of increasing plant weight (root and crown) with less frequent defoliation is in full agreement with many other reports (section 2.3.1.2.). Plant populations varied differently between treatments for each variety. The Chanticleer treatments responded in a manner suggesting decreasing ability to compete with other species with increasing defoliation frequency. This is the more usually reported situation (section 2.3.2; e.g. Dennis et al.; 1959; Cullen, 1967; Judd and Radcliffe, 1970) resulting in loss of vigour and the ultimate death of the weaker plants. Many of the above reports showed much larger population gradients over the defoliation frequencies used. In contrast, the response of the Wairau treatments additionally suggest inter-lucerne plant competition at low defoliation frequencies, and a greater ability to persist as small plants in the face of other species competition. The possibility of natural autumn seeding is unlikely, as the more frequently defoliated treatments were not permitted to flower the previous season.

A general equality of plant numbers between treatments of different defoliation frequencies was recorded by Gross et al., (1958), supported by reports of lack of correlation between shoot yield and stand density (Willard, 1931; Feltner and Massengale, 1965). The plant number distribution of the Wairau treatments is completely unusual. This varietal difference is expanded upon in chapter 10. The combination of plant sizes and numbers in the Wairau treatments, as compared to the Chanticleer treatments, indicates how in these circumstances point analysis measuring the amount of lucerne cover present, does not give reliable information on the "nature" of the lucerne's persistence. Plant numbers aside, comparison of the lucerne point analysis (table 4.6.) with the crown and root weights (table 4.14.) suggests some treatment interaction, in that for the 9" and 15" treatments root and crown weights decreased proportionately greater than crown size (spread). This suggestion is supported by the low significance of the regression between these two variables, $P = 0.25$, $r = 0.33$ (table 4A. 4.). At the same time though, comparison of the point analysis results of the thesis experiment (table 4.6.) with similar results of the previous spring (table 1.A. 7.), demonstrates that crown area and hence persistence was reduced in the more frequently defoliated treatments.

In previous years, all treatments were spelled with two hay harvests being taken in the spring and early summer. This has probably been important in helping to maintain the reasonably high populations of lucerne plants present for all treatments at the start of the thesis experiment. This was an approximate average of 10 plants/sq. ft. compared for example to 4-6/sq. ft. on irrigated 3 year lucerne (Judd and Radcliffe, 1970), and 5.4 to 7.7 plants per a foot of row alternately spaced with cocksfoot on 7" spaced rows (Cullen, 1967.). The decrease of plant numbers during the thesis experiment, especially for the 3" treatments (table 4.15.) supports the probable benefits of spelling frequently defoliated lucerne in the spring.

It appears as though the similarity of plant populations recorded resulted from the effects of different processes; these originating from higher first established populations. Inter-lucerne plant competition probably dominated in the H treatments, evidenced by the presence of some very small plants in these plots (section 5.2.2.). In the 3" treatments, the weakening effects of frequent defoliation and associated increasing other species competition, were probably most influential. The results of the 9" and 15" treatments are expected to represent a combination of these effects.

CHAPTER 5

THE EFFECT OF DEFOLIATION FREQUENCY ON THE AMOUNT AND NATURE OF LUCERNE PLANT GROWTH

Individual lucerne plants were sampled at intervals during the growth of the first harvest of each treatment. These plants were dissected according to their macro morphology, to enable a study of the growth of these components, their growth rates, the whole plant's growth form and its development. These results were supplemented by *in situ* measurements of identified shoot growth in the field.

5.1. Methods.

5.1.1. Experimental.

Within each treatment, plants were sampled at intervals concurrent with the average growth of the treatment (for the determination of see section 4.1.) attaining each of the cardinal treatment heights, the last sampling coinciding with the production harvest cut of the particular treatment. Since the sampling times were based on the physiological criterion of shoot height, common sampling growth stages between treatments and varieties did not coincide in time, and this presented statistical problems (section 5.1.2.). It was found necessary to discontinue the 9W and 15W treatments early in the study so as to ease the work load to manageable proportions. Some early measurements made before discontinuing these treatments have been referred to. This procedure resulted in further statistical complications (section 5.1.2.). It should be noted that the 3" sampling of the 3R and H treatments were fully representative of the 3" and HR treatments respectively, as the respective plots had identical treatments prior to the thesis experiment. The sampling schedule of the treatments used are summarised in table 5.1.

The sampling procedure on each occasion involved taking six plants from each small plot of each replication. Within each of these small plots two plants were taken from each of three sub-plots (section 4.1.). Individual plants were identified prior to digging as that plant nearest the end of a 2 ft long batten dropped at random at each end of each sub-plot. Plants were dug with a drainage spade (10 cm wide blade) so as to take at least 15 cm of root below the cotyledonary node. This procedure, in association with the

Table 5.1. The Schedule of Plant Sampling.

Growth	Treatments											
Stage	3RC		9C		15C		HC		3RW		HW	
RD	8/8*	0**	8/8	0	8/8	0	8/8	0	8/8	0	8/8	0
4"	4/9	27	31/8	23	26/8	18	21/8	13	8/9	31	2/9	25
9"	22/9	45	14/9	37	11/9	34	9/9	32	25/9	48	15/9	38
15"	9/10	61	-		28/9	51	25/9	48	15/10	67	28/9	51
15/H	-		-		-		15/10	67	-		15/10	67
H	10/11	93	-		-		5/11	88	11/11	94	7/11	90

* The date of sampling.

** The days of growth.

stony nature of the soil resulted in only the tap root and main lateral roots being obtained intact. The plants were removed from the field and all the soil washed from the roots which were trimmed to 15 cm length below the cotyledonary node. They were then stored in plastic bags in a refridgerator until dissected. It was assumed that between plants the tap root was proportionately representative of the total root weight (Nelson and Smith, 1968a, b; Smith and Silva, 1969; Ueno and Smith, 1970; Smith and Marten, 1970). The validity of the procedure has been discussed (section 2.4.1.1.).

Each plant was dissected into the root, crowns, stubble and complete shoots greater than 1 cm long.* The root and crowns were divided at the cotyledonary node, and the crowns and stubble at the soil level when-ever their individual identification was difficult. The seperation of the shoots into stubble and basal shoots (Leach, 1968a; Keoghan, 1970) was unsuccessfully attempted (see discussion 5.3.1.) and hence only the total shoot growth is considered. New basal shoots* arising in mature growth were separated out and counted. A sub-sample of each of the main shoots and new basal shoots, when present, was sub-divided into leaf and stem, the latter including the petioles; the length of these shoots was measured and the total leaf and stem were then calculated from this basic data. All plant parts were dried on trays in a forced draught oven at 80 C for 24 hours. At times, whole plants were held in the refrigerator for up to 7 days due to the pressure of work. Deterioration was not noticeable, although some respiratory losses may have

* These were not separated into buds and shoots (Nelson and Smith 1968a).

occurred. It is likely though, that these were of small significance when the large plant size variability in all treatments is considered (section 5.2.2.)

To make the *in situ* field growth measurements which were confined to the Chanticleer 3R, 9", 15" and H treatments, crown growths were randomly located within three sub-plots, one at each end giving six locations for each small plot. These were marked out by permanently placed white plastic coated wire rings of 10 cm diameter, placed immediately after the pre-treatment defoliation (plate 5.1.). To permit observation in the frequently defoliated 3R treatment,it was necessary to remove a small amount of other species growth in the immediate vicinity of the crowns identified. It is considered that any competitive advantage to these plants was small in view of the slow lucerne growth rates that were measured in the first two to three weeks.

Commencing on the 15th. of August and thereafter at weekly intervals for the duration of the experiment, all new shoots arising within the ringed areas and being greater or equal to 5 cm length, measured to the shoot apex, were identified by placing split soft plastic rings about their bases (plate 5.2.). It was considered that shoots less than 5 cm long would probably be damaged if labelling was attempted. One in every five of the new shoots identified each week was labelled with a coloured ring in accordance with a colour code allotted to each week. The other shoots were identified with white rings. Each week the following measurements and records were taken: the total number of new shoots 5 cm or greater in length; the length of all colour identified shoots according to identification; the death of any of these latter shoots; the number of buds and shoots (not separated) less than 5 cm; the number of new basal buds and shoots in the more mature growth, but this time separately, the shoots in this case being identified as having at least one expanded leaf. As the marking wire rings were not randomly placed within the plots and further as the number of plants contributing to the encircled crowns could not be determined without disturbing the surrounding top layers of soil, shoot numbers could not be considered on an area basis and only as approximations on a single plant basis. Consequently they are considered within plant and between treatments as relative shoot numbers, *viz*, relative to the total number recorded for each treatment/replication combination).

Plate 5.1. Field crown growths located with plastic coated wire rings.

Plate 5.2. The identification of individual shoots using split soft plastic rings.

5.1.2. Statistical Analysis.

For each growth stage harvest, a separate analysis of variance (ANOVA) was calculated (section 3.5.), as the number of harvests varied between treatments. This was also without a direct variety comparison because of the uneven number of variety/treatment combinations (table 5.1.). Further, the computer programs available could not handle unequal sub-class numbers. This analysis did not take into consideration the treatment differences of varying growth periods for each sampled growth stage (table 5.1.).

To enable direct statistical comparison between treatments while incorporating this growth time factor, response curves were fitted for each treatment and each variable considered using replication means. In each case curves of the form -

$$Y = a_1 + a_2 t + a_3 t^2 \ldots\ldots\ldots\ldots\ldots a_i t^{i-1}$$

- were fitted, with in some cases the dependent variable, Y, having a square root or logarithmic transformation. The curve fitting was performed by standard Multiple Regression methods using modified Massey University Computer Unit library programs (section 5A.1.). The modifications enabled the sequential removal of the previous highest power of the independent variable after selecting up to a sixth power for the initial fitting. This range satisfied the fit of all curves tried. From this range, that of best fit was selected to represent each treatment's response on the basis of a standard F-test, the relative size of the standard error (SE) of estimate and the size of the coefficient of multiple determination.

The SE of estimate for the selected curve aas calculated in the program thus -

$$s_e = \sqrt{s_y^2 \, (1 - R^2)(N/(N - M))} \qquad (5F.1.)$$

where:

s_e = SE of estimate.
s_y = Standard deviation of the dependent variable mean.
R^2 = Coefficient of multiple determination.
N = Number of obsevations used to estimate the regression.
M = Number of variables including the dependent variable.

A number of values were selected at 14 day intervals for the independent variable. For each of these values the corresponding dependent variable values were calculated, this being done for all the fitted curves to be compared.

The SE's of these calculated values was obtained using the following formula (Snedecor and Cochran, 1968, pg. 392).

$$s_r = s_e \sqrt{1 + 1/N + c_{ii}x_i^2 + c_{jj}x_j^2 + c_{kk}x_k^2 + 2c_{ij}x_ix_j + 2c_{ik}x_ix_k + 2c_{jk}x_jx_k} \qquad (5F.2.)$$

where:

s_r = SE of the estimated value for the dependent variable.

c = Gauss Multipliers from the inverse matrix of the regression calculations.

$x_i = X_i - \overline{X}$ (i.e. X_i the selected independent value - $\overline{X}$ the mean of the observed independent values).

s_e, and N as in 5F.1.

The calculated values and their SE's were calculated using a further modification of the standard Multiple Regression program (section 5A.2.).

The calculated dependent variable values on each curve for a given selected independent variable value were compared for the significance of their differences.

To do this, a pooled variance from the SE's of these calculated values was determined as follows for each selected independent variable value.

$$s_p^2 = \frac{(N_1 - M_1)s_{r_1}^2 + (N_2 - M_2)s_{r_2}^2 \ldots\ldots + (N_i - M_i)s_{r_i}^2}{(N_1 + N_2 \ldots\ldots + N_i) - (M_1 + M_2 \ldots\ldots + M_i)} \qquad (5F.3.)$$

where:

s_p^2 = Pooled variance.

s_r, N and M are as in 5F.1. and 5F.2.

The comparison of the difference between pairs of calculated values was made with the method of the Least Significant Difference (LSD) using the pooled variance as the error term according to the formula (Steele and Torrie, 1960) -

$$LSD = t_{(0.01)(0.05)} \cdot s_p^2 (1/N_1 + 1/N_2) \qquad (5F.4.)$$

where:

t = Students two tailed t-test value at the required level of significance.

s_p^2 and N_i as in 5F.1. and 5F.3.

with degrees of freedom -

$$DF. = N_t - M_t$$

where:

$$N_t = N_1 + N_2 \ldots\ldots\ldots + N_i$$
$$M_t = M_1 + M_2 \ldots\ldots\ldots + M_i$$

A more conservative estimate of the significance of these comparisons was made using the Scheffé test which uses an F-test thus -

$$F = \frac{(Y_1 - Y_2)^2}{s_p^2 (1/N_1 + 1/N_2)(M_t - 1)} \qquad (5F.5.)$$

with degrees of freedom -

$$DF. = M_t - 1,\ N_t - M_t$$

where:

Y_i = A calculated dependent variable value.

s_p^2, N_t and M_t are as in 5F.3. and 5F.4.

Since there were different numbers of observations used to estimate each curve, the calculated values could only be compared in pairs. With several curves, all possible paired comparisons were made for each independent variable value selected (section 5.3.1.). A program aas written to make these comparisons and the estimation of the pooled standard error (section 5A.3.).

For other sections of this chapter, standard ANOVA and regression analyses were calculated (section 3.5.).

5.2. Results.

5.2.1. The Growth Yield of the Lucerne Plant.

5.2.1.1. Analysis by stage of growth comparison.

Reference was previously made to the difficulty of estimating the average shoot height (section 4.1.). This is discussed in section 5.3.6. In the first instance, ignoring this limitation and the harvest time differences between treatments, ANOVA analyses were made at each harvest and over all treatments for the various plant variables. The results are summarised in table 5.2. Frequency distributions which were calculated indicated the use of logarithmic transformations for the plant growth variables, while a square root transformation was used for shoot numbers.

Table 5.2. The Stage of Growth ANOVA Significances.

Plant Variable	Stage of Growth				
	RD	3"	9"	15"	H
Leaf+	2.5*(23.9)**	1.0 (26.6)	5.0 (21.0)	10.0 (21.6)	5.0 (32.4)
Shoot+	1.0 (24.8)	1.0 (15.7)	5.0 (18.0)	5.0 (17.8)	2.5 (21.0)
Stubble+	1.0 (24.3)	1.0 (14.0)	2.5 (27.2)	1.0 (24.6)	1.0 (18.5)
Plant+	1.0 (12.1)	1.0 (6.0)	5.0 (12.5)	5.0 (12.5)	1.0 (12.0)
Crown+	1.0 (21.6)	2.5 (16.9)	10.0 (23.4)	10.0 (23.5)	2.0 (23.2)
Root+	1.0 (13.3)	1.0 (10.6)	10.0 (14.8)	NS (16.3)	2.0 (14.6)
RT + CR+	1.0 (12.8)	1.0 (10.1)	10.0 (14.8)	NS (15.2)	2.0 (13.4)
Shoot No.++	1.0 (12.8)	1.0 (17.0)	1.0 (13.7)	2.0 (15.0)	1.0 (9.1)
	6***	6	6	5	4

* Percentage significance.
** Coefficient of variation.
*** The number of treatments compared.
\+ Analysis with logarithmic values.
++ Analysis with square root values.
Appendices: Data 3A.5.2.
Statistics 4A.5.1.

Treatment differences were significant over most harvests for each variable, but with a tendency to be less significant for the 9" and 15" harvests. All variables responded similarly. The significance of these results using the basic ANOVA supports the results to follow obtained from the less orthodox methods of analysis used (section 5.1.2.).

The following results are presented separately for each variable considered. It was found that a square root transformation of the shoot number data gave the best curve fit, untransformed for root (tap root plus crowns) weight and logarithmic transformation for the remaining variables. The curves, the pooled SE's for the selected time values and the observed dependent value treatment means (geometric[+]) are presented in the detransformed form. As it was found that the Scheffé F-test did not greatly improve the significance of the results, the interpretations are confined to the LSD method at the 1% significance level.

5.2.1.2. Plant leaf growth.

The treatment curves are presented in fig. 5.1. and the statistical results and calculated values in table 5.3. The six curves all fitted their data significantly with significant F values (P = 0.01) and R^2 ranging between 0.746 and 0.864 (fig. 5.1.).

Table 5.3. Comparison of the Leaf Weight Estimated Values. (gm/plant)

	Day 0	Day 14	Day 28	Day 42	Day 56	Day 70	Day 84
3RC	0.103*A**	0.194 AB	0.324 AB	0.476 A	0.616 A	0.704 A	0.708 A
3RW	0.126 A	0.151 A	0.260 A	0.495 A	0.811 AB	0.889 A	0.505 A
9C	0.172 AB	0.280 BC	0.478 BC	0.855 C	-	-	-
15C	0.118 A	0.300 BC	0.597 C	0.931 C	1.137 BC	-	-
HC	0.221 B	0.428 C	0.730 C	1.096 CD	1.452 C	1.694 B	1.742 B
HW	0.368 C	0.671 D	1.055 D	1.434 D	1.684 C	1.708 B	1.496 B
	0.173***	0.154	0.149	0.154	0.159	0.154	0.153

* The detransformed values of the estimates calculated from the logarithmic curves of leaf weight.

** Within each day, values are compared at the 1% level.

*** Pooled SE.

Appendix: Statistics 4A.5.2.

The most obvious observation between treatments is the significant difference (P = 0.01) between the 3R and H treatments at all stages of growth, while the 9" and 15" treatments were intermediary and in particular after day 28. The four full term treatments demonstrated typical sigmoidal shaped

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[+] For logarithmic transformed means.

Figure 5.1. The curves of leaf growth per plant were fitted to data for which the dependent variable had been transformed to logarithms. The curve formulae and the associated statistics are in the transformed form while the curves are presented in the de-transformed form.

1. 3RC $\text{Log } Y = 0.012 + 0.217t - 0.014t^2$
   $F = 17.66$ $R^2 = 0.746$ SE. of estimate 0.192 DF = 12

2. 9C $\text{Log } Y = 0.235 + 0.144t + 0.005t^2$
   $F = 18.27$ $R^2 = 0.858$ SE. of estimate 0.120 DF = 6

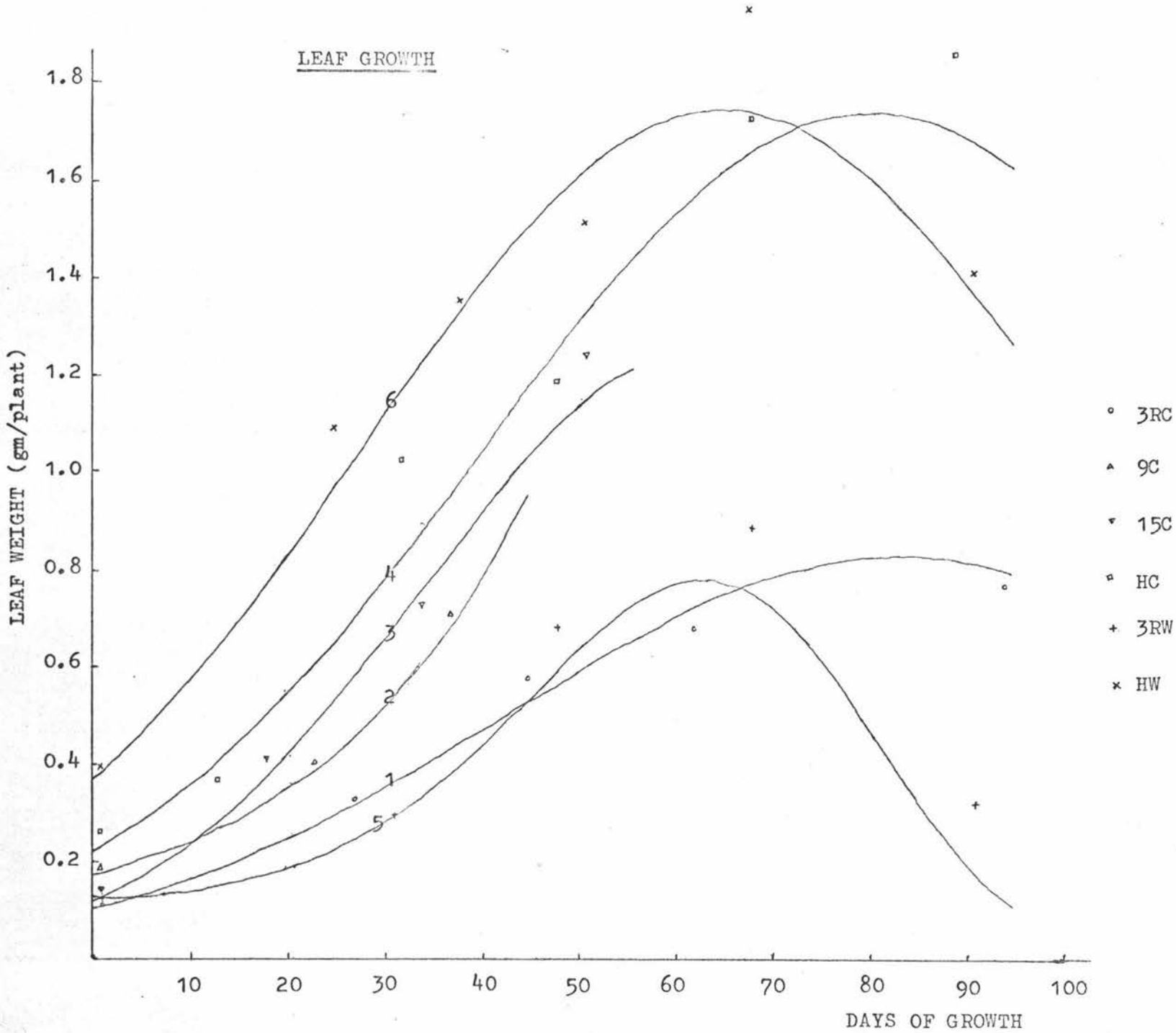
3. 15C $\text{Log } Y = 0.074 + 0.326t - 0.027t^2$
   $F = 19.31$ $R^2 = 0.811$ SE. of estimate 0.197 DF = 9

4. HC $\text{Log } Y = 0.345 + 0.224t - 0.014t^2$
   $F = 38.79$ $R^2 = 0.837$ SE. of estimate 0.154 DF = 15

5. 3RW $\text{Log } Y = 0.101 - 0.025t + 0.067t^2 - 0.006t^3$
   $F = 23.32$ $R^2 = 0.864$ SE. of estimate 0.138 DF = 11

6. HW $\text{Log } Y = 0.566 + 0.209t - 0.016t^2$
   $F = 20.24$ $R^2 = 0.729$ SE. of estimate 0.146 DF = 15

Appendix: Data 3A.5.2.


LEAF GROWTH
LEAF WEIGHT (gm/plant)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
10
20
30
40
50
60
70
80
90
100
DAYS OF GROWTH
6
4
3
2
1
5
3RC
9C
15C
HC
3RW
HW

curves attaining maximal leaf dry weight production, with this being achieved earlier for the Wairau treatments which followed these maximal levels with a greater nett loss of leaf.

5.2.1.3. Plant shoot growth.

The treatment curves are presented in fig. 5.2. and the statistical results and calculated values in table 5.4. The six curves all fitted their data significantly (P = 0.01) with R^2 ranging between 0.684 and 0.901.

Table 5.4. Comparison of the Shoot Weight Estimated Values. (gm/plant)

	Day 0	Day 14	Day 28	Day 42	Day 56	Day 70	Day 84
3RC	0.513*A**	0.673 AB	0.884 AB	1.162 A	1.526 A	2.004 A	2.631 A
3RW	0.638 AB	0.505 B	0.764 B	1.320 A	2.200 A	2.738 A	1.968 A
9C	0.521 A	0.829 AB	1.318 AC	2.098 B	-	-	-
15C	0.554 AB	0.918 A	1.519 CD	2.514 B	4.161 B	-	-
HC	0.878 B	1.396 C	2.120 D	3.075 B	4.257 B	5.628 B	7.104 B
HW	1.568 C	2.419 D	3.471 E	4.636 C	5.761 B	6.661 B	7.166 B
	0.160***	0.150	0.145	0.147	0.152	0.150	0.152

* The detransformed values of the estimates calculated from the logarithmic curves of shoot weight.

** Within each day, values are compared at the 1% level.

*** Pooled SE.

Appendix: Statistics 4A.5.3.

Basically the same treatment distributions and significances as shown with leaf growth, also occurred for shoot growth, the treatments being arranged in their defoliation frequency sequence.

As compared to leaf growth, only the 3RW treatment had a maximal growth level followed by a net loss of shoot dry weight. Of this loss 0.6 gm/plant was leaf and 0.9 gm/plant was non-leaf dry weight. Shoot growth of the HW treatment did not show any net loss, although levelling off in the latter growth stages to a near maximal level, highly significantly different from the 3RW maximum. IN contrast, both the Chanticleer 3R and H treatments,

Figure 5.2. The curves of shoot growth per plant were fitted to data for which the dependent variable had been transformed to logarithms. The curve formulae and the associated statistics are in the transformed form while the curves are presented in the detransformed form.

1. 3RC $\text{Log } Y = 0.710 + 0.084t$
   $F = 28.23$ $R^2 = 0.684$ SE. of estimate 0.193 DF = 13

2. 9C $\text{Log } Y = 0.717 + 0.144t$
   $F = 64.21$ $R^2 = 0.901$ SE. of estimate 0.079 DF = 7

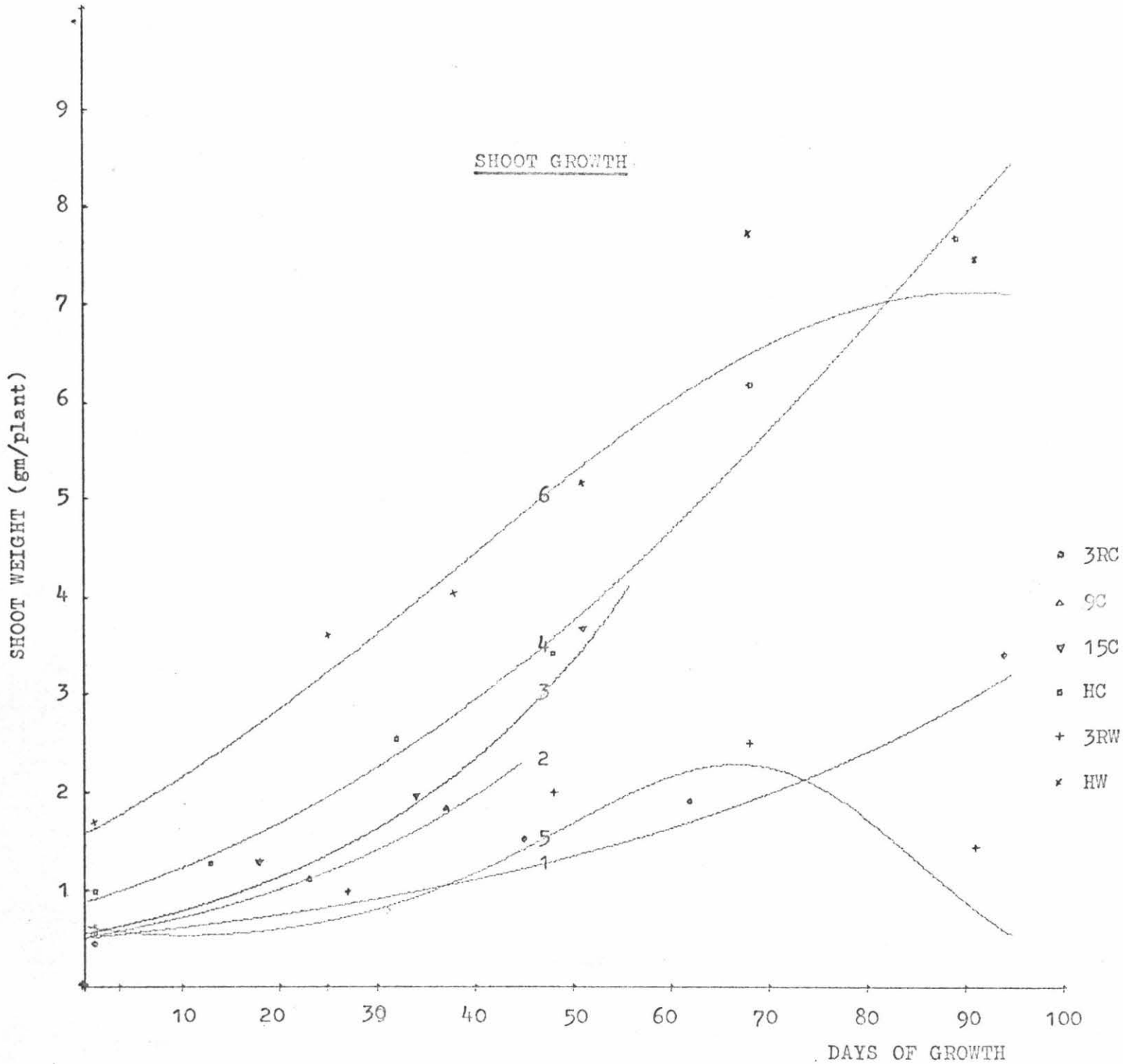
3. 15C $\text{Log } Y = 0.744 + 0.156t$
   $F = 29.85$ $R^2 = 0.749$ SE. of estimate 0.183 DF = 10

4. HC $\text{Log } Y = 0.943 + 0.151t - 0.005t^2$
   $F = 57.66$ $R^2 = 0.884$ SE. of estimate 0.127 DF = 15

5. 3RW $\text{Log } Y = 0.805 - 0.146t + 0.081t^2 - 0.007t^3$
   $F = 12.90$ $R^2 = 0.779$ SE. of estimate 0.139 DF = 15

6. HW $\text{Log } Y = 1.195 + 0.146t - 0.008t^2$
   $F = 22.16$ $R^2 = 0.747$ SE. of estimate 0.139 DF = 15

Appendix: Data 3A.5.2.


SHOOT GROWTH
SHOOT WEIGHT (gm/plant)
DAYS OF GROWTH
1
2
3
4
5
6
3RC
9C
15C
HC
3RW
HW

although together being significantly different, showed no tendancy to level off and attain a maximum production level. The associated cessation of net leaf dry weight gain resulted in a considerable degree of maintained non-leaf growth and hence an increasing stem/leaf ratio as illustrated in fig. 5.10. This continued growth of both treatments was shown to still occur after allowance had been made for the amount of new basal growth present in the final harvest (fig. 5.2.). Allowing for this in the HW treatment showed if anything, a decrease of mature shoot dry weight in the final harvest.

5.2.1.4. Plant root and crown growth.

All curves attempted for this data were poor fits. Those of best fit using the natural data are presented in fig. 5.3., but without associated statistical analysis. Transforming the data did not improve the fits.

Although not analysed, the shapes and relative positions of the presented curves are noteworthy because of:

1. The loss in weight of the roots and crowns for the first 20 days for the 3R treatments and 30-40 days and to considerably greater extents for the H treatments, this being followed by weight gains which continued longer for the Chanticleer treatments.

2. Again, the large overall difference between the 3R and H treatments.

3. The unexpected shapes of the 9C and more so the 15C curves, as compared to the more expected response of the other treatments (section 2.3.1.2.).

Freehand graphs of root and crown weight changes individually (fig. 5.9., 5.8.), indicate that a greater proportion of these weight changes were due to changes of root weights.

5.2.1.5. Total plant growth.

The treatment curves are presented in fig. 5.4. and the statisical results and calculated values in table 5.5. The fit of this set of curves was variable, although all but the 9C treatment fitted with a significance of $P = 0.05$ or better, 9C having $P = 0.20$. Apart from 9C, R^2 ranged between 0.316 and 0.703.

Figure 5.3. The curves of root plus crown weight changes per plant during growth were fitted to data in the natural form. Statistical comparisons were not made because of the poor curve fits. It was not possible to fit a curve to the 9C treatment data because of its variability.

1. 3RC $Y = 32.568 - 3.103t + 0.500t^2$
   $F = 2.713$ $R^2 = 0.311$ SE. of estimate 11.902 DF = 12

2. 9C No fitted curve

3. 15C $Y = 30.144 + 7.084t - 0.724t^2$
   $F = 1.421$ $R^2 = 0.240$ SE. of estimate 13.311 DF = 9

4. HC $Y = 58.078 - 8.237t + 1.298t^2$
   $F = 5.701$ $R^2 = 0.431$ SE. of estimate 17.946 DF = 15

5. 3RW $Y = 29.37 - 7.065t + 2.201t^2 - 0.163t^3$
   $F = 1.143$ $R^2 = 0.237$ SE. of estimate 6.133 DF = 11

6. HW $Y = 75.204 + 7.624t - 9.691t^2 + 2.158t^3 - 0.129t^4$
   $F = 2.607$ $R^2 = 0.445$ SE. of estimate 12.573 DF = 13

Appendix: Data 3A.5.2.

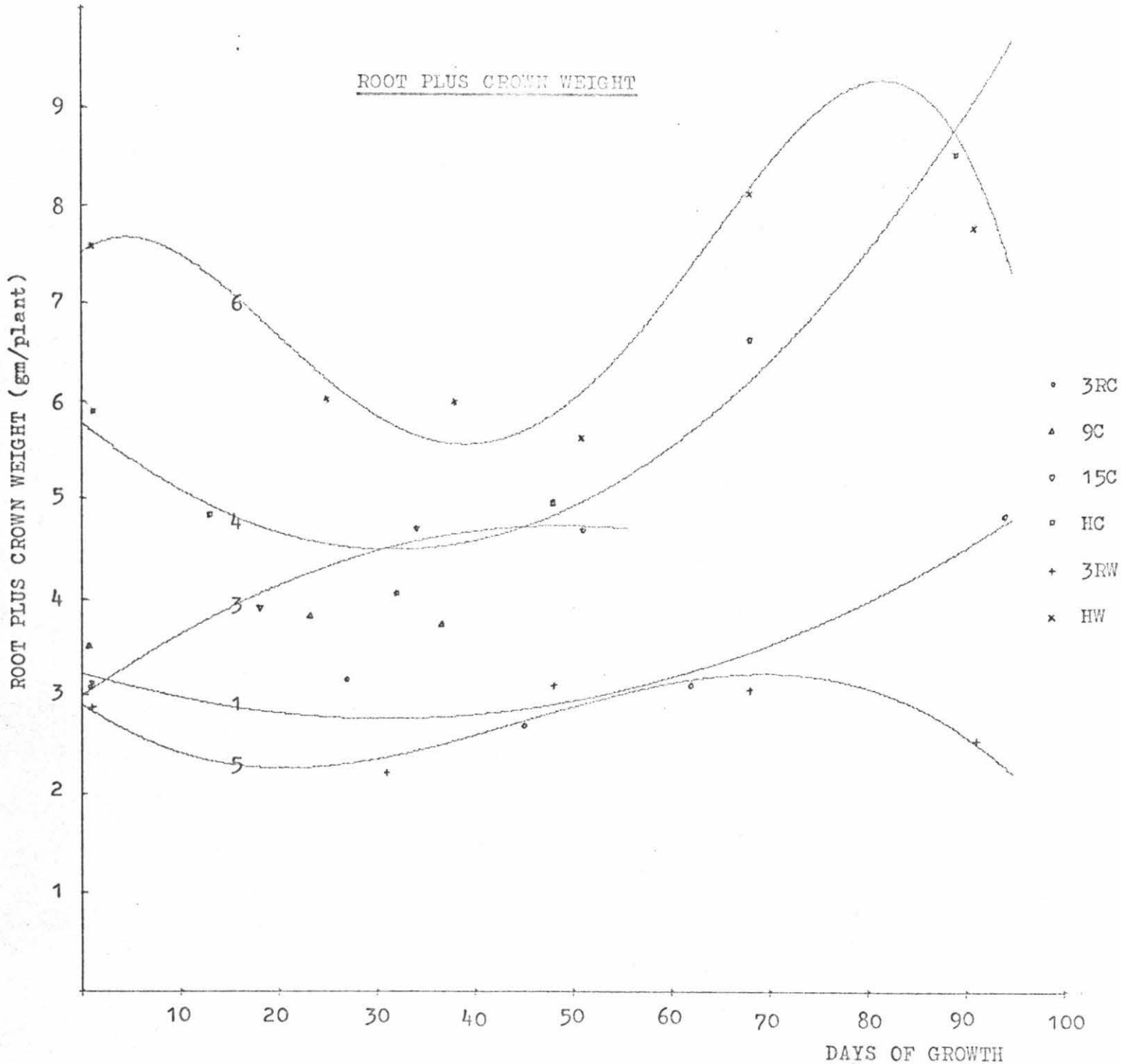

ROOT PLUS CROWN WEIGHT
ROOT PLUS CROWN WEIGHT (gm/plant)
DAYS OF GROWTH
3RC
9C
15C
HC
3RW
HW
1
2
3
4
5
6
10
20
30
40
50
60
70
80
90
100

Table 5.5. Comparison of the Plant Weight Estimated Values. (gm/plant)

	Day 0	Day 14	Day 28	Day 42	Day 56	Day 70	Day 84
3RC	3.429*A**	3.798 AB	4.206 AB	4.658 AB	5.159 A	5.713 A	6.327 A
3RW	3.857 A	3.008 A	3.251 A	4.167 A	5.422 A	6.131 A	5.155 A
9C	4.196 A	4.693 BC	5.249 BC	5.871 BC	-	-	-
15C	3.947 A	4.872 C	6.013 C	7.421 C	9.159 B	-	-
HC	7.594 B	6.346 C	6.523 C	7.745 C	9.968 B	13.058 B	16.343 B
HW	10.127 C	9.236 D	9.731 D	11.180 D	13.222 C	15.194 B	16.015 B
	0.138***	0.136	0.135	0.134	0.136	0.135	0.136

* The detransformed values of the estimates calculated from the logarithmic curves of plant weight.

** Within each day, values are compared at the 1% level.

*** Pooled SE.

Appendix: Statistics 4A.5.4.

These curves represent the combined influence of the reliable shoot growth and the less reliable root plus crown weight changes. The latter mostly influenced the plant weight changes in the early growth stages when some treatments and particularly the H treatments had initially negative growth rates (figs. 5.3., 5.4.). During later growth stages the increasing amount of shoot growth dominated the plant weight changes. The overall treatment groupings were significant (table 5.5.) and followed those already described for shoot growth.

Curves were not fitted to the shoot stubble, but consideration of the stubble weights for each treatment (fig. 5.7.) indicates that there were no important weight changes during regrowth. As with the other plant parts there were distinct differences between the 3R and H treatments with the HW treatment having the largest stubble weights. The significance of these differences is supported by the significant ANOVA's calculated on the basic data (table 5.2.).

5.2.1.6. Plant shoot number.

The treatment curves are presented in fig. 5.5. and the statistical results and calculated values in table 5.6. A curve was not successfully fitted to the 9C treatment. For all the other treatments, curves of significant fit were obtained, R^2 ranging between 0.619 and 0.915.

Figure 5.4. The curves of total plant weight changes per plant were fitted to data for which the dependent variable had been transformed to logarithms. The curve formulae and the associated statistics are in the transformed form while the curves are presented in the detransformed form.

1. 3RC $\text{Log } Y = 1.535 + 0.032t$
   $F = 6.019$ $R^2 = 0.316$ SE. of estimate 0.157 DF = 13

2. 9C $\text{Log } Y = 1.622 + 0.035t$
   $F = 1.800$ $R^2 = 0.205$ SE. of estimate 0.114 DF = 7

3. 15C $\text{Log } Y = 1.596 + 0.065t$
   $F = 9.67$ $R^2 = 0.491$ SE. of estimate 0.134 DF = 10

4. HC $\text{Log } Y = 1.880 - 0.094t + 0.029t^2 - 0.002t^3$
   $F = 11.08$ $R^2 = 0.703$ SE. of estimate 0.114 DF = 14

5. 3RW $\text{Log } Y = 1.586 - 0.144t + 0.053t^2 - 0.004t^3$
   $F = 4.79$ $R^2 = 0.565$ SE. of estimate 0.091 DF = 11

6. HW $\text{Log } Y = 2.005 - 0.057t + 0.022t^2 - 0.002t^3$
   $F = 4.38$ $R^2 = 0.484$ SE. of estimate 0.097 DF = 14

Appendix: Data 3A. 5.2.

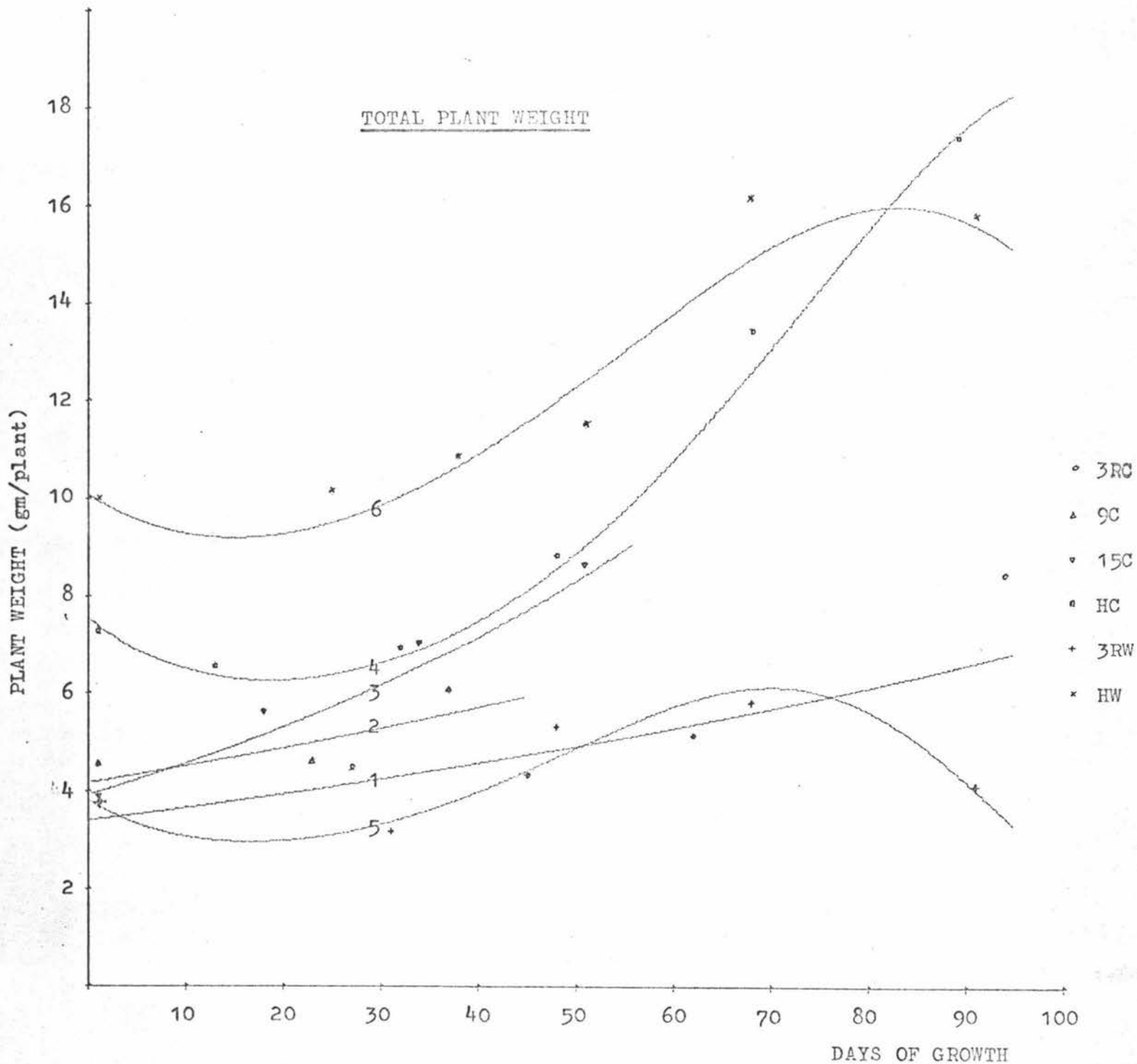

TOTAL PLANT WEIGHT
PLANT WEIGHT (gm/plant)
DAYS OF GROWTH
18
16
14
12
10
8
6
4
2
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
3RC
9C
15C
HC
3RW
HW

Table 5.6. Comparison of the Shoot Number Estimated Values. (No./plant)

	Day 0	Day 14	Day 28	Day 42	Day 56	Day 70	Day 84
3RC	15.07*AB**	11.07 A	8.12 A	5.98 A	4.48 A	3.50 A	2.98 A
3RW	18.58 A	12.89 AB	9.54 AB	7.45 A	5.94 A	4.57 A	3.08 A
15C	10.09 B	16.36 B	13.04 BC	7.98 AB	6.93 A	-	-
HC	15.03 A	16.29 B	14.06 C	10.35 B	6.99 A	5.01 A	4.84 AB
HW	44.92 C	40.66 C	31.82 D	22.00 C	13.87 B	8.63 B	6.37 B
	15.14***	9.05	5.52	4.40	6.86	7.69	9.88

* The detransformed values of the estimates calculated from the square root curves of shoot number.

** Within each day, values are compared at the 1% level.

*** Pooled SE.

Appendix: Statistics 4A.5.5.

The very noticeable feature was the very significantly different HW shoot number (greater than 1 cm). At the first recording there was a high level of 45 shoots per plant, this decreasing steadily throughout regrowth. In contrast, the HC treatment shoot number was much lower (18 shoots per plant maximum) and also showed a decrease during growth after a small initial increase. The 15C and 9C shoot number followed the same pattern as that of the HC treatment. The 3RC and 3RW treatments which were alike in shoot number also showed a decline throughout the growth period. There was a significant difference between the latter two and the other treatments between days 14 to 42. In the latter part of the growth period only the HW treatment had significantly greater shoot number, although only marginally so for the last harvest. The final shoot number similarity between treatments, especially between the 3RC and HC treatments is unexpected. The freehand 9C curve suggests a shoot number response similar to that of the 15C and HC treatments.

These shoot number patterns are in part supported by the field growth measurements (section 5.2.3.).

5.2.1.7. Plant growth rates.

As a general measure of average crop growth rates (CGR), linear regressions were fitted to the observed natural shoot growth data of each treatment. Between treatments there were significant differences (table 5.7.).

Figure 5.5. The curves of shoot number per plant during growth were fitted to data for which the square root of the dependent variable was used. The curve formulae and the associated statistics are in the transformed form while the curves are presented in the detransformed form.

1. 3RC $\sqrt{Y} = 12.276 - 1.342t + 0.063t^2$
   $F = 21.38$ $R^2 = 0.780$ SE. of estimate 1.423 DF = 12

2. 9C No fitted curve

3. 15C $\sqrt{Y} = 10.047 + 4.142t - 1.814t^2 + 0.182t^3$
   $F = 4.346$ $R^2 = 0.619$ SE. of estimate 1.545 DF = 8

4. HC $\sqrt{Y} = 12.259 + 1.023t - 0.527t^2 + 0.039t^3$
   $F = 37.76$ $R^2 = 0.890$ SE. of estimate 0.901 DF = 14

5. 3RW $\sqrt{Y} = 13.629 - 1.926t + 0.235t^2 - 0.014t^3$
   $F = 39.79$ $R^2 = 0.915$ SE. of estimate 1.025 DF = 11

6. HW $\sqrt{Y} = 21.194 - 0.122t - 0.490t^2 + 0.037t^3$
   $F = 26.63$ $R^2 = 0.850$ SE. of estimate 2.214 DF = 14

Appendix: Data 3A.5.2.

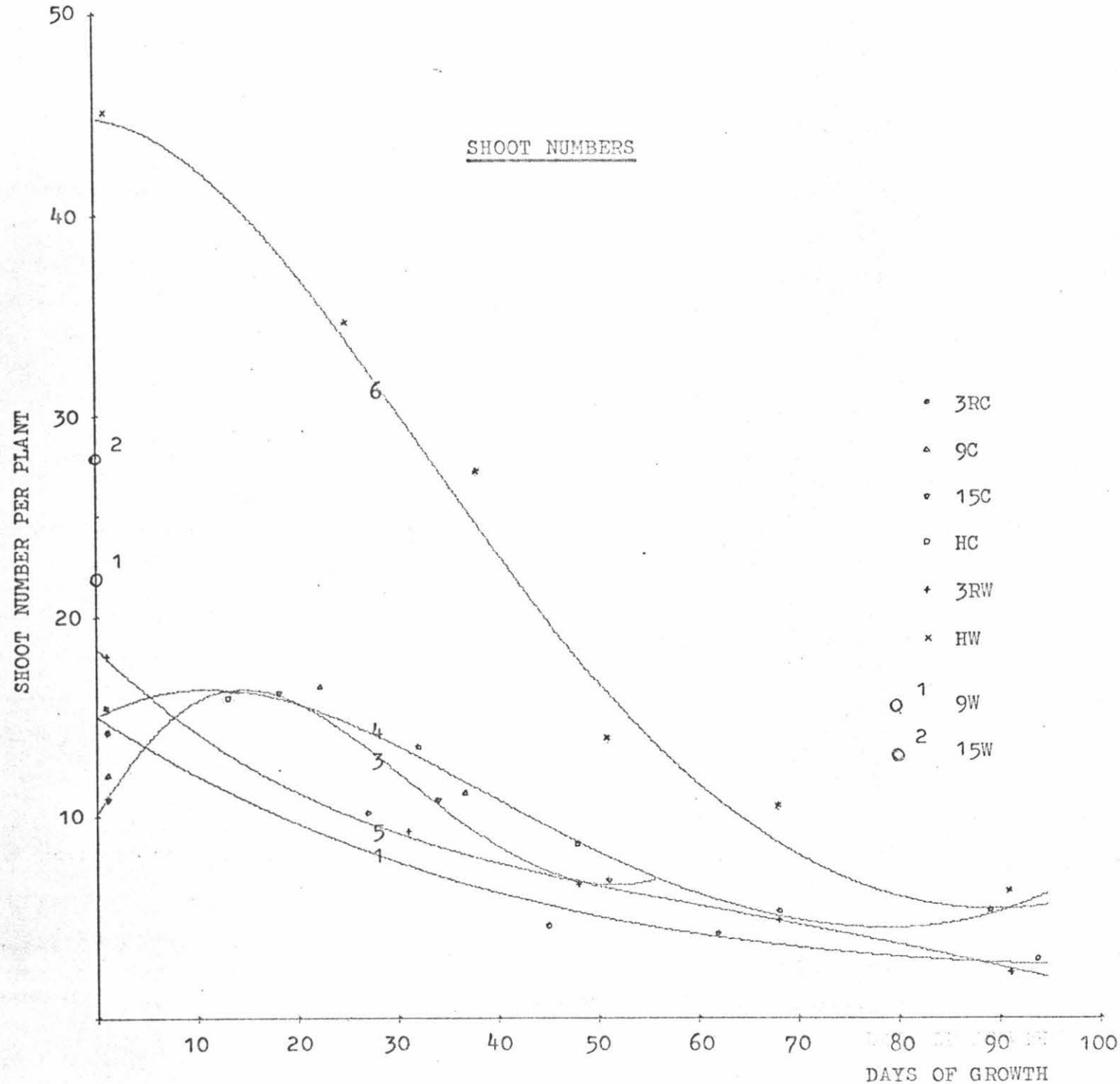

SHOOT NUMBERS
SHOOT NUMBER PER PLANT
DAYS OF GROWTH
50
40
30
20
10
10
20
30
40
50
60
70
80
90
100
3RC
9C
15C
HC
3RW
HW
9W
15W
1
2
3
4
5
6

Table 5.7. Comparison of the Shoot Growth Average Crop Growth Rate Regressions. (gm/week)

	DF	Regression	SE	Correl.	Statistics
3RC	7	0.23**	0.06	0.82	Av. regression 1%
9C	7	0.34**	0.07	0.88	
15C	7	0.42*	0.13	0.76	Between individual
HC	7	0.52**	0.11	0.86	group regressions
3RW	7	0.26**	0.07	0.80	10%
HW	7	0.65*	0.21	0.75	
Av.	47	0.37**	0.05	0.74	
3RC	10	0.24*	0.08	0.67	Av. regression 1%
15C	10	0.60**	0.16	0.76	
HC	10	0.54**	0.11	0.83	Between individual
3RW	10	0.30**	0.05	0.88	group regressions
HW	10	0.67**	0.16	0.79	5%
Av.	54	0.43**	0.05	0.73	
3RC	10	0.24*	0.08	0.67	Av. regression 1%
HC	13	0.75**	0.12	0.87	
3RW	10	0.29**	0.50	0.88	Between individual
HW	13	0.84**	0.14	0.85	group regressions
Av.	49	0.56**	0.07	0.77	1%

Regression coefficient significance; *P = 0.05, **P = 0.01

Appendices: Data 3A.5.2.
Statistics 4A.5.6.

Comparing all treatments in each combination of regressions it is seen that the average CGR increased as defoliation frequency decreased, the treatment differences becoming greater and more significantly so, the longer the growth period. Also the Wairau treatments had a higher average CGR for most of the experiment.

Average relative growth rates (RGR) were compared by fitting linear regressions to the logarithmically transformed observed data in the same treatment combinations as above. The same treatment differences were not observed (table 5.8.).

Table 5.8. Comparison of the Shoot Growth Average Relative Growth Rate Regressions. (gm/gm/week)

	DF	Regression	SE	Correl.	Statistics
3RC	7	0.50**	0.12	0.86	Av. regression 1%
9C	7	0.67**	0.10	0.93	
15C	7	0.77**	0.21	0.82	Between individual
HC	7	0.80**	0.16	0.88	group regressions
3RW	7	0.49**	0.13	0.82	NS
HW	7	0.74*	0.22	0.78	
Av.	47	0.63**	0.06	0.82	
3RC	10	0.44**	0.13	0.74	Av. regression 1%
15C	10	0.85**	0.16	0.85	
HC	10	0.74**	0.12	0.88	Between individual
3RW	10	0.51**	0.08	0.89	group regressions
HW	10	0.69**	0.15	0.82	NS
Av.	54	0.61**	0.06	0.82	
3RC	10	0.44**	0.13	0.74	Av. regression 1%
HC	13	0.80**	0.09	0.92	
3RW	10	0.51**	0.08	0.89	Between individual
HW	13	0.71**	0.10	0.88	group regressions
Av.	49	0.63**	0.05	0.86	10%

Regression coefficient significance; *P = 0.05, **P = 0.01

Appendices: Data3A.5.2.
Statistics 4A.5.7.

Only with the 3R and H treatment combination were there significant regression differences, the H treatment having a greater average RGR. Observation of the 9C, 15C and HC regression coeficients shows them to have had very similar average RGR's, although with the 9C regression being slightly less.

The shapes of the plant weight curves (fig 5.4.) were not suitable for fitting linear regressions to. It is clearly apparent though, that initial negative whole plant crop growth rates occurred in the H treatments, with positive faster average CGR's in the latter half of the growth period as both

shoots and roots gained weight together. This latter applied to both the 3R and H treatments, but particularly so to the H treatments.

5.2.2. Within Plant Dry Matter Distribution and Plant Size Variability.

The dry matter distribution patterns of the major plant components, taken from the fitted curves are illustrated within treatments in fig 5.6. The between treatment stubble, crown and true root weights, using the observed data, are illustrated in figs. 5.7., 5.8. and 5.9.

To aid the interpretation of these various patterns several ratios were established.

For shoot growth, stem/leaf ratios were calculated from the preceding leaf and shoot growth estimates (sections 5.2.1.2., 5.2.1.3.), the results being presented in table 5.9. and illustrated in fig. 5.10.

Table 5.9. Stem/Leaf Ratios.

	C	W	C + W	Statistics
3R	2.23	2.38	2.31 A*	Varieties 1%
H	2.33	2.78	2.55 B	Treatments 1%
Av.	2.28 M	2.58 N		Var x Treat 1%
				Harvests 1%
	SE. 0.076	CV% 3.12		Treat x Har 1%

LSD for treatments and varieties 0.07 (5%) and 0.16 (1%).

* Means are compared at the 1% level.

Appendices: Data Tables 5.3. 5.4. Statistics 4A.5.8.

The H treatment was significantly greater (P = 0.01) while between varieties, Wairau had a significantly greater (P = 0.01) ratio. The significant variety x treatment interaction was due to the high HW ratio. The differences between harvests are readily observed from fig. 5.10., all treatments showing a mid-growth period minimal ratio, this being achieved slightly earlier for the H treatments. The treatment x harvest interaction was due to an interchange of the relative values of the 3R and H treatments in the first 28 days (fig. 5.10.), the 3R ratios decreasing from above to below the H ratios. The 9C and 15C ratios showed somewhat different patterns and were considered reservedly; they were not included in any analysis.

Root (root plus crown)/shoot ratios (R/S) were calculated from the

Figure 5.6. The dry weight distribution patterns of leaf, shoot and root plus crowns within the plant during growth are illustrated along with the total plant weight during growth for the six indicated treatments.
The curves are -

1. Leaf weight.
2. Shoot weight.
3. Root plus crown weight.
4. Plant weight.

DRY WEIGHT DISTRIBUTION PATTERNS WITHIN PLANTS

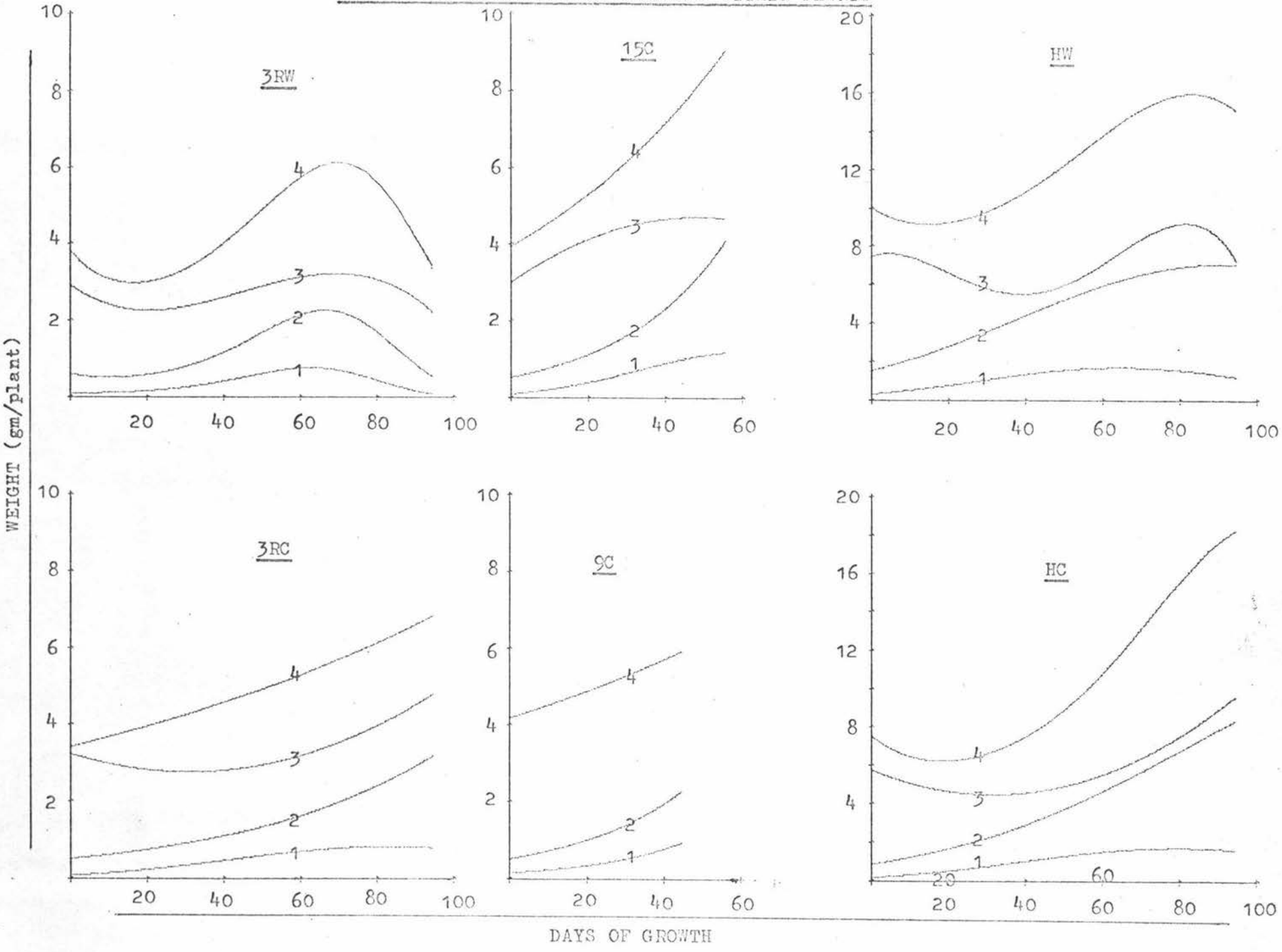
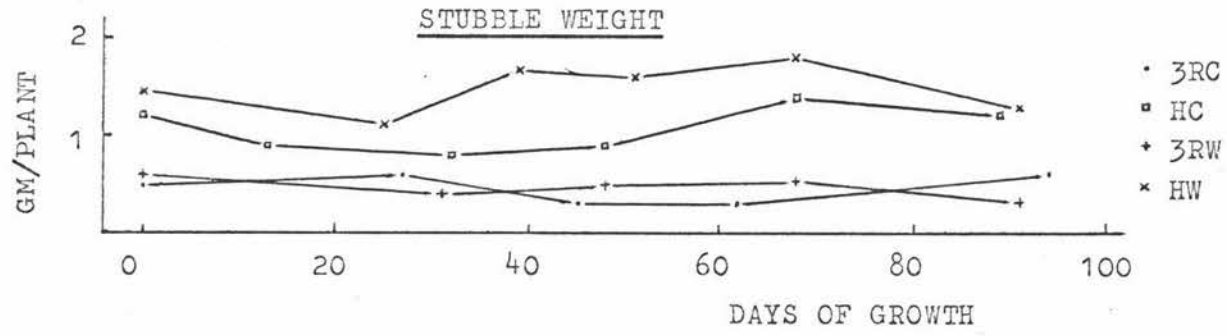
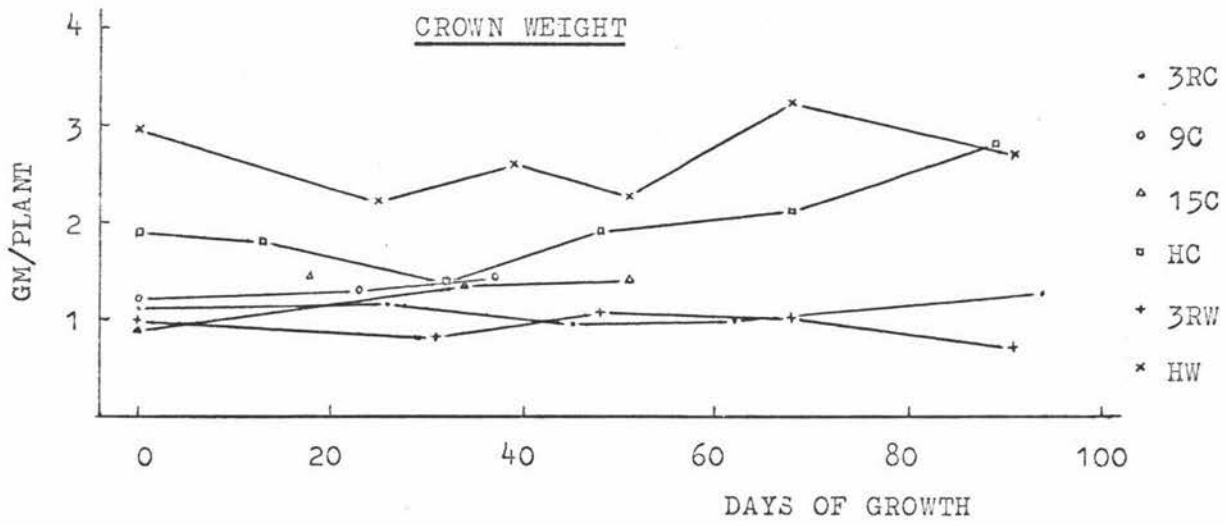


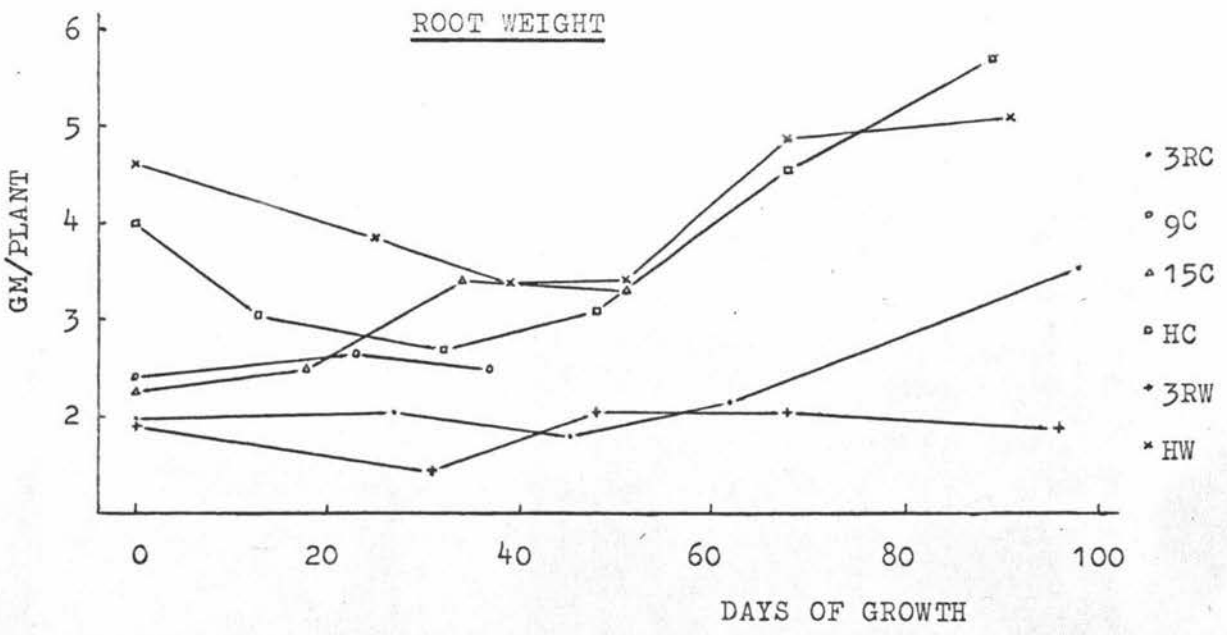
Figure 5.7. Stubble weight changes during growth for the two extreme treatments of both varieties. Points plotted are the measured values.

Figure 5.8. Crown weight changes during growth for the indicated treatments. Points plotted are the measured values.

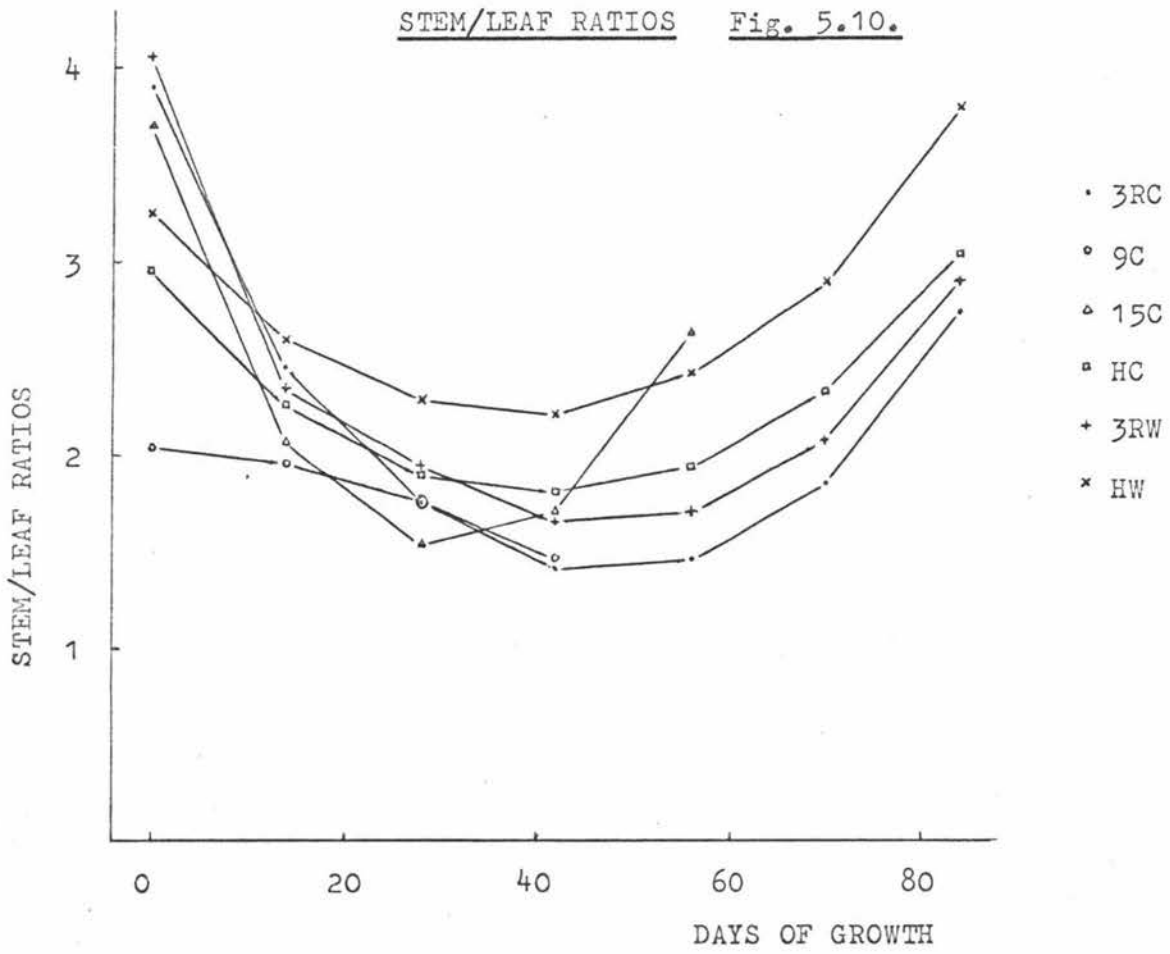
Figure 5.9. Root weight changes during growth for the indicated treatments. Points plotted are the measured values.


STUBBLE WEIGHT
GM/PLANT
2
1
0
20
40
60
80
100
DAYS OF GROWTH
3RC
HC
3RW
HW


CROWN WEIGHT
GM/PLANT
4
3
2
1
0
20
40
60
80
100
DAYS OF GROWTH
3RC
9C
15C
HC
3RW
HW


ROOT WEIGHT
GM/PLANT
6
5
4
3
2
0
20
40
60
80
100
DAYS OF GROWTH
3RC
9C
15C
HC
3RW
HW

STEM/LEAF RATIOS Fig. 5.10.



preceding data (sections 5.2.1.3., 5.2.1.4.). They are illustrated for the 3R and H treatments in combination with both varieties in fig. 5.11. and for Chanticleer with all treatments in fig. 5.12. The ratios were not analysed as the source root curves were not significant (section 5.2.1.4.), but in view of the general significance of the growth stage ANOVA results (section 5.2.1.1.), the illustrated trends are presented. All treatment/variety combinations showed the same basic responses, decreasing rapidly after defoliation under the influence of shoot growth associated with little change or a decrease of root weight; the mid-growth decrease being slower and leveling out in the later growth stages in response to increased root growth. All Chanticleer treatments had higher initial R/S ratios, although the 3RW day 0 ratio may have been an anomaly. Also, both H treatments had steeper R/S ratio decreases over the first 4-6 weeks regrowth, consistent with their considerable root weight decreases over this period. The responses of the 9C and 15C treatments are again considered reservedly, although showing a more representative response in this instance (fig. 5.12.).

Plant sizes were compared within and between treatments using the root (root plus crown) size as the most representative measure. Size variability was determined as the within treatment coefficient of variation obtained from within treatment ANOVA's over harvests (table 5.10.). The variation was high for all treatments. The higher HW variation would appear to be explained by the associated broader size distribution (fig. 5.13.). The high 9C variation is not explained other than to consider the smaller sample size to be responsible.

Table 5.10. Plant Size Variability* for the Root plus Crown Weight. (gm/plant)

	3RC	9C	15C	HC	3RW	HW
Std. Dev.	1.83	2.79	2.18	2.97	1.67	4.78
Gen. Mean	3.02	3.80	4.12	5.30	2.83	6.68
CV%	60.60	73.50	53.00	56.00	59.00	71.50

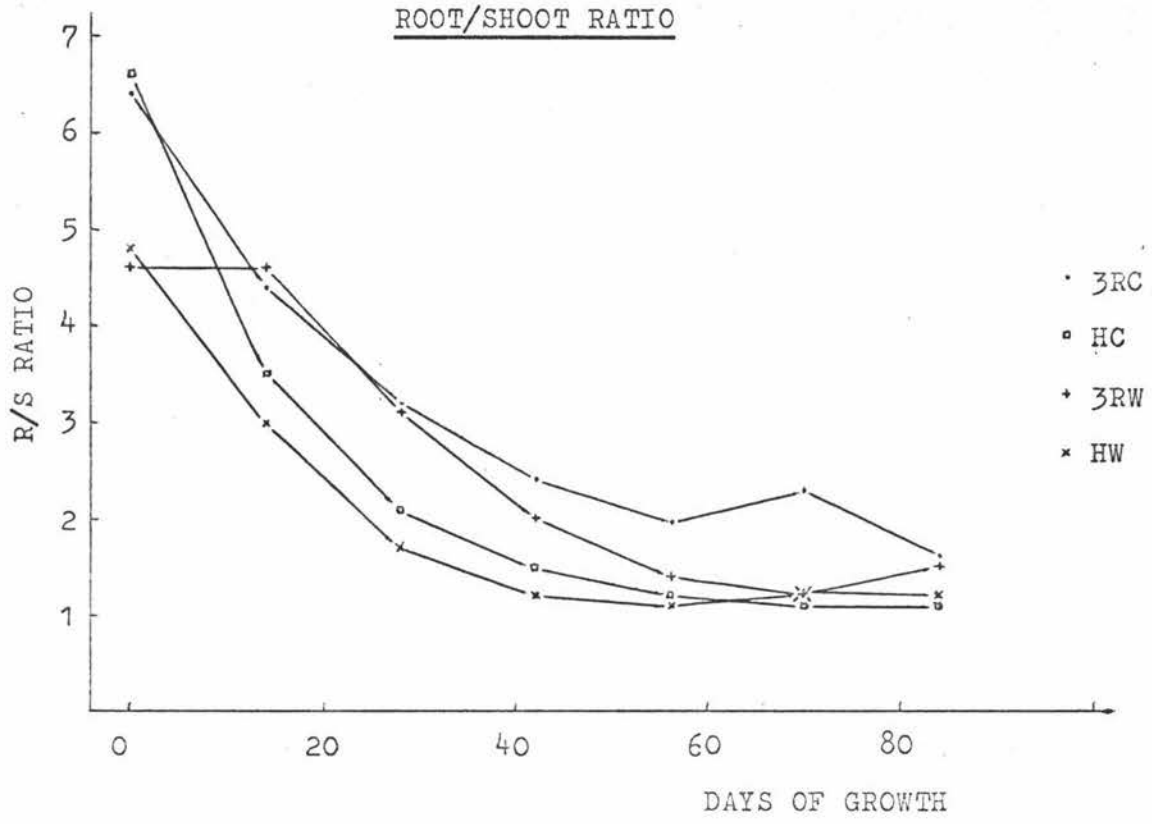
* The within replication variability.

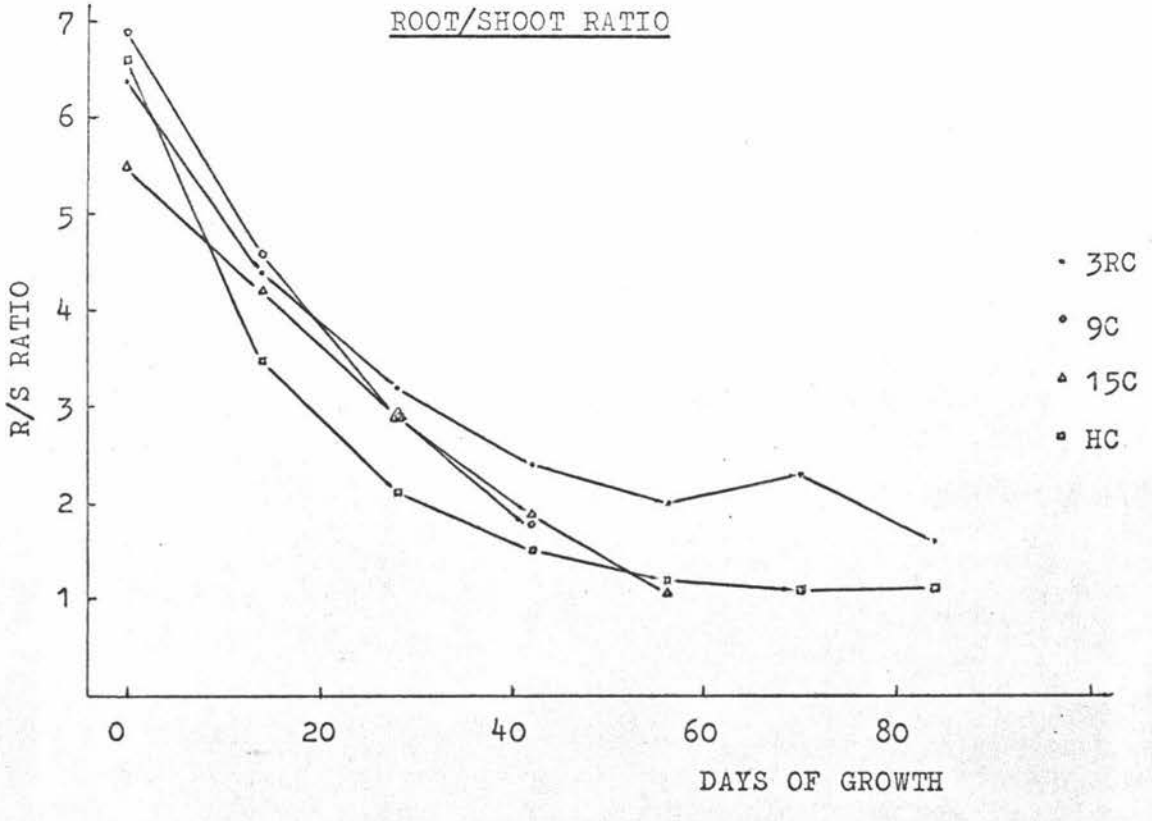
Appendices: Data 3A.5.2.
Statistics 4A.5.9.

To illustrate the plant size distribution within and between treatments over the RD to 15" or 15/H harvests (* footnote next page), frequency

Figure 5.11. The changes of the root/shoot ratios during growth and the comparison of these between the extreme treatments of both varieties.

Figure 5.12. A comparison between the four Chanticleer treatments of the changes of the root/shoot ratios during growth.


ROOT/SHOOT RATIO
R/S RATIO
7
6
5
4
3
2
1
0
20
40
60
80
DAYS OF GROWTH
3RC
HC
3RW
HW


ROOT/SHOOT RATIO
R/S RATIO
7
6
5
4
3
2
1
0
20
40
60
80
DAYS OF GROWTH
3RC
9C
15C
HC

distribution histograms were developed using the computer program previouly described (section 3.5.). Beforehand though, to eliminate the growth differences between harvests, the individual root weights were adjusted. Within each treatment, determinations were made of the differences between the general mean over all harvests and the mean for each harvest. The root weights within each harvest were then adjusted by the appropriate difference with reference to its sign. This calculation is illustrated in appendix 8A. Fig. 5.13. illustrates these distributions.

Distinct treatment effects were demonstrated. The mean root weight increased regularly as the defoliation frequency decreased. The root size range was more complex, there being three treatment groupings. The 3R treatments were similar. The 9C, 15C and HC treatments were each about two-thirds greater and the HW treatment more than twice the 3R treatment range. Within these ranges all treatments showed some more isolated large root weights relative to the treatment means, although there tended to be less of these in the15C and the other more frequently defoliated treatments. In contrast, both H treatments had quite extended low frequency tails extending out to the largest plants.

The 9C, 15C, HC and 3RW treatments were or tended to be normally distributed, while the 3RC treatment had a negatively skewed distribution, this latter contrasting with that of the 3RW treatment. In further contrast, the HW treatment had a very broad high frequency range (3.0 to 8.0 gm) extending to 12.0 gm with lower frequencies.

A limited number of measurements were available for the 9W and 15W treatments. Their means and distribution patterns were rather similar to those of the 9C and 15C treatments, although the wide range of the 15W treatment (up to 15.0 gm) suggests an approach to a distribution similar to that o f the HW treatment.

5.2.3. The Nature of Lucerne Shoot Growth.

This was largely determined from the field growth measurements. Within the limitations of the measurements made (section 5.1.1.), the nature of the shoot growth was considered as being determined by:

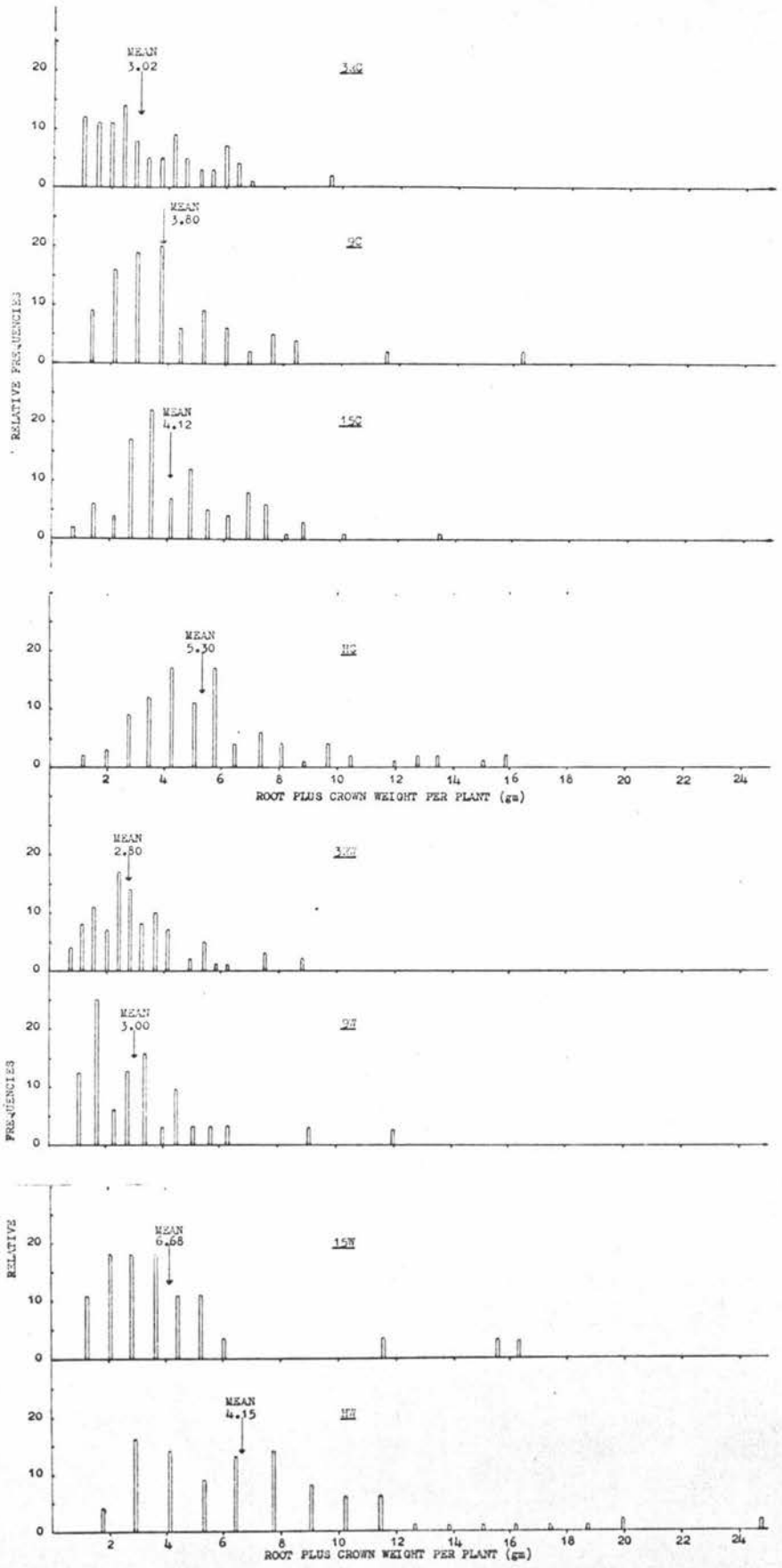
1. the number of shoots produced,

---

* The H harvests were not included because of the large root weights of the 3RC and HC treatments (table 3A.5.1.).

Figure 5.13. The distribution of plant sizes as indicated by the root plus crown weights per plant.

3RC.	N = 72	Range = 9.01	Class interval = 0.450
9C.	N = 54	Range = 15.70	Class interval = 0.785
15C.	N = 72	Range = 13.32	Class interval = 0.666
HC.	N = 90	Range = 15.41	Class interval = 0.770
3RW.	N = 72	Range = 8.51	Class interval = 0.425
9W.	N = 32	Range = 10.90	Class interval = 0.600
15W.	N = 28	Range = 16.00	Class interval = 0.800
HW.	N = 90	Range = 24.23	Class interval = 1.212


MEAN
3.02
3.80
4.12
5.30
2.80
3.00
6.68
4.15
RELATIVE FREQUENCIES
FREQUENCIES
ROOT PLUS CROWN WEIGHT PER PLANT (gm)

2. when each shoot first started elongating,

3. at any one time the heights attained as measures of each shoot's production,

4. a relative measure of overall production of each shoot group. This was calculated as the product of the relative shoot numbers (RNS) - see section 5.1.1. - and the associated heights. This gave the relative shoot production (RSP).

For clarity, measurements made each week are identified by the date alone while shoot groups measured over consecutive weeks were termed groups. A new shoot group was formed on each of the first six weeks, the first being measured on the 15/8.

The relative number of shoots first measured for each group were analysed but showed no significant treatment differences. Group differences were highly significant (P = 0.01) (table 5.11.).

Table 5.11. Relative Shoot Number First Identified each Week.

Group	Natural Means	Transformed Means*	Statistics
15/8	26.6	0.529 C**	Treatments NS
22/8	30.3	0.573 C	Group 1%
29/8	9.0	0.298 B	
5/9	23.1	0.487 C	SE. 0.146
12/9	10.0	0.299 B	CV% 39.00
19/9	0.6	0.063 A	

LSD for groups 0.122 (5%) and 0.164 (1%).

* Arcsin transformation.

** Means are compared at the 1% level.

Appendices: Data 3A.5.4. Statistics 4A.5.13.

The first, second and fourth groups had similarly high RSN's. The lower value of the third group was probably a seasonal temperature effect (sections 3.6., 8.2.). The fifth and sixth groups showed an expected decrease in the number of shoots arising. This latter observation is supported by a concomittant decrease in the number of shoots and buds less than 5 cm long arising on each crown growth (table 5.12.).

Table 5.12. Shoot Number Less than 5 cm Length Arising on the Field Identified Crown Growths.

Treatment	Weeks					
	22/8	29/8	5/9	12/9	19/9	26/9
3RC	3.29	2.30	1.90	1.10	0.37	0.00
9C	4.60	4.70	4.50	3.20	-	-
15C	5.50	5.60	5.30	2.50	0.90	0.05
HC	7.20	7.30	4.40	3.20	0.60	0.01

These results in table 5.12. are as the absolute values and are not analysed.* They do indicate a similar decreasing trend with time for all treatments, except that this was sooner for the 3RC treatment. The increasing trend of numbers between treatments on the 22/8 is suggestive of a greater shoot number producing capacity of plants less frequently defoliated.

The weekly measurements of identified shoot heights within each group gave a measure of the shoot growth between groups. Within the 3RC and HC treatments, linear regressions of shoot height against time representing shoot height crop growth rates, were fitted for each of the first five groups over the period of relatively linear growth between the 5/9 and 3/10 and similarly for the 15C treatment between the 5/9 and 26/9. The 9C treatment growth was of too short a duration. The regressions are tabulated in tables 5.13., 5.14. and 5.15. for the 3RC, 15C and HC treatments respectively.

Table 5.13. Comparison of the 3RC Shoot Height Group Regressions on Time.

Group	DF	Regression	SE	Correl	Statistics
15/8	13	6.714**	0.348	0.983	Av. regression 1%
22/8	13	6.423**	0.464	0.967	
29/8	13	6.980**	0.547	0.962	Between individual
5/9	13	4.985**	0.319	0.974	group regressions.
12/9	10	5.390**	1.026	0.856	5%

Regression coefficient significances: * P = 0.05, ** P = 0.01

Appendices: Data 3A.5.4.

Statistics 4A.5.10.

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* The delimited crown areas were approximations of single plants.

Table 5.14. Comparison of the 15C Shoot Height Group Regressions on Time.

Group	DF	Regression	SE	Correl	Statistics
15/8	10	9.333**	0.708	0.972	Av. regression 1%
22/8	10	7.500**	0.896	0.935	
29/8	10	9.400**	2.006	0.828	Between individual
5/9	10	9.085**	0.774	0.965	group regressions.
12/9	4	3.595ns	2.202	0.632	10%

Appendices: Data 3A.5.4.
Statistics 4A.5.10.

Table 5.15. Comparison of the HC Shoot Height Group Regressions on Time.

Group	DF	Regression	SE	Correl	Statistics
15/8	15	9.009**	0.615	0.970	Av. regression 1%
22/8	15	8.514**	1.507	0.842	
29/8	15	6.000ns	3.248	0.455	Between individual
5/9	15	4.114*	1.698	0.557	group regressions
12/9	12	1.038ns	2.017	0.160	10%

Regression coefficient significances: * P = 0.05, ** P = 0.01
Appendices: Data 3A.5.4.
Statistics 4A.5.10.

The important feature is the similar growth rates of the first groups within each treatment. These were the first 3, 4 and 2 groups of the 3RC treatment (table 5.13.), 15C treatment (table 5.14.) and the HC treatment (table 5.15.) respectively. The balance of the groups had lower growth rates for each treatment.

ANOVA's over the first five groups of all treatments (3RC,9C,15C and HC) on the 12/9 and for the 3RC, 15C and HC treatments on the 26/9, in both cases revealed significant shoot height differences between both treatments and groups (tables 5.16., 5.17.; fig. 5.14.).

On both dates (two weeks apart), averaged over all treatments, the shoot height order remained the same between groups, group differences being significant. Likewise, the increasing divergence of the fourth and fifth groups with time supports their lower growth rates. On both dates the signif-

icant shoot height differences between treatments was due to the shorter 3RC treatment shoots compared to the other treatments which in each case had similar heights. This treatment effect is supported by a later more accurate between treatment analysis of shoot heights adjusted fo the respective relative shoot number.

Table 5.16. Shoot Growth Heights Measured 12/9.

Treatment		Shoot Group		Statistics	
3RC	10.54 A*	15/8	19.07 A	Treatments	1%
9C	13.46 B	22/8	16.05 B	Group	1%
15C	14.02 B	29/8	14.05 B	Treat x Grp	NS
HC	13.93 B	5/9	9.64 C	SE.	2.14
		12/9	6.12 D	CV%	16.50

LSD for treatments 1.60 (5%) and 2.17 (1%).
LSD for groups 1.80 (5%) and 2.44 (1%).
* Means are compared at the 1% level within each column.
Appendices: Data 3A.5.4. Statistics 4A.5.11.

Table 5.17. Shoot Growth Heights Measured 26/9.

Treatment		Shoot Group		Statistics	
3RC	18.41 A*	15/8	29.62 A	Treatments	5%
15C	24.65 B	22/8	25.55 AB	Groups	1%
HC	22.18 AB	29/8	24.02 AB		
		5/9	19.04 B	SE.	5.88
		12/9	10.48 C	CV%	27.00

LSD for treatments 4.56 (5%) and 6.28 (1%).
LSD for groups 5.89 (5%) and 8.11 (1%).
* Means are compared at the 1% level within each column.
Appendices: Data 3A.5.4. 4A.5.12.

The average shoot heights measured on the 15th. of August through to the 25th. of October. These were averaged for each group.

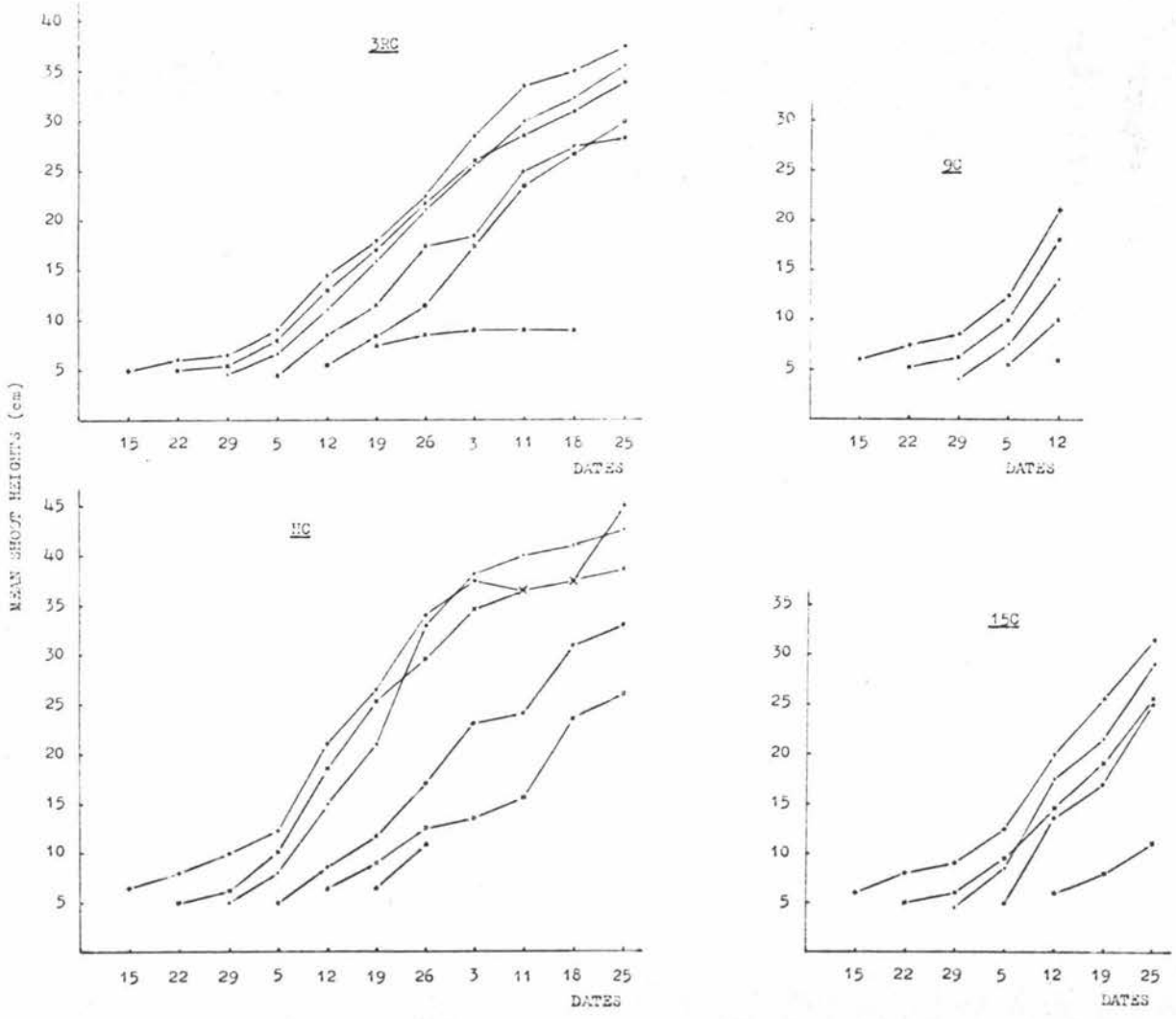
Figure 5.14.

a. (top left) 3RC

b. (top right) 9C

c. (bottom right) 15C

d. (bottom left) HC


3RC
9C
11C
15C
MEAN SHOOT HEIGHTS (cm)
DATES
15 22 29 5 12 19 26 3 11 18 25
15 22 29 5 12
15 22 29 5 12 19 25

Relative shoot numbers were still the same as the initial values (table 5.11.) on the 12/9 (table 5.18.) while two weeks later on the 26/9 (table 5.19.) there had been a little shoot death, but still with the same significant group ranking with no significant treatment differences (fig. 5.15.).

Table 5.18. Relative Shoot Numbers Measured 12/9.

Shoot Group		Statistics	
15/8	0.517*	Treatments	NS
22/8	0.569	Groups	1%
29/8	0.302		
5/9	0.487	SE. 0.159	
12/9	0.299	CV% 36.60	

LSD for groups

* Arcsin transformed values.

** Means are compared at the level.

Appendices: Data 3A.5.4. Statistics 4A.5.11.

Table 5.19. Relative Shoot Numbers Measured 26/9.

Shoot Group		Statistics	
15/8	0.459*AB**	Treatments	NS
22/8	0.520 A	Groups	1%
29/8	0.261 B		
5/9	0.388 B	SE. 0.165	
12/9	0.278 B	CV% 43.30	

LSD for groups 0.164 (5%) and 0.221 (1%).

* Arcsin transformed values.

** Means are compared at the 1% level.

Appendices: Data 3A.5.4. Statistics 4A.5.12

The relative shoot numbers 5 cm or greater in length measured on the 15th. of August through to the 25th. of October. These were averaged for each 'group'.

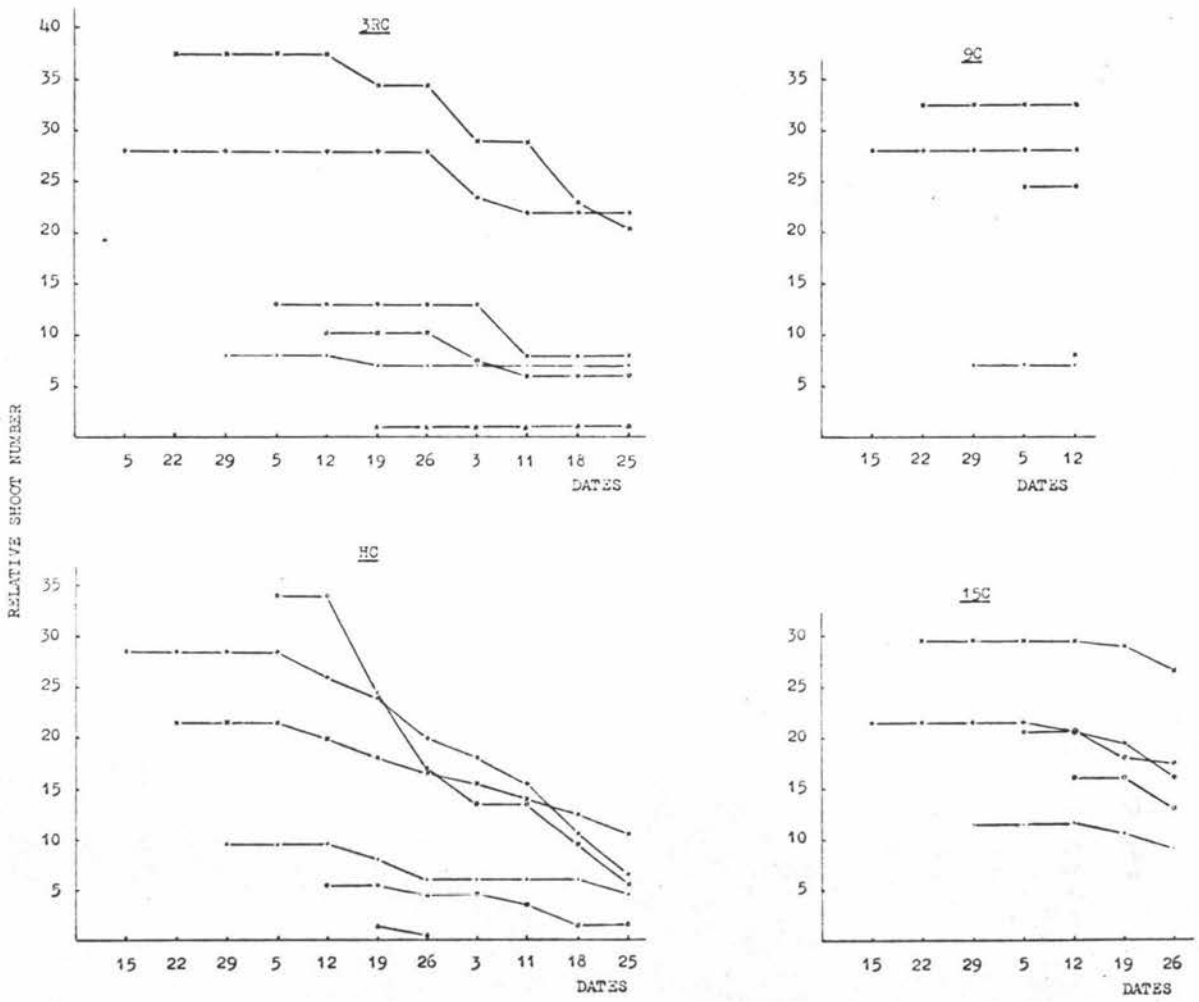
Figure 5.15.

a. (top left) 3RC

b. (top right) 9C

c. (bottom right) 15C

d. (bottom left) HC


3RC
9C
HC
15C
RELATIVE SHOOT NUMBER
DATES
DATES
DATES
DATES
40
35
30
25
20
15
10
5
5 22 29 5 12 19 26 3 11 18 25
15 22 29 5 12
15 22 29 5 12 19 26 3 11 18 25
15 22 29 5 12 19 26

As a measure of production, the relative shoot production on the same dates was similarly analysed (tables 5.20., 5.21.; fig. 5.16.).

Table 5.20. Relative Shoot Production Measured 12/9.

Shoot Group		Statistics	
15/8	478.75 A*	Treatments	NS
22/8	458.25 A	Groups	1%
29/8	133.00 B		
5/9	231.83 B	SE.	172.93
12/9	62.33 B	CV%	63.30

LSD for groups 143.2 (5%) and 189.2 (1%).

* Means are compared at the 1% level.

Appendices: Data 3A.5.4. Statistics 4A.5.11.

Table 5.21. Relative Shoot Production Measured 26/9.

Shoot Group		Statistics	
15/8	632.11 A*	Treatments	NS
22/8	623.66 A	Groups	1%
29/8	209.66 B		
5/9	325.77 AB	SE.	296.80
12/9	119.66 B	CV%	77.80

LSD for groups 300.5 (5%) and 405.5 (1%).

* Means are compared at the 1% level.

Appendices: Data 3A.5.4. Statistics 4A.5.12.

Being a relative measure, treatment differences were negligable, but group differences were highly significant on both dates. The salient features are the much greater values of the first two groups compared with later groups. The productive effect of the high relative shoot number of the fourth group (table 5.11.) was halved by their much shorter length (tables 5.16., 5.17.). This latter effect was particularly apparent in the HC treatment where on the 12/9 the fourth group's RSN was greatest (fig 5.15d.) and yet its RSP was only ranked third (fig. 5.16d.). However, the third and later groups increasingly contributed to the total RSP as the treatment defoliation frequency decreased.

The relative production of the field growth shoots (relative numbers x average shoot height) calculated for the 15th. of August through to the 25th. of October. These were averaged for each group.

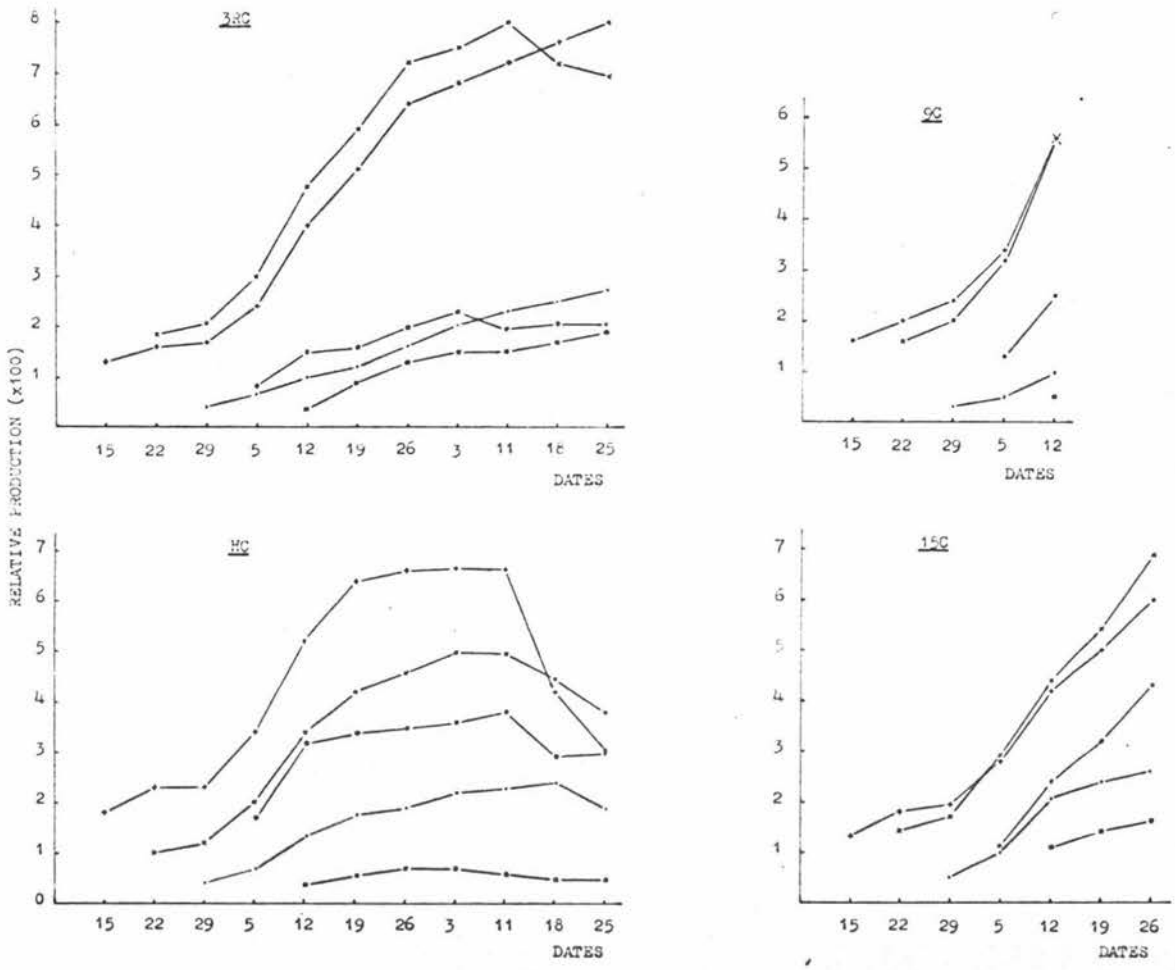
Figure 5.16.

a. (top left) 3RC

b. (top right) 9C

c. (bottom right) 15C

d. (bottom left) HC


3RC
9C
MC
15C
RELATIVE PRODUCTION (x100)
DATES
15 22 29 5 12 19 26 3 11 18 25

As a more accurate growth comparison between treatments an adjusted average shoot height (over all groups) was calculated for each treatment and for each week of measurement. The total RSN was divided into the total RSP thus making allowance for the RSN difference between groups. The 9C, 15C and HC treatments had very similar adjusted heights while the 3RC treatment was consistently shorter (fig. 5.17.). These differences were supported by the associated ANOVA (table 5.22.) calculated for the adjusted shoot heights on the 26/9. It was also readily apparent that shoot height growth rates were similarly grouped.

Table 5.22. Adjusted Average Shoot Heights Measured 26/9.(cm)

		Statistics
3R	19.36 A*	Treatments 1%
15	25.50 B	SE. 1.18
H	26.90 B	CV% 4.87

LSD for treatments 2.64 (5%) and 4.38 (1%).

* Means are compared at the 1% level

Appendices: Data 3A.5.4. Statistics 4A.5.14.

In all treatments, any shoots arising in the sixth week were of no productive consequence, senescing within the next week or two.

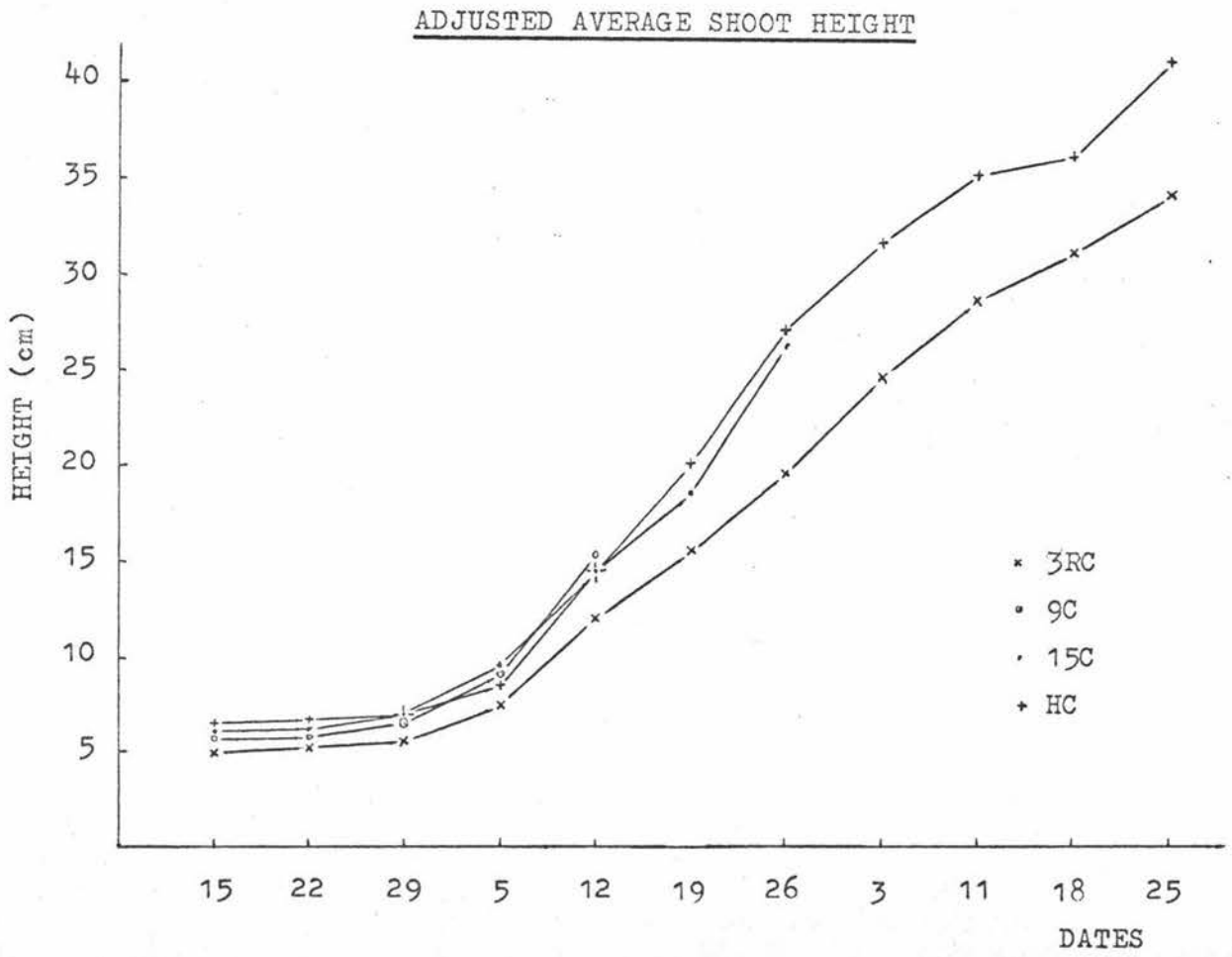
5.2.4. The Basal Shoot Growth of Mature Lucerne.

No new basal shoots (one leaf expanded, section 5.1.1.) were found on the dissected plants of the 3R and H treatments of the 15" and 15/H samples respectively, dug approximately four weeks before the H harvests. During the latter period new basal shoot growth occurred in all treatments. As a percentage of the H harvest total shoot growth, this was 11-12% for the H treatments and 5% and 23% for the 3RC and 3RW treatments respectively (table 5.23.). On a shoot weight basis this treatment pattern was different.

Table 5.23. Basal Shoot Growth as a Percentage of the Total Hay Harvest.

	C	W
3R	5.38	22.80
H	11.10	12.23

Figure 5.17. The adjusted average shoot height for the four Chanticleer treatments. For each day of measurement the average shoot height of each treatment was adjusted according to the relative shoot number as explained in the text (section 5.2.3.).


ADJUSTED AVERAGE SHOOT HEIGHT
HEIGHT (cm)
40
35
30
25
20
15
10
5
15
22
29
5
12
19
26
3
11
18
25
DATES
3RC
9C
15C
HC

The ANOVA's for shoot dry weights and shoot numbers were calculated using square root transformed data in accordance with frequency distributions previously prepared (section 3.5.). While varietal differences were not significant for either variable, the H treatment was greater for each (tables 5.24., 5.25.), although LSD differences were not quite significant (P = 0.05). The results are illustrated in fig. 5.18.

Table 5.24. Basal Shoot Growth. (gm/plant)

	Natural	Transformed*	Statistics	
3R	0.255	11.032	Varieties	NS
H	0.885	13.512	Treatments	1%
	SE. 2.260	CV% 18.40		

LSD for treatments 2.60 (5%) and 3.48 (1%).

* Square root transformation

Appendices: Data 3A.5.3. Statistics 4A.5.16.

Table 5.25. Basal Shoot Number. (No./plant)

	Natural	Transformed*	Statistics	
3R	9.55	30.56	Varieties	NS
H	19.83	43.33	Treatments	1%
	SE. 13.37	CV% 36.95		

LSD for treatments 15.4 (5%) and 20.5 (1%).

Appendices: Data 3A.5.3. Statistics 4A.5.16.

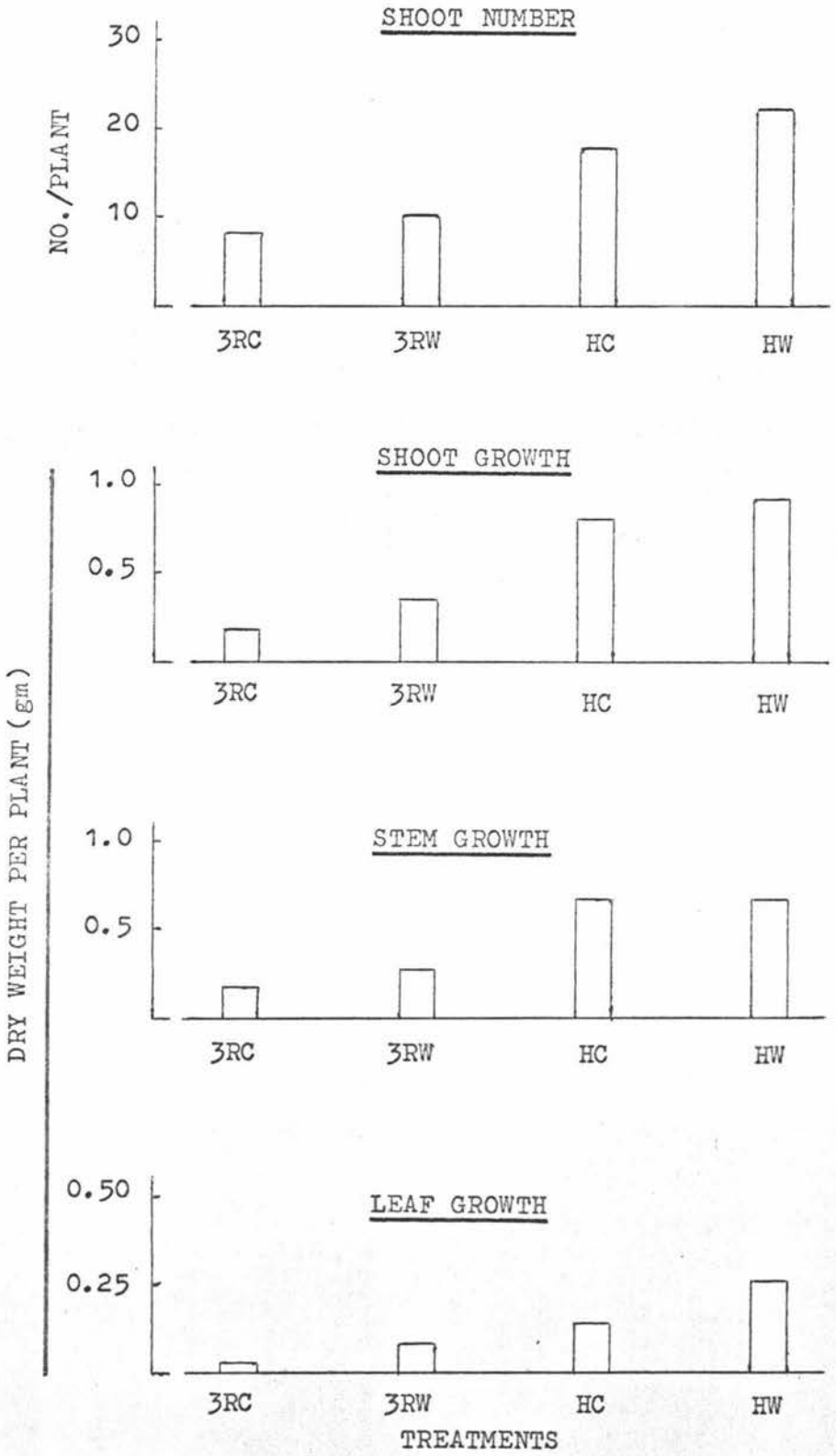
Figure 5.18. The components of the new basal shoot yield of the mature growth at the hay harvest of the 3R and H treatments of both varieties.

The number of basal shoots (including buds) greater than 1 cm long.

The total shoot yield

The yield of stems.

The leaf yield.


SHOOT NUMBER
NO./PLANT
30
20
10
3RC
3RW
HC
HW
SHOOT GROWTH
1.0
0.5
STEM GROWTH
LEAF GROWTH
0.50
0.25
DRY WEIGHT PER PLANT (gm)
TREATMENTS

The shoot stem/leaf ratio ANOVA showed both varieties and treatments to be significant, but with only the treatments having LSD significance (table 5.27.). The 3R treatment had the greater ratio. The greater Chanticleer variety ratio approached LSD significant difference (P = 0.05) over Wairau.

Table 5.27. Basal Shoot Stem/Leaf Ratio.

	C	W	C + W	Statistics
3R	10.03	5.90	7.96 a*	Varieties 5%
H	4.71	3.30	4.02 b	Treatments 2%
Av.	7.38	4.60		SE. 1.72
				CV% 28.60

LSD for varieties and treaments 2.96 (5%) and 4.48 (1%).

* Means are compared at the 5% level.

Appendices: Data 3A.5.5. Statistics 4A.5.16.

On the field growth plants, basal shoots and bud numbers were counted from the 3/10 and the 11/10 respectively, through to the 31/10 for the 3RC and H treatments (table 5.28.). Only the Chanticleer variety was measured.

Table 5.28. Basal Shoot Growth of Mature Lucerne as Measured on the Field Growth Plants.

Basal Bud Numbers.

	3/10	11/10	18/10	25/10	31/10
3RC	-	5.40	5.30	5.50	5.80
HC	-	7.20	7.90	4.90	2.70

Basal Shoot Numbers.

	3/10	11/10	18/10	25/10	31/10
3RC	0.10	0.30	0.40	1.40	2.30
HC	0.20	0.40	1.50	5.10	5.20

The results, although not analysed are described. The basal buds were high at the start of measurement in both treatments, but then started to decrease for the H treatment while staying costant for the 3RC treatment. In contrast, starting from near nothing, the HC basal shoot numbers levelled at a maximum in the last two weeks, while the 3RC shoot numbers still increased throughout the measurement period.

5.3. Discussion.

5.3.1. Lucerne Plant Growth.

The lucerne top growth has been analysed without reference to shoot types. During the experiment an attempt was made to differentiate between stubble and basal shoots. This was not successful as it was later realised that an inappropriate classification had been used. Shoots arising from the base of stubble stems were erroneously classified as stubble shoots (section 2.3.3.). These as is to be expected (Leach, 1970a; Keoghan, 1970), represented up to 50% of the total shoot number especially in the early growth.

The overall significance of the ANOVA results in table 5.2. provides strong support for the curve comparisons made. In similar support was the generally lower significance of the root and crown dry weight comparisons. The relative accuracies of the curve fits supported these conditions. The leaf and shoot weight curves all had R^2 greater than 0.684, while the maximum R^2 for any root (root plus crown, RTCR) curve was 0.445 and for total plant weight 0.703. The scatter of observed mean values about each curve suggests support (figs. 5.1., 5.2., 5.3., 5.4.)

The comparison and fitting of th curves was only practically feasible because of the availability of computer facilities. More frequent observations in time, if available, would have given more representative and accurate fits. Apart from this, the experimental design limitations meant that this method of analysis was the only satisfactory one available. Aspects of improved experimental design are discussed in chapter 10. Within the analysis used, the major point of criticism is the use of the Least Significant Difference (LSD) method used for the comparison of means. This is recognised as the least powerfull of the available methods (Steele and Torrie, 1960; Snedecor and Cochran, 1967; Roscoe, 1969). As there were differences in the number of observations used to fit individual curves, the range of methods available

was restricted to the LSD method (Steele and Torrie, l.c.) and the Scheffé test (Roscoe, 1969). The validity of these methods for these circumstances has been verified (Steele and Torrie, 1960). In view of the low increase of significance obtained with the Scheffé test, as earlier indicated (section 5.2.1.1.), most of the significance interpretation was based on the LSD results. To improve the performance of the LSD method, t-values with P = 0.01 were used and the results interpreted in accordance with the more obvious and general treatment differences and trends indicated; this interpretation approach was also used to reduce the disadvantages arising from the comparison of all possible pairs of means (Steele and Torrie, l.c.; Snedecor and Cochran, l.c.).

Although the leaf and shoot growth curves showed the expected treatment trend of increasing growth with reduced defoliation frequency (section 2.3.1.1.; figs. 5.1., 5.2.), within the Chanticleer variety the general lack of significance between the 9", 15" abd H treatments compared to the significantly lower leaf and shoot growth of thw 3R treatments was unexpected. Similar significant observations of the field growth measurements support this (section 5.2.3.). Further measurements of the 9C and 15C treatments would have been needed to establish the continuation of these treatment groupings through to mature growth.

For the 3RC, HC and HW treatments it was apparent from a comparison near maturity (i.e. day 70 onwards) of their shoot and leaf weight changes that considerable stem weight increase occurred. This is supported by the relatively uniform but steep increase of the stem/leaf ratios (fig. 5.11.) over this period. Between varieties, the earlier maxima of leaf production for the Wairau variety is at variance with the similarity of the patterns of stem/leaf ratio change between the two varieties. This indicates a lower rate of stem growth for the Wairau treatments during these mature stages in association with the leaf loss. Because of the lateness of flowering in both varieties it is difficult to interpret this as a difference of the time of maturity. Normally the sativa type Chanticleer would have been expected to mature first (section 2.1.1.).

These mature shoot growth responses were supported by an associated decrease of the rate of shoot height growth as measured in the field for the 3RC and HC treatments (fig. 5.16a,d) as also observed by Keoghan (1970). In the 3R and H treatments the initiation of new basal shoots (section 5.2.4.)

indicated a change of the plants physiological state which may have led to a reduction of mature shoot elongation. Recent work by Bailey et al. (1970) indicates that the apparent stem weight increase would have been largely due to an increase of the structural carbohydrates, cellulose and lignin.

A comparison of the leaf and shoot growth curves for each treatment (figs. 5.1., 5.2.) over the first 60 days growth, indicates the close relationships between these growth variables. A highly significant slightly curving regression grouping all treatments verified this (fig. 5.21.). Smith, Mott and Bula (1964) demonstrated a close lucerne LAI/ top growth relationship, while Steinke (1963) showed these same variables to have a highly correlated linear relationship, as also did Brougham (1956) with a grass sward. Although the dependence of the top growth on leaf growth is indicated, it is only the basic aspect of what is in fact a very complex relationship evidenced by the recent investigations of the LAI/CGR relationships and the many associated influencing factors (section 2.3.4.).

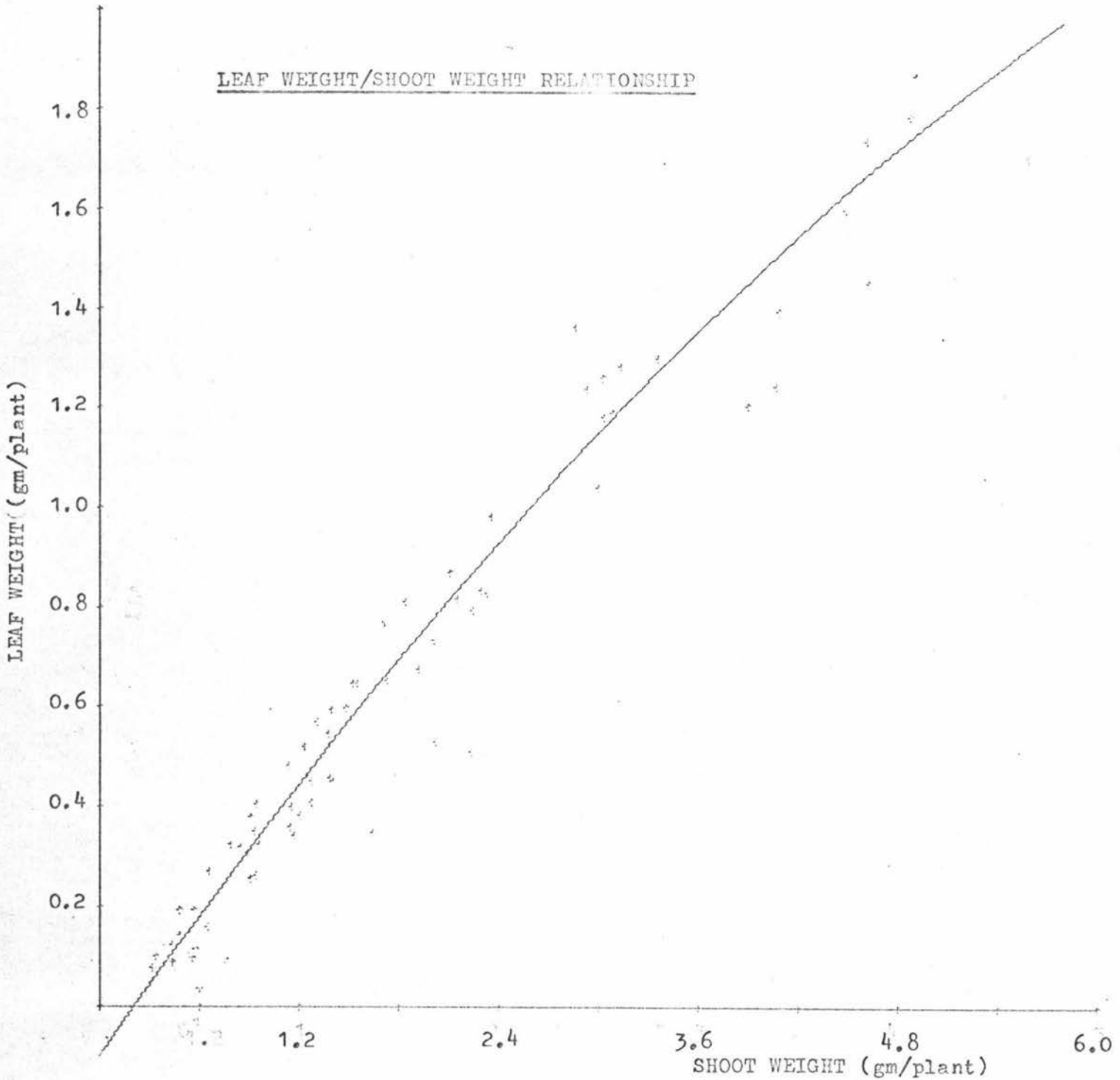
The higher relative rate of leaf production for the first 30-40 days for all treatments, observed from the stem/leaf ratios (fig. 5.11.), was also observed by Keoghan (1966), after which the maturity effects discussed earlier started to be effective. The significant stem/leaf ratio differences between the 3R and H treatments could have been due to a complex of several factors such as the relative differences of stem thickness, average leaf size and number per stem associated with internode length differences. No appropriate measurements were available to verify these factors. The regularity of the differences of stem/leaf ratio between varieties is difficult to explain other tnan to suggest a genetically based varietal difference which would have to be verified. An unanswered problem is the explanation for the 9C and 15C treatment responses, especially the 9C response.

The below ground parts, root and crown were combimed (RTCR). This is considered valid as the dry weight of both had a similar cyclic response to defoliation (figs. 5.9., 5.10.) and both are organic reserve storage organs (section 2.2.2.). The lower RTCR weights of the more frequently defoliated 3R treatment compared to the H treatment was typical of previous reports (section 2.3.1.2.), as also was the H treatment's initial decrease with time to minimal RTCR weight levels. For the H treatments, the period of this RTCR weight decrease lasted 5-6 weeks compared to the more often reported 2-4 weeks (section 2.3.1.2.). This was probably associated with the slower

Figure 5.21. The relationship between the weight of shoot growth and the associated weight of leaf growth was calculated from the leaf and shoot weight values determined from the leaf and shoot growth curves (figs. 5.1., 5.2.). The values for all treatments were used for the regression calculation.

$Y = -0.090 + 0.433t - 0.019t^2$

$F = 1406.83$ $R^2 = 0.975$ SE. of estimate 0.091 DF = 72


LEAF WEIGHT/SHOOT WEIGHT RELATIONSHIP
LEAF WEIGHT (gm/plant)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1.2
2.4
3.6
4.8
6.0
SHOOT WEIGHT (gm/plant)

spring growth and an associated slower rate of organic reserve depletion. For the 3R treatments, the variability of the results indicates that the RTCR weight changes which were small, were also largely insignificant, this latter also applying to the 3RW treatment's H harvest decrease (fig. 5.3.). The measured RTCR responses for the 9C and 15C treatments is not physiologically explainable and to some extent at least, is probably explained by sampling errors. At the same time though, the consistency of the trends between sampling dates indicates that there were possibly other factors involved. It must be remembered that these weight changes refer to the bulky storage organs; no consideration was given to the weight changes of the smaller roots which collectively represent a large proportion of the total root weight. Physiologically, this unmeasured portion of the root system may be of equal importance for its nutrient suppling capacity (sections 2.4.1.2., 2.4.1.4.).

The total plant growth responses (fig. 5.4.) as a collective result of the RTCR and shoot growth emphasised the significant differences between the 3R and H treatments and the greater HW plant size relative to the other treatments. The 9C and 15C results were suspect, largely because of the measured response of their RTCR components.

The decrease of shoot numbers observed over the whole experimental period for all treatments and the extent of these decreases was a significant aspect of total shoot production. This shoot senescence was directly verified from the field growth measurements (sections 5.2.3., 6.2.) and as such represents a considerable direct loss as actual dry weight (from shoot death) and indirectly as lost potential production (from shoot growth not completed).

The RD harvest shoot numbers for the 9W and 15W treatments were available with these being intermediate between the 3RW and HW treatments. This provides supporting evidence for the large initial HW shoot numbers. This Wairau response is in keeping with what is generally expected from such a range of defoliation frequencies (section 2.3.3.) and is in sharp contrast to the unexpected similarity of the shoot numbers recorded for the equivalent Chanticleer treatments. Only the lower 3RC treatment number satisfied the expected relative treatment response. The reasons for this Chanticleer response are not known, but it is partly supported when the replication mean number of shoots counted on the respective field growth crowns are compared.*

---

* For such a comparison it is a reasonable approximation to consider the crowns identified as being single plants (section 5.1.1.).

The treatment means of the 3RC, 9C, 15C and HC treatments were 31.3, 47.3, 57.3 and 51.7 shoots respectively. This similarity of the 9C, 15C and HC treatments was also observed for their individual shoot rates of elongation (section 5.2.3.).

The initial Wairau shoot numbers were proportional to the initial plant size (table 5.30), an obsevation similarly made by Ueno and Smith (1970). This relationship was less satisfactory for the Chanticleer variety as might be expected from the lack of shoot number significance between the defoliation treatments. These relationships are further indicated by the shoot number/plant size correlations using the single plant data. These were

r = 0.82 for Wairau**

r = 0.57 for Chanticleer.(table 4A.5.

Table 5.30. Shoot Number/Plant Size Relationship on Day 0.*

	3RC	9C	15C	HC
Shoot No. (No./plant)	14.30	12.20	11.00	15.40
Root Weight** (gm/plant)	3.09	3.61	3.12	5.92
	3RW	9W	15W	HW
Shoot No.	18.10	21.50	27.90	45.20
Root Weight	2.89	2.99	4.15	7.61

* Observed data was used.

** Root plus crown (RTCR) weight.

Average single shoot weights were determined (table 5.31.) from the calculated shoot growth and number values (tables 5.2., 5.5.). Within the Wairau variety, there was little difference between the 3R and H treatments for all the sampled days, except for day 84 when the H treatment's average shoot weight had increased sharply. Ueno and Smith (1970) observed a similar average shoot weight similarity between small,medium and large plants in pots using Vernal lucerne; a falcata type (Iversen and Meijer, 1967).

** Both correlation coefficients were highly significant (P = 0.001).

However, the Chanticleer 3R and H treatments had different average shoot weights, the latter being considerably larger at all stages, while the 3RC results closely resembled those of the Wairau treatments.

Table 5.31. Average Shoot Weights.(gm)

Days	0	14	28	42	56	70	84
3RC	0.034	0.061	0.109	0.195	0.340	0.570	0.880
9C	0.043	0.050	0.090	0.190	-	-	-
15C	0.055	0.056	0.116	0.315	0.600	-	-
HC	0.058	0.086	0.151	0.297	0.610	1.120	1.460
3RW	0.034	0.039	0.080	0.177	0.370	0.600	0.640
HW	0.035	0.059	0.109	0.210	0.415	0.772	1.120

There is evidence that the lower shoot weights of the 3R treatments were associated with growth limitations (secteon 5.3.4.), while the low HW shoot weights were probably due to inter-shoot competition up until day 70 when the lower shoot number (fig. 5.5.) may have permitted quicker, more competitive growth. The shoots of the HC treatment on the other hand probably had less inter-shoot competition due to their smaller numbers and so were able to grow larger. The 15C treatment's shoot weights were similar. In contrast to the 9C, 15C and HC treatment's shoot number similarity, the 9C treatment's average shoot weight was similar to that of the 3RC treatment. Evidence for these competitive situations and shoot size plasticity has been presented severally (section 2.4.2.3.).

5.3.2. Lucerne Growth Rates.

The general increase of the average CGR's with decreasing defoliation frequency was in agreement with the shoot growth curves (fig. 5.2.). Between the extreme 3R and H treatments there were distinct differences.

Within the Chanticleer variety the average RGR's were very similar for the 9, 15 and H treatments. It would have been interesting to know if this was also the case for Wairau with the larger shoot number differences between it's treatments (fig. 5.6.). The average RGR comparisons indicated that the 3R treatments grew less efficiently than the less frequently defoliated

treatments. This suggests that the plants of this treatment were the only ones in which the efficiency of the actual growth processes had been reduced. This suggestion is further discussed in section 5.3.4. The lower growth efficiency of the 3R treatments confirms similar defoliation effects observed by Steinke (1963) in a glass house experiment.

5.3.3. Lucerne Plant Morphology and Size.

The aspect of stem/leaf ratio has been fully discussed (section 5.3.1.)

The root/shoot (R/S) ratio responses for all treatments were in line with the expected post-defoliation responses, but in this case, the high initial R/S ratio was largely due to the lack of winter/early spring growth. The main treatment difference was the greater shoot growth associated with a greater RTCR weight loss of the H treatment in the first weeks of growth, causing the R/S ratio to decrease quicker and further than the more gradual 3R treatment changes. Although the RTCR values used did not include the finer lateral root system, the growth of these latter roots was probably initially restricted by low soil temperatures (Leopold 1964); thus, if the whole root system had been available the root weight defoliation responses would probably still have been similar.

Although the 3R treatments appeared to have slightly higher R/S ratios with the more mature growth suggesting less efficient shoot productivity per plant, all treatments tended to reach a stable level giving a R/S ratio between 1 and 2. There appears to be more probability of fluctuations being associated with seasonal and growth conditions than from treatment effects. With the same root measurement as here, Nelson and Smith (1968a) obtained R/S ratios of 0.7, 2.0 and 4.0 for spring, summer and autumn yields respectively. It is interesting to note that at all growth stages with all treatments, the RTCR weight was greater than the associated maximum shoot growth, and this being markedly so if the whole root system is considered.

Consideration was given to whether the total shoot productivity relative to plant size was affected by the treatments. To obtain an indication from the four extreme treatments, the ratios of peak shoot weight to initial crown plus stubble weight (on day 0) were calculated and compared (table 5.32.).

Table 5.32. Shoot/Crown + Stubble Ratios

	3RC	3RW	HC	HW
Peak Shoot Weight *	2.63	2.74	7.10	7.17
Crown + Stubble**	1.37	1.27	2.52	3.67
S/C	1.92	2.16	2.80	1.95

* Estimated values from the growth curves (gm/plant).

** Initial (day 0) values from the observed data (gm/plant).

From these it is apparent that within the Wairau treatments, the relative crown plus stubble productivity was similar. For the Chanticleer variety there was a marked decrease from the H to the 3R treatments, the latter being comparable to the Wairau treatments. The greater HC relative crown productivity was associated with the smaller crown size as the shoot growth between the H treatments was identical.

The large plant size variability of all treatments and both varieties (table 5. 12.) limited the accuracy of the single plant measurments. Most other workers have avoided this problem by using area based measurements or for more controlled studies,spaced or potted plants of common clonal origin. It was only recently that Ueno and Smith (1970) considered plant size growth differences. Using three year old transplanted Vernal lucerne plants, they formed three plant size groups of 1.80, 5.20 and 15.80 gm per plant based on the combined initial weight of the tap root 10cm, crown and 5cm stubble. Vernal lucerne, a more falcata type, has a type classification similar to Wairau (Iversen and Meijer, 1967) and the above weights suggest a range not unlike the HW treatment weights (fig.5.15.). The only other known plant size study was made by Silva((1968). In their respective studies, both related total shoot yields to plant size at the start of growth. It was not possible to establish this relationship in the thesis experiment, but the relative constancy of the Wairau ratios of peak shoot growth to the tap root plus crown weights on day 0 (table 5.33.) suggests these treatments were in agreement. The Chanticleer treatments did not comply. The HC treatment with the higher ratio showed greater productiviyy on this basis. It must be remembered that the significance of these ratios is restricted in that only part of the total root weight is involved.

Table 5.33. Shoot/Root plus Crown Ratios.

	3RC	3RW	HC	HW
Peak Shoot Weight*	2.63	2.74	7.10	7.17
Root + Crown**	3.09	2.90	5.90	7.60
S/R	0.85	0.94	1.20	0.94

* Estimated values from growth curves. (gm/plant)

** Initial (day 0) values from the observed data. (gm/plant)

The similarity of plant size for varieties contrasts with the varietal differences observed between treatments for other plant variables. The relatively regular increase of mean RTCR weight as defoliation frequency decreased was in line with the expected results (sections 2.3.1.2., 2.3.2.). The tendency for the range of size to increase similarly has not been reported before. The larger range of the H treatments, especially for Wairau, may have been related to the greater stem densities and long periods with a closed canopy, resulting in greater inter-plant competition with some resultant smaller plants. This could have been associated with extended root and crown growth of the larger plants during the longer periods of more mature growth (section 2.3.1.2., fig. 5.3.). Even so, within all treatments of both varieties some very small plants were present, indicating a high degree of persistence for these plants in the less frequently defoliated treatments in particular.

The single lucerne plant is in most cases a discrete plant unit and as such is, generally more amenable to single plant level growth studies in comparison with other species, although this is likely to be fraught with a very large plant size variability, particularly with field studies.

5.3.4. The Nature of Lucerne Shoot Growth.

The techniques used in this study can be criticised on two counts. The first is the use of a shoot height/weight relationship. This normally decreases, particularly during more mature growth stages (Keoghan, 1970), but such decreases are unlikely to have been great up until the 3/10 when the measurements pertinant to this chapter were completed. Secondly, some degree of manual shoot and maybe growth hinderance probably resulted from the handling involved with the weekly measurement of each shoot. This was not visually apparent and is assumed to have been similar for all treatments.

All treatments had an extended period of active new shoot extension lasting for 4 to 5 weeks. This is likely to be shorter and at a faster rate later in the season with warmer growing conditions. Compared to the other treatments, the 3RC treatment showed a tendency, although not significant, to have a lower rate of new shoot extension after the first two weeks. The different patterns of plant shoot number changes with time between treatments (fig. 5.17.) indicates this. It is suggested that this 3RC treatment limitation may have been of physiological origin such as an insufficient supply of organic and/or mineral substrates necessary for growth and possibly a growth hormonal limitation. This probably being related to the weakened plant condition (section 2.4.1.4.).

Within each treatment, the similar shoot height growth rates between the first groups (fig. 5.16.) strongly indicated a relative self-sufficiency in growth for each shoot once it reached a minimal size, or more likely, a minimal leaf area as reported by Silva (1968)(section 2.4.1.3.). At any given time during regrowth it is thus apparent, that the earliest elongating shoots generally contribute most to the total yield. The relative production results (tables 5.21, 5.22,fig. 5.18.) clearly showed that this size advantage of the earliest elongating shoots was much enhanced when there was a large number of these. Thus, in the "first instance", high levels of total shoot production have a basic dependence on the number of shoots present, and secondly, are strongly influenced by the time when each starts to elongate. These conclusions are the same as those of Leach (1969a, 1970b) and Keoghan (1970). Total shoot yield differences between treatments of different defoliation frequency are expected to be largely expressed in terms of these two factors.

Later elongating shoots are presumably in competition for light resulting in slower growth rates and hence size, and, being of smaller number, their combined production contribution is small. The associated cessation of new shoot initiation during the same period (table 5.14.) is likely to be in part at least a hormonal based inhibition comparable to apical dominance (Leopold, 1964), although internal competition for growth substrates may be implicated.

The above aspects are initially the important yield components of total shoot growth. With later growth in the thesis experiment, whole shoot senescence became apparent in all treatments of long enough duration. This was at about the time new shoot development ceased. Whole shoot senescence became a major determinant of total shoot yield. This may be typical of other spring grown field experiments although similar reports do not appear to exist. This aspect of senescence is expanded upon later (chapter 6).

The above general results were equally applicable to all treatments. The important treatment difference was the significantly slower 3RC treatment's shoot height growth rates, which applied to all the 3RC shoots irrespective of when they started elongating. This condition, and the associated reasons, are probably related to the similar condition pertaining to the limited initiation and extension of new 3RC treatment shoots as previously discussed. Of equal importance between treatments was the similar shoot height growth rates of the 9C*, 15C and HC treatments, indicating that the above requirements of shoot numbers and when each starts elongating were major determinants of their yield differences. These two treatment differences suggest that in the one environment with Chanticleer lucerne, increasing defoliation frequency does not affect individual shoot growth per se, until a critical defoliation frequency is attained. More work is needed to verify this conclusion. Further, varietal differences are likely to be existent because of the very different shoot number patterns between treatments already observed (section 5.2.1.5.).

5.3.5. The Basal Shoot Growth of Mature Lucerne.

This represented quite a substantial component of the final yield, for the H treatment in particular. In absolute terms the significantly greater basal shoot weight of the H treatments is expected, if only because of the larger plant size. The very high 3RW percentage of total shoot growth was partly due to the low amount of mature shoot growth measured (table 5.4.),

With the Chanticleer variety, a further factor was the earlier development of more basal shoots in the H treatment of the field growth study indicating earlier maturity (table 5.28.). It would have been interesting to know if the 9C and 15C treatments had intermediate maturity times or not, by this criterion. These results should not be extrapolated to the Wairau variety regardlessly. The measured but non-significant basal shoot yield advantage for the Wairau 3R and H treatments (fig. 5.18.), coupled with the earlier attainment of maximum whole plant leaf and shoot weights (figs. 5.1., 5.2.), implies that the Wairau treatments matured earlier. This is not the expected varietal order of response as the more sativa type lucernes are generally acknowledged as maturing earlier (Iversen and Meijer, 1967). It could be that this is only applicable to the spring growth.

Among the other variables measured, the greater basal shoot number for the H treatments is as expected and similarly for their lower stem/leaf ratios indicating measurement at a later and hence leafier stage of development. This

is further supported by their greater average shoot weights. The greater stem/leaf ratio of Chanticleer was expected, as sativa type shoots of the same age are less leafy (section 2.1.1.).

The productive value of the basal shoot growth per se is questionable. When cutting the H harvest, a significant number of new basal shoots were removed. A regrowth delay may have been induced by the time taken for further new replacement shoots to establish and reach a photosynthetically self-sufficient stage of growth. It is considered that defoliation as new basal shoots are just starting to appear is more efficient. The plant is then considered to be physiologically prepared for regrowth (Mitchell and Denne, 1967); what shoots are present would probably be retained with apices intact even with quite close defoliation; in these conditions the resumption of active shoot regrowth would normally be rapid. The advantages of these aspects have been recognised by Nelson and Smith (1968a) and Leach (1969a).

With delayed hay defoliation as in the thesis experiment, the period of lower mature shoot growth rates (fig. 5.2.)also represented a period of reduced growth efficiency. The very rapid mean crop growth rates of the 15" treatments' second harvest growth for both varieties (table 4.15.), strongly indicated that for the H treatment at least, significant growth advantages would have been obtained by defoliating at about the time of the 15/H sampling. At this time field growth observations indicated new basal shoots were starting to arise (table 5.28.). This relationship and associated yield benefits have been observed in other studies (Tysdal and Kiesselbach, 1939; Crowder et al., 1960). In practical terms though, it may be difficult in some instances to coordinate cutting times with the commencement of new basal shoot extension.

5.3.6. Defoliation Criteria.

The use of shoot height as a defoliation criterion is physiologically sound as it incorporates the influence that the complex of physiological, environmental and management factors have on lucerne growth. With suitable experimental design these can be incorporated into treatment growth comparisons. The aspect of experimental design is discussed later (section 10.1.). In practical terms, this criterion is generally less efficient.

This last statement was applicable in the thesis experiment, in which the mean shoot height estimates were mostly erroneous. The equality of the adjusted average shoot heights between the 9C, 15C and HC treatments for the field growth measurements (section 5.2.3.) indicated that for each growth stage these

treatments should have been sampled at about the same time. This, in contrast to the considerable sampling time differences that occurred (table 5.1.). From the sampled growth study plants (section 5.2.1.) the lengths of the shoots were available. The mean shoot length for each treatment at the 3", 9" and 15" sampled growth stages were calculated and compared with the expected values in a Chi-square analysis (table 5.34a.). The observed values were very significantly different from the expected values. From the subsequent Chi-square analyses of treatment totals and sampled growth stage totals (tables 5.34b,c.) it was shown that the judgement error increased with stage of growth, but more noticably for the less frequently defoliated treatments.

Table 5.34. The Accuracy of Shoot Height Estimations. (cm)

a.

	4"			9"			15"		
	Days	Obs	Obs-Exp	Days	Obs	Obs-Exp	Days	Obs	Obs-Exp
3RC	27	9.1	- 1.1	45	21.3	- 1.5	61	28.2	- 9.9
9C	23	7.3	- 1.9	37	17.2	- 5.6	(-	29.7	- 8.4)*
15C	18	6.4	- 3.8	34	13.2	- 9.6	51	32.8	- 5.3
HC	13	6.4	- 3.8	32	11.2	-11.6	48	25.3	-12.8
3RW	31	8.5	- 1.7	48	22.4	- 0.4	67	34.5	- 3.6
HW	25	8.4	- 1.8	38	14.7	- 8.1	51	27.3	-10.8
	Exp = 10.2 cm			Exp = 22.8 cm			Exp = 38.1 cm		

$\chi^2 = 31.41$ DF = 9 P = 0.005

b. Treatment Totals.

	Exp	Obs	Obs-Exp
3RC	23.7	19.87	-3.83
9C	23.7	18.06	-5.64
15C	23.7	17.46	-6.24
HC	23.7	14.30	-9.40
3RW	23.7	21.80	-1.90
HW	23.7	16.80	-6.90

$\chi^2 = 10.84$ DF = 5

$0.10 > P > 0.05$

c. Growth Stage Totals.

	Exp	Obs	Obs-Exp
3RC	10.2	7.68	-2.52
9"	21.8	16.66	-5.13
15"	38.1	29.63	-8.47

$\chi^2 = 3.70$ DF = 2

$0.25 > P > 0.10$

* 9C observed value estimated with the method of section 3.5.

Only the 3R treatments showed any consistent judgement accuracy. This was probably associated with the longer growth periods of these treatments (table 5.34a.) and maybe partly due to the larger proportion of the shoots of these treatments tending to arise in the first two weeks of growth (section 5.2.3.) and thus resulting in a more uniform shoot length distribution. In contrast, the 9C, 15C and HC treatments were sampled after shorter growth periods, these decreasing in this treatment sequence and further they had a more diverse distribution of shoot height and ages (figs. 5.16a,b,c,d., 5.17a,b,c,d.). These factors, when considered in association with the relative similarity between treatments of the adjusted average shoot heights of the field growth plants, collectively support and provide the basic reasons for the erroneous nature of the shoot height estimations made. Probably, this judgement error, largely originated from an expectation of faster growth and hence height, as defoliation frequency decreased. The resultant psycological bias would have influenced the visual estimates made. This was certainly the case for Chanticleer, but also appears to have been similar for Wairau, although the larger initial shoot numbers (fig. 5.5.) may result in a more uniform shoot length and hence more accurate shoot height estimation.

A further problem is how to estimate the mean shoot height. With there being such a diversity of shoot heights in the lucerne canopy (also Cowett and Sprague, 1962; Leach, 1968a; Keoghan, 1970), it is very difficult to select a random sample of shoots which give a good estimate of the mean shoot height. Further, as here, this is impractical if frequent measurements are needed for determining the attainment of a specific mean shoot height.

Statistically, it is preferable that all samples to be compared should be taken at the same time. From the above considerations, it would appear that this would have given a reasonable physiological comparison for all but the 3R treatments. From table 5.34a, the 3R and H data suggests that the psychological bias may have also been operating between varieties, for the Wairau variety tended to have a greater mean shoot height at each growth stage. For a given growth period, the falcata type Wairau was expected to have shorter shoots than the more sativa type Chanticleer (Iversen and Meijer, 1967). A direct variety comparison of shoot height growth over equal time intervals was not obtained.

The determination of the hay stage of growth also presented some difficulty. For flowering,lucerne is a long day species (Thomas, 1967). This accounted to some extent for the long time taken for flowering to occur during this

spring growth. This was possibly contributed to by the associated cooler temperatures (section 3.6.) extending the vegetative growth period (Dermine et al., 1967; Smith, 1969a). For the seaon and conditions of the thesis experiment, the presence of new basal shoots would have been the preferable hay stage defoliation criterion (section 5.3.5.).

To reiterate, the probable physiological readiness for defoliation associated with the commencment of new basal shoot extension, has been acknowledged by several workers in recent years (section 2.4.2.1.) supporting the suggestion made many years earlier by Wing (1909), that cutting be done when "new shoots" appeared on the crowns.

In conclusion, for immature lucerne, mean shoot height is not a satisfactory defoliation criterion for experimental treatment comparisons for which time intervals are probably the most satisfactory, especially for growth studies. With more mature lucerne, early new basal shoot presence is probably the preferable criterion, especially in the spring. For general practical purposes, very general shoot height estimations are probably useful defoliation criteria providing to a limited degree, estimations of the stage of growth and the relative amount of growth present within a given lucerne sward.

CHAPTER 6.

Senescence, Sward Physiognomy and Light Transmission.

These interrelated subjects are considered together. The senescence measurements were drawn from several previous studies, while a limited study was made of several aspects of the lucerne plant's leaf canopy, their changes with time, varietal influences, and the effects of some selected treatments. Leaf area height distribution was related to the associated relative light intensity profiles within the canopies.

6.1. Method:

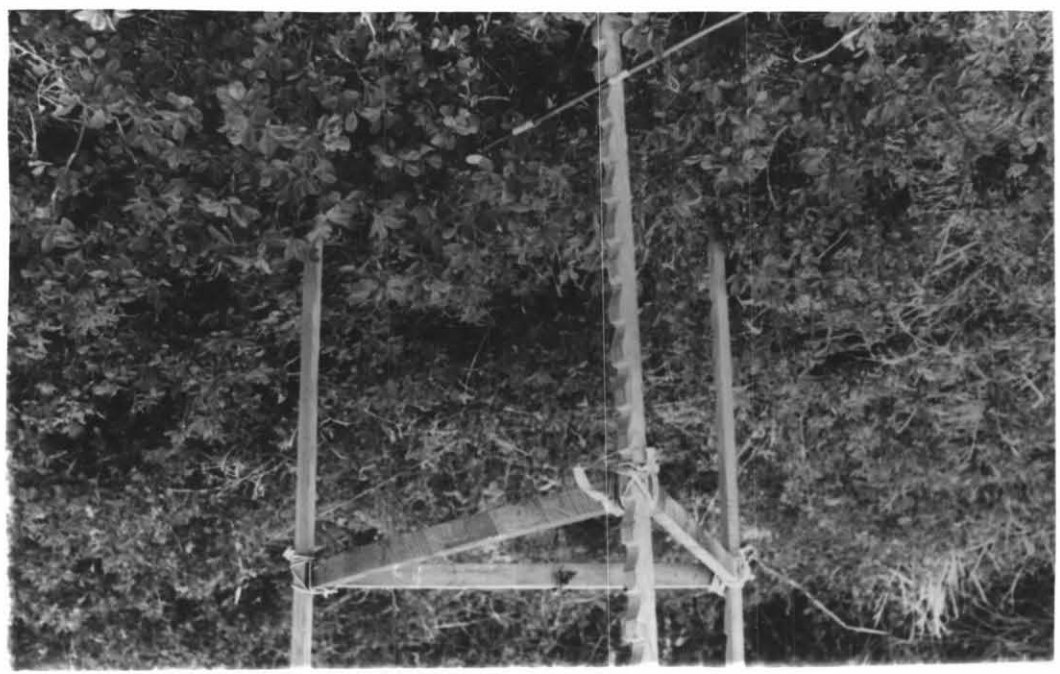
6.1.1. Experimental.

Using the identified field growth shoots of the Chanticleer variety only (section 5.1.1.), the leaf canopy's total height was represented by total shoot height. The base height of the leaf canopy was represented by the lowest leaf of each shoot in sequential 10 cm. height intervals above ground level. These measurements were averaged over all shoots measured and are presented as replication means in (table 3A. 6.). Shoot numbers measured per replication ranged between 23 and 7 depending on the treatment and stage of growth.

The leaf area height distribution was measured for the 6 major treatment/variety combinations (3RC, 9C, 15C, HC, 3RW, and HW) on the single plants dug for the plant growth studies (section 5.1.1.). As each shoot was removed it was placed against a board on which was drawn a grid of parallel lines 4 cm. apart, so that the position of the shoot's stem that had been at ground level, or such extrapolated position for shoots arising on the stubble, coincided with the zero grid line. The leaf area for each 4 cm. portion of shoot was measured using photographic standards developed by Williams et. al. (1964), and recorded accordingly. From these records the mean leaf area per replication for each 4 cm. height interval was calculated (table 3A. 6.2.).

The light profiles were measured in the sward canopies just prior to sampling the above plants. A light meter was developed and built for this purpose (Appendix 6A). Within each treatment, six light readings were taken for each replication at 4 cm. height intervals within the total lucerne canopy using a stand prepared for this purpose (plate 6.1). Each reading was coupled with a reference probe reading taken immediately afterwards,

Plate 6.1. The stand and probe used to measure the light intensity at 4 cm intervals in the lucerne canopies.



to enable each canopy reading to be calculated as the percentage of incident sunlight at that time. Readings were made in the 15C, 15W, HC, HW and 9C treatments. The 3R treatments were not measured as the openness of their swards did not permit representative canopy transmission patterns to be obtained. Further, the large amount of other species growth was a confounding factor. As the leaf area distributions and light profiles were to be compared, there was only a limited flexibility in the choice of light conditions, although very patchy cloud and windy conditions were avoided. The continual use of the reference probe enabled the smaller changes in the incident light intensities to be accounted for to a large extent. Readings were only made between 1000 hours and 1400 hours to minimise the effects of the changing angle of incidence of the sun.

Two forms of senescence are considered, viz., whole shoot and leaf senescence. The whole shoot measurements were extracted from both the single plant studies of shoot number changes (section 5.2.1.6.)and the field growth study of shoot number (section 5.2.3.). Leaf senescence was studied indirectly from the measurements of leaf canopy ground clearance and also from the total leaf growth per plant study (section 5.2.1.2.).

6.1.2. Data preparation and Statistical Analysis:

The leaf canopy depth and base height data was analysed using traditional ANOVA analysis from and including day 28 onwards for the 3RC and HC treatments. There were insufficient 9C and 15C measurements to warrant their inclusion.

The leaf area height distribution and the respective height measurements were all calculated to give replication mean values and these were then converted to percentage cumulative values of their respective totals. These measurements were termed the Relative Leaf Area (RLA), Relative Height (RHT), and the light profile values as Relative Light Intensity (RLI). In this form, differences of canopy height between replications and treatments did not hinder comparisons being made.

Multiple regression curves of the form -

$$Y = a_1 + a_2 t + a_3 t^2 \ldots\ldots\ldots a_i t^{i-1}$$

- were fitted to the RHT x RLA and RHT x RLI data using the

methods previously described (section 5.1.2.). Treatments were compared directly from these curves. The RHT x RLA histograms were prepared using RLA values determined from the RHT x RLA fitted curves.

6.2. Results:

The occurrence of considerable whole shoot senescence was demonstrated with the single plant studies (section 5.2.1.6.; Fig 5.5.). These measurements involved all shoots (buds included) greater than 1 cm length. Consequently these measurements were not representative of established shoot senescence, but are important here in providing the only variety comparison of senescence. Within these limitations the notable features are the large amount of shoot (and bud) senescence, this being much greater for theWairau variety.

The field growth study of individual shoot life gave more accurate results. Only shoots greater than or equal to 5 cm length were measured. These results were representative of the senescence of established shoots. The relative shoot numbers (RSN) of each shoot group (Section 5.2.1.) for each Chanticleer treatment are illustrated in Fig. 6.1. It is readily apparent that considerably more shoots senesced in the H treatment than the 3R treatment, the only treatments grown to the hay stage. On day 77 they had RSN's of 28 and 64 respectively. There was also the indication of shoot senescence having started sooner in the 15" and H treatments. No shoot senescence had occurred in the 9" treatments at the completion of this treatment's measurement. Between shoot groups there were no apparent senescence differences other than for the much faster senescence rate of group 4 of the H treatment, with its large shoot numbers (Fig. 6.1.).

The plant leaf data (section 5.2.1.2, Fig. 5.1.) showed that nett weight loss did not occur until after approximately 65 and 80 days growth for the Wairau and Chanticleer treatments respectively. The canopy base height measurements showed that leaf senescence started much earlier at approximately 28 days and continued for the duration of the measured growth (Fig. 6.2.). Using this measure as an approximate estimate of senescence, the H treatment, compared to the 3R treatment, had a significantly higher level of leaf senescence after day 42 (Fig. 6.2., table 6.1.). In terms of mean full canopy depth (18.7 and 18.5 cm for 3R and H treatment) the day 77 amount of leaf senescence was 1.1 and 1.7 canopy depths for the 3R and H treatments respectively.

The relative shoot numbers 5 cm or greater in length measured in the field growth study on the 15th. of August through to the 25th. of October as a measure of whole shoot senescence.

Figure 6.1.

a.	(top left)	3RC
b.	(top right)	9C
c.	(bottom right)	15C
d.	(bottom left)	HC

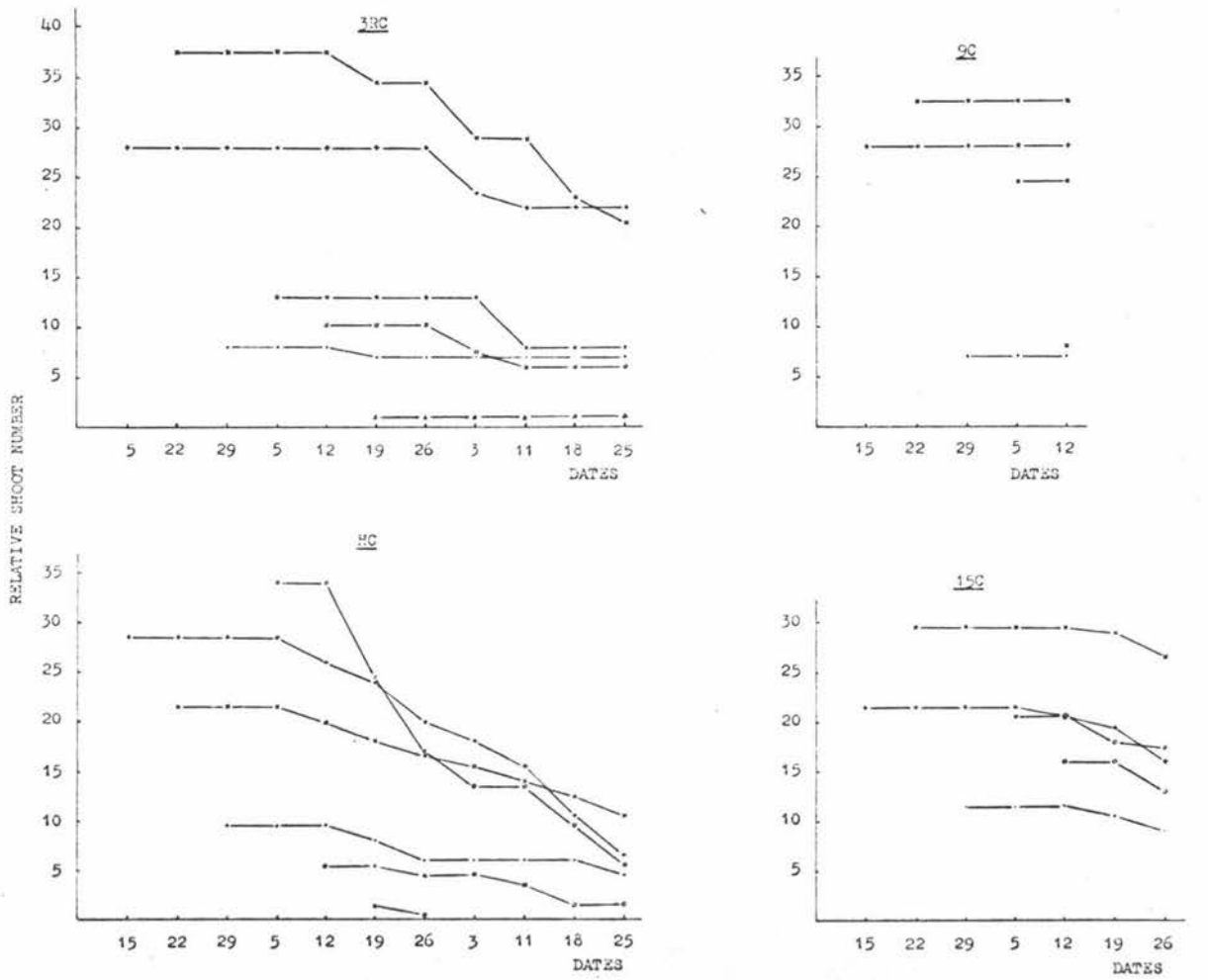
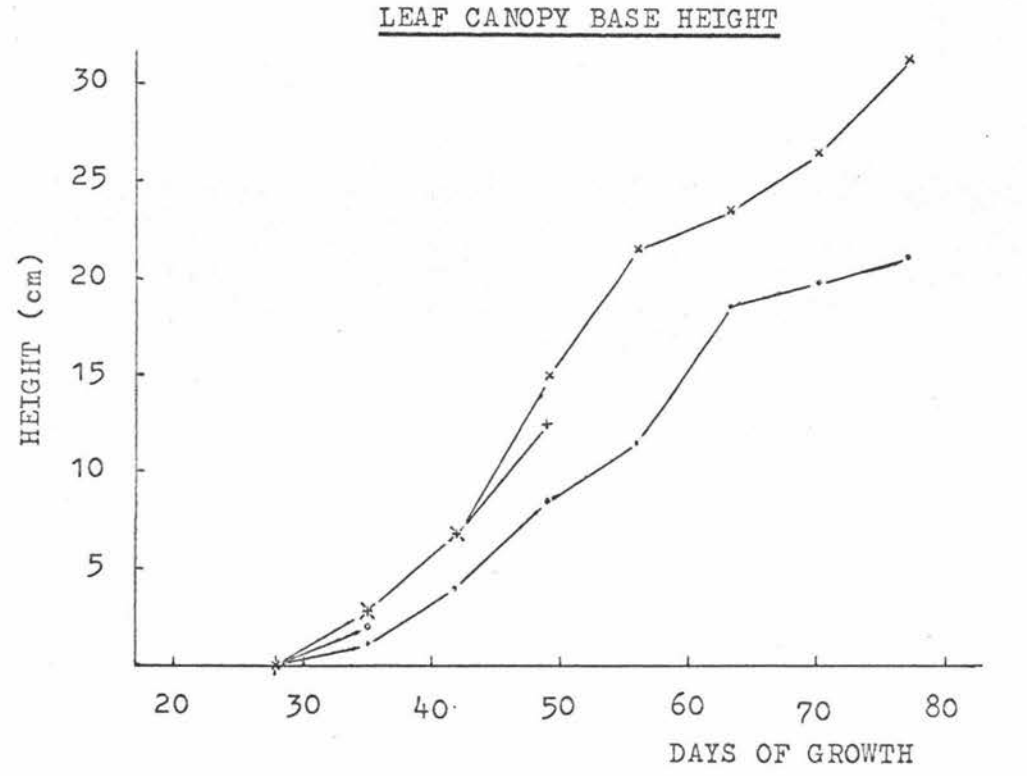

3RC
9C
11C
15C
RELATIVE SHOOT NUMBER
DATES
5 22 29 5 12 19 26 3 11 18 25
15 22 29 5 12
15 22 29 5 12 19 26

Figure 6.2. The vertical movement of the leaf canopy base during growth for each Chanticleer treatment. The canopy base height was the average height of the lowest leaves.

Figure 6.3. The changes of leaf canopy depth during growth for the 3RC and HC treatments. These measurements were taken from fig. 6.4.


LEAF CANOPY BASE HEIGHT
HEIGHT (cm)
30
25
20
15
10
5
20
30
40
50
60
70
80
DAYS OF GROWTH

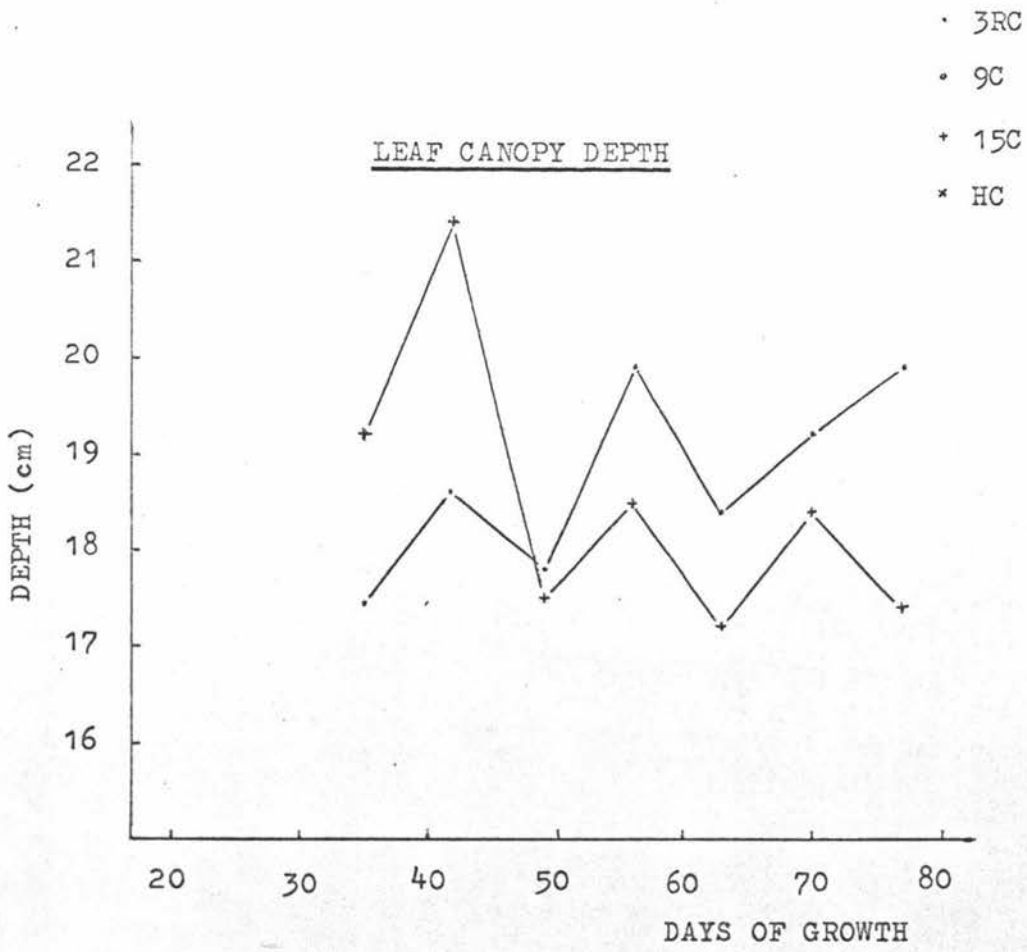

3RC
9C
15C
HC
LEAF CANOPY DEPTH
DEPTH (cm)
22
21
20
19
18
17
16
20
30
40
50
60
70
80
DAYS OF GROWTH

Table 6.1. ANOVA of Leaf Canopy Depth and Base Height (cm)

Variation	Depth	Base Ht.
Replication	10%*	1%*
Time (Ti)	NS	1%
Treatment (Tr)	NS	1%
Ti x Tr	10%	1%
SE	1.61	1.69
CV%	8.63	11.17

* ANOVA significances

Appendices: Data 3A.6.1. Statistics 4A.6.1.

Table 6.2. Leaf Longevity Estimates (days)

Day*	3RC	HC
49	34(approx)	22
56	32	21
63	28	26
70	33	30
77	38	30

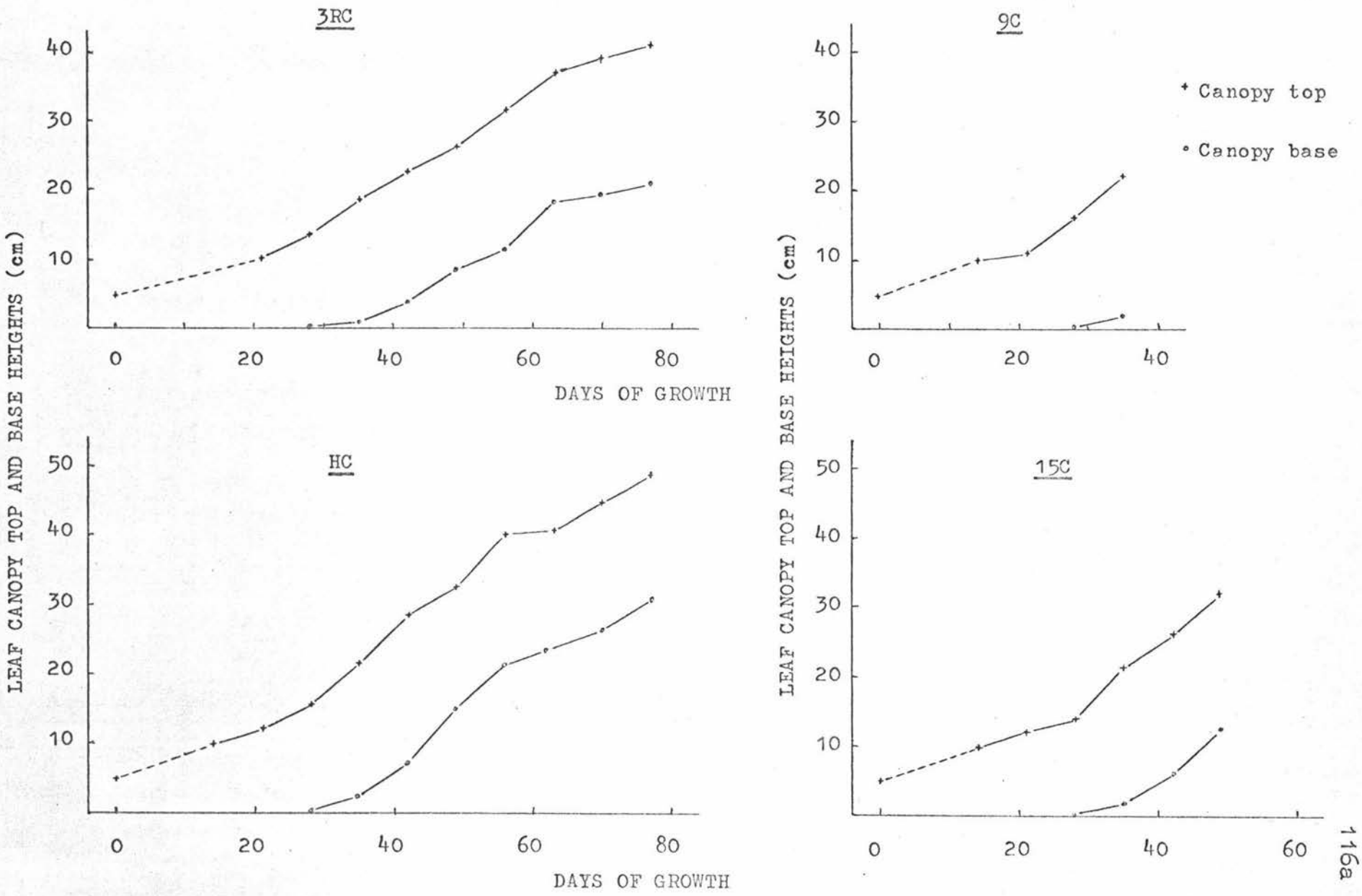
*Selected days for comparison were determined from the leaf canopy base curve.

An estimate of leaf longevity was determined from the graphs of Fig. 6.4 as a series of time intervals between the top and base lines of the leaf canopy, the estimates being tabulated in table 6.2. Leaf longevity was greatest for the 3RC treatment over all measured days, but with different time patterns. The H treatment showing increased leaf longevity with later measurements, while the 3RC treatment had a minimal value on day 63, the mid-date. The longevity of the first leaves formed was not determined.

There was no significant treatment difference for leaf canopy depth, but there was a weak interaction (P=0.10) for time x treatment (table 6.1.), with the 3RC treatment initially having the shallowest and later the thickest leaf canopy, as compared with the HC treatment (Fig. 6.3.).

Figure 6.4. The vertical movement of the leaf canopy for each ChanticLeer treatment during growth. The canopy top height was the average shoot height measurement. The canopy base height was the average height of the lowest leaves.

Top left	3RC
Top right	9C
Bottom right	15C
Bottom left	HC


3RC
9C
HC
15C
LEAF CANOPY TOP AND BASE HEIGHTS (cm)
DAYS OF GROWTH
+ Canopy top
° Canopy base
0
10
20
30
40
50
60
80

For both leaf senescence and canopy height and depth measurements, the 9C and 15C treatments had too few measurements to enable adequate comparisons. The leaf canopy base height replication significance was due to a lower value for replication one.

Fig. 6.5. illustrates the cumulative RLA height distributions per plant for the main treatments, as determined by the fitted curves. All curves had very significant fits (see fig. 6.5.). The cumulative RLA at any given RHT other than the very top layers was noticeably greater for the HC and 15C treatments compared with the 3R treatments. The results of the 9C treatment were between. These differences were in response to their different cumulative RLA height gradients which were relatively regular for these treatments. The HW treatment was less regular with a consequently more complex RLA height distribution.

Except for the 3R treatments, the RLA height distribution of each treatment (as histograms, fig. 6.6.) are described with their associated RLI transmission patterns which they complimented. The 3R treatments had a regular RLA height distribution confined to the top two-thirds of their canopy (fig. 6.6e). There was quite a high leaf area density in the top-most layers. Both varieties were similar. For the other treatments, the 15C treatment (fig. 6.6b.) had a regular decrease of light intensity with canopy depth increase in association with a relatively even basipetal RLA increase to a broad maximum at 45% RHT. The HC treatment (fig. 6.6a.) had a slightly more abrupt RLI decrease in the top canopy layers associated with a slightly greater leaf area concentration here. At lower RHT levels the 15C and HC treatments had rather similar light profiles. Of all treatments, the HW treatment (fig. 6.6d.) had the most abrupt decrease of light in the top canopy layers in association with a greater RLA concentration in these layers. At the lower RHT's the decreasing RLA's permitted a more gradual decrease of light intensity. Again, the 9C treatment (fig. 6.6c.) had intermediary RLI and RLA characteristics. The 15W treatment light measurements were available. This treatment had a light profile very similar to that of the 9C treatment.

The RLI curves are compared on the one graph (fig. 6.7.). There were not any large light intensity differences at selected RHT values between the 9C, 15C, HC and 15W treatments. Only the HW treatment had distinctly lower light intensities over the mid RHT values. The lack of coincidence of all the curves at the 100/100 coordinate as theoretically required, is an

Figure 6.5. A comparison of treatment multiple regression curves of the cumulative relative leaf area per plant with the associated relative heights. Measurements were made at the estimated 9" growth stage height for each treatment (ie. 22.86 cm).

3RC $Y = 64.273 - 47.027t + 10.24t^2 - 0.517t^3$
$F = 201.40$ $R^2 = 0.979$ SE of estimate 7.064 DF = 18
Max. shoot height 36 cm.

9C $Y = 8.080 - 12.877t + 5.045t^2 - 0.282t^3$
$F = 327.49$ $R^2 = 0.979$ SE of estimate 5.686 DF = 21
Max. shoot height 40 cm.

15C $Y = -16.332 + 8.080t + 1.898t^2 - 0.155t^3$
$F = 111.75$ $R^2 = 0.943$ SE of estimate 8.425 DF = 20
Max. shoot height 36 cm.

HC $Y = 6.296 - 7.390t + 4.599t^2 - 0.293t^3$
$F = 464.84$ $R^2 = 0.987$ SE of estimate 4.055 DF = 18
Max. shoot height 36 cm.

3RW $Y = 69.648 - 50.997t + 10.626t^2 - 0.520t^3$
$F = 271.66$ $R^2 = 0.977$ SE of estimate 6.443 DF = 19
Max. shoot height 36 cm.

HW $Y = -38.372 + 36.454t - 10.105t^2 + 1.486t^3 - 0.070t^4$
$F = 627.91$ $R^2 = 0.991$ SE of estimate 3.344 DF = 21
Max. shoot height 40 cm.

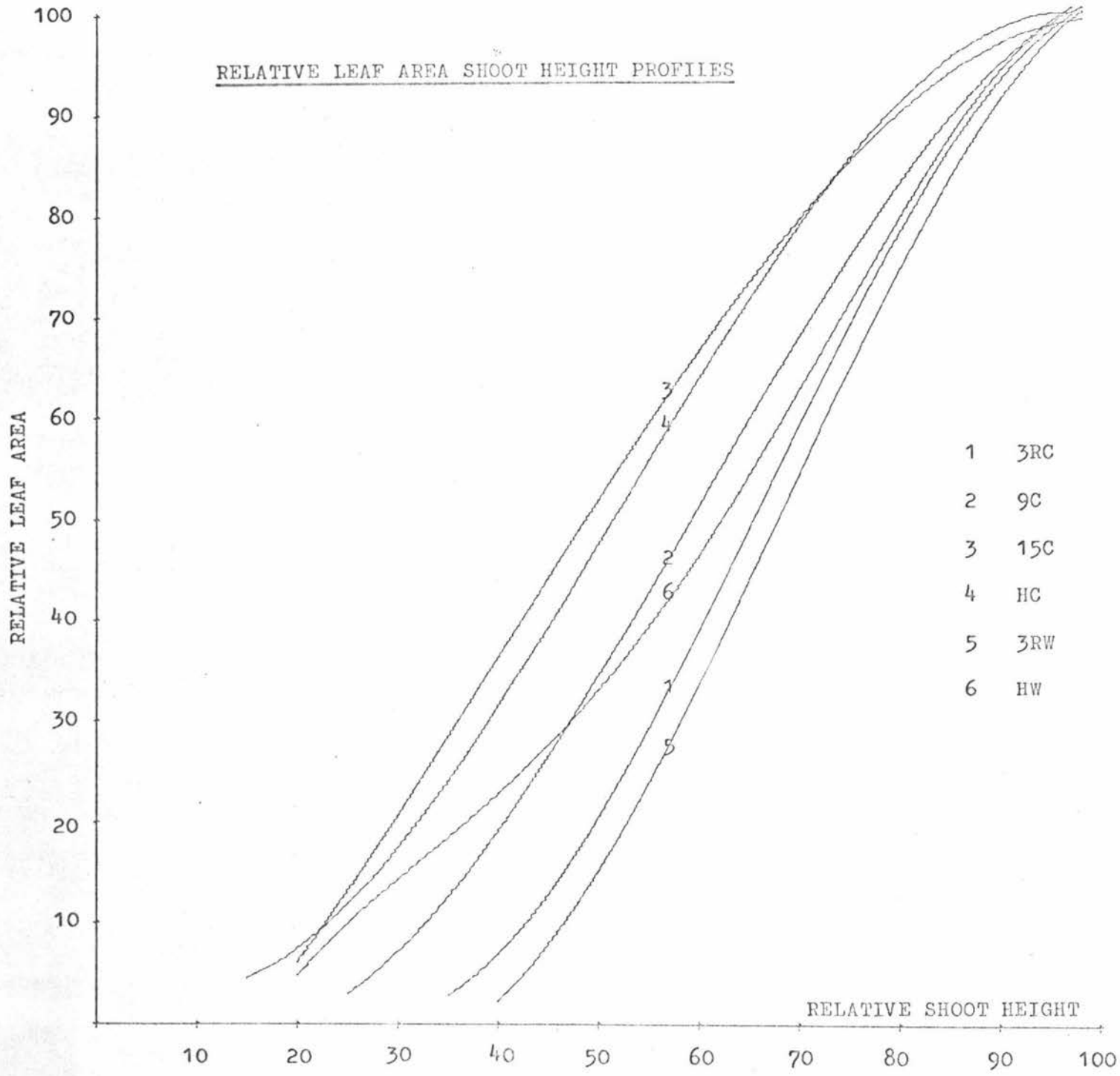

RELATIVE LEAF AREA SHOOT HEIGHT PROFILES
RELATIVE LEAF AREA
RELATIVE SHOOT HEIGHT
100
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
70
80
90
100
1 3RC
2 9C
3 15C
4 HC
5 3RW
6 HW

Figure 6.6. The height distribution of relative leaf area for sequential intervals of shoot height is presented as a histogram for each treatment. The values were calculated from the relative leaf area shoot height profile curves. For the 9C, 15C, HC and HW treatments, their relative leaf area height distributions are compared with their relative light intensity transmission patterns.

a. HC

b. 15C

c. 9C

d. HW

e. 3RC, 3RW

RELATIVE LEAF AREA HEIGHT DISTRIBUTIONS/RELATIVE LIGHT INTENSITY TRANSMISSION PATTERNS

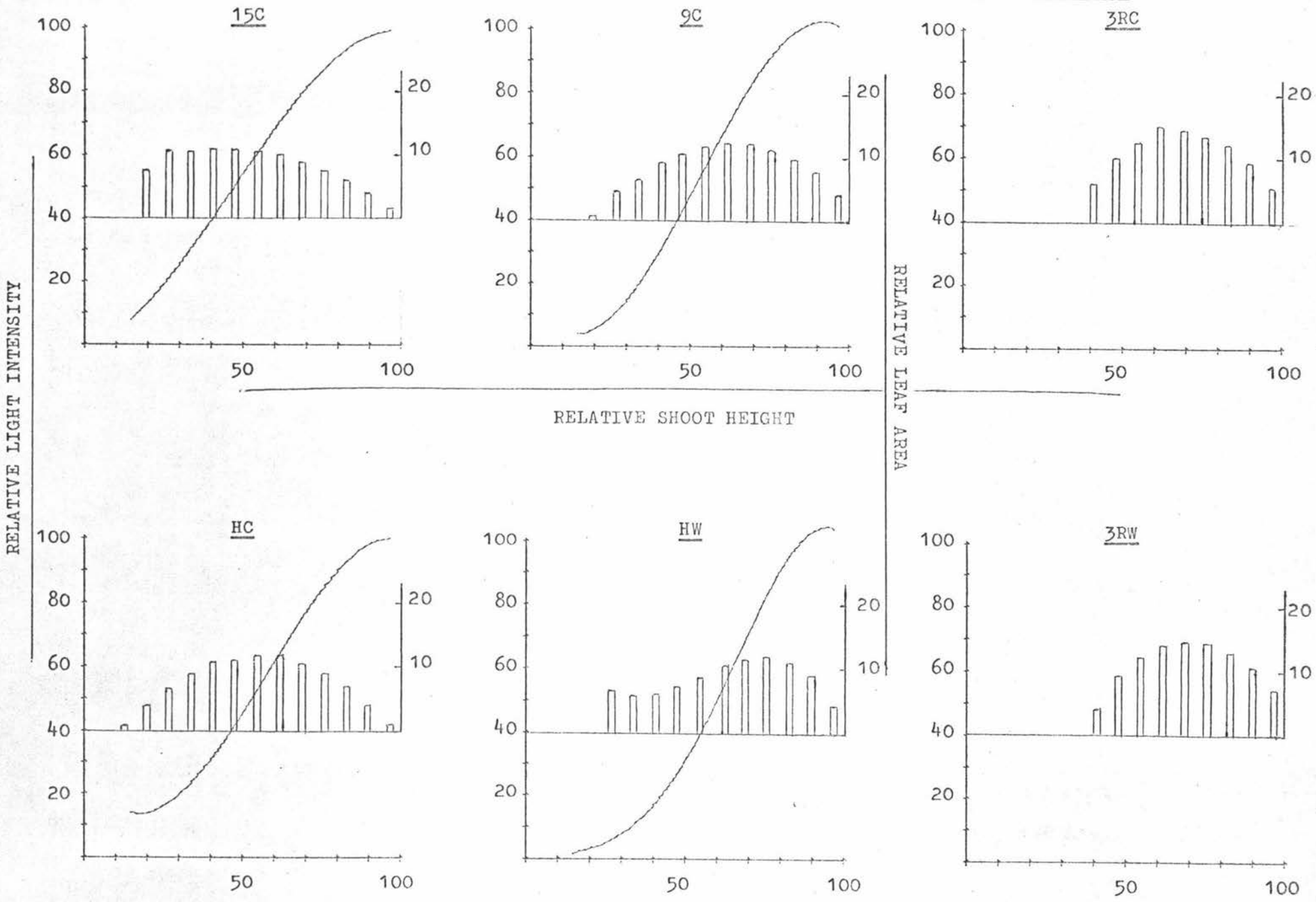


Figure 6.7. A treatment compsrison of multiple regression curves representing light intensity height profiles in the lucerne canopies. Measurements were made at the 9" growth stage height for each treatment.

9C $Y = 15.771 - 17.029t + 6.786t^2 - 0.426t^3$

$F = 111.97$ $R^2 = 0.959$ SE of estimate 8.657 DF = 14

15C $Y = -1.253 + 2.944t + 2.522t^2 - 0.181t^3$

$F = 377.98$ $R^2 = 0.981$ SE of estimate 4.960 DF = 21

HC $Y = 27.801 - 17.049t + 5.772t^2 - 0.334t^3$

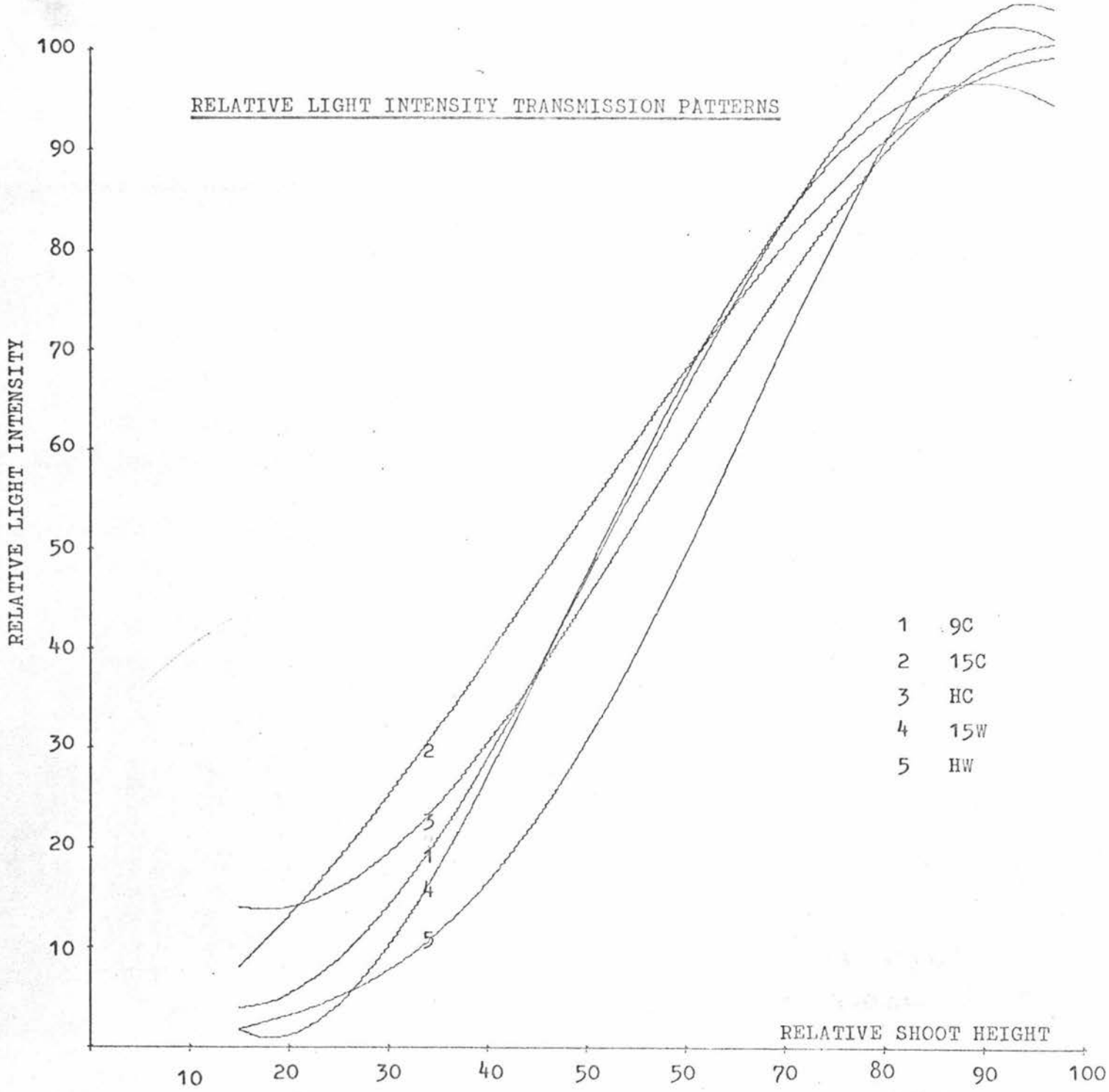
$F = 96.44$ $R^2 = 0.941$ SE of estimate 8.597 DF = 18

15W $Y = 32.106 - 38.494t + 14.085t^2 - 1.344t^3 + 0.039t^4$

$F = 324.93$ $R^2 = 0.984$ SE of estimate 5.461 DF = 21

HW $Y = -5.096 + 8.817t - 4.294t^2 + 1.138t^3 - 0.069t^4$

$F = 474.60$ $R^2 = 0.990$ SE of estimate 4.250 DF = 18


RELATIVE LIGHT INTENSITY TRANSMISSION PATTERNS
RELATIVE LIGHT INTENSITY
100
90
80
70
60
50
40
30
20
10
RELATIVE SHOOT HEIGHT
10
20
30
40
50
50
70
80
90
100
1 9C
2 15C
3 HC
4 15W
5 HW
2
3
1
4
5

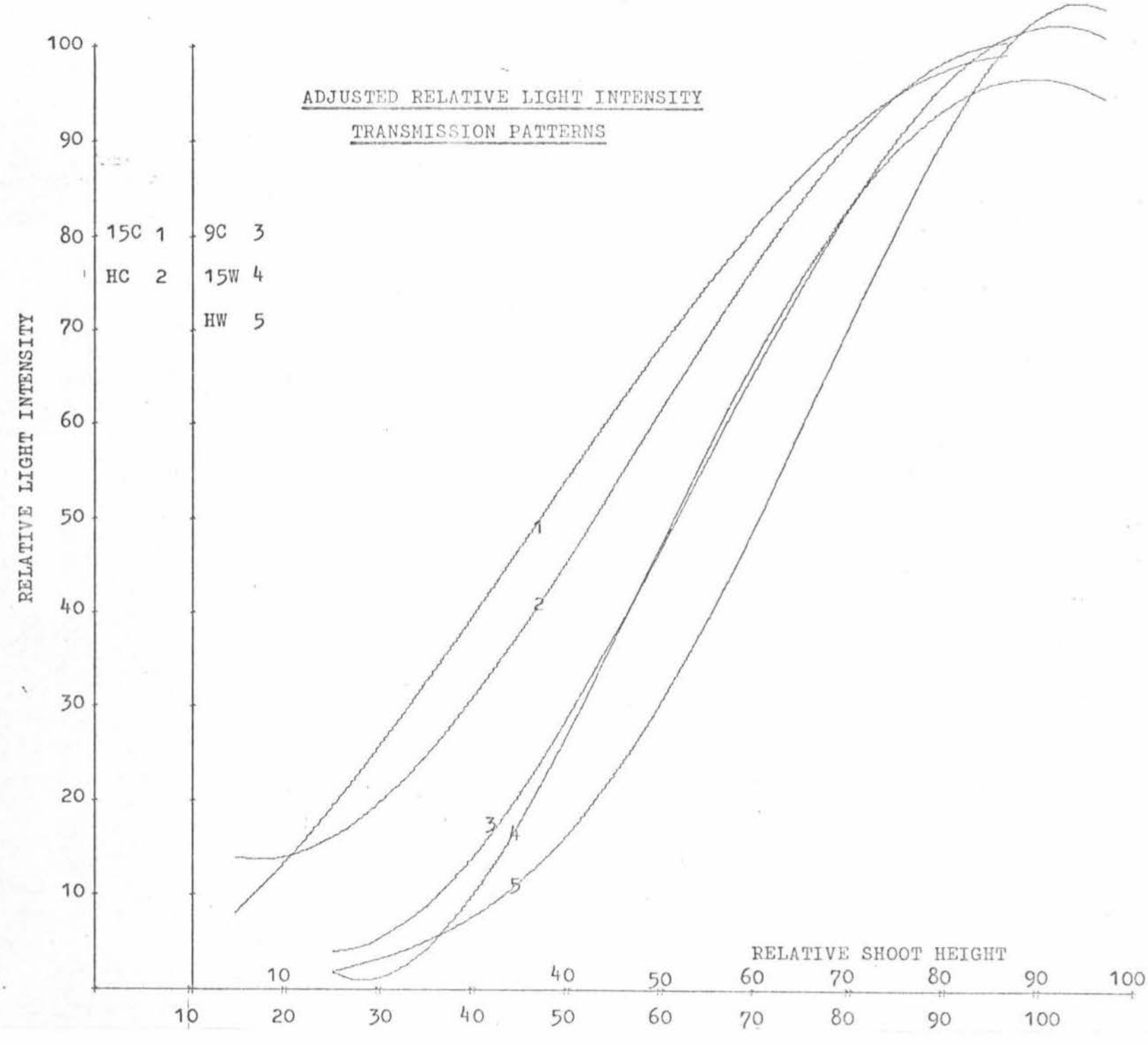
artifact attributed to the curve fitting process associated with differences of data distribution (table 3A. 6.) at these high RHT levels. To eliminate most of this factor so as to give an improved light attenuation gradient comparison, the curves were plotted using a double ordinate scale as illustrated in Fig. 6.8. Comparing the respective pairs of RLA and RLI curves for the 9C, 15C and HC treatments, there is a marked similarity of position, shape and gradient of curves and order between treatments (refer to the Fig. 6.8. overlay). The HW treatment curves did not compare so well, although in each case, their position relative to the other treatments was similar.

The height of 5% RLA varied considerably between treatments, but when compared to the leaf base canopy heights (Fig. 6.4.) on the dates of measurement (table 5.1. - the 9" plant samplings) the relative base heights were reasonably comparable. The 3R treatments had some leaf area down to a RHT of 22% but with this being quite small relative to the 44% RHT value (table 3A.6.2.), and hence was not important in the determination of the fitted curve.

6.3. Discussion:

It is obviously apparent that the considerable extent of whole shoot senescence represented a large reduction of the potential shoot production on a shoot number basis. This applied to all treatments but was greater with the less frequently defoliated Wairau treatments, for which this result suggests considerable inter-shoot competition. Even though this is to be expected with small shoots (less than 5 cm) and particularly if they arose later, the field growth measurements demonstrated considerable established shoot senescence. This occurred for shoots of all ages after the fourth week of growth. Light competition was probably a major factor, and particularly for the later elongating shoots. It was observed that some of the earliest elongating shoots attained a height of about 10 cm and longer in a few cases, and then senesced. These could have been grown in isolated low light intensity pockets shaded by older adjacent shoots. The very close proximity of the roots of some plants almost certainly meant that some inter-plant edaphic competition was occurring and similarly for shoot growth aerial competition. Other internal plant factors have also been implicated in inter-shoot competition (Hodgkinson, 1967).

Figure 6.8. The light transmission patterns of the 9C, 15C and HW treatments and the 15C and HC treatments were plotted as two groups so as to approximately co-ordinate their 100% relative light intensity values on the graph(see text). This gave a better comparison of the treatment transmission patterns.


ADJUSTED RELATIVE LIGHT INTENSITY
TRANSMISSION PATTERNS
15C 1
HC 2
9C 3
15W 4
HW 5
RELATIVE LIGHT INTENSITY
RELATIVE SHOOT HEIGHT
100
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
70
80
90
100

RELATIVE LEAF AREA

OVERLAY:
RELATIVE LEAF AREA SHOOT
HEIGHT PROFILES

1 15C
2 HC
3 9C
5 HW

Further, it is possible that the regular disturbance of the field growth shoots may have contributed to the senescence of a few shoots, even though care was taken to minimise this eventuality. With the lower shoot densities of the frequently defoliated canopies, such factors were probably less active, although in the 3R treatment the competitive effect of the numerous other species was evident.

The above results are supported by Nelson and Smith (1968a) who with a two-year-old lucerne sward demonstrated a spring growth shoot (one open leaf at least) number loss at the hay harvest, of 70% of the maximum number attained. In a growth cabinet experiment Keoghan (1970) observed some first and later shoot senescence over 56 days regrowth, but considerably less than that observed in sward conditions. It is probable that the rigors of climate and general environmental variability in the sward are largely responsible for these differences. A similar situation exists for inter and intraplant competition within swards compared to pot or singly grown plants.

Keoghan (1970) demonstrated the effect of different experimental conditions on the amount of stubble senescence, this being much greater in sward conditions. From the single plant samplings, there were no important changes of stubble weight (Fig. 5.8.) but in the later reversal study (section 9.2.1.) stubble weight decreased noticeably over the two weeks of the experiment. The reasons for this seasonal difference are not certain. It could be that the drier and hotter conditions in November resulted in quicker death and loss of the mature stubbles left after defoliation.

Lucerne leaf senescence has been clearly demonstrated in the more mature lucerne, noteably by Fuess and Tesar (1968), and also shown here (section 5.2.1.2.). Using the leaf canopy base height it was shown that basal leaf senescence occurred for much of the hay crop's growth period, in this case starting approximately at 28 days and probably earlier for each treatment. This is earlier than Keoghan's (1970) 30 day period in a growth cabinet. The latter conditions probably contributed to enhanced leaf longevity compared to sward conditions.

In general terms, the similarity of the leaf canopy depth of the 3RC and HC treatments, considered in association with the steeper rate of canopy base height increase (basal leaf senescence) (Fig. 6.4.) and shorter leaf longevity (table 6.2.) for the H treatment and the converse for the 3R treatment, indicates that lucerne basal leaf senescence is correlated with the leaf canopy depth. A major controlling factor of leaf senescence

and hence canopy depth is the light environment of basal leaves (Pearce et.al., 1968). With an assumed constant canopy depth determined by leaf senescence, the faster the mean shoot height growth rate, the shorter the mean leaf longevity - i.e. the time for a leaf to pass from an apical position to the largely light determined senescence level at the leaf canopy base. In turn, the canopy depth and hence leaf longevity may be altered if the light interception properties of the canopy change due to foliage rearrangement, i.e. if the mean extinction coefficient changes. The treatment leaf longevity estimates are discussed in view of these factors. The shorter leaf longevity of the HC treatments was associated with a greater shoot height growth rate (Fig. 6.4.; section 5.2.3.). The greater leaf longevity of later growth was possibly due to improved light penetration resulting from fewer shoots. The 3RC treatment showed a more complex response. The over-all greater leaf longevity being associated with the slower growth rates while the high initial values may have resulted from better light penetration around the fewer lucerne stems. On day 63 it was observed that the leaf canopy base was close to the height of the adjacent other species growth, indicating that with the sparcer lucerne shoot population of this treatment, the then basal leaves probably commenced to enjoy an improved light regime and hence reduced leaf senescence rate. A slight shoot height growth rate decrease may have assisted (Fig. 6.4.).

These results suggest that defoliation treatments can indirectly affect the rate of leaf senescence of residual growth through treatment induced factors affecting the leaf canopy depth. More detailed evidence is needed to verify the above suggestions made. The different light interception patterns between varieties (fig. 6.6., 6.8.) would suggest that there may have been varietal differences for leaf senescence patterns.

The changes of leaf canopy dimensions and position as indicators of leaf senescence have no bearing on the amounts of dry matter involved, as within these dimensions the canopy is composed of the major variables of stem number, stem height, leaf number/unit length of stem, and leaf size and weight.

In all cases shoot and leaf senescence together represented a large loss of potential shoot production, with both aspects apparently being aggravated by field conditions. In terms of actual production at later growth stages the energy converted to plant tissue was considerably greater than that harvested

At the same time though, some senescence, especially of leaf is a necessary sacrifice for the attainment of high production levels due to the growth form and physiognomy of the lucerne canopy.

The RLA and RLI were based on per plant and area measurements respectively. To compare treatments required that they have similar plant populations. This was so for the treatments compared, their population counts having no different significance at the LSD level of $P = 0.01$ (section 4.2.3.). The RLA measurements were made between the 32nd and 48th days growth coinciding with the start of basal leaf senescence. This resulted in the relatively even height distribution of leaf area, as compared with others (Warren Wilson, 1965; Keoghan, 1966, 1970 etc.) measuring leaf height distributions at later growth stages finding a predominance of leaf area or weight in the upper canopy layers. The leaf area distributions obtained are partly determined by the distribution of the varying individual shoot heights, and the fact that internodes are closer and hence leaf area and/or weight is more concentrated near the top of shoots.

The greater concentration of leaf area in the upper layers of the 3RC and 3RW canopies may have been related to the 3R treatments tending to extend more of their shoots in the first two weeks growth (section 5.2.3.) and hence having a greater proportion of shoot tops in these layers. At the same time there was heavy other species growth in the lower portion of the canopy, resulting from the long growth period (table 5.1.). This probably induced greater lower leaf senescence by shading, evidenced by the negligeable RLA values in the lower 40% of the canopy. The HW treatment with its high initial shoot numbers (section 5.2.1.5.) had a high leaf concentration in the upper canopy layers (Fig. 6.6d.) probably for the same reason, *viz*, relative evenness of shoot height. In contrast, the more even RLA height distribution of the HC and 15C treatments was associated with a shoot population of more diverse age and hence height (section 5.2.3.). The extention of this RLA height distribution to the lower (20%) canopy height levels was probably associated with the combination of lower amounts of other species growth (section 4.2.1.), and shorter growth periods.

The measured light transmission patterns for all treatments were not typical of those previously reported (section 2.4.3.1.) where a greater proportion of the incident light was intercepted in the top third of the canopy, typifying a red clover pattern (Mitchell and Calder, 1958). The relatively even attenuation patterns with canopy depth measured were more typical of grass light transmission patterns (Stern and Donald, 1962).

These were related to the more even RLA distribution patterns measured. The RLA measurements did not include an estimate of the stem light interception capacity as Keoghan (1970) did. To this extent the results are probably understimated, especially in the lower canopy layers where stem tissue predominates (Warren Wilson, 1965).

In contrast to the conclusions of Keoghan (1970) that the light transmission pattern was not closely related to the pattern of leaf distribution Figs 6.6a,b,c,d. suggest good relationships for the associated treatments as described before (section 6.2.). Admittedly these canopies were still relatively short, with the transmission patterns largely relating to leaf canopies which basically were also the total canopy in those cases measured. More mature swards with raised leaf canopies, would probably more closely resemble the more often reported light transmission patterns.

Comparing all the light transmission curves (Fig. 6.7.) the more abrupt light extinction in the HW canopy is most noticeable and probably being related to the greater shoot density. The overall similarity between the other treatments was surprising. Keoghan (1966, 1970) observed that previous management can modify the light transmission patterns. If measured at later stages of growth treatment differences may have become more apparent.

For a more detailed study of the light relations in these lucerne canopies a more intensive light measuring and plant sampling routine would have been required.

CHAPTER 7

ORGANIC RESERVES

The role of the organic reserves in the regrowth of lucerne and the effects of defoliation frequencies on their concentrations and amounts have been the subjects of numerous investigations. Recent work has done much to help elucidate the role of organic reserves, while their changes in response to defoliation have been well documented from a number of descriptive studies (sections 2.4.1.1.; 2.3.1.3.). In view of this, it was pertinent to investigate the changes of organic reserve levels in the various treatments and their associated relevance to the growth responses obtained. Both carbohydrate and nitrogen organic reserves were considered. The study of these changes was descriptive, rather than providing imformation on the role of these reserves in regrowth.

7.1. Methods.

The plant samples for the following analyses were obtained by digging 6 plants, 2 per a sub-plot, from each replication of each treatment sampled. This was done in the morning between 8-00 and 9-00 am. to miminise diurnal variation of soluable carbohydrate concentration. As soon as all plants were dug, they were removed from the field, washed free of dirt, the roots cut to 10cm from the cotydonary node, and the plants then divided into roots, crowns and the stubble plus shoot growth. The crowns and stubble were divided by cutting at the ground level mark. The roots and crowns of each group of six plants were then dried for one hour at 100 C in a forced draught oven to obtain a rapid kill of tissue, followed by 23 hours at 80 C. The dry weight of each plant part group was recorded, the material then being stored in paper bags.

At a later date each sample of dry plant material was ground in a hammer mill to pass through a 1mm sieve. The ground material was collected in screw top glass bottles, redried for 12 hours at 80 C and then sealed and stored to await analysis.

Both total non-structural carbohydrates (TNC) and total nitrogen (TN) determinations were made. In both cases the ground sample was placed in an oven at 80 C the night before sampling to ensure uniform dryness. A full account of the extraction and determination methods, a discussion of these and the problems encountered are presented in appendix 7A. Briefly, the TNC was extracted by refluxing the sample with 0.5% ammonium oxalate, the carbo-

hydrate extract obtained being determined with the Auto-Analyser using an anthrone reagent. The TN was extracted by the standard micro-Kjeldahl method and determined with the Auto- Analyser using the Berthelot method.

The results were expressed as the TNC% and TN%, for the roots and crowns separately. The weights of TNC and TN per replication and the C/N ratios were calculated for each plant component and for the combination of root plus crown (RTCR). Standard ANOVA was performed on all data.

There were three separate studies. The Main study followed the organic reserve levels in the 3RC, HC,3RW and HW treatments for the first 56 days of the thesis experiment at weekly intervals. As a subsidary aspect, one sampling was made during the winter on the 7/7/69, one month before the start of the thesis experiment. The second study was a comparision of the 4 basic treatments for both varieties. This consisted of a single sampling for each treatment/variety combination taken at the end of the first growth of the 9", 15" and H treatments and at the commencement of the residual study for the 3" treatment. The sampling time schedule for both studies is summarised in table 7.1. The third study looked at the reversal treatment effect (section 3.1.) and is considered in chapter 9.

Table 7.1. Organic Reserve Sampling Times

1. Organic reserve changes with time.

Treatments sampled: 3RC, HC, 3RW and HW.
Sampling dates: Pre-experiment, 6/8, 13/8, 20/8, 27/8, 3/9, 10/9, 20/9, 30/9.

2. Treatment comparison.

	3"	9"	15"	H
Chanticleer	10/11	13/9	29/9	5/11
Wairau	11/11	16/9	5/10	7/11

A secondary reserve study for comparison with the chemical analysis method involved measuring the quantity of dark regrowth obtained. This was done with the 3RC, HC, 3RW and HW treatments. To provide the dark environment, two boxes 32" x 22" x 8" and 28" x 16" x 6", the smaller inside the larger, were placed with three sets per a small plot, one on each of three sub-plots. This was done immediately after the pre-treatment defoliation. The outer box was painted white for insulation with vents cut in the sides. The inner box provided the dark growth environment. Both boxes were made

from heavy weight cardboard. The etiolated lucerne growth was finally harvested on the 23rd of September. It was necessary to take intermediate partial harvests,as older etiolated shoots tended to start decaying. At the final harvest, two plants per box set were dug for chemical analysis as above, with the difference that the roots and crown were combined.

7.2. Results.

7.2.1. Organic Reserve Changes over Time Following Different Previous Defoliation Frequencies.

These results are considered over the days stipulated. The day 90 values are plotted on the appropriate graphs (figs. 7.1., 7.2.) for comparative observation while being considered in detail later in the reversal experiment (chapter 9) with which the day 90 values were directly implicated.

7.2.1.1. Root and crown dry weights.

These results are summarised in table 7.2. The sampling variability was such that there was no significance between harvests for any variable. Between varieties, only the crown dry weights approached significance ($P = 0.10$) with Wairau being greater in accordance with previous observations (fig. 5.9.). Between treatments the H treatment was significantly greater ($P = 0.01$) than the 3R treatment for all variables while between variables the root dry weight was significantly greater ($P = 0.01$) than the crown dry weight. This latter significance, in practise, is greater still, as the measured root weight was only partially representative of the total root weight.

7.2.1.2. The percentages of total non-structural carbohydrates.

The root and crown TNC percentages are the analysis values, while the RTCR TNC percentages were calculated from the RTCR dry weight and the root and crown TNC weight values.

Between harvests for each variable, there were significant differences, each variable's response over time being typically cyclic (section 2.2.2., 2.3.1.3., fig. 7.1a,b.). The interaction between roots and crowns over harvests was very significant ($P = 0.01$). The roots showed a large drop of TNC

Table 7.2. Root and Crown Dry Weights (gm/6 plants)

	Root	Crown	RTCR
	Harvests		
ANOVA	NS	NS	NS
	Varieties		
C	18.10	11.69	29.79
W	17.86	13.51	31.37
ANOVA	NS	10%	NS
	Treatments		
3R	12.00 A*	7.00 A	19.00 A
H	23.97 B	18.22 B	42.19 B
ANOVA	1%	1%	1%
LSD**	(2.21) 2.94	(2.01) 2.67	(3.94) 5.24
SE.	4.76	3.34	8.80
CV%	26.48	26.50	28.78
	Root vs Crown		
MEAN	17.98 A	12.60 B	
ANOVA	1%		
LSD	(3.10) 4.10		
SE.	9.16		
CV%	30.00		

* Means are compared at the 1% level.

** (P = 0.05), P = 0.01

Appendices: Data 3A.7.2.

Statistics 4A.7. 1a, g.

Figure 7.1a. The changes of the Total Non-structural Carbohydrate percentages during the spring in the roots and crowns of the 3R and H treatments. The varieties were combined.
-30 was the mid-winter sampling.
Day 90 TNC percentages were those at the respective hay harvests.

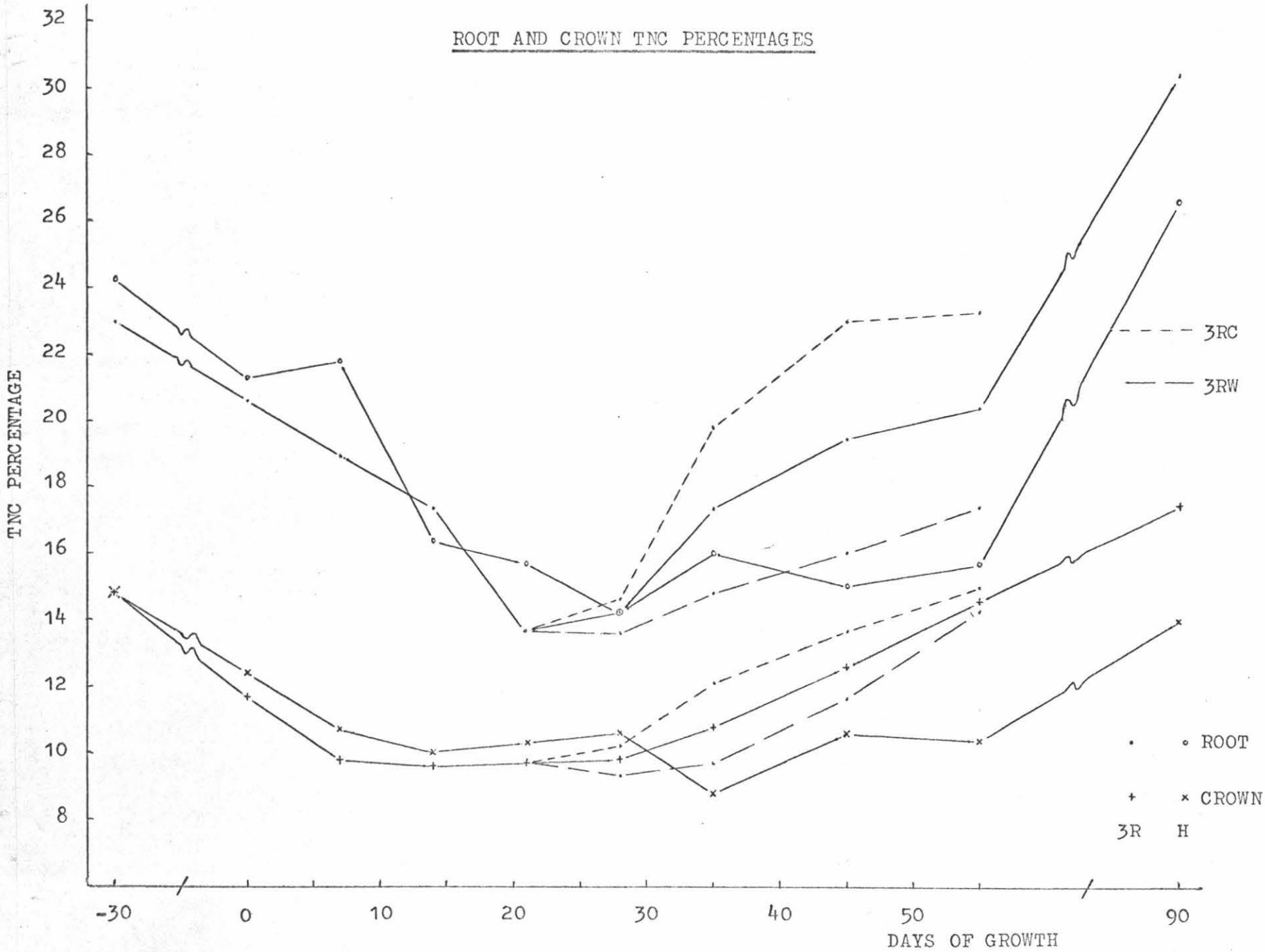

ROOT AND CROWN TNC PERCENTAGES
TNC PERCENTAGE
32
30
28
26
24
22
20
18
16
14
12
10
8
-30
0
10
20
30
40
50
90
DAYS OF GROWTH
3RC
3RW
ROOT
CROWN
3R H

Figure 7.1b. The changes of the Total Non-structural Carbohydrate percentages during the spring in the RTCR for the 3R and H treatments in combination with the two varieties.
-30 was the mid-winter sampling.
Day 90 TNC percentages were those at the respective hay harvests.


RTCR TNC PERCENTAGE
TNC PERCENTAGE
30
28
26
24
22
20
18
16
14
12
-30
0
10
20
30
40
60
70
DAYS OF GROWTH
3RC
HC
3RW
HW

Table 7.3. Percentage of Total Non-structural Carbohydrates

	Root	Crown	RTCR
	Harvests		
RANGE	0.475 - 0.384 (21.0 - 14.0)*	0.360 - 0.318 (12.5 - 9.8)	0.437 - 0.360 (18.0 - 12.2)
ANOVA	1%	1%	1%
LSD***	(0.025), 0.034	(0.015), 0.020	(0.019), 0.026
INTERACT LSD	1% (0.021), 0.028		
	Varieties		
C	0.438 (18.23) A**	0.337 (11.03) a	0.404 (15.62) A
W	0.418 (16.65) B	0.329 (10.54) b	0.382 (14.03) B
ANOVA	1%	5%	1%
LSD	(0.013), 0.017	(0.007), 0.010	(0.009), 0.013
	Treatments		
3R	0.432 (17.74)	0.338 (11.09) a	0.400 (15.35) A
H	0.425 (17.14)	0.329 (10.48) b	0.382 (14.30) B
ANOVA	NS	5%	1%
LSD	-	(0.007), 0.010	(0.009), 0.013
	Harvests x Treatments		
ANOVA	5%	1%	1%
	Varieties x Treatments		
	3R H	3R H	3R H
C	0.454 A 0.423 B (19.43) (17.02)	0.343 0.331 (11.44) (10.63)	0.419 A 0.389 B (16.70) (14.54)
W	0.410 B 0.427 B (16.04) (17.27)	0.333 0.326 (10.74) (10.33)	0.382 B 0.383 B (14.01) (14.05)
ANOVA	1%	NS	1%
LSD	(0.018), 0.024	-	(0.014), 0.018
INTERACT LSD	1% (0.015), 0.019		
SE.	0.028	0.013	0.015
CV%	6.69	3.85	3.87
	Root vs Crown		
MEAN	0.429 (17.44) A	0.334 (10.79) B	
ANOVA	1%		
LSD	(0.007), 0.009		
SE.	0.026		
CV%	6.89		

* The untransformed percentage values *** (P = 0.05), P = 0.01

** Means are compared at the (A) 1% and the (a) 5% levels.

Appendices: Data 3A.7.2. Statistics 4A.7.1b,g.

percentage (6%) with this reaching a minimum at about 28 days, while the crowns showed a smaller drop (2%), only over the first 14 days. Both gave similar responses over the last 20 days. Between the roots and crowns, the roots had significantly greater (P = 0.01) TNC percentages, but also a greater variability - CV%'s of 6.69 and 3.85 respectively (table 7.3.).

These relative variabilities are expressed in the treatment interactions. The root treatment differences were non-significant, although with a mildly significant harvest interaction (P=0.05). Fig 7.1a illustrates that this interaction was largrly due to the marked increase of the 3R treatment's TNC percentage over the last 20 days of measurement. Crown treatment differences were significant (P=0.05)*. The more consistent treatment significances of the RTCR support these results. The treatment x variety interactions (table 7.3) showed that this last 20 day dominance of the 3R treatments was mostly due to the large TNC percentage increase of the 3RC treatment as compared to a similar but lower 3RW treatment increase (fig 7.1 a,b).This 3RC response was largely responsible for the significant variety differences which were smaller for the crowns (P=0.05).

7.2.1.3. Weight of total non-structural carbohydrates:

These results were dominated by the considerable influence of the very significant dry weight treatment differences (table 7.2), and to a lesser extent, by the significant TNC percentages between harvests (table 7.3).

Between harvests the crown TNC weight did not vary significantly, the roots did (P=0.01), and RTCR was intermediate (P=0.05). This difference between roots and crowns was supported by the interaction (P=0.05) of roots and crowns over harvests. Further, the roots TNC weight was very significantly greater than that of the crowns. For all variables, the treatment differences were very significant, the H treatments having the greatest TNC weight, while the variety differences were non-significant (table 7.4.).

* while the interaction was basically the same as for the roots, but highly significant (P = 0.01).

Table 7.4. Weight of Total Non-structural Carbohydrates (gm/6 plants)

	Root	Crown	RTCR
	Harvests		
RANGE	4.38 - 2.39	1.48 - 1.16	5.75 - 3.56
ANOVA	1%	NS	5%
LSD	(0.75), 1.00	-	(1.20), 1.59
INTERACT	5%		
LSD	(0.73), 0.97		
	Varieties		
ANOVA	NS	NS	NS
	Treatments		
3R	2.12 A*	0.76 A	2.88 A
H	4.11 B	1.89 B	6.01 B
ANOVA	1%	1%	1%
LSD	(0.37), 0.50	(0.22), 0.29	(0.60), 0.80
INTRRACT	1%		
LSD	(0.36), 0.48		
SE.	0.68	0.31	0.68
CV%	22.10	23.13	15.20
	Root vs Crown		
MEAN	3.12 A	1.33 B	
ANOVA	1%		
LSD	(0.26), 0.34		
SE.	0.91		
CV%	40.77		

* Means are compared at the 1% level.

** (P = 0.05), P = 0.01

Appendices: Data 3A.7.2.

Statistics 4A.7.1c,h.

7.2.1.4. The percentages of total-nitrogen.

These were determined in the same way as the TNC percentages (section 7.2.1.2.). TN percentage harvest differences were very significant (P=0.01) for all variables, and in each case showed a relatively steady decline over the full period of measurement (table 7.5., fig 7.2.a,b.). Treatment differences were also very significant, the H treatment consistently having the greater values. This is well illustrated in figs 7.2a,b, and less clearly for the significant treatment x harvest interactions of each variable. The 3R treatment's TN% decreased at a slightly greater rate. This treatment range was greater for the roots compared to the crowns. Comparing the roots and crowns, the crowns had significantly greater (P=0.01) TN percentages, while the root/crown x treatment interaction (fig 7.2a) was mostly due to the low 3R treatment values.

Variety differences were not great, with only the roots showing Chanticleer to have a slightly higher TN percentage. The variety x treatment interaction showed that for roots and RTCR, Wairau showed less difference between treatments with its values being within the Chanticleer's range (table 7.5, fig 7.2b). There was no interaction for the crowns.

7.2.1.5. The weight of total nitrogen.

Only the root TN weight harvest differences were significant while variety differences were non-significant (table 7.6). In contrast, treatment differences were highly significant (P=0.01) for all variables, the H treatment being greatest, due to the combined influence of both treatment dry weight and TN% differences. Root TN weights were significantly greater than crown values because of the greater root dry weights even though root TN percentages were lower.

Table 7.5. Percentage of Total Nitrogen

	Root	Crown	RTCR
	Harvests		
RANGE	0.155 - 0.130 (2.41 - 1.71)*	0.163 - 0.140 (2.67 - 1.97)	0.158 - 0.134 (2.50 - 1.81)
ANOVA	1%	1%	1%
LSD**	(0.005), 0.007	(0.003), 0.005	(0.004), 0.005
	Varieties		
C	0.142 (2.04) *** A	0.150 (2.26)	0.145 (2.11)
W	0.138 (1.91) B	0.151 (2.28)	0.143 (2.07)
ANOVA	1%	NS	NS
LSD	(0.003), 0.004	-	-
INTERACT	1%		
LSD	(0.003), 0.004		
	Treatments		
3R	0.127 (1.62) A	0.145 (2.10) A	0.134 (1.79) A
H	0.153 (2.34) B	0.157 (2.45) B	0.155 (2.39(B
ANOVA	1%	1%	1%
LSD	(0.003(, 0.004	(0.002), 0.003	(0.002), 0.003
INTERACT	1%		
LSD	(0.003), 0.004		
	Harvests x Treatments		
ANOVA	5%	1%	5%
	Varieties x Treatments		
	3R H	3R H	3R H
C	0.127 A 0.157 B (1.62) (2.46)	0.144 0.157 (2.07) (2.45)	0.133 A 0.157 B (1.78) (2.46)
W	0.127 A 0.149 C (1.62) (2.22)	0.146 0.157 (2.13) (2.45)	0.135 A 0.153 C (1.81) (2.32)
ANOVA	1%	NS	1%
LSD	(0.004), 0.005	-	(0.003), 0.004
SE.	0.0038	0.0025	0.0029
CV%	2.70	1.70	2.05
	Root vs Crown		
MEAN	0.140 (1.97) A	0.151 (2.27) B	
ANOVA	1%		
LSD	(0.002), 0.003		
SE.	0.0058		
CV%	4.01		

* The untransformed percentage values

** (P = 0.05), P = 0.01

*** Means are compared at the 1% level.

Appendices: Data 3A.7.2. Statistics 4A.7.1d,g.

Figure 7.2a. The changes of the Total Nitrogen percentages during the spring in the roots and crowns of the 3R and H treatments. The varieties were combined.
-30 was the mid-winter sampling.
Day 90 TN percentages were those at the respective hay harvests.

ROOT AND CROWN TN PERCENTAGES

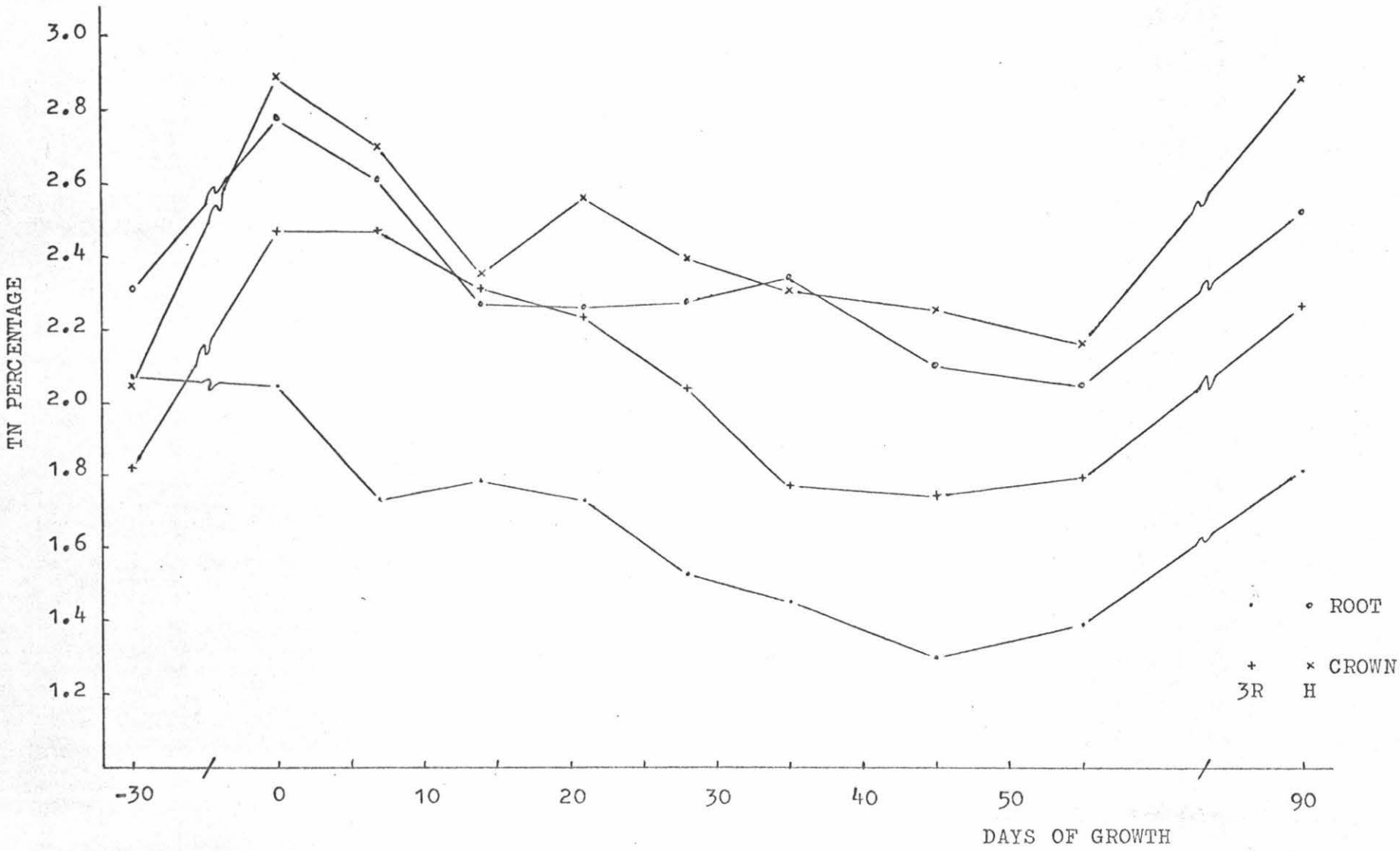


Figure 7.2b. The changes of the Total Nitrogen percentages during the spring in the RTCR for the 3R and H treatments in combination with the two varieties.

-30 was the mid-winter sampling.

Day 90 TN percentages were those at the respective hay harvests.

RTCR TN PERCENTAGE

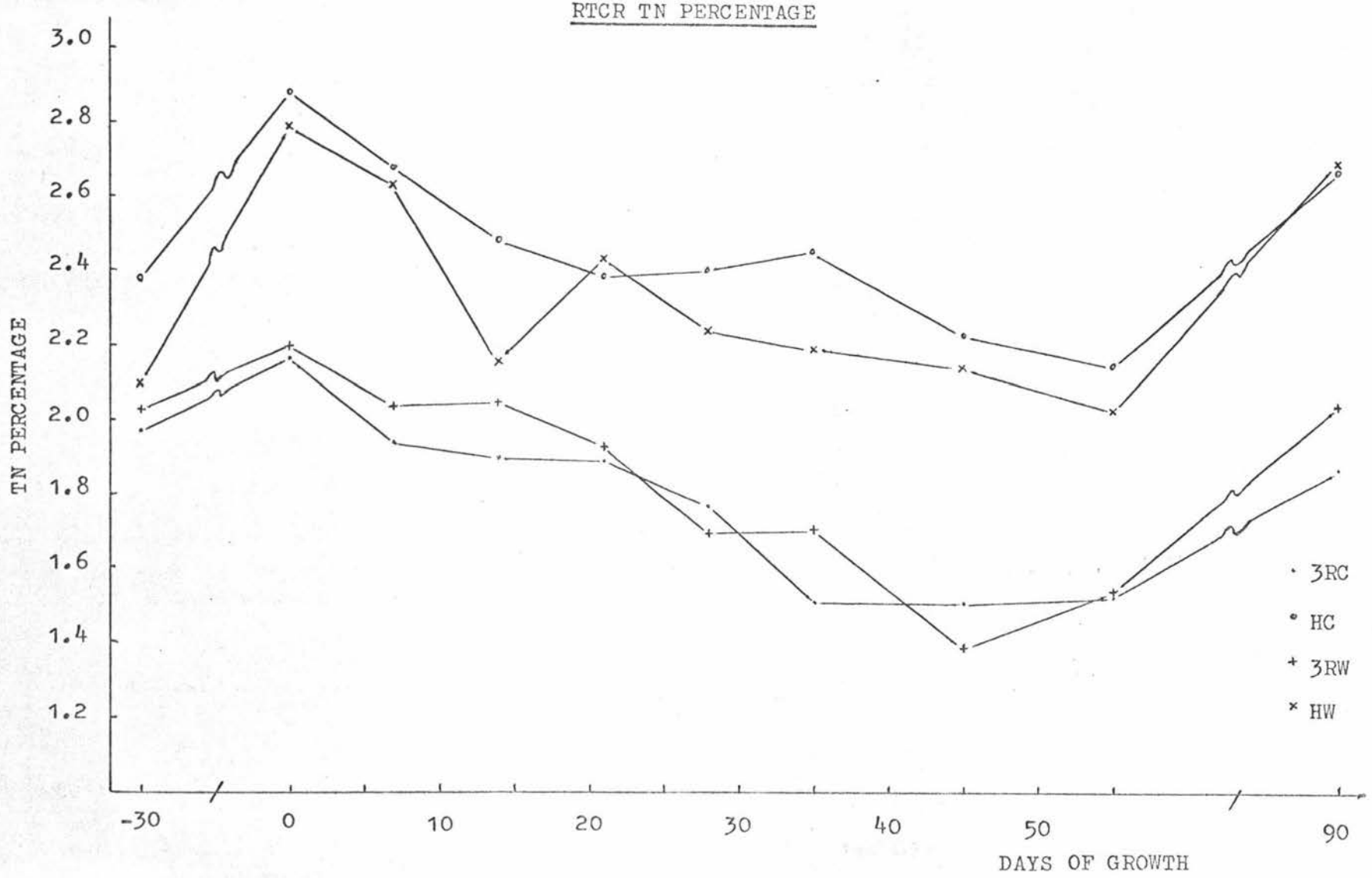


Table 7.6. Weight of Total Nitrogen (gm/6 plants)

	Root	Crown	RTCR
	Harvests		
RANGE	0.515 - 0.331	0.320 - 0.263	0.836 - 0.607
ANOVA	1%	NS	NS
LSD	(0.098),0.131	-	-
	Varieties		
C	0.395 A*	0.272 C	0.668
W	0.359 AB	0.319 BC	0.679
ANOVA	NS	NS	NS
INTERACT	5%		
LSD	(0.051), 0.067		
	Treatments		
3R	0.194 A	0.145 A	0.340 A
H	0.560 B	0.446 B	1.007 B
ANOVA	1%	1%	1%
LSD	(0.049)0.065	(0.051),0.067	(0.093),0.123
SE.	0.113	0.090	0.129
CV%	30.00	30.52	19.25
	Root vs Crown		
MEAN	0.377 A	0.296 B	
ANOVA	1%		
LSD	(0.036), 0.047		
SE.	0.127		
CV%	37.96		

* Means are compared at the 1% level.

Appendices: Data 3A.7.2.
Statistics 4A.7.1e,g.

7.2.1.6. Total non-structural carbohydrate/total nitrogen (C/N) weight ratios:

For each variable, harvest ANOVA'S were significant. The patterns of change are best explained by the significant (P=0.01) harvest x treatment interactions. (table 7.7, figs 7.3 a,b.).

With the roots and RTCR, the 3R treatment C/N ratio was significantly (P=0.01) greater than the H treatment over all harvests. The crown C/N ratio was also significantly different, but only after day 28. The harvest x treatment interactions were due largely to the rapid increase of the 3R treatments C/N ratio after day 28. This was much more marked with the roots which also showed an initial decrease compared to the crowns, the latter initially having a stable C/N ratio. Evidence of a root/crown difference is supported by the significance (P=0.01) of the root/crown x treatment interaction. Compared with the 3R treatments, the H treatments showed relatively little change over time for both roots and crowns. These results are illustrated in figs 7.3.a,b.

Varietal C/N ratio differences were more significant (P=0.01) for the RTCR, roots and crowns being less so (P=0.05). In all cases Chanticleer had the greater mean value. The variety x treatment interaction was significant (P=0.01) for the roots and RTCR; in each case the differences between treatment means were greater for Chanticleer compared with Wairau - eg. the roots had C/N ratio ranges of 5.76 and 2.36 respectively. These interactions were largely due to the higher 3RC treatment values during the initial 14 days, but more particularly after day 28. These treatment's responses were also the major cause of the treatment x harvest interactions. In contrast, the crowns showed no significant variety x treatment interaction. The significant root/crown x variety x treatment interaction supported this root/crown difference (table 7.7).

Between the roots and crowns, the roots had significantly greater (P=0.01) mean values.

The ratios of the weights of Total Non-structural Carbohydrates to Total Nitrogen.

-30 was the mid-winter sampling.

Figure 7.3.

a. For roots and crowns with varieties combined.

b. For RTCR (roots plus crowns).

TNC/TN RATIOS

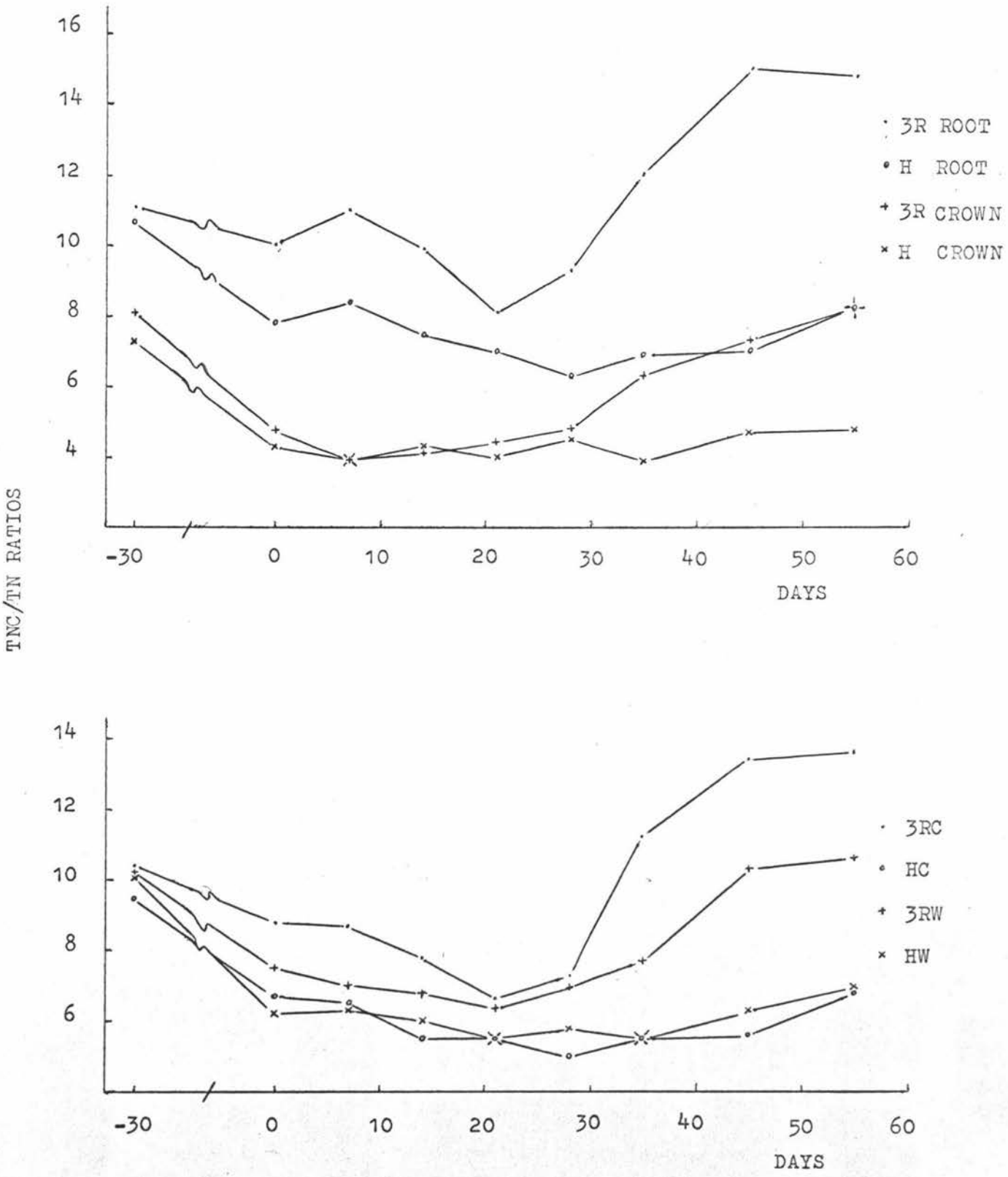


Table 7.7. Total Non-structural Carbohydrate/Total Nitrogen Weight Ratio

	Root	Crown	RTCR
	Harvests		
RANGE	7.52 - 11.50	3.96 - 6.53	5.98 - 9.45
ANOVA	1%	1%	1%
LSD**	(1.42), 1.89	(0.55), 0.73	(0.96), 1.28
INTERACT	1%		
LSD	(1.056), 1.390		
	Varieties		
C	9.79 a*	5.04 a	7.89 A
W	9.01 b	4.74 b	6.99 B
ANOVA	5%	5%	1%
LSD	(0.71), 0.84	(0.27), 0.36	(0.48), 0.64
	Treatment		
3R	11.43 A	5.48 A	8.90 A
H	7.37 B	4.29 B	5.98 B
ANOVA	1%	1%	1%
LSD	(0.71), 0.94	(0.27), 0.36	(0.48), 0.64
INTERACT	1%		
LSD	(0.52), 0.69		
	Harvests x Treatments		
ANOVA	1%	1%	1%
	Varieties x Treatments		
	3R H	3R H	3R H
C	12.67 A 6.91 C	5.74 4.34	9.89 a 5.89 c
W	10.19 B 7.83 C	5.22 4.25	7.91 b 6.07bc
ANOVA	1%	NS	1%
LSD	(1.00), 1.34	-	(1.92), 2.55
INTERACT	1%		
LSD	(0.74), 0.98		
SE.	0.869	0.300	0.479
CV%	9.24	6.15	6.44
	Root vs Crown		
MEAN	9.40 A	4.89 B	
ANOVA	1%		
LSD	(0.37), 0.49		
SE.	1.267		
CV%	17.70		

* Means are compared at the (A) 1% and the (a) 5% levels.

** (P = 0.05), P = 0.01

Appendices: Data 3A.7.2. Statistics 4A.7.1f,h.

7.2.1.7. Winter organic reserve changes:

Interesting changes occurred over the month of measurement. The TNC percentage of the roots, crowns and RTCR all decreased significantly (P=0.01) over this period. In contrast, the RTCR TN percentages increased for each treatment, but more so for the H treatments, giving rise to a significant harvest x treatment interaction (fig 7.2b). From a comparision of the root and crown changes, it is seen that the above interaction was due almost entirely to the 3R treatment's roots showing no change (fig 7.2a). The crown treatment responses were very similar and comparable to the H treatment root response.Varieties responded similarly. (table 7.8, fig 7.2.b.).

The C/N ratio decreased significantly (P=0.01) for all variables with as before, the 3R treatment having the greater ratio (table 7.8). There was a significant (P=0.05) treatment x time interaction for the roots (fig 7.3.a.) resulting from the similar TN% interaction (fig 7.2.a.)

7.2.2. Treatment Comparision :

For the TNC and TN percentages but not the C/N ratios, there were very significant treatment differences (table 7.9). These are further illustrated for the TNC and TN percentages and C/N ratios in figures 7.4a,b,c.

There was a regular increase of root TNC percentage as defoliation frequency decreased. All means were close to being significantly different (table 7.9.). In contrast, for the crown TNC percentages only the H treatment was significantlt greater. As in the previous study, the roots had consistently greater TNC percentaged. (fig 7.4a).

Apart from a close similarity of TN% between the 3" and 9" treatment, the other treatment's TN% significantly increased as defoliation frequency decreased. Again as before, the crowns had the higher TN% over all treatments (table 7. 9, fig 7.4b).

Comparing the C/N ratios, they were notable for their almost lack of significance, only the 3RC root C/N ratio being significantly lower (P=0.5) (table 7.9, fig 7.4c).

For all variables there were no significant trends between varieties.

Table 7.8. The Winter Organic Reserve Changes

	Root	Crown	RTCR

Total Non-structural Carbohydrate Percentages

	Harvests		
JULY	0.508 (23.70*) A**	0.395 (14.83) A	0.478 (21.20) A
AUGUST	0.475 (21.00) B	0.355 (12.08) B	0.438 (18.01) B
ANOVA	1%	1%	1%
LSD***	(0.024), 0.032	(0.017), 0.024	(0.021), 0.029
SE.	0.027	0.020	
CV%	5.55	5.42	

Total Nitrogen Percentages

	Harvests		
JULY	0.148 (2.19) a	0.139 (1.93) A	0.146 (2.12) A
AUGUST	0.155 (2.41) b	0.164 (2.41) B	0.158 (2.51) B
ANOVA	5%	1%	1%
LSD	(0.006), 0.008	(0.006), 0.008	(0.005 , 0.006
	Treatments		
3R	0.144 (2.06) A	0.146 (2.14) A	0.145 (2.09) A
H	0.160 (2.54) B	0.157 (2.46) B	0.159 (2.54) B
ANOVA	1	1%	1%
LSD	(0.006), 0.008	(0.006), 0.008	(0.005), 0.006
	Harvests x Treatments		
ANOVA	5%	NS	5%
SE.	0.007	0.007	
CV%	4.86	4.80	

Total Non-structural Carbohydtate/Total Nitrogen Weight Ratios

	Harvests		
JULY	10.88 A	7.69 A	10.02 A
AUGUST	8.89 B	4.56 B	7.31 B
ANOVA	1%	1%	1%
LSD	(0.85), 1.17	(0.56), 0.77	(0.65), 0.90
	Treatments		
3R	10.57 A	6.44 a	9.21 A
H	9.19 B	5.82 b	8.12 B
ANOVA	1%	5%	1%
LSD	(0.85), 1.17	(0.56), 0.77	(0.65), 0.90
SE.	0.98	0.64	0.76
CV%	9.90	10.50	8.75

* Untransformed percentages *** (P = 0.05), P = 0.01

** Means are compared at the (A) 1% and the (a) 5% levels.

Appendices: Data 3A.7.1. Statistics 4A.7.2.

Table 7.9. Organic Reserve Treatment Comparisons

	Root	Crown	RTCR
Total Non-structural Carbohydrate Percentages			
	** *	Treatments	
3"	0.358 A (12.33)	0.295 A (8.50)	0.334 A (10.82)
9"	0.438 B (18.06)	0.312 A (9.48)	0.390 B (14.52)
15"	0.491 BC(23.33)	0.319 A (9.92)	0.430 B (17.45)
H	0.542 C (26.66)	0.381 B (13.92)	0.481 C (21.47)
ANOVA	1%	1%	1%
LSD***	(0.039), 0.055	(0.024), 0.033	(0.033), 0.046
SE.	0.027	0.020	0.022
CV%	5.93	6.23	5.52
Total Nitrogen Percentages			
		Treatments	
3"	0.124 A (1.54)	0.138 A (1.92)	0.130 A (1.69)
9"	0.129 A (1.66)	0.146 B (2.11)	0.136 A (1.85)
15"	0.146 B (2.14)	0.153 C (2.33)	0.149 B (2.21)
H	0.159 C (2.52)	0.170 D (2.88)	0.164 C (2.67)
ANOVA	1%	1%	1%
LSD	(0.008), 0.012	(0.004), 0.006	(0.006), 0.008
SE.	0.007	0.004	0.005
CV%	4.86	2.66	3.45
Total Non-structural Carbohydrate/Total Nitrogen Weight Ratio			
		Treatments	
3"	8.04 A	4.45	6.42
9"	10.77 B	4.48	7.83
15"	10.67 B	4.25	7.98
H	10.60 B	4.86	8.06
ANOVA	5%	NS	NS
LSD	(2.08), 0.71	-	-
SE.	1.42	0.61	1.00
CV%	14.23	13.50	13.26

* The untransformed values

** Means are compared at the 1% level.

*** (P = 0.05), P = 0.01

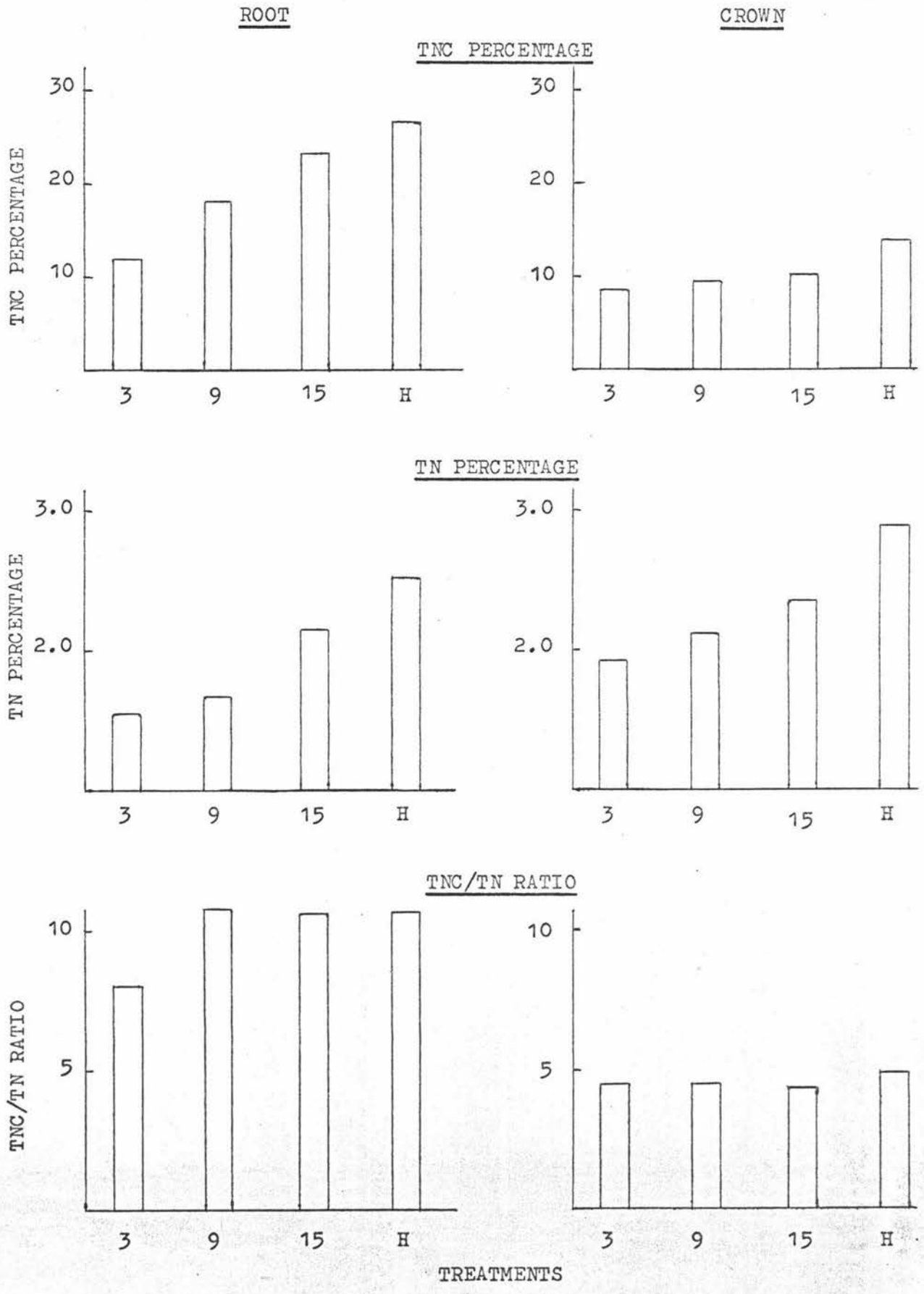
Appendices: Data 3A.7.3. Statistics 4A.7.3.

Figure 7.4. A comparison of the organic reserve composition of the roots and crowns of the plants from the four treatments sampled at the end of the first growth of the 9", 15" and H treatments and at the end of the experiment for the 3" treatment.

a. The Total Non-structural Carbohydrates (TNC) percentages.

b. The Total Nitrogen (TN) percentages.

c. The Total Non-structural Carbohydrate/Total Nitrogen (TNC/TN) ratios.


ROOT
CROWN
TNC PERCENTAGE
TNC PERCENTAGE
30
20
10
3
9
15
H
TN PERCENTAGE
TN PERCENTAGE
3.0
2.0
TNC/TN RATIO
TNC/TN RATIO
10
5
TREATMENTS

7.2.3. The Dark Growth of Lucerne:

The shoot growth obtained was not analysed as the treatment differences were obvious. The H treatments grew four times more shoot dry weight There were no major varietal differences (table 7.10).

Table 7.10. Lucerne Growth from Beneath the Dark Covers.*

	C	W	C + W
3R	4.16	4.33	4.24 (18.79**)
H	15.06	17.11	16.09 (45.79)
Av	9.61	10.72	

* (gm/3 sq ft)

** Bracketed values are the initial (day 0) mean root plus crown weights (gm/6 plants)

Appendix: Data 3A.7.4.

The TNC percentages were similar to the lowest TNC% of the same treatments in the major study (fig. 7.1b). Both treatment and variety differences were non-significant (table 7.11a.).

Table 7.11. Residual Organic Reserves of Plants from Beneath the Dark Covers

a. TNC%

	C	W	C + W
3R	11.50	10.80	11.15
H	12.50	10.30	11.30
AV	12.00	10.55	

b. TN%

	C	W	C + W
3R	2.12	2.15	2.14
H	2.70	2.78	2.74
AV	2.41	2.47	

Appendices:
Data 3A.7.4.
Statistics 4A.7.4.

In sharp contrast to the TNC% decrease there was no similar reduction of the the TN percentages. For the respective treatments, these were equal to the highest values of the major study (fig. 7.2b.). Also in keeping with these previous results, the H treatments had the greatest values (P = 0.01). Varieties were similar (table 7.11b.). Root weights were too variable to permit similar comparisons of any meaning.

7.3. Discussion.

7.3.1. The Changes of Organic Reserves over Time and their Relative Significances.

The marked variability of the plant dry weight values was partly due to a large plant size variability (section 5.2.2.) and partly due to sampling errors. To counter this problem, more emphasis is placed on the TNC and TN percentages and the C/N values. As plant weight differences between treatments were consistently large (table 7.2) it was possible to make satisfactory treatment comparisons of the TNC and TN weights. The significantly larger roots and crowns of the frequently defoliated H treatment were expected (section 2.3.1.2, 5.2.1.3.).

For the TNC reserves, the time study only contained a residual treatment effect in the form of root and crown dry weight differences. On day 0, the treatment TNC percentages were basically the same. Apparently there was sufficient uninterrupted previous autumn growth to enable the accumulation of this high level of TNC reserves to be attained in the 3R treatments (table 7.2b), as compared to their expected lower levels from this high frequency defoliation treatment (section 2.3.1.3.). Consequently, this TNC study was more one of plant size than of defoliation effect per se.

On a root plus crown (RTCR) weight basis, the plant classification of Ueno and Smith (1970) (section 2.4.1.1.), into small, medium and large plants was directly comparable to the small and large plants of the 3R and H treatments respectively. In both studies, similar results were obtained, in that smaller plants had a quicker TNC% recovery. Why this latter occurs is uncertain.* Also, the TNC% similarity between the two treatments, although unexpected, is acceptable in view of their similar periods of autumn/winter uninterrupted growth and hence energy availability relative to plant size.

The cyclic response patterns for TNC% were typical of the early spring responses reported by others (section 2.2.2.). The pre-experiment trimming defoliation may have had some influence on the decrease of TNC, but this is not readily apparent from the results. Both treatments and varieties had similar patterns of TNC% decrease until day 28 after which the 3R treatments increased more rapidly than the H treatments, with the 3RC treatment giving rise to the greatest difference and hence having the major

* It is noted that storage capacity increases by the cube while photosynthate production (leaf area) increases by the square.

influence on the observed interactions (table 7.3.). Over the full growth period of the experiment, all treatments and varieties accumulated high TNC% by day 90 (Fig. 7.2b). It is apparent that the TNC increase for the H treatments would have been very rapid over the last weeks of mature growth; this also being observed by Ueno and Smith (1970).

In general terms, both the roots and crowns displayed similar responses to those discussed for the RTCR. More particularly, the roots showed greater extents of TNC depletion and re-accumulation, the crowns only showing measureable depletion in the first week followed by a relatively constant TNC% until the 3R treatment started to increase after day 28. The greater TNC capacity of the roots compared with the crowns is exemplified by their much greater TNC% increase by day 90 above their previous minimal levels. This was 100% and 50% for the roots and crowns respectively, averaged over both treatments. Similarly, there was a greater TNC depletion in the roots. Hence the roots had a greater proportionate use and storage of carbohydrate, this being at varience with the proportionate (on a weight basis) equality of use and storage between different storage tissues reported by Ueno and Smith (1970). Other than the greater 3R treatment reaccumulation, there were no obvious varietal or plant size interactions with these storage tissue differences.

It is not known why this difference of TNC capacity exists between the crowns and roots. Ueno and Smith (1970) showed that the crowns (wood plus bark) consistently had lower TNC% than either the bark or wood of the roots thus implying that the difference is not likely to be related to the proportions of tissue types. It is more likely to have a physiological basis.

The TN results were in cont-rast to those of the TNC. The steady decline of TN% in all cases over the 55 day measurement period indicates that TN was depleted to some extent, presumably mostly for growth. Of equal importance in explaining this TN% decrease was the over-riding influence of the TNC% changes, there being an overall average of 6.6 times more TNC than TN by weight. This influence is more satisfactorily described from the C/N ratios.

The TN% results show the 3R treatments consistently had lower concentrations of total nitrogen. This appears to have been a genuine residual defoliation treatment effect. The possible reasons are discussed in the next section. In absolute terms of TN weight, the residual treatment

effect was quite clear, the H treatment having approximately three times more TN weight due to the combined effects of greater TN% and RTCR weight.

The higher TN% of the crowns, is in further contrast with the TNC% distribution between different storage tissues. These greater crown TN% values were more apparent with the smaller 3R treatment plants. These observations lead to the suggestion that the crowns being relatively active sites of new shoot growth initiation and development, would be expected to have higher TN concentrations resulting from the high nitrogen involvement in these processes and the associated tissues. This, as compared to the tap root and larger lateral roots in which such new growth activity is normally considerably less. In consequence, with higher TN concentrations, the percentage of non-structural nitrogen and hence more readily available, is likely to be greater in the roots.

In terms of TN weights, the measured difference between the roots and crowns was much less (4:3 ratio) compared to that for TNC weight (3.1 ratio). But as discussed, this TN weight proportioning does not necessarily represent the relative importance of roots and crowns as storage sites of available nitrogen reserves.

While the C/N ratios indicated the relative changes of TNC and TN weights, they did not indicate how each or both factors contributed to these changes. Normally, this information is shown by the trends of TNC and TN weight changes. In this case, it was considered that these could not be relied upon because of the large variability of the root and crown weights sampled (section 7.2.1.1.). Within these limitations, the steady decrease of the RTCR C/N ratio over the first three weeks (Fig. 7.3b) indicated a proportionate TN weight increase, but as both the TNC% and TN% decreased, this proportionate weight change was logically an actual TN weight decrease, but proportionately less so than the TNC weight decrease. Between the roots and crowns (Fig. 7.3a), it is concluded that most of the above decrease resulted from similar changes in the roots, the crown weight changes being minor by comparison. Within the above limitations this is supported by the crown and root dry weight changes (table 3A.7.2.). The later C/N ratio changes are less easy to interpret in that the increases observed, being most marked for the 3R treatments, were in part caused by a TNC increase, but could equally well have been

modified by either a TN weight decrease, little change or actual increase. Any of these are possible even though the TN% decreased over this period. Smith and Silva (1969) reported a similar prolonged TN% decrease to the 25th day of lucerne regrowth, while the TN weight minimum was 14 days earlier on the 28th day.

A preferable study of the relative importance of concommitant changes of TN and TNC reserve levels during lucerne growth involves having not only satisfactory percentage values but also accurate weight change values over time. These requirements were not met to satisfaction in this experiment.

7.3.2. The Influence of Different Defoliation Frequencies on Organic Reserves at Harvest:

The associated results (section 7.2.2.) of this study represent the true defoliation treatment effects. It must be remembered that in this study the 3" treatment had been defoliated frequently through the spring. The decreasing TNC% of the roots with defoliation frequency increase agrees with previous reports (section 2.3.1.3.), in this case, a regular decrease over the wide treatment range used. The lower crown TNC% values are consistent with the previous study although these were little affected by the different defoliation frequencies.

Comparing these results with those of the time study it is considered that prolonged frequent defoliation has a dual action on the TNC reserves. In a general manner it results in the lucerne crowns and roots becoming considerably reduced in size and hence they store less weight of TNC reserves. More specifically, the TNC concentration is reduced only so long as the frequent defoliation regime is retained. The range of TNC% between treatments as here, resulted from the TNC accumulation being curtailed at later stages of growth with decreasing defoliation frequency. Return to an infrequent defoliation regime enables a rapid TNC concentration build-up, apparently irrespective of the previous defoliation frequency. Further, the greater proportion of these fluctuations occurs in the roots as compared to the crowns.

The reported adverse effects of defoliation on root nodule numbers and activity (section 2.3.1.3.) is supported by the TN% responses obtained here. Of these factors, root nodule numbers and/or weight per unit root

weight would have presumably decreased in association with root weight decreases arising from more frequent defoliation. The reports of these effects of defoliation on lucerne and other species appear to have been exclusively concerned with the immediate post-defoliation response as compared to the effect of a prolonged defoliation treatment as here. The lower TN% of the 3R treatment implies that there was a relatively permanent decrease in the level of one or more of these factors. Chu (1971) observed that following defoliation of Trifolium repens, the nodule weight decreased proportionately more than root weight decrease while nodule number decreased proportionately. Alternatively a mineral limitation, especially Mo and Co, may have arisen from the reduced root size, growth and absorpitive capacity (sections 2.3.1.2., 2.4.1.2.), and have reduced nodule activity. While making these suggestions, it is fully realised that considerable care must be exercised when extrapolating between species and between short and long term effects. No such long term effects are known to have been reported for lucerne or other legume species.

The lack of TN% recovery for both roots and crowns in the 3R treatments by day 90 compared with the H treatments contrasts with their similar TNC% at this time. In this instance, the supply of energy substrate was obviously not limiting nodule activity. This is a complex problem requiring more detailed work to elucidate the various aspects. The similarity of the 9" and 3" TN% of both the roots and crown individually, is suggestive of a threshold level of TN concentration being approached i.e. the stage when much of the nitrogen present is incorporated in structural tissue and is thus relatively non-labile. It is interesting to note that the greater TN concentration of the crowns persisted over the full range of treatments, in agreement with the results of the main study (section 7.3.1.).

The similarity of the C/N ratios (weight based) between all four treatments for roots, crowns and RTCR indicates that with consistent defoliation treatments, even though these may be diverse, the plant maintains a balance of TNC and TN in its tissues. In terms of the previous discussions, this may come about by a direct treatment effect on the TN% and the treatment associated growth period length limiting the TNC% proportionately. From the time study it is apparent that the C/N ratio will change with the stage of growth. Further, a change of defoliation frequency will probably result in the C/N ratio being different at the first few harvests, largely from the influence of the more readily varied TNC concentration.

To establish if there were any significant varietal differences would have required more intensive and accurate investigation. These studies have not contributed further information as to the roles of lucerne carbohydrate and nitrogen reserves during regrowth. Rather they contribute to the descriptive knowledge of the changes and levels of these reserves under several defoliation frequencies, and particularly with the extreme 3" and H treatments. Most previous studies have only considered the one growth condition.

7.3.3. Winter Changes of Organic Reserves:

Two periods are of interest, namely the concentrations attained during the autumn/early winter period, and the changes of these during the winter month prior to the commencement of the experiment.

The autumn increase of TNC% in lucerne if not defoliated has been well documented (section 2.2.2.). During the autumn prior to the commencement of the thesis experiment, all treatments were spelled for approximately six weeks. This management is reflected in the similar high mid-winter TNC% of the extreme 3R and H treatments (Figs. 7.1a,b), but particularly the 3R treatment's high concentration when compared to its lower day 90 value (Fig. 7.4.).

Reasonably high mid-winter TN concentrations were attained in accordance with other reports (section 2.2.2.). For the 3R treatment, the combined TNC% and TN% increase indicates that a nett accumulation of nitrogen occurred. This was not so obvious with the H treatments. The treatment TN concentration difference was basically maintained.

During the winter months the TNC% decrease of both treatments is assumed to have largely been due to its use for root and crown respiration (sections 2.2.2, 2.4.1.1.). At the same time, these TNC% decreases were probably largely responsible for the TN% increases recorded, as TN weight changes if any, were probably minor. These TN% increases were greatest in the crowns of both treatments. The smaller TN% increase of the H treatment roots and the lack of TN% change in the 3R treatment roots (for both varieties - table 3.A.7.) is not readily explained, but appears to be a definite trend.

Throughout this period, the small amount of shoot growth that did occur would have drawn on the supply of root and crown TN reserves reducing

the potential TN% increase. This would have been accentuated by the high TN concentration of this shoot growth relative to that of other seasons (Bailey et. al., 1970). Between treatments and for both varieties it was observed although not measured, that the H treatments had longer shoots at the pre-experiment defoliation (7th August) compared to the 3" treatments. The TNC% was similar for both treatments. The greater TN% of the H treatment may have contributed to its greater growth. It is probable that other factors related to plant size and probably reduced plant vigour were implicated. A further aspect is whether the reported substantial nitrogenase activity of lucerne root nodules at temperatures of 3 and 5 C (Day and Dent, 1970) could have led to small increases of TN so complicating the above changes. Again, more detailed work is needed to confirm and explain these changes.

7.3.4. The Use of Dark Growth to Estimate the Carbohydrate Reserve Status:

This method has been used by several workers in the past, using two approaches. Firstly, plants have been dug, defoliated, replanted in pots and then regrown in the dark, roots being periodically and/or finally sampled and analysed for TNC content (Graber et. al., 1927; Smith and Silva, 1969.). Secondly, light proof covers have been placed on areas of defoliated lucerne, with the shoot growth obtained being a relative measure of the initial TNC reserve levels between treatments (Tsuma, 1968; Causley, 1968). The latter method was that used here, with the residual TNC% being determined chemically.

The experiment was successful in that the dark growth obtained demonstrated the greater reserve capacity of the H treatments. Comparison with the initial (day 0) RTCR weights (table 7.10) supports the observation of Causley (1968) that such dark growth was correlated with root weight, and thus demonstrates these defoliation treatment effects. With less diverse treatments, the ability of the method to enable the identification of treatment differences would be more difficult.

The correlation of dark growth with the initial TNC weights was good (tables 7.10, 7.4.), although this mostly arose from the RTCR dry weight differences. It is obvious that the TNC% has no meaning in such a study (Fig. 7.11.b.), unless the root weight is very similar between

comparisons. From the maintained residual TN% treatment difference (table 7.11b.) and the similarity with the day 0 TN% (Fig. 7.2b.), it is apparent that the TN reserves were not significantly involved in, or determinants of, the amount of dark shoot growth obtained. The residual TNC%'s were not particularly low as seen by comparison with the minimal levels measured in the other studies (table 7.11a, Fig. 7.1.b.). Some continued shoot growth was observed indicating that minimal TNC levels had not been reached. Also, Smith and Silva (1969) obtained a minimal TNC% of 2.1 in a dark growth pot experiment.

Technically, the field method suffers from the cost and handling problems of the covers. Those used were satisfactory except that they could have been higher to contain the etiolated growth. Agronomically, the etiolated regrowth tended to start decaying in these experimental conditions and hence the need for intermediate harvests. This may be a greater problem in warmer weather; an observation made by Causley (1968).

These results plus those of the reversal treatments (chapter 9) have confirmed many of the reported observations pertaining to organic reserves. At the same time the major effects of the different defoliation treatments have been demonstrated, showing that the root and crown nitrogen content was also strongly influenced by these treatments. The importance and actual role of these nitrogen levels in respect to new growth (both shoot and root) has still to be positively established compared to the recent advances with carbohydrate reserve studies (section 2.4.1.1.).

CHAPTER 8.

The Early Spring Temperature/Shoot Growth Correlation.

The influence of the early spring temperature fluctuations on the growth of lucerne was investigated in association with various methods of temperature measurement.

8.1. Method:

Temperature recordings were taken at the experimental site (see Fig. 3.1). This was done at half-hourly intervals using a copper/constantan 25 s.w.g. thermocouple located above the crop approximately 1 metre above ground level in an unobstructed position. An aluminium foil cover was positioned above the thermocouple to eliminate the direct rays of the sun. The thermocouple was connected to a Honeywell recorder through a timing switch unit. The reference used was a thermocouple placed 1 metre deep in the soil. Every 10 - 14 days the recorded was calibrated.

Measurements were made for the first seven weeks of the experiment. The results were calculated two ways. Firstly, the half-hourly values were summated and averaged for each day and in turn averaged for each week (FIELD SUM). Secondly, the maximum and minimum values were averaged for each day and week (FIELD AV.). For comparison, the daily mean temperature (maximum + minimum/2) and from these the weekly means were calculated from the D.S.I.R. records (DSIR AV, section 3.6.). The data is tabulated in appendix 3A.8.1.

These temperature results were correlated with the Chanticleer field growth data (section 5.2.3.) of weekly increments of shoot length growth and the numbers of shoots arising during each of the first four weeks. Linear and multiple regression analyses were used.

8.2. Results:

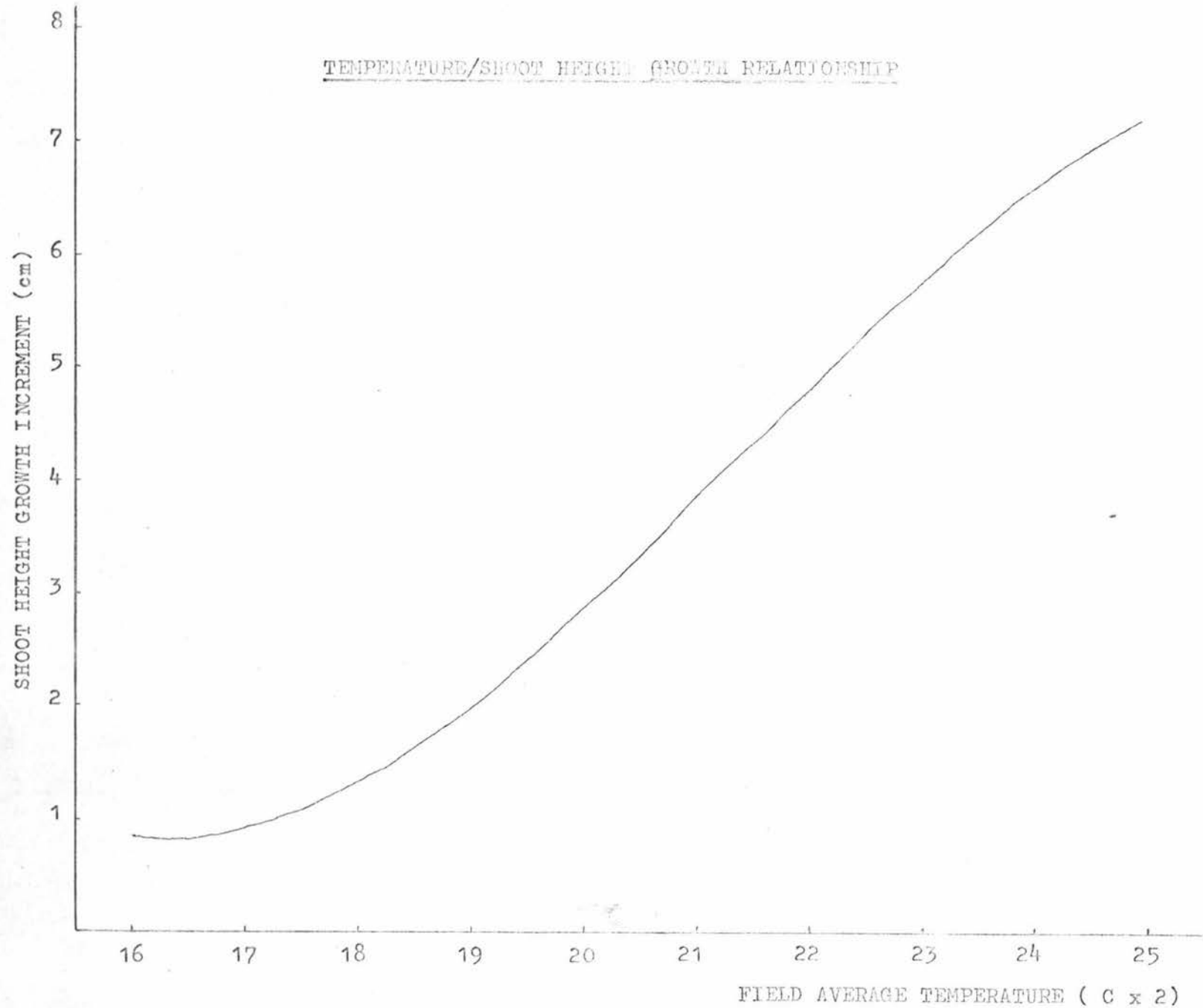
The shoot length growth increments had the most significant correlation with the (FIELD AV) values. The fitted curve is illustrated in fig. 8.1., the data in appendix 3A.8.2. Between 9°C and 12°D there was a steadily

Figure 8.1. The multiple regression of the spring 'field average temperature' for each week with the associated weekly shoot height growth increment measured on the field growth plants.

$$Y = 109.643 + 9.724t + 0.471t^2 + 0.007t^3$$

$F = 53.64$ $R^2 = 0.721$ SE. of estimate 1.531 DF = 62

TEMPERATURE/SHOOT HEIGHT GROWTH RELATIONSHIP



increasing temperature response. Below 9°C shoot growth decreased quite rapidly.

For shoot numbers, the best correlation was obtained with (FIELD SUM) r = 0.30, the regression coefficient being significant at the 5% level (table 8.1). For FIELD AV r = 0.11 and DSIR AV r = 0.26.

Table 8.1 Regression of FIELD SUM Temperature x Shoot Numbers.

DF	REGRESSION	S.E.	CORRELATION
43	1.0116*	0.4901	0.300

* P = 0.05

Appendixes: Data 3A.8.1.

8.3. Discussion:

The shoot length correlation indicates that early spring temperature is an important determinant of shoot growth at this immature growth stage. With older growth, shoot weight would be a preferable measurement. In these conditions of relatively low light levels and adequate soil moisture (section 3.6, fig. 3.2.), temperature was possibly the main growth determinant supported by the relatively linear growth response measured above 9°C suggests that 8 - 9°C may be an approximate temperature threshold level for lucerne shoot growth. No such value is known to have been reported.

Low significance of the shoot number regression was probably in part due to the nature of the data. There was a very poor spread of associated temperature values hindering the estimation of a significant regression (table 3A. 8.1.). It would appear that new shoot initiation was influenced by these spring temperatures.

It is suggested from these results that the early spring temperatures had at least two direct controlling influences on shoot growth. It is suspected that this would be more direct for new shoot initiation and initial elongation as these factors would be less likely to be confounded by other environmental and plant factors. As Wairau shoot growth was not measured, it is not known if there were any varietal temperature response differences.

As to why each shoot variable should correlate best with different temperature parameters is not known.

CHAPTER 9

A REVERSAL STUDY OF THE EXTREME DEFOLIATION TREATMENTS

The two extreme treatments, 3" and H, were compared with their respective reciprocal treatments of 3R (3" grown to haystage) and HR (H cut with 3" growth) to observe their respective rates of vigour recovery and depletion. This is considered in association with the nature of these changes.

9.1. Method.

After taking the final harvest of the previous studies in November 1969, a short two week study was made of the residual vigour of the 3", 3R, HR and H treatments for both varieties. This was in respect to their top growth, root and crown weight and organic reserve composition. Sampling was performed on the residual growth immediately after the last production cut (section 4.1.) and twice more at weekly intervals. These last production cuts were taken at different times between treatments over a six day period similarly affecting the measurements of this study (table 9.1.).

Table 9.1. Reversal Sampling Schedule.

	Chanticleer			Wairau		
Harvest	1	2	3	1	2	3
3"	10*	17	24	11	18	25
3R	10	17	24	11	18	25
HR	10	17	24	8	15	22
H	5	12	19	5	12	19

* The day of November, 1969.

Plant numbers - these were sampled as before (section 4.1.), in the first week of the study.

Top growth - three 2'x1' quadrats were cut at ground level with electric sheep shears from each small plot (section 3.2.) on each sampling day, the quadrats being located as described in section 4.1. Care was taken to avoid double cuts with the handpiece so as to keep the lucerne growth as intact as possible. The samples from the three quadrats were grouped, the total sample

being dried in a forced draught oven at 80 C for 24 hours after taking a representative sub-sample for botanical analysis and lucerne growth composition. For the botanical analysis, lucerne, 'other species', dead matter and soil were separated. For the lucerne growth composition, the lucerne was divided into its component fractions of stubble and new shoots, with a sub-sample of the latter being divided into stem and leaf. All lucerne shoots greater than 1 cm in the botanical analysis sample were counted. All components were dried as above. Total dry weights of the various fractions were subsequently calculated.

Chemical analysis - at the time of the last production cut of each treatment, six plants were dug from each small plot for chemical analysis of the roots and crowns. The preparation and analysis was as described in section 7.1. Both total non-structural carbohydrates (TNC) and total nitrogen (TN) were analysed.

Statistical analysis was by conventional analysis of variance (section 3.5.).

9.2. Results.

9.2.1. Plant Numbers.

The plant numbers present at the time of this study and their ANOVA results are presented in table 9.2. Treatment and variety differences were not significant.

Table 9.2. Plant Number Measurements. (No./1 sq ft)

	C	W	C + W	Statistics	
3"	6.00	7.55	6.77	Varieties	NS
3R	5.49	8.55	7.02	Treatments	NS
HR	6.71	7.27	6.99	Var x Treat	5%
H	8.33	7.11	7.72	SE.	1.27
Av.	7.62	7.62		CV%	17.80

Appendices: Data 3A.9.3. Statistics 4A.9.1.

9.2.2. Top Growth Yield and Composition.

The results and ANOVA of the lucerne, 'other species' and total yields are presented in table 9.3.

Table 9.3. Crop Production.(gm/6 sq ft)

	Lucerne	Other Species	Total
	Varieties		
C	125.21[α] (25.87)[*]A**	120.71*	146.72a*
W	143.28 (33.22)B	125.39	158.48b
ANOVA	1%	NS	1%
LSD***	(7.28), 9.73	-	(9.86), 13.18
	Treatments		
3"	89.69 (7.53)A	141,71A	149.24A
3R	138.38 (26.69)B	142.14A	169.02B
HR	133.44 (22.63)B	121.62B	144.06A
H	175.47 (61.34)C	86.75C	148.09A
ANOVA	1%	1%	1%
LSD	(10.37), 13.77	(15.61), 20.87	(13.95), 18.64
	Harvests		
1	125.45 (22.32)A a	120.40ABa	143.05A a
2	133.07 (27.95)ABa	137.10B b	165.06B b
3	144.22 (38.37)B b	111.66A a	149.70ABa
ANOVA	1%	1%	1%
LSD	(8.92), 11.92	(13.52), 18.07	(12.08), 16.14
	Treatment x Harvest		
ANOVA	NS	NS	1%
SE.	15.577	14.925	11.240
CV%	11.60	12.13	7.36

* Natural values. [α] Log transformed means.

** Means are compared at (A) the 1% and (a) the 5% levels.

*** (P = 0.05), P = 0.01

Appendices: Data 3A.9.1.

Statistics 4A.9.2.

With each variable, there were significant treatment differences (P = 0.01) but with each having a different treatment response pattern. The 3R and HR treatment lucerne yields were similar while at either extreme the 3" and H treatment yields were significantly different (P = 0.01). The 3" and 3R treatments of 3" origin had similar 'other species' yields. These were significantly higher than the HR and still lower H treatments. The total yields were similar between treatments except for the significantly greater (P = 0.01) 3R treatment. This was due to the combined influence of both higher lucerne and 'other species' yields.

The lucerne yield increased slowly with later harvests, but only significantly so for the third harvest (P = 0.05). For both the 'other species' and total yields the second harvest was significantly greater (P = 0.05) than the first and third harvests. These latter results were influenced by an apparent nett decrease of other species production in the second week. The significant total production's treatment/harvest interaction largely resulted from the variable 'other species' growth between treatments.

Between varieties, Wairau had a significantly greater (P = 0.01) lucerne yield, a small non-significant 'other species' advantage and a significantly greater (P = 0.05) total yield.

The results and ANOVA of the lucerne growth components are tabulated in table 9.4. All three variables had significant (P = 0.01) treatment differences with each expressing the same basic response pattern of 3" < (3R and HR) < H. Significant harvest differences were also measured but with different response patterns between variables. Significant increases between adjacent harvests were measured for shoot growth (P = 0.01) and shoot numbers (P = 0.05). Stubble response was the reverse, although with no significant differences between harvests 1 and 2. Both shoot growth and shoot numbers had significant treatment x harvest intractions due to an increase of treatment differences with time (fig. 9.1.). The stubble showed no such interaction. Between varieties, Wairau was significantly (P = 0.01) greater for each variable. The variety x treatment interactions were significant (P = 0.01) for shoot growth and shoot numbers only for varied reasons.(fig. 9.2.). For both variables, these interactions resulted from a greater disparity between the H and HR treatments of the Chanticleer variety.

The shoot growth compnents of leaf and stem dry weight had the same treatment significances as the total shoot growth (tables 4A.9.2.)

Table 9.4. The Major Components of the Lucerne Growth.(gm/6 sq ft)

	Shoot	Stubble	Shoot Number
	Varieties		
C	95.58 (15.69)A**	90.79*(10.09)A	227.36*(277.16)A
W	109.65 (17.66)B	110.07 (15.55)B	255.57 (438.50)B
ANOVA	1%	1%	1%
LSD***	(7.12), 9.52	(8.19), 10.95	(8.43), 11.27
	Treatments		
3"	64.85 (3.83)A	63.36 (3.70)A	207.90 (143.16)Aa
3R	100.87 (13.45)B	104.73 (13.06)B	235.20 (269.44)Bb
HR	106.07 (13.02)B	96.68 (9.60)B	249.90 (398.84)Bc
H	138.66 (36.41)C	136.95 (24.93)C	272.87 (619.77)Cd
ANOVA	1%	1%	1%
LSD	(10.07), 13.47	(11.58), 15.48	(11.92), 15.93
	Harvests		
1	67.24 (4.34)A	113.54 (17.83)Aa	228.16 (238.58)Aa
2	106.37 (14.99)B	104.26 (12.96)Aa	242.85 (387.83)Bb
3	134.22 (30.69)C	83.49 (7.68)Bb	253.40 (447.08)Bc
ANOVA	1%	1%	1%
LSD	(8.73), 11.66	(10.03), 13.41	(10.32), 13.79
	Varieties x treatments		
ANOVA	1%	NS	1%
	Treatments x Harvests		
ANOVA	1%	NS	5%
SE.	6.927	8.392	6.846
CV%	6.75	8.36	2.84
FORM	LOGS	LOGS	LOGS

* Natural values are bracketed.

** Means are compared at (A) the 1% and (a) the 5% level.

*** (P = 0.05), P = 0.01

Appendices: Data 3A.9.1.

Statistics 4A.9.2.

Figure 9.1. Comparison of the lucerne growth parameters of the four reversal experiment treatments over the two week growth period.

True shoot growth (ie. without stubble) - top left,

Shoot number greater than 1 cm long - top right.

Stubble weight - bottom.

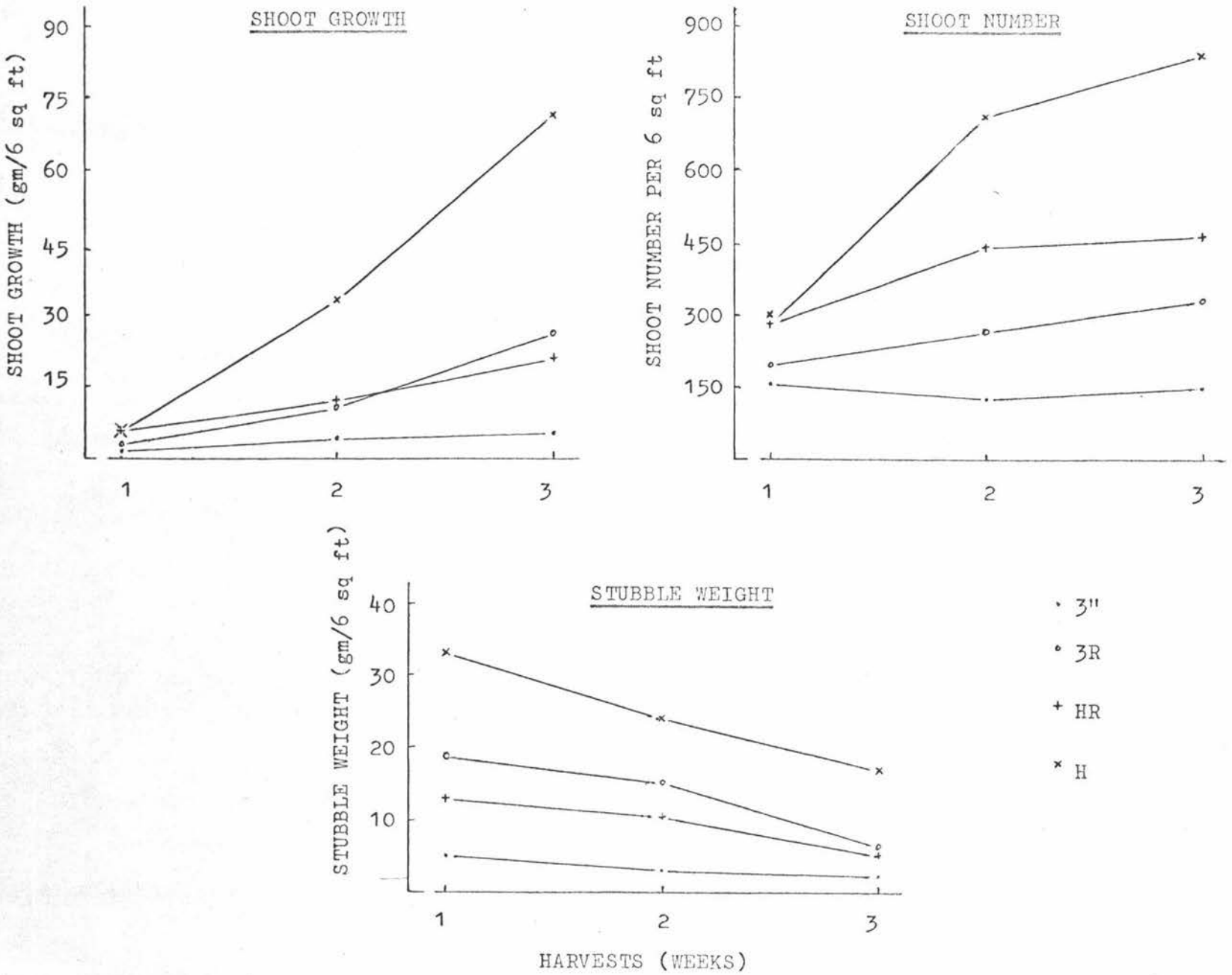
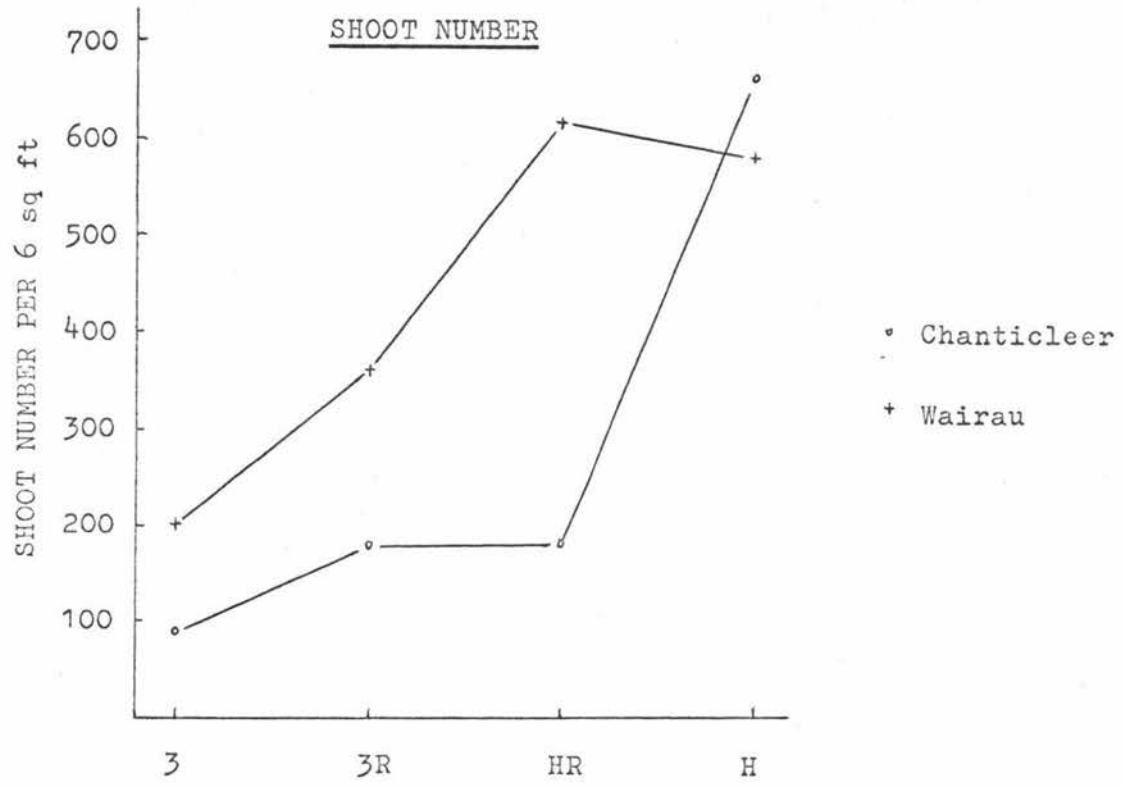
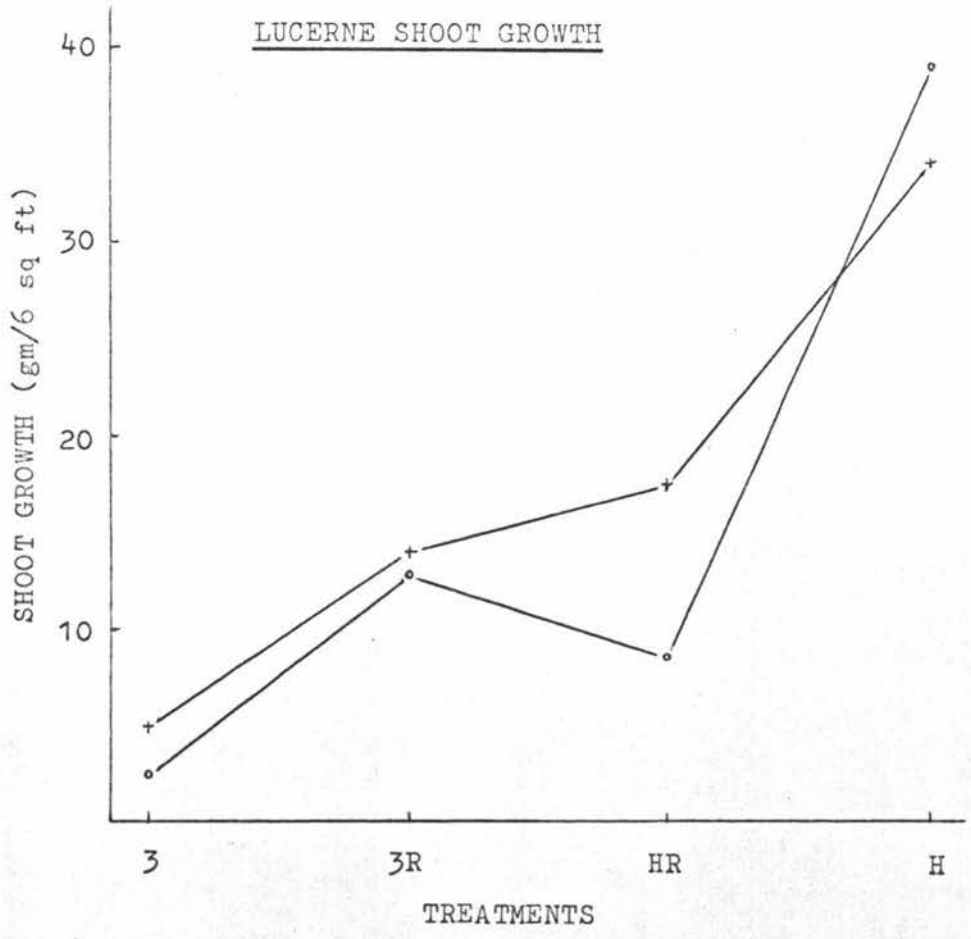

SHOOT GROWTH
SHOOT GROWTH (gm/6 sq ft)
90
75
60
45
30
15
1
2
3
SHOOT NUMBER
SHOOT NUMBER PER 6 sq ft
900
750
600
450
300
150
1
2
3
STUBBLE WEIGHT
STUBBLE WEIGHT (gm/6 sq ft)
40
30
20
10
1
2
3
HARVESTS (WEEKS)
· 3"
° 3R
+ HR
× H

Figure 9.2. Comparison of selected lucerne growth parameters for the two varieties with the four reversal experiment treatments.

Shoot numbers greater than 1 cm long.

True lucerne shoot growth (ie. without stubble)


SHOOT NUMBER
SHOOT NUMBER PER 6 sq ft
700
600
500
400
300
200
100
3
3R
HR
H
Chanticleer
Wairau


LUCERNE SHOOT GROWTH
SHOOT GROWTH (gm/6 sq ft)
40
30
20
10
3
3R
HR
H
TREATMENTS

9.2.3. Growth Rates.

Treatment CGR's and RGR's were respectively compared by natural and logarithmic linear regressions. Significant differences occurred (P = 0.01) with both comparisons. For each, all regression coefficients were significant (tables 9.5., 9.6.).

Table 9.5. Crop Growth Rate Comparisons.

	DF	Regress	SE	Correl	Statistics
3"	16	0.196*	0.089	0.479	Av. regression 5%
3R	16	1.638**	0.217	0.884	
HR	16	1.049**	0.244	0.731	Between individual
H	16	4.646**	0.414	0.942	group regressions
Av.	67	1.882**	0.243	0.687	1%

* P = 0.05, ** P = 0.01

Appendices: Data 3A.9.1.
Statistics 4A.9.3.

Table 9.6. Relative Growth Rate Comparisons.

	DF	Regress	SE	Correl	Statistics
3"	16	1.682*	0.732	0.498	Av. regression 5%
3R	16	6.237**	0.818	0.885	
HR	16	3.825**	0.870	0.739	Between individual
H	16	7.393**	0.697	0.935	group regressions
Av.	67	4.784**	0.468	0.781	1%

* P = 0.05, ** P = 0.01

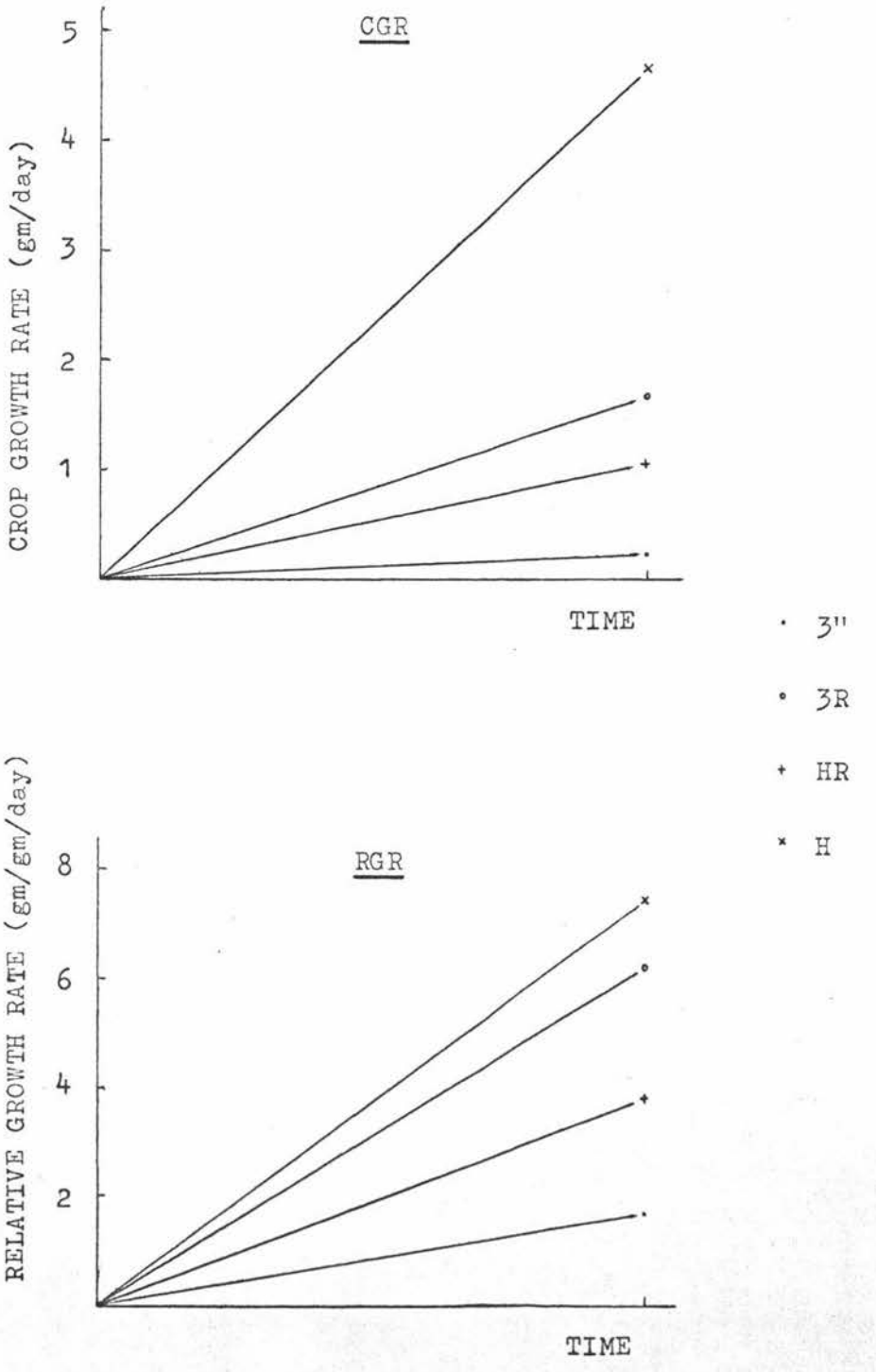
Appendices: Data 3A.9.1.
Statistics 4A.9.4.

As expected, CGR's were of a similar treatment order as shoot growth dry weights (table 9.5.). RGR's, as measures of growth efficiency (table 9.6.) were more interesting. The infrequently defoliated 3R and H treatments had high similar RGR's, the 3" treatment less and the HR treatment intermediate.

Figure 9.3. Comparison of the shoot growth rate regressions between treatments for the two week growth period of the reversal experiment.

Crop growth rate regressions.

Relative growth rate regressions.


CGR
CROP GROWTH RATE (gm/day)
5
4
3
2
1
TIME
· 3"
° 3R
+ HR
× H
RGR
RELATIVE GROWTH RATE (gm/gm/day)
8
6
4
2
TIME

9.2.4. Root and Crown Weights.

These measurements were taken from the plants sampled for chemical analysis. The results and ANOVA are presented in table 9.7.

Table 9.7. Root and Crown Weights. (gm/6 plants)

	Root	Crown	RTCR
	Varieties		
C	17.85	9.86A*	27.70
W	17.76	14.69B	32.46
ANOVA	NS	1%	NS
LSD	-	(3.08), 4.27	-
	Treatments		
3"	8.67A a	5.69A	14.36A a
3R	18.99BCb	8.45A	27.44B b
HR	17.23B b	16.22B	33.45BCb
H	26.33C c	18.73B	45.06C c
ANOVA	1%	1%	1%
LSD	(5.69), 7.89	(4.35), 6.04	(9.48), 13.17
INTER-ACTION	NS	NS	NS
SE.	3.72	3.27	6.41
CV%	20.89	26.62	21.33

* Means are compared at (A) the 1% and (a) the 5% levels.

Appendices: Data 3A.9.2.
Statistics 4A.9.5a.

In view of the equality of plant numbers (table 9.2.), these results which were on a per plant basis, are also representative of area measurements. The 3R and HR treatments had similar root and RTCR weights. They were significantly ($P = 0.01$) different from the extreme values of the 3" and H treatments. Contrastingly, the crown weights were not sgnificantly affected by the reversal treatments. Those treatments of H treatment origin were significantly greater ($P = 0.01$)(table 9.7.). Between varieties, the Wairau crown weights were significantly greater ($P = 0.01$) with no treatment interaction.

9.2.5. Organic Reserve Levels.

The TNC%'s directly reflected the defoliation frequencies; the infrequently defoliated 3R and H treatments having significantly greater (P = 0.01) values than the frequently defoliated 3" and HR treatments (table 9.8.). While varietal differences were non-significant, a significant (P = 0.05) variety x treatment interaction was due to the response range between treatments being greater for the Chanticleer variety (fig. 9.4a). These results were the same for each plant variable.

Table 9.8. Total Non-structural Carbohydrate Percentages.

	Root	Crown	RTCR
VARI-ETIES	NS	NS	NS
	Treatments		
3"	0.358 (12.33)A**	0.295 (8.50)A	0.334 (10.82)A
3R	0.582 (30.33)B	0.430 (17.50)B	0.538 (26.47)B
HR	0.326 (10.33)A	0.276 (7.50)A	0.303 (8.96)A
H	0.542 (26.66)B	0.382 (13.92)C	0.481 (21.47)B
ANOVA	1%	1%	1%
LSD***	(0.037), 0.051	(0.029), 0.040	(0.035), 0.048
INTER-ACTION	5%	5%	5%
SE.	0.038	0.027	0.036
CV%	8.45	7.87	8.65

* Natural means.

** Means are compared at the 1% level.

*** P = 0.05, P = 0.01

Appendices: Data 3A.9.2.
Statistics 4A.9.5b.

Between treatments, the TNC weights reflected the relative dominance of of the plant part weights and the associated TNC%'s. With the roots and RTCR these factors operated in unison while for the crowns, the 3R and HR treatments interacted within the 3" and H treatment range (table 9.9.). These results are more easily discerned from a combined cosideration of tables 9.7., 9.8. and 9.9. Between varieties, the greater Wairau crown weight resulted in a similarly significantly greater TNC weight (table 9.9.).

Table 9.9. Total Non-structural Carbohydrate Weight. (gm/6 plants)

	Root	Crown	RTCR
	Varieties		
C	4.23	1.19A*	5.43
W	3.66	1.67B	5.34
ANOVA	NS	1%	NS
LSD**	-	(0.34), 0.48	-
	Treatments		
3"	1.03A	0.47A	1.51A
3R	5.88B	1.44B	7.33B
HR	1.81A	1.22B	3.03A
H	7.06B	2.59C	9.66B
ANOVA	1%	1%	1%
LSD	(1.83), 2.55	(0.49), 0.68	(2.20), 3.06
INTER-ACTION	NS	NS	NS
SE.	0.98	0.26	1.05
CV%	24.98	17.96	19.38

* Means are compared at the 1% level.

**(P = 0.05), P = 0.01

Appendices: Data 3A.9.2.

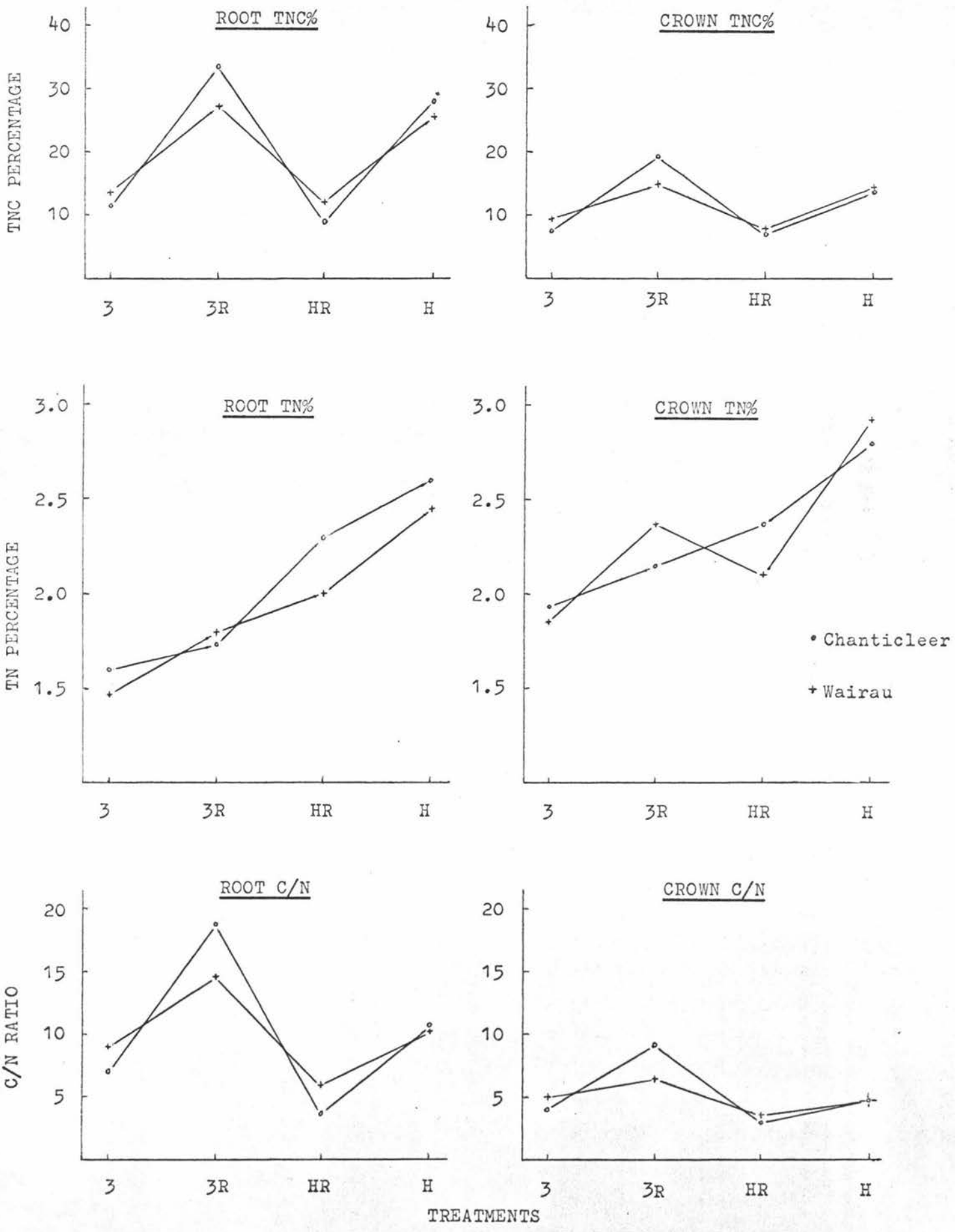
Statistics 4A.9.5c.

Figure 9.3. The organic reserve composition of the roots and crowns of the plants of the reversal experiment treatments.

a. The Total Non-structural Carbohydrate percentages of the roots (left graph) and crowns (right graph).

b. The Total Nitrogen percentages of the roots and crowns.

c. The TNC/TN ratios of the roots and crowns.


ROOT TNC%
CROWN TNC%
TNC PERCENTAGE
40
30
20
10
3
3R
HR
H
ROOT TN%
CROWN TN%
TN PERCENTAGE
3.0
2.5
2.0
1.5
• Chanticleer
+ Wairau
ROOT C/N
CROWN C/N
C/N RATIO
20
15
10
5
TREATMENTS

The TN%'s are presented in table 9.10. The root and RTCR values were significantly different (P = 0.01) between all treatments in the increasing sequence of 3", 3R, HR and H treatments. Except for the similarity of the 3R and HR treatments the crown TN%'s were in the same significant (P = 0.01) sequence. Varietal analyses were non-significant as also was the root variety x treatment interaction. This interaction was significant for the crowns (P = 0.01) and less so (P = 0.05) for RTCR. These significant interactions were due to the Wairau variety's greater response to the changed defoliation treatments (fig. 9.4b.).

Table 9.10. Total Nitrogen Percentages.

	Root	Crown	RTCR
VARIETIES	NS	NS	NS
	Treatments		
3"	0.124 (1.54)A**	0.139 (1.92)A	0.130 (1.69)A
3R	0.135 (1.81)B	0.151 (2.27)B	0.140 (1.96)B
HR	0.147 (2.16)C	0.150 (2.24)B	0.148 (2.19)C
H	0.159 (2.52)D	0.170 (2.88)C	0.164 (2.68)D
ANOVA	1%	1%	1%
LSD***	(0.006), 0.009	(0.005), 0.007	(0.005), 0.007
INTERACTION	NS	1%	5%
SE.	0.0059	0.0051	0.0048
CV%	4.21	3.33	3.31

* Natural means.

** Means are compared at the 1% level.

*** (P = 0.05), P = 0.01

Appendices: Data 3A.9.2.

Statistics 4A.9.5d.

The TN weights (table 9.11.) were mostly influenced by the plant part weights (table 9.7.). This was shown by their treatment response patterns and significances being similar. Again, between varieties, the Wairau crown TN weight was greater due to the crown's greater weight (table 9.7.).

Table 9.11. Total Nitrogen Weight. (gm/6 plants)

	Root	Crown	RTCR
	Varieties		
C	0.38	0.24A*	0.63
W	0.36	0.35B	0.72
ANOVA	NS	1%	NS
LSD**	-	(0.07), 0.10	-
	Treatments		
3"	0.13A	0.11A	0.24A
3R	0.35B	0.19A	0.54B
HR	0.37B	0.35B	0.72B
H	0.66C	0.54C	1.20C
ANOVA	1%	1%	1%
LSD	(0.11), 0.15	(0.10), 0.14	(0.21), 0.29
INTER-ACTION	NS	NS	NS
SE.	0.088	0.085	0.166
CV%	23.51	28.39	25.31

* Means are compared at the 1% level.

** (P = 0.05), P = 0.01

Appendices: Data 3A.9. 2.

Statistics 4A.9.5e.

The C/N ratios reflect the greater response of the TNC compared to the TN to the treatment changes imposed. For all plant variables, the 3" and H treatments were similar or close to being so, while the 3R and HR treatments reflected their greater respective increase and decrease of TNC wei t relative to the associated smaller TN weight changes (table 9.12). The very significant (P = 0.01) variety x treatment interactions were all due to the smaller Wairau response range (fig. 9.4c.).

Table 9.12. TCN/TN Weight Ratios.

	Root	Crown	RTCR
VARI-ETIES	NS	NS	NS
	Treatments		
3"	8.04A*	4.45ABa	6.42Aa
3R	16.73B	7.80C b	13.59Cb
HR	C	3.37A c	4.15Bc
H	10.60D	4.86B a	8.06Ad
ANOVA	1%	1%	1%
LSD	(1.48), 2.05	(0.91), 1.26	(1.35), 1.87
INTER-ACTION	1%	1%	1%
SE.	1.31	0.82	1.29
CV%	12.99	16.07	15.99

* Means are compared at the (A) 1% and the (a) 5% levels.

** (P = 0.05), P = 0.01

Appendices: Data 3A.9.2.

Statistics 4A.9.5f.

9.3. Discussion:

It was previously shown that the continued 3" and H treatments in the main experiment resulted in some reduction of plant numbers for both treatments with both varieties (table 4.14). The infrequently defoliated 3R treatment, surprisingly also showed reductions of plant numbers. This was particularly evident for the 3RW treatment. It is probable that this reduction of what were intially small plants on average, was due to the competition from the other species growth. The frequently defoliated HRC treatment, had a small further reduction of plant numbers beyond that of the HC treatment, while the HRW plant numbers were not further reduced.

Because of the short duration of the study, it is only indicative of the longer term production potential of each treatment. Other restrictive variables were the dry conditions leading up to and including the first half of the study were observed to limit lucerne growth to some extent (section 3.6.); the dates of growth variation between treatments (table 9.1) may have interacted with the climatic factors. Although the results should be considered within these limitations, they do agree with the expected responses.

As with the previous production study (section 4.2.1.) lucerne and other species growth tended to compensate for each other giving similar total yields between treatments. It is probable that the H treatment, and to a lesser extent the 3R and HR treatments, would have had greater total mature yields due to their greater lucerne content combined with its faster growth during this season.

All the lucerne growth parameters showed the same treatment influences. The infrequent reversed 3R treatment had a significant recovery of regrowth vigor, while the reversed HR treatment had a significant decrease of vigor. These vigor changes are best represented by the associated shoot RGR's (table 9.5) and are further exemplified by the growth parameters of the average shoot weight (table 9.13) and shoot stem/leaf ratio (table 9.14).

These were both noticeably greater for the lenient 3R and H treatments, indicating greater individual shoot growth capacity. The second week shoot

number increase of the infrequently defoliated 3R and H treatments compared to little change for the frequently defoliated 3" and HR treatments (Fig. 9.1.) would have diminished rather than increased the former treatments average shoot weight advantage. This supports the observation of their more efficient growth.

Table 9.13. Average Individual Shoot Weight (gm)

	C	W	C + W
3	3.15*	2.46	2.80
3R	7.17	4.00	5.54
HR	4.63	2.86	3.74
H	5.86	5.90	5.87

* A x 10^2; calculated from the shoot weight and shoot number replication mean values (table 3A.9.1.)

Table 9.14. Shoot Stem/Leaf Ratios

	C	W	C + W
3	0.90	0.87	0.88
3R	1.36	1.23	1.29
HR	0.87	0.90	0.89
H	1.20	1.05	1.13

Appendix: Data 3A.9.1.

The greater stem content of the 3R and H treatments indicates either more efficient leaf photosythesis or a greater available supply of reserve growth substrates. The associated higher TNC content and concentration (tables 9.8, 9.9) strongly supports the latter hypothesis in light of the established immediate post-defoliation role of carbohydrate reserves in new shoot growth (section 2.4.1.1.) (Hodgkinson, 1967; Smith and Marten, 1970). The residual 7 and 14 day leaf weights per shoot are tabulated in table (9.15).

It is obvious that the 3R and H treatments did not have any initial treatment growth advantage because of their lower residual leaf area per shoot. It is equally evident that the following rapid rate of new leaf production and the associated commencement of photosynthate export soon after (Hodgkinson, 1967) would have soon confounded the contributing role of TNC reserves to new shoot growth.

Table 9.15. Leaf Weight per Shoot (gm/x 10^3)

	Day		
	0	7	14
3"	5.80	10.66	21.44
3R	3.30	17.20	37.00
HR	7.95	14.40	25.80
H	5.35	20.08	41.50

Appendix: Data 3A.9.1.

The greater residual leaf areas per shoot of the 3" and HR treatments in association with the low TNC levels, suggests this residual leaf area may have been of greater importance for their slower shoot growth. In this respect, the complex of residual leaf origin, age and photosynthetic efficiency should be kept in mind (section 2.4.1.3; Keoghan, 1970). Even for these treatments, new leaf growth per shoot was quite substantial over the period of measurement (table 9.15).

The high TNC levels of the 3R and H treatments almost certainly means that the TN reserves, which were probably adequate in each case, would not have limited growth. In contrast it is suggested that the low similar TNC levels of the 3" and HR treatments may have meant that the TN reserves were of greater importance for these treatments. The HR treatments average RGR was greater. This may have been aided by the higher TN levels (1/3rd greater than the 3" treatment) supplementing the low TNC levels by being used as respiratory substrates and/or as a source of carbon skeletons for growth. For the 3" treatments, this advantage was possibly lacking, contributed to their lower RGR's (section 2.4.1.1.). The individual shoot weights (table 9.13) support these observations. For the 3" treatment, a restricted root system and possibly low internal plant levels of mineral nutrients (sections 2.4.1.2, 2.4.1.4) may have contributed to the growth restrictions.

The nature of the shoot growth obtained is considered along with some interesting varietal differences. Shoot CGR differences between treatments were largely determined by the respective shoot numbers in association with the individual shoot growth efficiencies. The greater 3R treatment growth compared to the 3" treatment, arose from the former's greater shoot

growth efficiency in association with an increase of shoot numbers. Between varieties, Wairau shoot numbers were twice those of Chanicleer for both treatments, although with a lower individual shoot growth (table 9.13) resulting in the small Wairau shoot growth advantage (Fig. 9.2.). The lower average shoot weights for Wairau suggests that inter-shoot competition for available growth substrates occurred. The same form of varietal difference was measured for the HR treatment, while there was none for the H treatment. These differences of the HR treatment were that the reversed frequent defoliation resulted in no change of shoot numbers for Wairau, but with a large decrease for Chanticleer. For Chanticleer, the low growth efficiency of this treatment restricted any benifits from reduced competition that may have resulted from the lower shoot numbers.

That the large number of shoots for the HC treatment were similar to the number for the HW treatment (Fig. 9.2.) was unexpected, particularly in light of the similar plant numbers of the main experiment (Fig. 5.6). It is difficult to provide an explanation, other than that the HC treatment may have been defoliated at a stage of high basal bud activity. Keoghan (1970) also observed that Wairau lucerne plants had large reserves of such buds. This was observed here for both varieties in the H treatments.

The greater total lucerne top growth for Wairau (table 9.3) was largely due to it having significantly more stubble, this being similar for all treatments (Fig. 9.2). Of particular note was the relatively quick decrease of stubble weight over the growth period for all treatments (Fig. 9.1) of both varieties.

This loss may be as: 1. a natural senescence loss (section 6.2.)
2. a further calculated productive loss if the productive yield is corrected for a largely senesced previously residual stubble weight. With a relatively well defined plant such as lucerne it is reasonably easy and rapid to separate the shoot growth from the stubble and so obtain an accurate estimate of the actual growth obtained. With this procedure, only a single ground level cut at harvest would be required. It would not permit a suitably accurate estimate of the other species growth if this was required.

Below ground level, the roots showed much more response to the reversal treatments than did the crowns (table 9.7). The respective TNC differences

would have been major contributors, plus probably, some growth changes. The larger Wairau crown weight is an expected response (section 2.2.1., 2.5.) which was maintained over all treatments.

The organic reserve treatment and variety responses were in general agreement with the preceding studies (chapter 7.).

Although treatment differences of individual shoot growth efficiency were strongly indicated, to determine the actual differences would have needed a more detailed study similar to the field growth study (section 5.2.3.). In this way the confounding influences of the different shoot numbers and when each shoot commenced elongating could be partly accounted for.

CHAPTER 10.

DISCUSSION

10.1 Experimental.

Looking in retrospect at the main experiment, it is apparent that the design of parts of the study could have been improved. The production study of chapters 4 and 9 were satisfactory, although the appraisal period of the latter would have benefited from being longer and with all treatments synchronised in time.

The plant growth study of chapter 5 and associated chapters was the more unsatisfactory part of the thesis in respect to design. Although this was approached as a residual study, this was limited by the growth time to the first production harvest of the respective treatments (table 5.1.). This, associated with the growth stage (shoot height) sampling system*, were responsible for the two main criticisms of experimental design:

1. Because of the shorter growth periods of the 9" and 15" treatments, this meant that they were of limited value for growth and growth rate comparisons with the 3R and H treatments.

2. The inability to make satisfactory direct comparisons between treatments because of the growth stage time differentials (table 5.1.). Some of the statistical methods used to overcome the latter problem were involved and probably not as satisfactory as an orthogenal comparison between treatments over time. A preferred design using this suggestion, would have been a full residual study in which all treatments were grown through to maturity with plant sampling being at regular and probably shorter time intervals. Similar further benefits would have been obtained if the permanent field identified plants of all treatments had been measured through to maturity. With this design, the statistical aspects of treatment comparison would have been simpler and more conventional.

With this approach, the periodic nature of sampling can result in work load difficulties. It is probable, that if this approach had been used, some reduction of the number of measurements made would have been necessary. In particular, the measurements of all shoots as one type,

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* The limiting nature of this method of growth stage estimation was discussed in section 5.3.6.

instead of dividing them into stubble and basal shoots as was unsuccessfully attempted (section 5.3.1.). In the field, a portion of the plot could readily have been set aside for this growth to maturity study, leaving the balance for the basic treatment defoliations (chapter 4.).

Stopping the measurements of the 9" and 15" Wairau treatments was not the best method for easing the work load. It would have been preferable to reduce the number of measurements made for these two treatments for both varieties. This would have retained some statistical orthogonality and provided bridging measurements between the extreme 3" and H treatments for variety comparisons. This would have been particularly pertinent for the shoot number per plant (section 5.2.1.5.) and individual shoot height growth rates (section 5.2.3.).

Several other aspects were limiting to this study. Between the dug plants and the field growth studies, more uniformity for shoot numbers and associated patterns of change may have been achieved if the shoots and buds had been separately identified, viz, shoots having at least one expanded leaf (Nelson and Smith, 1968a). For the dug plants there was a significant number of buds greater than 1 cm. but less than 5 cm. long counted, compared to the field study where all counted shoots were greater than 5 cm. long. The stony nature of the soil made digging plants for study or counting a difficult and often time consuming operation. Needless to say, a stone free soil would have been preferable. In the frequently defoliated 3" plots, the high incidence of other species growth made sampling and field measurements difficult, but at the same time, gave a more realistic treatment response. In all treatments the predominance of winter annual weeds and grasses in the more frequently defoliated treatments tended to confound low level light intensity measurements. For a detailed light transmission comparison between treatments, control of the other species growth with herbicides at or prior to the last previous defoliation would probably be necessary. This is particularly applicable in the early spring with the associated slower rates of lucerne growth.

Although these deficiencies of design and other problems were very real, and it would undoubtably have been benificial to improve them where possible, the results obtained have proven to be of interest and value

in explaining the effects of the pre-thesis treatments.

Studies of the nature of plant growth are normally performed in at least partly controlled small plot conditions and in some cases, in glass-houses or growth cabinets (e.g. Steinke, 1963; Keoghan, 1966, 1970; Leach, 1968a, 1969a, 1970a). The results obtained from these studies have still to be extrapolated to field conditions where they are not necessarily entirely representative of field responses. This particularly applies if the non-field studies are done with single plants (Leach, 1968a; Chisci, 1968). The results from these more controlled studies do provide important lines of investigation to be verified or otherwise in the field studies which in turn consider the more natural treatment response. To some extent, this extension into the field has been successfully achieved in this thesis.

10.2. Varieties.

Palmer (1967) described the origins and the observed relative advantages between the two varieties used, Wairau and Chanticleer. Wairau was described as being high producing with good persistence when used for either hay or grazing. In comparison, Chanticleer was described as producing well throughout the spring, summer and autumn. It has substantially higher production in April and May than Wairau and commences growth somewhat earlier in the spring, although this advantage is short lived. From unpublished data, Palmer (l.c.) suggested that Chanticleer stands may not remain productive for as long as those of Wairau, particularly under very severe grazing.

Apart from the autumn growth which was not considered, these observations tended to be supported in this thesis study. There was also general support for the growth form differences which other workers have observed between the *sativa* (Chanticleer) and *falcata* (Wairau) lucerne types (section 2.1, 2.5.).

While there were no significant total shoot production or plant size differences between varieties, there were significant differences for some of the component factors of this growth.

The most notable morphological factors were the greater shoot number (Fig. 5.6.) and crown size (Fig. 5.9.) of Wairau. The resultant

greater ground coverage was initially indicated by Wairau's significantly greater (P = 0.01) point analysis record, associated with a significantly lower (P = 0.05) bare ground record (tables 4.7., 4.9.). The defoliation frequency treatments showed that this variety difference was negligable with frequent defoliation but that it became increasingly apparent as defoliation frequency decreased. The closer relationship between shoot number and crown size for Wairau has been indicated by this variety's more significant day 0 shoot number x RTCR correlation (table 5.30) and more uniform shoot/crown plus stubble (table 5.32) and shoot/RTCR (table 5.32) ratios.

These observations suggest that the number of shoots produced per plant has a greater dependence on crown size for Wairau than Chanticleer. Leach (1969a) showed a similar result in respect to the amount of stubble left after defoliation. With a given defoliation height the amount of stubble will be partly depenedent on the size of crown. The equality of the H treatment's shoot number between varieties in the reversal experiment (Fig. 9.2.) indicates that these varietal differences can vary in some situations. Using Wairau, Keoghan (1970 observed a high reserve potential of dormant buds on the crowns. A similar situation was observed, although not measured, on the crowns of the Chanticleer H treatment plants. It appears that in particular growth circumstances with vigorous plants, a greater proportion than usual of these basal buds may become active following defoliation.

Mean individual shoot weights interacted between defoliation frequency and varieties in a manner similar to shoot numbers, except, that the varietal order was reversed; Chanticleer had greater weight (table 5.30.). The complexity of this relationship is discussed in section 10.3.

These varietal differences of crown size, shoot numbers per plant and individual shoot weight agree with previous reports (sections 2.1., 2.5.).

It was suggested that the Chanticleer variety was more heterogenous in respect to shoot age and hence height (sections 5.3.6., 6.3.). The greater leaf area density in the top most layers of the 9" growth stage for the HW treatment suggested support for Wairau having a more even shoot height and possibly age.

The stem/leaf ratio varietal differences varied between different parts of the experiment. The most usually reported observation is for this ratio to be greater for the sativa varieties (section 2.1.1.). This was observed here for the new basal shoot growth (table 5.27.) and the reversal experiment's infrequently defoliated 3R and H treatment shoot growth (table 9.14.). In contrast, Wairau had the greater ratio for the duration of the main experiment (Fig. 5.10.). Again in this latter and the reversal experiment, these differences were only existent or greater for the infrequently defoliated treatments. Zaleski and Dent (1960) measured a full years lucerne growth and found the stem/leaf ratio to be greater for the falcata type varieties. They did not comment on this as being a difference from the more usually reported results. In the main experiment, the higher Wairau stem density resulted in a more abrupt interception of light (Fig. 6.8.) and hence greater light competition between shoots. This may have induced a greater proportionate shoot stem elongation compared with the Chanticleer shoots, without having a similar proportionate increase of leaf growth. This implies that different stem densities, or more explicitly, different resultant canopy light environments, may lead to stem/leaf ratio changes within a variety. If so, genetic varietal differences would only be comparable if the varieties were grown with similar growth conditions. This would have tended to be the situation for the basal shoot growth (table 5.27.) and the reversal experiment's 3R and H treatments shoot growth (table 9.14.). The age difference between the shoots of these treatments and the older shoot growth of the main experiment suggests reason for some caution in respect to the above stem/leaf ratio discussion.

In the literature, it has generally been agreed that the sativa type varieties are less persistent (section 2.5.). This tended to occur in this study with most of the reported aspects being indicated. Although at the end of the experiment there were no significant plant number differences between varieties (table 9.2.), the first plant count showed Wairau to have significantly ($P = 0.01$) more plants (table 4.12.). This was associated with a highly significant variety x treatment interaction which was discussed in section 4.3.3.

The reported reasons for such persistence differences between varieties were discussed in section 2.5. The lower stem/leaf ratios of the

Wairau basal shoots and the shoots of the reversal experiment's 3R and H treatments indicates that this variety has a proportionately faster rate of new leaf growth. If so, these Wairau shoots are expected to reach the stage of carbohydrate independence (Hodgkinson, 1967) or critical leaf area (Silva, 1968) sooner than similar Chanticleer shoots. In respect to persistence, this suggests that the initial shoot growth of Wairau will be less dependent on organic reserves and hence the concentration of these would fluctuate less during regrowth. This has been observed by other workers (section 2.5.). It was also shown here between the treatments of the reversal experiment; the greater fluctuations of the TNC%'s for Chanticleer was observed for both the roots and crowns (Fig. 9.3a.) ($P = 0.05$ each, table 9.8.). Interestingly, in contrast, the Wairau TN%'s fluctuated more than those for Chanticleer, particularly in the crowns. The relevance and reasons for this are not known. It would appear that although decreasing defoliation frequencies are more detrimental to lucerne persistence than varietal differences, the Wairau variety may have been slightly more persistent than Chanticleer by way of its earlier leaf development.

The later commencement of active spring growth for Wairau was not apparent in this study on a crop growth basis (tables 5.2., 5.7.). The larger Wairau shoot number apparently compensated for its slightly, although non-significantly lower RGR during this early spring period (table 5.8.). This aspect would have been more certainly established if shoot height growth rates had also been available for the Wairau treatments.

As discussed, there were several significant varietal differences established in these studies. Possibly the most notable feature was the frequently observed variety interaction with defoliation frequency. In most cases, infrequent defoliation was necessary to enable these varietal differences to be expressed. With frequent defoliation, both varieties tended to be suppressed to similar levels. These results indicate the need for more work to further investigate and verify these varietal differences and establish their relevance in terms of growth and lucerne management.

10.3 Lucerne Yield and Growth.

The various aspects of lucerne growth have been individually considered in the preceding chapters. It is intended here to briefly discuss the way in which these aspects collectively contribute to lucerne yield and nature of growth as observed during these spring growth experimental conditions.

The unexpected equality of total production over the range of defoliation frequencies used was probably in response to the cooler spring temperatures, in which conditions the volunteer species are generally more competitive. It was suggested (section 4.3.2.) that later in the warmer seasons of the year the winter annuals die out, the lucerne grows considerably faster and is hence more competitive, in its turn. In these circumstances it is more likely that the more often reported total yield increase with decreasing defoliation frequency (section 2.3.1.1.) would be realised. This situation when considered with the fast lucerne growth rates and low other species composition of the 15" treatment's second growth (section 4.3.1.), suggests that spring defoliation before full maturity of previously less frequently defoliated lucerne may result in greater annual production. This would have to be consistent with a reasonable replenishment of organic reserves and higher seasonal temperatures and radiation levels (section 3.6.) at the time of this spring defoliation. The faster lucerne growth is expected to compensate for the reduced other species composition. Vartha (1967) demonstrated this, showing that the time of the first spring defoliation can be used to control grass competition. To do this, the lucerne plants need to be vigorous and large enough to respond with the required degree of competitiveness. Other workers with single early spring defoliations at an immature stage of growth, have found reduced annual yields (Dent, 1950; Jackobs et al., 1955; Langille et al., 1965).

The response of the volunteer species was interesting. The increase of the grass and clovers (relatively permanent sward components) associated with the decrease of the lucerne sward content as defoliation frequency increased, clearly showed that lucerne is more vulnerable to frequent defoliation. The erect shoot growth of lucerne is very vulnerable to apice removal by defoliation. For much of the year the grasses and clovers (white clover in this case) have basally located apices and are consequently less vulnerable. They may also adapt to a more prostrate

growth form. Depending on the variety and species this can result in a greater residual photosynthetic area after defoliation with an associated slower loss of vigour (Wolf et al., 1962; Paulsen et al., 1968). It seems that the 'other weeds' (not the grasses and clovers) tend to be transistory sward components. These fluctuate seasonally, largely at the dictates of their inherent seasonal growth, the climatic conditions and the lucerne, grass and clover respective seasonal growth rates and densities.

During the spring season it has been indicated that the climatic conditions are important determinants of the lucerne growth obtained. This is mainly due to the influence of the rising spring temperatures and increasing solar radiation levels, on the lucerne growth rates. It is also indirectly due to the differential growth responses of lucerne and the volunteer species. Soil moisture levels may interact with the above factors, although in most years this is not a major determinant of spring growth in the Palmerston North environment.

It has been shown that the range of defoliation treatments were able to alter the top growth yields of the lucerne plants in three basic ways:

1. By altering the number of plants per a unit area.

2. By altering the plant size with an associated change of the number of shoots per a plant.

3. To a lesser extent, by altering the efficiency of individual shoot growth.

With 1. and 2. there were important varietal interactions.

The plant populations were shown to be a dynamic entities, although in a declining sense over the period of the experiment (section 4.2.3.). This precluded any adequate conversion of the plant study results to an area basis. Although the initial plant number varied considerably between treatments and varieties, the large consistent plant size difference between treatments was a greater determinant of the total lucerne shoot yield obtained. This was particularly so in view of the relative equality of plant numbers between the extreme treatments at the end of the experiment. Suggestions have been made as to how these initial and final shoot numbers came about (section 4.3.3.). They are interesting because of their divergence from the more often reported cases of plant number

decreases with increasing defoliation frequency (section 2.3.2.).

The conclusion of Leach (1968a, 1969a) "....that the yield of regrowth within lucerne cultivars depends primarily on the number of shoots and the time when each resumes growth", was supported by the field growth study results using the Chanticleer (section 5.2.3.). Although this was not directly verified for Wairau, the same situation is expected to have applied as Leach (1969a) made his observations from a study of the three varieties, Totana, Hunter River and Rhizoma. These ranged from a strong sativa type through to a strong falcata type. Within the H treatment for each variety of the thesis experiment, there is some suggestion that for this spring growth there may have been variations in the form of this response. The large initial Wairau shoot numbers compared with those of Chanticleer, indicated a greater intensity of inter-shoot competition in the former variety supported by the large amount of whole shoot senescence (Fig. 5.5.). In these conditions it is probable that relatively few later arising shoots would have been important contributors to the total shoot yield. By comparison for Chanticleer, with fewer shoots, each shoot arising in the first three weeks was individually an important contributor to the

mean shoot size differences (see above). It would appear that for plants of similar vigour and size, growing in similar spring conditions, that differences of shoot numbers between varieties could result in shoot yields being similar. Again by comparison, in active growth conditions varietal shoot number and size differences may lead to total shoot yield differences. Leach (1969a) demonstrated this with Totana which compared with Rambler had fewer but larger mean shoot weights associated with a resultant greater total shoot yield.

Within a given variety there is evidence that any inverse shoot number/shoot size relationship between plants of similar size and vigour will only be expressed by very low shoot numbers (1 to 4) per a plant growing in conditions conducive to high growth rates (Leach, 1971). This contrasts with such an inverse relationship being demonstrated by Hodgkinson (1967). Leach (l.c.) considered that the lack of this inverse relationship, which is less likely to occur in the more rigorous growth conditions in the field, was due to competition between shoots for growth substrates. Between plants of different sizes any compensatory shoot number/size relationship would be further limited in respect to total shoot yield by their differing root and crown sizes, potential shoot numbers and shoot growth efficiency.

The third basic effect of defoliation, shoot growth efficiency changes, is additional to the plant size differences. Leach (1968a, 1969a) observed that the growth of individual shoots was independent of the defoliation treatment applied. This was only partly upheld here. The inefficient growth of the 3R treatment accentuated the growth restricting effect of this treatment's lower shoot number. With less frequent defoliation (9C, 15C and HC treatments) of Chanticleer, the above observation was confirmed, although with less certainty for the 9C treatment. These treatments were of longer duration and for the frequently defoliated ones, more severe than those of Leach (l.c.).

It was not possible to ascertain the reasons for this 3R treatment's lower growth efficiency. TNC reserves were not limiting and although TN levels were lower, they were almost equally low for the 9C treatment. Other reasons have been suggested and discussed (sections 2.4.1.4., 5.3.4.).

The reversal experiment (chapter 9) successfully demonstrated the beneficial direct and indirect effects of high TNC concentrations at defoliation initially promoting rapid shoot growth. This is in keeping with current knowledge (section 2.4.1.1.). TN may have been growth limiting for the 3" treatment, but did not appear to be so for the other reversal treatments.

It has been shown that the main determinants of lucerne crop top growth, are plant numbers, shoot numbers per plant, when each shoot commences to elongate and individual shoot growth efficiency. A further important factor in this study was the high incidence of whole shoot senescence. Compared with other work, this was a major determinant of shoot yield in the later growth stages of the longer term treatments of the main experiment. For both varieties, this appeared to be the main determinant of the final shoot yields of the 3R and H treatments. Two reasons are suggested for the high incidence of shoot senescence in this experiment. As discussed (section 6.3.), this is more likely for sward growth with the associated greater climatic and competitive growth limitations. It may also be more prevelent in circumstances of slower growth over long periods, as here in the spring, when some shoots may have died from a basic aging process. The growth period through to the hay stage was 12 weeks compared to the 4 to 6 weeks in the summer. In this latter case with vigorous plants, the oldest shoot age would be considerably less at crop maturity with probably much less whole shoot senescence. Thus there may be an inverse relationship between the incidence of whole shoot senescence and crop growth rate. This senescence loss is a productive loss, but far less so physiologically because of the established fact of nutrient re-mobilisation from senescing to growing tissues (section 2.4.2.2.). In crop conditions, some of the importance of a greater proportion of early elongating shoots may be in providing light competition inhibiting the growth and establishment of the other species after defoliation.

Leaf senescence was extensive and also an important source of dry matter loss after the first 4 to 5 weeks of spring growth, although for lucerne crops this is an inherent unavoidable component of high top growth yields.

The aspect of organic reserves was discussed fully in chapter 7. The nature of the experiment did not enable these results to be used to describe the roles of organic reserves in regrowth. The recorded spring, post-defoliation and treatment responses largely agreed with previous reports (sections 2.2.2., 2.3.1.3.).

CHAPTER 11.

SUMMARY AND CONCLUSIONS

The production, botanical composition and persistence of two varieties of lucerne which were and had been previously defoliated at different defoliation frequencies were studied in the field. These were defoliating at shoot growth heights of 3", 9" and 15" and at a hay stage of growth. They were combined with measurements of the responses of single lucerne plants in the sward for which the 3" treatment was grown to the hay stage of growth. These were plant size, growth form, growth efficiency, and their organic reserve composition. Further, the nature of the lucerne plants regrowth in these sward conditions, the amount and nature of senescence and the lucerne canopies physiognomy and the related manner of light interception, were studied both individually and as they were affected by the defoliation treatments used. Varietal differences or similarities were compared at all levels.

The effect of spelling part of the 3" defoliation height treatments and frequently defoliating part of the hay stage treatments was each considered as it affected their respective recovery and loss of vigour.

Chapter 4.

1. Lucerne production decreased with increasing defoliation frequency, with a concommittant increase of volunteer species.

2. Early spring high levels of volunteer species caused total production to be similar between treatments

3. There was evidence that an earlier first spring defoliation (15" growth stage) may give greater lucerne yields and volunteer species control, providing seasonal temperatures and solar radiation levels have increased sufficiently.

4. Lucerne persistence decreased with increasing defoliation frequency in terms of reduced plant size, but with little difference for plant numbers.

Chapter 5.

1. Limitations of the effectiveness of the study resulted from the selection of treatments and the timing of sampling used.

2. Shoot growth and root plus crown and total weight per plant were significantly greater for the H treatments, compared to the 3R treatments.

3. Similar shoot number (greater than 1 cm.) per plant differences were measured, but with a highly significant varietal interaction. Wairau had a wide range; Chanticleer had a narrow range.

4. The distribution of dry matter between plant parts was proportionately similar for all treatments. Between varieties, Wairau tended to have larger crown and stubble dry weights.

5. Wairau peak shoot growth and shoot numbers per plant were related to the initial root plus crown size; Chanticleer had a poor shoot number relationship, and a proportionately greater shoot productivity as plant size increased (equivalent to decreasing defoliation frequency).

6. As defoliation frequency decreased, average shoot size was similar for Wairau, but increased for Chanticleer.

7. Mean plant size (root plus crown dry weight) and size range (variability) increased considerably with decreasing defoliation frequency. Wairau H treatment had the greatest values.

8. The previously frequently defoliated 3R treatments had a lower relative growth rate than the H treatments. The Chanticleer 9C and 15C treatments tended to be similar to the HC treatment.

9. Over all treatments there was a close relationship between total leaf and total shoot growth.

10. For Chanticleer, the importance of the number of shoots and when each starts elongating as determinants of total yield was confirmed. Shoots starting to elongate in the first 3-4 weeks (early spring) had similar shoot height growth rates.

11. Significant new basal shoot growth occurred in all mature treatments before flowering.

12. Shoot height estimation was not a good practical or physiological criterion of stage of growth.

13. For this spring growth, new basal shoot appearance was a preferable criterion for efficient hay stage defoliation.

Chapter 6.

1. Considerable leaf senescence occurred in treatments grown to maturity.

2. The evidence indicated that the rate of leaf senescence was increased and leaf longevity reduced with faster shoot height growth rates due to quicker shading by higher growth.

3. Whole shoot senescence was a major determinant of lucerne yield, and tended to be greater with higher shoot densities.

4. There were treatment differences of relative leaf area height distribution associated with varietal differences, crop age and other species content.

5. Light transmission patterns showed a relatively even decrease of light with canopy depth in the immature growth measured. Light transmission patterns and leaf area distribution tended to be related in Chanticleer, but less so for Wairau.

Chapter 7.

1. Total non-structural carbohydrates (TNC) and total nitrogen (TN) percentages decreased with increasing defoliation. A constancy of TNC/TN ratios between treatments suggested that both factors were proportionately equally affected.

2. With similar growth conditions, previously frequently defoliated plants (3R) appeared to maintain lower TN% levels during growth compared to the previously infrequently defoliated plants.

3. Roots had greater TNC% and concentration fluctuations than crowns during growth. In contrast, crowns had greater TN% than roots, with this difference being greater for the 3R treatment plants.

4. During the spring growth, TNC% followed the typical cyclic pattern. TN% decreased steadily, only increasing during mature growth.

5. During the winter, TNC% decreased while TN% increased.

6. TNC% at defoliation appeared to be largely determined by the length of the growth period and hence energy availability rather than the previous defoliation treatment. TN%'s were less readily changed by changes of defoliation frequency.

7. Between treatments, root and crown dry weights, were greater determinants of the respective treatment TNC and TN weights, than the TNC and TN concentrations.

8. Dark grown shoot growth was an indication of the carbohydrate reserve weights and regrowth potential on an area basis. Some limitations were discussed.

Chapter 8.

1. Shoot height growth rates of immature lucerne were correlated with spring temperatures.

Chapter 9.

The plants of the 3R treatment showed good recovery of growth vigour, but were productively restricted by their still small size and limited shoot numbers. TNC% were very high, while TN% had started to recover.

The plants of the HR treatment had reduced growth vigour, but less reduction of shoot numbers. TNC%'s were low (same as the 3" treatment) while TN%, although reduced were still reasonably high.

Hence, growth efficiency, plant size and plant morphology were modified. Differences of organic reserve levels were important aspects, particularly TNC concentrations.

Chapter 10.

1. Between varieties, Wairau had larger crown dry weights, greater shoot numbers and a greater plant size variability for the less frequently defoliated treatments. There were indications that Wairau was more persistent than Chanticleer.although plant number differences were variable.

2. The development of these varietal differences required an infrequent defoliation management.

3. The spring growth of Wairau had the greater stem/leaf ratios, contrary to most other reports for this lucerne type (more falcata)

4. In conclusion, reduced lucerne yield from increasing defoliation frequency was evidenced by reduced plant size, shoot numbers and with higher defoliation frequencees, reduced shoot growth efficiency. Plant numbers were less affected, while whole shoot senescence was an important shoot yield determinant during later growth.

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CHAPTER 13.

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A STUDY OF DIFFERENT FREQUENCIES OF DEFOLIATION ON THE RECOVERY GROWTH OF TWO VARIETIES OF LUCERNE (*Medicago sativa* L.)

VOLUME TWO

J. M. ABBOTT

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APPENDICES

APPENDIX 1A

A SUMMARY OF THE ORIGINAL EXPERIMENT

This experiment was sown down in November, 1965. Details of establishment were provided by Tsuma (1968). Other descriptive aspects have been presented with the experiment. Namely; the experimental site (section 3.3.), the experimental layout (Fig. 3.1.) (Section 3.2.), and four of the treatments (table 3.1.) (section 3.1.). The remaining three treatments were (1) continuous grazing

(2) only the first summer hay cut and then left uncut, and

(3) a treatment of no cutting.

In the spring of each year all treatments were spelled while two crops were taken, after which the respective treatments were applied through to the late autumn. The treatment period usually commenced in late December.

In the Spring of 1968 (the year preceding the thesis experiment), the then residual effects of the applied treatments were measured. Two single cut production harvests were made on the 9th of November and the 11th of December, the dry weight being determined. From a sub-sample botanical analysis, the productive dry weight of lucerne and other species were determined. These measurements and some later point analysis results obtained in late November, are presented for the four treatments of the thesis experiment. Statistical analysis is not included.

The first harvest had a relatively similar total yield for all treatments, but with lucerne yield increasing with decreasing defoliation frequency. Other species yield showed the reverse treatment order. (tables 1A.1, 1A.2, 1A.3).

In the second harvest, there was a more definite trend of increasing total yield with decreasing defoliation frequency. ANOVA of these and the other three treatments revealed significant differences ($P = 0.01$) while no significance was obtained in the first harvest (Robinson, 1969). The lucerne and other species showed the same treatment responses as in the first harvest, except that for all treatments there was approximately a ten-fold increase in the proportion of lucerne. There were no obvious varietal differences (tables 1A.4, 1A.5, 1A.6).

The point analysis results showed no real treatment or variety differences, and similarly for the amount of bare ground. The amount of total other species increased markedly with increasing defoliation frequency. This was distributed evenly between grass, clovers and other weeds. Varietal differences were not apparent.

First Production Cut - 9th November

Table 1A.1. Total Yield (lb/8 sq ft)

TREAT.	C	W	C + W
3"	0.983	1.036	1.009
9"	1.068	1.032	1.050
15"	1.100	1.082	1.092
H	1.120	1.148	1.134
AV	1.080	1.064	

Table 1A.2. Lucerne Yield (lb/8 sq ft)

TREAT.	C	W	C + W
3"	0.759	0.711	0.735
9"	0.915	0.754	0.834
15"	0.983	0.962	0.972
H	1.076	1.062	1.046
AV	0.950	0.878	

Table 1A.3. Other Species Yield (lb/8 sq ft)

TREAT.	C	W	C + W
3"	0.174	0.320	0.247
9"	0.153	0.278	0.216
15	0.117	0.120	0.119
H	0.035	0.132	0.083
AV	0.117	0.185	

Second Production Cut - 11th December

Table 1A.4. Total Yield (lb/78 sq ft)

TREAT.	C	W	C + W
3"	15.05	14.82	14.94
9"	16.98	15.77	16.38
15"	16.14	15.94	16.04
H	18.50	17.70	18.09
AV	16.73	16.02	

Table 1A.5. Lucerne Yield (lb/78 sq ft)

TREAT.	C	W	C + W
3"	14.67	14.26	14.46
9"	16.82	15.52	16.17
15"	15.94	15.66	15.80
H	18.55	17.58	18.03
AV	16.56	15.66	

Table 1A.6. Other Species Yield (lb/78 sq ft)

TREAT.	C	W	C + W
3"	0.37	0.57	0.47
9"	0.16	0.26	0.21
15"	0.19	0.28	0.24
H	0.03	0.12	0.07
AV	0.21	0.15	

Table 1A.7. Point Analysis Record**

a. Lucerne

TREAT	C	W	C + W
3"	34	39	36.5
9"	34	44	39.0
15"	41	51	46.0
H	47	36	41.5
AV	39.0	42.5	

b. Other Species

TREAT	C	W	C + W
3"	19	17	18.0
9"	5	10	7.5
15"	9	6	7.5
H	0	2	1.0
AV	8.2	8.7	

c. Bare Ground

TREAT	C	W	C + W
3"	91	88	89.5
9"	105	90	97.5
15"	94	87	90.5
H	97	106	101.5
AV	96.7	92.7	

d. Other Weeds*

TREAT	C	W	C + W
3"	5	2	3.5
9"	0	2	1.0
15"	1	1	1.0
H	0	1	0.5
AV	1.5	1.5	

e. Grass

TREAT	C	W	C + W
3"	7	7	7.0
9"	1	5	3.0
15"	4	2	3.0
H	0	1	0.5
AV	3.0	3.7	

f. Clover

TREAT	C	W	C + W
3"	6	8	7.0
9"	4	2	3.0
15"	4	3	3.5
H	0	0	0.0
AV	1.5	1.5	

* Othe Species less the grass and clovers.

**The values are the number of hits obtained in each category out of a total of 144 points measured per plot. The other species values are the sum of grass, clover and other weeds.

APPENDIX 2A

Data of the Climatic Parameters During the Experimental Period

Date - daily values.
Rad - radiation measured each day (Langleys/day).
Temp - mean temperature for each day (^{o}C) - (max + min/2).
Rain - rainfall for each day (points).
T - trace of rain.

Date	Rad	Temp	Rain	Date	Rad	Temp	Rain
7 Aug.	114	9.6	58	16 Sept.	289	13.6	10
8	106	8.7	08	17	368	11.4	T
9	92	10.8	47	18	367	10.8	-
10	181	8.8	04	19	357	9.8	-
11	253	6.9	-	20	373	9.8	04
12	133	9.8	05	21	231	11.8	T
13	148	11.6	04	22	411	11.9	-
14	178	12.2	06	23	467	11.7	-
15	103	11.5	06	24	396	12.5	08
16	129	13.0	T	25	257	13.6	03
17	101	11.0	01	26	213	14.4	-
18	249	11.5	-	27	369	12.8	-
19	244	10.5	-	28	390	11.0	-
20	198	10.7	-	29	337	11.5	-
21	97	8.8	06	30	276	11.5	-
22	205	5.8	01	1 Oct.	477	12.9	-
23	225	7.8	-	2	200	10.9	01
24	241	8.4	-	3	388	9.8	-
25	284	7.6	-	4	514	8.9	-
26	228	6.9	-	5	277	10.4	01
27	66	9.1	45	6	278	11.5	-
28	198	8.8	-	7	416	10.8	18
29	359	7.7	-	88	258	10.5	08
30	231	10.4	04	9	380	13.7	03
31	148	9.8	09	10	305	8.1	-
1 Sept.	191	12.1	T	11	375	5.2	-
2	265	11.2	-	12	402	7.4	-
3	187	10.2	-	13	527	10.1	-
4	168	12.4	01	14	526	11.5	T
5	218	12.4	01	15	243	12.9	02
6	363	13.3	-	16	285	12.4	19
7	339	13.1	-	17	114	12.4	45
8	345	12.9	-	18	417	12.6	-
9	295	13.3	-	19	541	11.4	-
10	95	15.1	32	20	456	12.2	-
11	125	15.5	10	21	451	12.2	01
12	419	13.8	-	22	228	13.6	-
13	125	12.8	53	23	441	12.4	06
14	397	10.7	01	24	516	13.6	-
15	265	9.9	06	25	412	14.1	-

Date	Rad	Temp	Rain	Date	Rad	Temp	Rain
26 Oct.	329	13.3	16	13 Nov.	510	17.8	-
27	163	12.4	26	14	494	16.6	-
28	502	8.1	T	15	484	16.3	-
29	448	12.2	-	16	638	17.1	-
30	416	11.9	-	17	517	15.1	-
31	393	11.8	03	18	608	17.1	-
1 Nov.	392	11.1	-	19	388	17.8	-
2	543	8.9	-	20	607	14.3	-
3	595	13.9	-	21	615	19.2	-
4	298	10.8	-	22	157	15.5	54
5	597	13.8	-	23	322	13.3	10
6	514	15.8	-	24	514	11.6	-
7	439	13.8	-	25	468	13.8	07
8	544	16.7	-	26	223	15.0	31
9	608	18.2	-	27	307	17.5	22
10	399	16.8	-	28	398	16.5	-
11	545	16.3	-	29	546	17.6	-
12	522	16.3	02	30	443	17.9	05

APPENDIX 3A

DATA

Most data was coded for identification using the following symbols.

V	Variety	1, Chanticleer 2; Wairau
T	Treatments	Identified with the table heading.
H	Harvest number	
R	Replication	
P	Plant number identification	

Table 3A.4.1. Crop production and its composition for each harvest. Lucerne crop growth rates. (gm/6 sq ft and gm/6 sq ft/day)

V	T	H	R	LUCERNE	OTHER SPECIES	TOTAL	PERCENT LUCERNE	CGR
1	1	1	1	12.20	59.29	71.49	17.06	.43
1	1	1	2	17.90	50.87	68.77	26.02	.63
1	1	1	3	36.54	52.32	88.86	41.12	1.30
1	1	2	1	11.36	28.24	39.60	28.68	.56
1	1	2	2	16.55	115.41	131.96	12.54	.82
1	1	2	3	30.26	83.63	113.89	26.56	1.51
1	1	3	1	2.42	46.59	49.01	4.93	.10
1	1	3	2	9.78	57.83	67.61	14.46	.42
1	1	3	3	16.13	58.22	74.35	21.69	.70
1	1	4	1	2.63	8.37	11.00	23.90	.21
1	1	4	2	0.00	18.62	18.62	0.00	0.00
1	1	4	3	4.55	76.57	81.12	5.60	.37
1	1	5	1	4.20	0.00	4.20	100.00	.35
1	1	5	2	0.00	12.80	12.80	0.00	0.00
1	1	5	3	2.30	23.02	25.32	9.08	.19
1	2	1	1	32.17	1.22	33.39	96.34	2.29
1	2	1	2	16.23	2.34	18.57	87.39	1.15
1	2	1	3	31.94	0.00	31.94	100.00	2.28
1	2	2	1	20.59	14.64	35.23	58.44	1.14
1	2	2	2	0.00	32.35	32.35	0.00	0.00
1	2	2	3	17.95	0.00	17.95	100.00	.99
1	2	3	1	11.17	58.73	69.90	15.97	.93
1	2	3	2	4.20	47.21	51.41	8.16	.35
1	2	3	3	39.12	47.55	86.67	45.13	3.26
1	2	4	1	8.38	24.75	33.13	25.29	.55
1	2	4	2	17.15	2.95	20.10	85.32	1.14
1	2	4	3	32.47	0.00	32.47	100.00	2.16
1	2	5	1	7.87	26.77	34.64	22.71	.52
1	2	5	2	19.82	17.85	37.67	52.61	1.32
1	2	5	3	2.58	37.74	40.32	6.39	.17
1	2	6	1	3.94	15.79	19.73	19.96	.43
1	2	6	2	1.81	9.59	11.40	15.87	.20
1	2	6	3	16.93	2.10	19.03	88.96	1.88

V Variety 1, Chanticleer 2, Wairau

T Treatment
1, 3" 2, HR
3, 9" 4, 15"
5, 3R 6, H

H Harvest

R Replication
1, 2, 3.

/3A.4.1.

Table 3A.4.1. cont.

V	T	H	R	LUCERNE	OTHER SPECIES	TOTAL	PERCENT LUCERNE	CGR
1	2	7	1	11.60	7.30	18.90	61.37	.96
1	2	7	2	15.97	0.00	15.97	100.00	1.33
1	2	7	3	5.68	8.42	14.10	40.28	.47
1	3	1	1	89.31	58.24	147.55	60.52	2.35
1	3	1	2	110.75	34.84	145.59	76.06	2.91
1	3	1	3	32.39	16.95	49.34	65.64	.85
1	3	2	1	91.26	20.95	112.21	81.32	2.34
1	3	2	2	38.15	45.12	83.27	45.81	.97
1	3	2	3	64.64	33.97	98.61	65.55	1.65
1	3	3	1	22.75	24.39	47.14	48.26	1.19
1	3	3	2	26.99	13.17	40.16	67.20	1.42
1	3	3	3	19.77	11.51	31.28	63.20	1.04
1	4	1	1	67.22	59.44	126.66	53.07	1.26
1	4	1	2	57.38	76.39	133.77	42.89	1.08
1	4	1	3	87.42	66.10	153.52	56.94	1.54
1	4	2	1	159.02	25.62	184.64	86.12	3.69
1	4	2	2	175.42	0.00	175.42	100.00	4.08
1	4	2	3	97.38	0.00	97.38	100.00	2.26
1	5	1	1	90.47	191.29	281.76	32.10	.95
1	5	1	2	.94	365.49	366.43	.25	.01
1	5	1	3	58.23	194.76	252.99	23.01	.61
1	6	1	1	122.57	16.78	139.35	87.95	1.36
1	6	1	2	269.31	0.00	269.31	100.00	2.99
1	6	1	3	197.62	44.46	242.08	81.63	2.19
2	1	1	1	17.58	78.30	95.88	18.33	.54
2	1	1	2	18.95	68.66	87.61	21.62	.59
2	1	1	3	46.77	42.99	89.76	52.10	1.46
2	1	2	1	15.35	81.36	96.71	15.87	.64
2	1	2	2	17.49	81.35	98.84	17.69	.72
2	1	2	3	42.32	53.87	96.19	43.99	1.76
2	1	3	1	16.32	22.09	38.41	42.48	.77
2	1	3	2	20.33	0.00	20.33	100.00	.96
2	1	3	3	4.24	67.32	71.56	5.92	.20
2	1	4	1	6.43	24.70	31.13	20.65	.35
2	1	4	2	23.05	37.04	60.09	38.35	1.28
2	1	4	3	16.86	21.19	38.05	44.31	.93

/3A.4.1.

Table 3A.4.1. cont.

V	T	H	R	LUCERNE	OTHER SPECIES	TOTAL	PERCENT LUCERNE	CGR
2	2	1	1	24.58	12.47	37.05	66.34	.94
2	2	1	2	80.00	35.12	115.12	69.49	3.07
2	2	1	3	64.19	21.41	85.60	74.98	2.46
2	2	2	1	33.09	5.90	38.99	84.86	2.36
2	2	2	2	41.11	0.00	41.11	100.00	2.93
2	2	2	3	49.53	0.00	49.53	100.00	3.53
2	2	3	1	13.55	17.91	31.46	43.07	.84
2	2	3	2	33.59	36.28	69.87	48.07	2.09
2	2	3	3	40.79	18.61	59.40	68.67	2.54
2	2	4	1	26.22	10.04	36.26	72.31	1.45
2	2	4	2	35.07	43.24	78.31	44.78	1.94
2	2	4	3	24.10	12.54	36.64	65.77	1.33
2	2	5	1	16.74	24.13	40.87	40.95	.51
2	2	5	2	34.46	33.06	67.52	51.03	1.05
2	2	5	3	24.16	14.87	39.03	61.90	.73
2	3	1	1	80.21	73.09	153.30	52.32	1.82
2	3	1	2	39.40	98.57	137.97	28.55	.89
2	3	1	3	93.33	19.05	112.38	83.04	2.12
2	3	2	1	51.04	14.66	65.70	77.68	1.30
2	3	2	2	66.49	95.34	161.83	41.08	1.70
2	3	2	3	58.33	99.22	157.55	37.02	1.49
2	3	3	1	3.25	14.25	17.50	18.57	.25
2	3	3	2	19.69	.73	20.42	96.42	1.51
2	3	3	3	24.52	0.00	24.52	100.00	1.88
2	4	1	1	174.93	56.34	231.27	75.63	2.96
2	4	1	2	126.10	50.08	176.18	71.57	2.13
2	4	1	3	115.46	104.47	219.93	52.49	1.95
2	4	2	1	160.59	0.00	160.59	100.00	4.34
2	4	2	2	145.86	0.00	145.86	100.00	3.94
2	4	2	3	136.45	11.83	148.28	92.02	3.68
2	5	1	1	22.66	216.42	239.08	9.47	.23
2	5	1	2	106.22	147.47	253.69	41.86	1.10
2	5	1	3	64.84	71.00	135.84	47.73	.67
2	6	1	1	154.23	33.44	187.67	82.18	1.67
2	6	1	2	166.50	40.40	206.90	80.47	1.81
2	6	1	3	218.86	87.96	306.82	71.33	2.37

Table 3A.4.2. Crop production and its composition summated over harvests for each treatment/variety combination. (gm/6 sq ft)
Abreviations as for table 3A.4.1.

V	T	R	LUCERNE	OTHER SPECIES	TOTAL	PERCENT LUCERNE
1	1	1	32.81	142.49	175.30	18.70
1	1	2	44.23	255.53	299.76	14.75
1	1	3	89.78	293.76	383.54	23.40
1	2	1	95.72	149.20	244.92	39.05
1	2	2	75.18	112.29	187.47	40.70
1	2	3	146.67	95.81	242.48	60.45
1	3	1	203.32	103.58	306.90	66.20
1	3	2	175.89	93.13	269.02	65.40
1	3	3	116.80	62.43	179.23	65.05
1	4	1	226.24	85.06	311.30	72.85
1	4	2	232.80	76.39	309.19	75.05
1	4	3	184.80	66.10	250.90	55.50
1	5	1	90.47	191.29	281.76	32.10
1	5	2	.94	365.49	366.43	.25
1	5	3	58.23	194.76	252.99	23.01
1	6	1	122.57	16.78	139.35	87.95
1	6	2	269.31	0.00	269.31	100.00
1	6	3	197.62	44.46	242.08	81.63
2	1	1	55.68	206.45	262.13	21.20
2	1	2	79.82	187.05	266.87	29.90
2	1	3	110.19	185.37	295.56	37.35
2	2	1	114.18	70.45	184.63	62.00
2	2	2	224.23	147.70	371.93	60.04
2	2	3	202.77	67.43	270.20	75.00
2	3	1	134.50	102.00	236.50	56.90
2	3	2	125.58	194.64	320.22	39.10
2	3	3	176.18	118.27	294.45	59.80
2	4	1	335.52	56.34	391.86	85.70
2	4	2	271.96	50.08	322.04	84.50
2	4	3	251.91	116.30	368.21	68.45
2	5	1	22.66	216.42	239.08	9.47
2	5	2	106.22	147.47	253.69	41.86
2	5	3	64.84	71.00	135.84	47.73
2	6	1	154.23	33.44	187.67	82.18
2	6	2	166.50	40.40	206.90	80.47
2	6	3	218.86	87.96	306.82	71.29

Table 3A.4.3. Point analysis data records, percent lucerne and plant number counts (No./1 sq foot)

V	T	R	LUCERNE	BARE GROUND	WEED	CLOVER	GRASS	OTHER SPECIES	PERCENT LUCERNE	PLANT" NUMBER
1	1	1	7	10	13	6	23	42	11.66	3.16
1	1	2	3	15	8	6	28	42	5.00	10.60
1	1	3	9	9	21	16	5	42	15.00	7.30
1	2	1	8	20	15	4	13	32	13.33	10.60
1	2	2	10	12	9	1	28	38	16.67	10.83
1	2	3	10	15	29	0	6	35	16.67	8.00
1	3	1	8	14	13	10	15	38	13.33	9.15
1	3	2	16	12	24	2	5	31	26.67	8.60
1	3	3	10	14	25	1	10	36	16.67	9.60
1	4	1	15	29	13	1	2	16	25.00	11.16
1	4	2	19	21	20	0	0	20	31.67	10.00
1	4	3	14	35	11	0	0	11	23.33	9.00
2	1	1	7	12	12	6	22	40	11.66	12.83
2	1	2	3	12	19	2	24	45	5.00	13.16
2	1	3	11	5	17	3	24	44	18.33	16.60
2	2	1	9	15	18	2	15	35	15.00	12.15
2	2	2	11	8	9	11	21	41	18.33	13.33
2	2	3	19	14	7	6	14	27	31.67	15.30
2	3	1	15	17	12	3	13	28	25.00	10.00
2	3	2	26	7	12	0	15	27	43.33	9.60
2	3	3	21	6	24	2	7	33	35.00	12.00
2	4	1	21	15	24	0	1	25	35.00	8.16
2	4	2	23	17	20	0	0	20	38.33	7.60
2	4	3	24	14	19	0	2	21	40.00	9.60

" The mean of six samples per plot.

Table 3A.5.1. The dry weight of plant parts (gm/plant) and shoot numbers per plant for each plant sampled at selected growth stages.

V Variety; 1, Ghanticleer 2, Wairau
T Treatment; 1, 3R 2, 9" 3, 15" 4, H
H Harvests; 1, RD 2, 3" 3, 9" 4, 15" 5, H 6, 15/H
R Replications 1, 2, 3.
P Plant number 1 to 6
RTCR Root plus crown

V	T	H	R	P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
1	1	1	1	1	.07	.23	.23	5.70	1.61	3.63	5.24	10.00
1	1	1	1	2	.10	.30	.35	2.10	.39	1.06	1.45	8.00
1	1	1	1	3	.21	.65	.30	6.28	2.01	3.32	5.33	17.00
1	1	1	1	4	.34	1.41	.53	4.74	.69	2.10	2.79	46.40
1	1	1	1	5	.15	.79	.17	3.15	.53	1.66	2.19	17.00
1	1	1	1	6	.08	.25	.11	1.65	.35	.94	1.29	8.00
1	1	1	2	1	.10	.49	.07	4.74	1.13	3.05	4.18	12.00
1	1	1	2	2	.01	.06	.01	.88	.26	.55	.81	3.00
1	1	1	2	3	.03	.12	.13	3.60	1.99	1.36	3.35	3.00
1	1	1	2	4	.05	.32	.08	3.95	1.51	2.04	3.55	17.00
1	1	1	2	5	.20	1.24	.83	7.00	2.47	2.45	4.92	46.80
1	1	1	2	6	.10	.40	.24	6.33	2.38	3.30	5.68	13.50

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
1 1 1 3 1	.11	.32	.31	6.69	2.22	3.84	6.06	13.00
1 1 1 3 2	.18	.73	.24	2.73	.54	1.21	1.75	18.20
1 1 1 3 3	.01	.03	.06	1.00	.44	.47	.91	2.00
1 1 1 3 4	.07	.19	.10	2.59	.64	1.66	2.30	4.00
1 1 1 3 5	.04	.18	.13	1.72	.15	1.26	1.41	6.00
1 1 1 3 6	.13	.58	.28	3.39	.79	1.74	2.53	12.00
1 1 2 1 1	.22	.58	.14	1.89	.34	.83	1.17	5.00
1 1 2 1 2	.41	1.12	.24	5.83	1.59	2.88	4.47	6.00
1 1 2 1 3	.42	1.21	.32	4.44	1.28	1.63	2.91	7.00
1 1 2 1 4	.66	1.57	.78	6.43	1.20	2.88	4.08	27.00
1 1 2 1 5	.27	.78	.17	3.51	.84	1.72	2.56	6.00
1 1 2 1 6	.08	.23	0.00	1.21	.36	.62	.98	2.00
1 1 2 2 1	.57	2.16	.69	9.28	2.59	3.84	6.43	33.30
1 1 2 2 2	.28	.84	.25	5.03	1.45	2.49	3.94	8.00
1 1 2 2 3	.48	1.46	.39	6.35	1.28	3.21	4.49	15.50
1 1 2 2 4	.26	.64	.07	1.52	.29	.48	.77	7.00
1 1 2 2 5	.03	.10	.12	1.34	.39	.73	1.12	2.00
1 1 2 2 6	.05	.15	.07	.99	.29	.48	.77	2.00
1 1 2 3 1	.55	1.66	.75	7.04	1.86	2.77	4.63	14.00
1 1 2 3 2	.29	.82	.17	5.09	1.45	2.65	4.10	9.00
1 1 2 3 3	.61	1.83	.14	4.09	.61	1.51	2.12	16.00
1 1 2 3 4	.17	.77	.27	5.16	1.45	2.67	4.12	12.00
1 1 2 3 5	.21	.67	.18	6.75	2.50	3.40	5.90	5.00
1 1 2 3 6	.34	1.23	.30	4.27	.75	1.99	2.74	8.00
1 1 3 1 1	.13	.29	.02	1.15	.24	.60	.84	1.00
1 1 3 1 2	.28	.74	.07	2.32	.52	.99	1.51	3.00
1 1 3 1 3	1.00	2.60	.13	4.43	.57	1.13	1.70	8.00
1 1 3 1 4	.35	.87	.05	2.88	.73	1.23	1.96	3.00
1 1 3 1 5	.14	.33	.20	2.99	1.24	1.22	2.46	2.00
1 1 3 1 6	.30	.83	.08	2.25	.39	.95	1.34	3.00
1 1 3 2 1	2.50	6.76	.55	16.60	3.34	5.95	9.29	13.80
1 1 3 2 2	.07	.21	.02	1.40	.20	.97	1.17	1.00
1 1 3 2 3	1.19	3.22	.35	9.56	2.31	3.68	5.99	6.00
1 1 3 2 4	.45	1.13	.09	2.77	.56	.99	1.55	4.00
1 1 3 2 5	.40	1.06	.11	3.03	.64	1.22	1.86	5.00
1 1 3 2 6	.10	.28	0.00	1.75	.41	1.06	1.47	1.00
1 1 3 3 1	.23	.54	.12	2.60	.59	1.35	1.94	1.00
1 1 3 3 2	1.63	3.84	.33	10.47	2.12	4.18	6.30	10.00
1 1 3 3 3	.79	2.22	.12	5.16	.94	1.88	2.82	10.00
1 1 3 3 4	.26	.87	.31	3.73	.86	1.69	2.55	4.00
1 1 3 3 5	.41	1.20	.03	3.60	.41	1.96	2.37	5.00
1 1 3 3 6	.18	.50	.08	1.92	.35	.99	1.34	3.00

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
1 1 4 1 1	.28	.71	.15	2.64	.65	1.13	1.78	2.00
1 1 4 1 2	.09	.23	0.00	1.54	.23	1.08	1.31	1.00
1 1 4 1 3	.58	1.72	0.00	4.13	.68	1.73	2.41	3.00
1 1 4 1 4	.50	1.28	.17	4.97	.85	2.67	3.52	2.00
1 1 4 1 5	.25	.64	.09	1.64	.22	.69	.91	2.00
1 1 4 1 6	.07	.19	.05	1.60	.57	.79	1.36	1.00
1 1 4 2 1	.43	1.28	.18	5.04	1.32	2.26	3.58	7.00
1 1 4 2 2	.26	.71	.16	4.79	1.44	2.48	3.92	4.00
1 1 4 2 3	.56	1.36	.04	2.11	.19	.52	.71	3.00
1 1 4 2 4	.93	2.55	.23	6.41	.75	2.88	3.63	4.00
1 1 4 2 5	.90	2.11	.20	6.65	1.22	3.12	4.34	3.00
1 1 4 2 6	.41	1.33	.42	3.13	.49	.89	1.38	3.00
1 1 4 3 1	.86	2.54	.32	8.60	2.04	3.70	5.74	8.00
1 1 4 3 2	2.66	6.89	.12	13.52	1.46	5.05	6.51	12.00
1 1 4 3 3	.76	1.98	.08	4.26	.56	1.64	2.20	2.00
1 1 4 3 4	1.94	5.93	.19	11.80	2.44	3.24	5.68	11.00
1 1 4 3 5	.21	.88	.09	3.12	.66	1.49	2.15	3.00
1 1 4 3 6	.59	1.98	.09	6.97	1.64	3.26	4.90	5.00
1 1 5 1 1	.55	1.95	.41	8.33	1.95	4.02	5.97	2.00
1 1 5 1 2	1.20	4.72	.03	7.93	.63	2.52	3.15	2.00
1 1 5 1 3	.47	1.25	.25	4.38	.89	1.99	2.88	2.00
1 1 5 1 4	.70	2.68	.04	7.50	1.43	3.35	4.78	3.00
1 1 5 1 5	.47	1.87	0.00	5.68	.91	2.90	3.81	3.00
1 1 5 1 6	.45	1.90	.07	5.02	.50	2.55	3.05	2.00
1 1 5 2 1	1.29	3.85	.20	7.49	.65	2.79	3.44	3.00
1 1 5 2 2	.25	1.06	.17	4.08	.83	2.02	2.85	3.00
1 1 5 2 3	.29	4.07	1.03	11.56	2.14	4.32	6.46	5.00
1 1 5 2 4	.26	1.29	.42	5.65	1.02	2.92	3.94	2.00
1 1 5 2 5	.14	.41	.12	2.27	.67	1.07	1.74	1.00
1 1 5 2 6	.06	.31	.04	1.73	.42	.94	1.36	1.00
1 1 5 3 1	2.71	13.05	.24	22.24	1.98	6.97	8.95	6.40
1 1 5 3 2	1.33	6.59	.46	19.78	4.13	8.60	12.73	5.00
1 1 5 3 3	1.48	6.76	.42	14.96	1.43	6.35	7.78	5.00
1 1 5 3 4	1.21	7.03	.30	15.22	2.44	5.55	7.99	4.00
1 1 5 3 5	.56	1.49	.07	5.37	.55	3.25	3.80	2.00
1 1 5 3 6	.43	1.24	.11	3.82	.71	1.76	2.47	1.00
1 2 1 1 1	.05	.33	1.16	6.63	1.22	3.92	5.14	10.00
1 2 1 1 2	.42	.99	.93	8.46	2.40	4.14	6.54	19.00
1 2 1 1 3	.05	.14	.09	4.14	1.49	2.42	3.91	4.00
1 2 1 1 4	.15	.47	.20	2.55	.58	1.30	1.88	12.00
1 2 1 1 5	.14	.55	.18	5.11	1.16	3.22	4.38	13.00
1 2 1 1 6	.24	.44	1.20	9.72	2.77	5.31	8.08	14.20
1 2 1 2 1	.15	.52	.35	4.14	1.28	1.99	3.27	11.00
1 2 1 2 2	.22	.65	.16	3.25	.70	1.74	2.44	8.00
1 2 1 2 3	.06	.34	.34	3.58	.96	1.94	2.90	6.00
1 2 1 2 4	.09	.59	.17	3.14	.75	1.63	2.38	12.00
1 2 1 2 5	.18	.50	.12	1.82	.36	.84	1.20	5.00
1 2 1 2 6	.08	.31	.05	1.37	.29	.72	1.01	6.00

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
1 2 1 3 1	.18	.54	.41	4.56	1.19	2.42	3.61	12.20
1 2 1 3 2	.09	.29	.46	3.94	.72	2.47	3.19	7.00
1 2 1 3 3	.20	.51	.96	8.19	2.84	3.86	6.70	20.70
1 2 1 3 4	.39	1.15	.21	3.55	.68	1.51	2.19	21.00
1 2 1 3 5	.43	.94	.36	5.92	1.59	3.03	4.62	21.00
1 2 1 3 6	.19	.57	.13	2.31	.49	1.12	1.61	18.00
1 2 2 1 1	1.44	4.41	.50	10.57	2.89	2.76	5.65	31.70
1 2 2 1 2	.39	1.08	.10	4.16	.43	2.55	2.98	7.00
1 2 2 1 3	1.24	3.48	1.23	16.25	4.85	6.68	11.53	48.50
1 2 2 1 4	.43	1.11	.38	4.93	1.13	2.31	3.44	16.00
1 2 2 1 5	1.86	5.08	.61	11.30	1.34	4.26	5.60	48.40
1 2 2 1 6	.58	1.65	.21	3.67	.72	1.09	1.81	13.00
1 2 2 2 1	.43	1.67	.72	9.59	2.89	4.30	7.19	17.40
1 2 2 2 2	.26	.74	.16	4.65	.83	2.91	3.74	6.60
1 2 2 2 3	.77	2.42	.89	8.21	1.24	3.65	4.89	37.10
1 2 2 2 4	.20	.63	.20	3.14	.78	1.53	2.31	6.00
1 2 2 2 5	.05	.15	.06	1.29	.36	.72	1.08	2.00
1 2 2 2 6	.06	.19	.25	3.02	.86	1.72	2.58	6.00
1 2 2 3 1	.42	1.27	.16	2.99	.48	1.07	1.55	12.70
1 2 2 3 2	.19	.56	.10	1.96	.25	1.05	1.30	8.00
1 2 2 3 3	.88	2.19	.27	5.62	.88	2.27	3.15	15.10
1 2 2 3 4	.63	1.43	1.68	7.19	1.52	2.55	4.07	20.50
1 2 2 3 5	.23	.65	.27	5.52	.47	4.13	4.60	6.00
1 2 2 3 6	.27	.75	.20	3.68	.73	2.00	2.73	9.00
1 2 3 1 1	.46	1.26	.83	9.10	2.08	4.93	7.01	6.00
1 2 3 1 2	.37	.92	.13	2.84	.51	1.28	1.79	8.00
1 2 3 1 3	.37	1.01	.16	3.85	.57	2.11	2.68	6.00
1 2 3 1 4	1.23	3.02	.73	7.07	1.33	1.99	3.32	16.60
1 2 3 1 5	.40	1.18	.24	3.60	.64	1.54	2.18	10.00
1 2 3 1 6	.38	1.02	.22	2.33	.28	.81	1.09	4.00
1 2 3 2 1	2.97	8.00	1.96	26.30	7.91	8.43	16.34	68.50
1 2 3 2 2	.77	1.90	.39	7.43	2.13	3.01	5.14	10.00
1 2 3 2 3	.62	1.79	.10	3.41	.39	1.13	1.52	6.00
1 2 3 2 4	.34	1.00	.08	3.38	.52	1.78	2.30	4.00
1 2 3 2 5	.27	.69	.18	4.19	1.03	2.29	3.32	5.00
1 2 3 2 6	.35	.78	.35	4.28	1.36	1.79	3.15	9.00
1 2 3 3 1	.21	.53	.07	1.24	.17	.47	.64	2.00
1 2 3 3 2	2.09	5.15	1.07	14.67	3.41	5.03	8.44	22.00
1 2 3 3 3	.81	2.09	.28	5.90	1.06	2.47	3.53	10.00
1 2 3 3 4	.31	.79	.19	2.44	.48	.98	1.46	9.00
1 2 3 3 5	.14	.34	.06	2.62	.24	1.98	2.22	2.00
1 2 3 3 6	.61	1.40	.10	5.18	.75	2.93	3.68	4.00
1 3 1 1 1	.11	.38	.10	2.51	.52	1.51	2.03	4.00
1 3 1 1 2	.10	.46	.21	4.46	.86	2.93	3.79	11.00
1 3 1 1 3	.10	.46	.26	4.33	1.50	2.11	3.61	17.00
1 3 1 1 4	.02	.09	.20	1.74	.37	1.08	1.45	4.00
1 3 1 1 5	.08	.35	0.00	2.20	.48	1.37	1.85	9.00
1 3 1 1 6	.02	.18	.08	1.45	.36	.83	1.19	5.00

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
1 3 1 2 1	.33	1.17	.70	9.46	2.09	5.50	7.59	24.00
1 3 1 2 2	.17	.43	.35	3.20	.77	1.65	2.42	8.00
1 3 1 2 3	.15	.69	.16	4.73	.87	3.01	3.88	5.00
1 3 1 2 4	.29	1.72	.34	3.91	.55	1.30	1.85	8.00
1 3 1 2 5	.32	1.03	.10	4.89	1.30	2.46	3.76	20.10
1 3 1 2 6	.17	.64	.74	7.51	1.76	4.37	6.13	13.00
1 3 1 3 1	.22	.74	.11	2.81	.76	1.20	1.96	17.00
1 3 1 3 2	.04	.12	.10	3.50	.84	2.44	3.28	3.00
1 3 1 3 3	.11	.45	.18	3.76	.92	2.21	3.13	15.00
1 3 1 3 4	.14	.58	.11	5.55	.85	4.01	4.86	17.00
1 3 1 3 5	.02	.13	.11	1.32	.39	.69	1.08	3.00
1 3 1 3 6	.14	.62	.25	3.31	.76	1.68	2.44	15.00
1 3 2 1 1	.19	.52	.21	3.52	.68	2.11	2.79	9.00
1 3 2 1 2	1.06	3.46	.77	10.62	2.75	3.63	6.38	21.60
1 3 2 1 3	.15	.54	.16	2.54	.66	1.18	1.84	5.00
1 3 2 1 4	.61	1.61	.30	4.18	.82	1.45	2.27	26.00
1 3 2 1 5	.23	.85	.59	6.21	1.65	3.12	4.77	8.00
1 3 2 1 6	.20	.73	.33	3.69	.78	1.85	2.63	13.00
1 3 2 2 1	.47	1.41	.76	8.07	2.02	3.88	5.90	23.50
1 3 2 2 2	.20	.53	.20	4.47	.94	2.80	3.74	5.00
1 3 2 2 3	.30	.92	.23	3.78	.88	1.75	2.63	9.00
1 3 2 2 4	1.23	3.39	.56	10.09	1.66	4.48	6.14	37.40
1 3 2 2 5	.26	.69	.40	4.41	1.22	2.10	3.32	7.00
1 3 2 2 6	.49	1.39	.43	6.17	1.35	3.00	4.35	16.40
1 3 2 3 1	.35	1.14	.54	5.65	1.81	2.16	3.97	16.00
1 3 2 3 2	.32	1.16	.42	5.23	2.33	1.32	3.65	14.00
1 3 2 3 3	.42	1.56	.76	9.00	2.73	3.95	6.68	33.20
1 3 2 3 4	.46	1.77	.13	5.35	1.22	2.23	3.45	19.00
1 3 2 3 5	.34	1.18	.41	5.62	1.76	2.26	4.02	17.50
1 3 2 3 6	.19	.46	.17	2.81	.56	1.62	2.18	10.00
1 3 3 1 1	.85	2.11	.28	6.18	1.53	2.26	3.79	11.00
1 3 3 1 2	.66	1.89	.85	5.99	1.02	2.23	3.25	11.00
1 3 3 1 3	.98	2.12	.25	5.66	.98	2.31	3.29	14.00
1 3 3 1 4	2.67	7.96	.40	15.45	1.23	5.86	7.09	30.10
1 3 3 1 5	.74	1.79	.78	12.70	2.43	7.69	10.12	14.90
1 3 3 1 6	.91	2.32	.35	6.13	.98	2.48	3.46	8.10
1 3 3 2 1	.11	.28	.23	7.28	1.71	5.06	6.77	3.00
1 3 3 2 2	.46	1.36	.08	3.04	.55	1.05	1.60	9.00
1 3 3 2 3	.86	2.23	.33	5.43	.52	2.35	2.87	10.00
1 3 3 2 4	.75	1.84	.33	5.22	1.05	2.00	3.05	6.00
1 3 3 2 5	.31	.76	.10	2.17	.23	1.08	1.31	6.00
1 3 3 2 6	.59	1.44	.44	4.91	.97	2.06	3.03	13.00
1 3 3 3 1	.55	1.60	.19	7.29	1.24	4.26	5.50	9.00
1 3 3 3 2	.97	2.68	.64	11.87	2.75	5.80	8.55	8.00
1 3 3 3 3	.09	.20	0.00	1.67	.27	1.20	1.47	1.00
1 3 3 3 4	.22	.48	.71	8.72	2.91	4.62	7.53	11.00
1 3 3 3 5	.99	2.52	.46	10.28	2.36	4.94	7.30	20.00
1 3 3 3 6	.41	1.46	.62	7.09	1.43	3.58	5.01	10.00

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
1 3 4 1 1	1.06	3.03	.07	6.78	.74	2.94	3.68	3.00
1 3 4 1 2	3.27	8.61	.32	17.91	3.19	5.78	8.97	13.90
1 3 4 1 3	1.40	4.28	.23	9.15	1.40	3.24	4.64	16.00
1 3 4 1 4	.42	1.73	.05	3.41	.42	1.21	1.63	5.00
1 3 4 1 5	.15	.52	.04	1.27	.19	.52	.71	2.00
1 3 4 1 6	.12	.36	.10	2.08	.47	1.15	1.62	2.00
1 3 4 2 1	.21	.67	.17	3.49	1.02	1.63	2.65	2.00
1 3 4 2 2	.81	2.26	.22	6.32	1.57	2.27	3.84	3.00
1 3 4 2 3	.24	.94	.50	4.68	1.08	2.16	3.24	3.00
1 3 4 2 4	1.45	4.39	.29	7.82	.99	2.15	3.14	8.00
1 3 4 2 5	.67	2.10	.22	5.83	1.25	2.26	3.51	3.00
1 3 4 2 6	.60	1.77	.40	6.18	.96	3.05	4.01	2.00
1 3 4 3 1	.63	2.26	.44	16.73	3.42	10.61	14.03	9.00
1 3 4 3 2	4.88	13.06	.71	21.52	3.04	4.71	7.75	13.30
1 3 4 3 3	.58	1.44	.26	5.67	.50	3.47	3.97	1.00
1 3 4 3 4	2.34	8.68	.64	16.62	1.70	5.60	7.30	23.10
1 3 4 3 5	2.36	6.89	.49	13.99	1.92	4.69	6.61	9.00
1 3 4 3 6	1.12	3.28	.27	6.92	.89	2.48	3.37	6.00
1 4 1 1 1	.21	.92	.42	6.33	1.79	3.20	4.99	21.00
1 4 1 1 2	.28	1.08	1.51	12.55	5.68	4.27	9.95	38.60
1 4 1 1 3	.01	.07	.11	3.00	1.32	2.47	3.79	4.00
1 4 1 1 4	.06	.41	.96	8.43	3.28	3.78	7.06	10.00
1 4 1 1 5	.03	.09	.26	4.51	.81	3.35	4.16	1.00
1 4 1 1 6	.28	1.35	.59	9.22	2.30	4.98	7.28	24.00
1 4 1 2 1	.02	.07	.01	3.60	.44	3.08	3.52	3.00
1 4 1 2 2	.60	1.36	.50	9.77	3.15	4.75	7.90	22.20
1 4 1 2 3	.08	.21	1.00	9.45	2.93	5.31	8.24	5.00
1 4 1 2 4	.07	.38	.06	2.67	.39	1.84	2.23	6.00
1 4 1 2 5	.09	.30	.09	1.40	.20	.81	1.01	9.00
1 4 1 2 6	.54	3.15	2.60	20.88	2.68	12.44	15.12	35.30
1 4 1 3 1	.45	1.97	.65	8.47	1.99	3.86	5.85	9.00
1 4 1 3 2	.24	.61	.06	4.43	1.04	2.72	3.76	7.00
1 4 1 3 3	.42	1.22	.90	7.31	2.85	2.34	5.19	16.00
1 4 1 3 4	.96	3.63	1.03	15.13	3.05	7.41	10.46	50.50
1 4 1 3 5	.04	.25	.02	4.78	.40	4.11	4.51	6.00
1 4 1 3 6	.33	.79	.35	2.84	.42	1.28	1.70	10.00
1 4 2 1 1	.30	1.10	.31	4.62	1.75	1.46	3.21	15.00
1 4 2 1 2	.16	.44	.32	3.05	.60	1.69	2.29	11.00
1 4 2 1 3	.54	1.96	.68	14.86	5.93	6.29	12.22	32.10
1 4 2 1 4	.19	.69	.34	3.55	.67	1.85	2.52	5.00
1 4 2 1 5	.40	1.52	.37	7.45	2.48	3.08	5.56	15.00
1 4 2 1 6	.36	1.23	.43	6.67	2.14	2.87	5.01	16.00
1 4 2 2 1	.37	1.28	.45	6.55	1.77	3.05	4.82	16.20
1 4 2 2 2	.37	1.28	.45	6.55	1.77	3.05	4.82	16.20
1 4 2 2 3	.37	1.28	.45	6.55	1.77	3.05	4.82	16.20
1 4 2 2 4	.37	1.28	.45	6.55	1.77	3.05	4.82	16.20
1 4 2 2 5	.37	1.28	.45	6.55	1.77	3.05	4.82	16.20
1 4 2 2 6	.37	1.28	.45	6.55	1.77	3.05	4.82	16.20

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
1 4 2 3 1	.92	2.88	.45	5.30	.15	1.82	1.97	22.00
1 4 2 3 2	.10	.40	.09	4.02	1.18	2.35	3.53	5.00
1 4 2 3 3	.51	1.75	.74	9.71	2.60	4.62	7.22	25.00
1 4 2 3 4	.26	1.00	.22	5.57	1.22	3.13	4.35	11.00
1 4 2 3 5	.60	1.76	.84	9.69	2.35	4.74	7.09	25.00
1 4 2 3 6	.09	.55	.48	4.86	1.11	2.72	3.83	9.00
1 4 3 1 1	2.90	7.16	.67	16.71	3.46	5.42	8.88	29.20
1 4 3 1 2	1.50	4.18	.51	12.52	3.67	4.15	7.82	15.00
1 4 3 1 3	1.71	4.90	.60	9.61	1.67	2.44	4.11	13.00
1 4 3 1 4	.19	.45	.23	3.92	.80	2.44	3.24	5.00
1 4 3 1 5	.16	.38	.05	1.54	.37	.74	1.11	4.00
1 4 3 1 6	.23	.56	.02	1.43	.22	.63	.85	2.00
1 4 3 2 1	.73	1.76	.30	5.78	1.57	2.15	3.72	11.00
1 4 3 2 2	.88	2.32	.12	4.62	.58	1.60	2.18	14.00
1 4 3 2 3	1.14	2.85	1.03	8.84	1.45	3.51	4.96	14.00
1 4 3 2 4	.35	.93	.34	3.96	.84	1.85	2.69	6.00
1 4 3 2 5	.81	2.03	.13	3.87	.47	1.24	1.71	17.00
1 4 3 2 6	.48	1.17	.08	2.96	.44	1.27	1.71	13.00
1 4 3 3 1	1.70	3.84	.40	10.32	2.17	3.90	6.07	23.40
1 4 3 3 2	1.04	2.46	.38	6.75	1.30	2.61	3.91	15.50
1 4 3 3 3	.65	2.15	.34	5.58	1.27	1.82	3.09	19.00
1 4 3 3 4	.65	1.95	.29	6.36	.70	3.42	4.12	10.00
1 4 3 3 5	.93	2.30	.47	8.50	2.27	3.46	5.73	14.00
1 4 3 3 6	2.39	4.50	.73	12.53	1.97	5.33	7.30	19.00
1 4 4 1 1	2.62	7.98	.72	14.98	3.09	3.19	6.28	14.10
1 4 4 1 2	.84	1.37	.06	3.32	.58	1.31	1.89	2.00
1 4 4 1 3	1.64	4.48	.38	8.06	1.36	1.84	3.20	10.00
1 4 4 1 4	.71	1.83	.34	5.54	1.22	2.15	3.37	5.00
1 4 4 1 5	.42	1.37	.15	4.16	.79	1.85	2.64	5.00
1 4 4 1 6	.71	1.83	.34	5.54	1.22	2.15	3.37	7.00
1 4 4 2 1	.52	1.99	.43	5.65	1.11	2.12	3.23	15.00
1 4 4 2 2	.81	2.40	.27	6.11	1.35	2.09	3.44	6.00
1 4 4 2 3	.67	1.97	.45	5.65	1.08	2.15	3.23	6.00
1 4 4 2 4	1.68	5.27	.28	9.86	.98	3.33	4.31	9.00
1 4 4 2 5	.29	.98	.16	2.98	.43	1.41	1.84	4.00
1 4 4 2 6	.33	.90	.09	2.22	.39	.84	1.23	2.00
1 4 4 3 1	1.46	4.04	.53	17.06	5.37	7.12	12.49	7.00
1 4 4 3 2	2.48	7.31	1.31	24.10	7.18	8.30	15.48	21.00
1 4 4 3 3	2.45	7.34	.67	17.05	2.86	6.17	9.03	12.50
1 4 4 3 4	1.22	3.58	.45	8.77	1.31	3.43	4.74	5.00
1 4 4 3 5	1.40	3.97	.61	9.29	1.91	2.80	4.71	14.00
1 4 4 3 6	1.08	3.27	.87	9.33	1.51	3.68	5.19	11.60
1 4 5 1 1	1.18	8.93	1.01	28.62	6.14	12.54	18.68	8.00
1 4 5 1 2	3.91	11.42	1.39	29.67	.42	3.91	4.33	5.40
1 4 5 1 3	.43	3.90	.58	10.36	2.14	3.74	5.88	10.00
1 4 5 1 4	1.15	4.96	.43	16.09	.94	9.76	10.70	1.00
1 4 5 1 5	.46	1.59	.05	2.67	.29	.74	1.03	1.00
1 4 5 1 6	.03	.62	.14	4.55	.83	2.96	3.79	1.00

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTOP	SHOOT NO
1 4 5 2 1	1.88	6.91	.08	16.03	1.60	7.44	9.04	5.00
1 4 5 2 2	3.41	14.56	1.07	28.64	5.64	7.35	12.99	8.30
1 4 5 2 3	.90	4.72	.17	10.10	2.24	3.07	5.31	4.00
1 4 5 2 4	4.23	12.75	.69	34.43	10.99	9.99	20.98	6.70
1 4 5 2 5	3.21	10.25	.55	19.65	2.48	6.37	8.85	4.00
1 4 5 2 6	3.54	12.58	1.31	26.78	4.46	8.43	12.89	8.00
1 4 5 3 1	1.87	14.38	1.04	28.81	4.85	8.53	13.38	14.40
1 4 5 3 2	1.70	6.31	.06	10.01	1.07	2.57	3.64	3.00
1 4 5 3 3	3.90	11.83	.37	22.76	3.01	7.55	10.56	4.00
1 4 5 3 4	.92	6.71	.67	13.24	2.08	3.78	5.86	8.00
1 4 5 3 5	.71	5.19	.59	10.06	1.73	2.55	4.28	3.00
1 4 5 3 6	0.00	.26	.15	1.84	.29	1.14	1.43	2.00
1 4 6 1 1	1.41	4.72	.52	10.31	1.42	3.65	5.07	6.00
1 4 6 1 2	.26	1.11	.28	5.00	1.12	2.49	3.61	2.00
1 4 6 1 3	1.17	5.07	.62	10.87	1.44	3.74	5.18	6.00
1 4 6 1 4	1.21	5.27	.66	11.76	1.47	4.36	5.83	4.00
1 4 6 1 5	2.28	6.41	.35	13.14	2.37	4.01	6.38	3.00
1 4 6 1 6	.39	1.85	.22	5.53	1.21	2.25	3.46	3.00
1 4 6 2 1	3.08	11.57	1.59	27.91	5.04	9.71	14.75	7.00
1 4 6 2 2	1.52	5.46	1.44	19.70	2.54	10.26	12.80	7.00
1 4 6 2 3	3.62	9.80	1.27	18.63	3.96	3.60	7.56	5.00
1 4 6 2 4	.83	2.55	.37	6.00	1.88	3.20	5.08	2.00
1 4 6 2 5	.90	3.42	.50	8.28	1.09	3.27	4.36	3.00
1 4 6 2 6	1.95	6.56	1.03	16.50	2.90	6.01	8.91	4.80
1 4 6 3 1	5.52	20.59	1.35	35.51	5.22	8.35	13.57	8.00
1 4 6 3 2	2.04	7.48	.56	12.53	1.37	3.12	4.49	9.00
1 4 6 3 3	1.92	7.38	.47	11.86	.92	3.09	4.01	3.00
1 4 6 3 4	.85	2.91	.61	8.99	1.46	4.01	5.47	15.00
1 4 6 3 5	1.48	6.36	.70	12.91	1.79	4.06	5.85	6.00
1 4 6 3 6	.67	2.52	.28	5.96	.47	2.69	3.16	2.00
2 1 1 1 1	.16	.48	.10	3.43	.71	2.14	2.85	9.00
2 1 1 1 2	.06	.21	.10	2.83	.83	1.69	2.52	6.00
2 1 1 1 3	.03	.16	.05	1.27	.25	.81	1.06	10.00
2 1 1 1 4	.14	.47	.10	2.58	.63	1.38	2.01	9.00
2 1 1 1 5	.11	.49	.06	1.53	.24	.74	.98	16.00
2 1 1 1 6	.24	1.54	.77	7.54	2.00	3.23	5.23	42.10
2 1 1 2 1	.12	.67	.44	3.57	1.20	1.26	2.46	17.00
2 1 1 2 2	.13	.52	.23	3.28	.73	1.80	2.53	15.00
2 1 1 2 3	.18	1.09	.45	5.54	1.46	2.53	3.99	34.40
2 1 1 2 4	.18	1.71	.43	6.05	1.55	2.36	3.91	46.60
2 1 1 2 5	.03	.21	.12	3.31	1.03	1.95	2.98	5.00
2 1 1 2 6	.08	.36	.15	2.40	.56	1.33	1.89	6.00
2 1 1 3 1	.10	.48	.17	2.75	.72	1.38	2.10	14.00
2 1 1 3 2	.06	.52	.83	5.04	1.42	2.27	3.69	16.00
2 1 1 3 3	.26	.78	.19	4.48	.83	2.68	3.51	23.80
2 1 1 3 4	.26	1.13	.38	5.26	1.26	2.49	3.75	38.20
2 1 1 3 5	.09	.29	.11	3.35	1.05	1.90	2.95	8.00
2 1 1 3 6	.05	.28	.24	4.15	1.03	2.60	3.63	10.00

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RT:R	SHOOT NO
2 1 2 1 1	.36	.81	.12	3.01	.94	1.14	2.08	8.00
2 1 2 1 2	.43	1.33	.19	3.83	.81	1.50	2.31	11.00
2 1 2 1 3	.10	.25	.15	1.99	.62	.97	1.59	3.00
2 1 2 1 4	.14	.36	.09	1.34	.33	.56	.89	5.00
2 1 2 1 5	.03	.09	.26	2.56	.66	1.55	2.21	2.00
2 1 2 1 6	.19	.58	.15	1.62	.33	.56	.89	9.00
2 1 2 2 1	.78	2.21	.24	6.99	1.54	2.99	4.53	16.60
2 1 2 2 2	.42	1.00	.27	4.01	1.07	1.67	2.74	8.00
2 1 2 2 3	.32	.79	.41	6.57	1.79	3.58	5.37	11.00
2 1 2 2 4	.19	.48	.29	2.43	.72	.94	1.66	11.00
2 1 2 2 5	.05	.12	.06	1.05	.29	.58	.87	2.00
2 1 2 2 6	.17	.52	.03	1.42	.24	.63	.87	7.00
2 1 2 3 1	.14	.34	.16	1.68	.32	.86	1.18	4.00
2 1 2 3 2	.08	.20	.06	2.73	1.02	1.45	2.47	4.00
2 1 2 3 3	.23	.63	.13	1.68	.31	.59	.90	7.00
2 1 2 3 4	.55	1.60	.38	4.11	.96	1.17	2.13	25.40
2 1 2 3 5	.70	1.98	.36	6.35	1.04	2.96	4.00	18.00
2 1 2 3 6	.41	.90	.35	4.72	1.34	2.13	3.47	14.60
2 1 3 1 1	1.72	4.60	.22	12.35	2.48	5.05	7.53	11.10
2 1 3 1 2	.34	.96	.21	4.16	.80	2.19	2.99	4.00
2 1 3 1 3	.68	1.96	.25	8.04	3.32	2.50	5.82	4.50
2 1 3 1 4	.31	.77	.04	2.33	.40	1.12	1.52	2.00
2 1 3 1 5	.52	1.51	.14	3.54	.59	1.30	1.89	6.00
2 1 3 1 6	.16	.59	.15	1.69	.32	.63	.95	3.00
2 1 3 2 1	1.49	4.51	.41	12.57	2.34	5.31	7.65	11.40
2 1 3 2 2	.77	2.47	.25	5.60	.61	2.27	2.88	7.60
2 1 3 2 3	.88	2.51	.25	7.02	1.13	3.13	4.26	4.00
2 1 3 2 4	1.11	3.33	.30	7.23	1.54	2.06	3.60	9.00
2 1 3 2 5	.11	.36	.11	1.41	.29	.65	.94	3.00
2 1 3 2 6	.32	.81	.06	2.13	.32	.94	1.26	3.00
2 1 3 3 1	.96	2.88	.39	5.50	.25	1.98	2.23	18.00
2 1 3 3 2	.50	1.55	.50	6.11	1.71	2.34	4.05	6.00
2 1 3 3 3	.24	.73	.12	2.37	.38	1.14	1.52	2.00
2 1 3 3 4	1.51	4.47	.56	10.09	1.91	3.14	5.05	14.70
2 1 3 3 5	.40	1.16	.08	2.34	.32	.78	1.10	8.00
2 1 3 3 6	.24	.73	.04	1.35	.20	.38	.58	4.00
2 1 4 1 1	.36	.99	.16	3.48	.57	1.76	2.33	4.00
2 1 4 1 2	.82	2.32	.15	5.50	.84	2.19	3.03	6.00
2 1 4 1 3	.94	2.67	.18	4.43	.46	1.12	1.58	4.00
2 1 4 1 4	1.85	5.55	.10	9.00	.76	2.59	3.35	6.00
2 1 4 1 5	.47	1.49	.11	4.11	.47	2.04	2.51	4.00
2 1 4 1 6	.28	.79	.11	2.00	.35	.75	1.10	1.00
2 1 4 2 1	.21	.55	.07	3.23	.89	1.72	2.61	1.00
2 1 4 2 2	1.55	4.23	.39	8.14	1.30	2.22	3.52	5.00
2 1 4 2 3	.70	1.81	.13	4.23	.93	1.36	2.29	9.00
2 1 4 2 4	.38	1.03	.30	3.81	.99	1.49	2.48	3.00
2 1 4 2 5	1.24	3.80	.50	7.94	1.07	2.57	3.64	3.00
2 1 4 2 6	.54	1.53	.11	2.90	.46	.80	1.26	3.00

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
2 1 4 3 1	1.16	3.52	.89	13.47	3.41	5.65	9.06	8.00
2 1 4 3 2	1.60	4.08	.51	10.24	2.22	3.43	5.65	10.00
2 1 4 3 3	1.78	4.71	.26	8.05	.92	2.16	3.08	8.00
2 1 4 3 4	.54	1.58	.07	4.29	.94	1.70	2.64	5.00
2 1 4 3 5	1.07	3.15	.54	6.18	1.01	1.48	2.49	5.00
2 1 4 3 6	.43	1.19	.14	3.99	.51	2.15	2.66	3.00
2 1 5 1 1	.26	.99	.16	4.19	.85	2.19	3.04	3.00
2 1 5 1 2	.03	.29	.10	1.96	.40	1.17	1.57	2.00
2 1 5 1 3	.28	1.07	.35	5.91	1.65	2.84	4.49	2.00
2 1 5 1 4	.24	1.39	.22	5.36	1.35	2.40	3.75	3.00
2 1 5 1 5	.22	.68	.05	2.38	.37	1.28	1.65	1.00
2 1 5 1 6	0.00	.02	.09	1.02	.22	.69	.91	0.00
2 1 5 2 1	2.70	10.40	.11	17.59	1.13	5.95	7.08	5.00
2 1 5 2 2	.17	.72	0.00	2.19	.36	1.11	1.47	2.00
2 1 5 2 3	.08	.58	.04	2.20	.28	1.30	1.58	2.00
2 1 5 2 4	.31	1.80	.30	4.54	.61	1.83	2.44	4.00
2 1 5 2 5	.11	.42	.09	2.78	.52	1.64	2.26	1.00
2 1 5 2 6	.09	.35	.07	1.27	.21	.64	.85	2.00
2 1 5 3 1	.26	1.30	.14	4.01	.68	1.87	2.56	2.30
2 1 5 3 2	.42	2.02	.33	5.10	.65	2.10	2.75	4.00
2 1 5 3 3	.02	.12	.20	1.89	.52	1.05	1.57	0.00
2 1 5 3 4	.49	2.64	.17	6.95	1.30	2.84	4.14	4.00
2 1 5 3 5	0.00	.56	.07	2.62	.50	1.49	1.99	1.00
2 1 5 3 6	.11	.55	.15	2.73	.58	1.45	2.03	3.00
2 4 1 1 1	1.00	4.28	2.60	21.42	6.38	8.16	14.54	112.30
2 4 1 1 2	.30	1.25	.30	5.79	1.39	2.84	4.23	30.70
2 4 1 1 3	.26	1.43	.85	11.09	3.63	5.17	8.80	57.30
2 4 1 1 4	.02	.06	.33	5.06	1.16	3.51	4.67	5.00
2 4 1 1 5	.81	3.72	.33	10.20	2.31	3.84	6.15	39.40
2 4 1 1 6	.57	2.70	1.13	11.14	2.99	4.31	7.30	71.00
2 4 1 2 1	.35	1.04	.45	4.79	1.01	2.29	3.30	17.00
2 4 1 2 2	.60	2.27	.77	14.24	4.21	6.99	11.20	70.90
2 4 1 2 3	.16	.50	.15	3.79	.87	2.27	3.14	15.00
2 4 1 2 4	.38	1.11	1.04	13.06	3.25	7.65	10.90	45.80
2 4 1 2 5	.20	.89	.13	3.19	.57	1.60	2.17	16.00
2 4 1 2 6	.37	1.28	.48	7.80	1.87	4.16	6.03	32.20
2 4 1 3 1	.07	.23	.05	7.97	.16	7.53	7.69	5.00
2 4 1 3 2	.51	2.04	.63	13.90	5.56	5.67	11.23	100.20
2 4 1 3 3	.17	.59	.37	4.78	1.79	2.03	3.82	18.00
2 4 1 3 4	.50	4.41	1.52	26.23	10.76	9.53	20.29	125.60
2 4 1 3 5	.12	.49	.11	3.46	.77	2.09	2.86	10.00
2 4 1 3 6	.72	2.12	1.83	12.56	4.84	3.77	8.61	41.30
2 4 2 1 1	2.15	8.59	1.21	24.92	6.85	8.26	15.11	55.60
2 4 2 1 2	.11	.38	.13	2.13	.32	1.30	1.62	11.00
2 4 2 1 3	.38	1.47	.11	3.80	.88	1.34	2.22	16.60
2 4 2 1 4	.08	.42	.23	5.75	.89	4.21	5.10	10.00
2 4 2 1 5	.13	.47	.22	4.61	1.86	2.05	3.91	15.90
2 4 2 1 6	.22	.85	.20	7.30	2.82	3.43	6.25	13.00

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
2 4 2 2 1	.99	2.54	.24	6.36	.91	2.67	3.58	19.20
2 4 2 2 2	2.54	7.01	.89	16.00	2.76	5.34	8.10	42.20
2 4 2 2 3	1.49	3.86	1.40	24.11	6.26	12.59	18.85	58.50
2 4 2 2 4	2.91	10.01	1.22	18.96	2.87	4.85	7.72	94.60
2 4 2 2 5	1.20	3.59	.60	9.24	1.50	3.55	5.05	30.00
2 4 2 2 6	.71	2.27	.17	3.95	.53	.97	1.50	33.70
2 4 2 3 1	1.09	3.60	.55	10.20	2.19	3.85	6.04	34.70
2 4 2 3 2	2.83	9.63	.98	20.22	4.59	5.01	9.60	79.00
2 4 2 3 3	.46	1.63	.69	4.88	.57	1.99	2.56	14.00
2 4 2 3 4	1.38	5.26	.56	10.85	2.02	3.01	5.03	50.50
2 4 2 3 5	.48	1.78	.33	5.28	.99	2.18	3.17	30.80
2 4 2 3 6	.47	1.50	.19	4.95	.51	2.74	3.25	15.00
2 4 3 1 1	.72	1.68	.44	4.75	1.03	1.60	2.63	12.00
2 4 3 1 2	1.72	6.65	.23	15.77	3.16	5.72	8.88	55.40
2 4 3 1 3	1.17	3.04	.50	6.72	1.48	1.70	3.18	9.00
2 4 3 1 4	1.17	3.22	.59	10.23	2.88	3.54	6.42	21.60
2 4 3 1 5	.51	1.70	.23	6.82	1.78	3.11	4.89	13.80
2 4 3 1 6	.54	1.73	.26	4.19	.57	1.63	2.20	13.00
2 4 3 2 1	2.50	7.99	1.96	17.25	2.66	4.64	7.30	61.40
2 4 3 2 2	2.74	6.76	3.01	27.17	9.19	8.20	17.39	66.30
2 4 3 2 3	1.81	5.41	1.33	13.08	2.61	3.73	6.34	20.50
2 4 3 2 4	.68	1.74	.39	4.26	1.08	1.05	2.13	15.00
2 4 3 2 5	.93	2.50	.38	5.72	1.38	1.46	2.84	15.00
2 4 3 2 6	.91	3.36	.36	7.56	1.20	2.64	3.84	14.00
2 4 3 3 1	1.57	4.62	1.63	13.72	3.40	4.06	7.46	36.10
2 4 3 3 2	1.94	6.67	.82	13.61	2.51	3.61	6.12	33.90
2 4 3 3 3	1.55	5.37	1.51	16.41	4.29	5.23	9.52	46.90
2 4 3 3 4	2.05	5.79	.87	15.69	4.27	4.76	9.03	21.30
2 4 3 3 5	.65	1.60	.26	4.43	.97	1.59	2.56	15.20
2 4 3 3 6	1.07	2.93	.40	8.74	2.01	3.39	5.40	20.30
2 4 4 1 1	2.31	7.52	2.05	19.18	4.71	4.90	9.61	18.80
2 4 4 1 2	1.11	3.49	.71	9.74	2.54	3.00	5.54	9.00
2 4 4 1 3	.99	3.03	.25	5.68	.60	1.80	2.40	7.00
2 4 4 1 4	2.43	7.94	1.16	17.06	3.40	4.56	7.96	16.00
2 4 4 1 5	.24	.95	.08	2.82	.40	1.39	1.79	4.00
2 4 4 1 6	.66	1.64	.28	7.13	1.74	3.47	5.21	5.00
2 4 4 2 1	.63	2.12	.62	7.99	1.77	3.48	5.25	6.00
2 4 4 2 2	2.62	10.17	2.02	25.84	6.20	7.45	13.65	13.20
2 4 4 2 3	1.82	6.40	.94	13.40	2.79	3.27	6.06	14.00
2 4 4 2 4	1.92	5.79	.44	11.00	1.82	2.94	4.76	10.40
2 4 4 2 5	2.35	8.07	.42	13.20	1.45	3.25	4.70	23.00
2 4 4 2 6	2.12	7.96	.83	16.07	2.48	4.79	7.27	46.80
2 4 4 3 1	.26	1.03	.21	4.25	.74	2.27	3.01	6.00
2 4 4 3 2	3.08	10.42	1.72	22.86	4.95	5.77	10.72	29.30
2 4 4 3 3	2.58	9.00	.63	15.31	2.11	3.56	5.67	17.20
2 4 4 3 4	1.70	6.00	.78	11.49	1.43	3.28	4.71	17.00
2 4 4 3 5	.15	.50	.11	2.09	.40	1.08	1.48	4.00
2 4 4 3 6	.27	.84	.18	2.73	.72	.99	1.71	3.00

/3A.5.1.

Table 3A.5.1. cont.

V T H R P	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHOOT NO
2 4 5 1 1	1.69	7.29	.60	19.72	3.76	8.12	11.88	5.00
2 4 5 1 2	1.71	7.61	.19	13.83	2.24	3.79	6.03	5.00
2 4 5 1 3	1.39	6.74	.74	13.30	1.85	3.97	5.82	8.00
2 4 5 1 4	.14	2.95	.10	7.22	1.35	2.82	4.17	4.00
2 4 5 1 5	.48	2.64	.56	7.96	2.03	2.73	4.76	3.00
2 4 5 1 6	.28	1.84	.49	6.06	.99	2.74	3.73	3.00
2 4 5 2 1	5.46	25.87	1.49	39.33	2.93	9.03	11.96	18.30
2 4 5 2 2	2.53	14.18	.90	26.97	5.07	6.81	11.88	6.40
2 4 5 2 3	.88	4.46	.78	12.03	2.60	4.18	6.78	6.10
2 4 5 2 4	2.73	12.20	.48	18.42	1.14	4.60	5.74	10.00
2 4 5 2 5	.54	2.91	.41	7.66	1.34	3.00	4.34	3.00
2 4 5 2 6	1.91	10.94	.81	19.99	2.61	5.52	8.13	9.20
2 4 5 3 1	2.33	15.08	1.36	42.79	12.80	13.54	26.34	13.60
2 4 5 3 2	.64	4.41	.58	10.14	1.43	3.72	5.15	7.00
2 4 5 3 3	1.07	7.86	.76	18.48	2.86	7.00	9.86	5.00
2 4 5 3 4	.98	4.33	.46	11.00	1.62	4.59	6.21	5.00
2 4 5 3 5	.63	2.89	.19	7.44	1.19	3.17	4.36	2.00
2 4 5 3 6	0.00	.05	.29	3.39	.79	2.26	3.05	0.00
2 4 6 1 1	4.44	15.63	1.38	28.96	4.98	6.97	11.95	12.00
2 4 6 1 2	2.29	6.91	.52	16.56	2.06	7.09	9.15	14.00
2 4 6 1 3	.54	1.97	.57	8.43	1.86	4.03	5.89	9.00
2 4 6 1 4	1.01	3.80	.92	11.29	3.48	3.09	6.57	6.00
2 4 6 1 5	.65	2.30	.36	6.94	1.65	2.63	4.28	3.00
2 4 6 1 6	.46	2.95	.56	9.47	2.39	3.57	5.96	6.00
2 4 6 2 1	6.47	23.28	2.36	42.73	2.97	4.66	7.62	10.50
2 4 6 2 2	1.95	7.70	.92	16.25	10.83	15.38	26.21	21.80
2 4 6 2 3	2.22	9.52	.96	18.65	2.68	5.49	8.17	6.00
2 4 6 2 4	1.32	7.04	.71	13.01	2.14	3.12	5.26	15.00
2 4 6 2 5	.57	2.41	.22	4.68	.85	1.20	2.05	3.00
2 4 6 2 6	.13	.96	.29	3.23	.62	1.36	1.98	5.00
2 4 6 3 1	2.58	10.36	.89	21.45	4.74	5.46	10.20	7.00
2 4 6 3 2	1.13	6.13	.58	10.38	1.46	2.21	3.67	14.00
2 4 6 3 3	5.48	22.03	3.18	43.71	6.41	12.08	18.49	20.30
2 4 6 3 4	2.20	8.80	.96	21.07	5.14	6.17	11.31	14.00
2 4 6 3 5	1.48	6.39	1.04	13.01	2.94	2.64	5.58	19.00
2 4 6 3 6	.14	.46	.14	2.06	1.11	.95	2.06	4.00

Table 3A.5.2. Replication means of the dry weight of plant parts (gm/plant) and shoot numbers per plant at selected growth stages. Abreviations as for table 3A.5.1.

V T H R	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHT NO
1 1 1 1	.15	.60	.28	3.93	.93	2.11	3.04	17.73
1 1 1 2	.08	.43	.22	4.41	1.62	2.12	3.74	15.88
1 1 1 3	.09	.33	.18	3.02	.79	1.69	2.49	9.20
1 1 2 1	.34	.91	.27	3.88	.93	1.76	2.69	8.83
1 1 2 2	.27	.89	.26	4.08	1.04	1.87	2.92	11.30
1 1 2 3	.36	1.16	.30	5.40	1.43	2.49	3.93	10.66
1 1 3 1	.36	.94	.09	2.67	.61	1.02	1.63	3.33
1 1 3 2	.78	2.11	.18	5.85	1.24	2.31	3.55	5.13
1 1 3 3	.58	1.52	.16	4.58	.87	2.00	2.88	5.50
1 1 4 1	.29	.79	.07	2.75	.53	1.34	1.88	1.83
1 1 4 2	.58	1.55	.20	4.68	.90	2.02	2.92	4.00
1 1 4 3	1.17	3.36	.14	8.04	1.46	3.06	4.53	6.83
1 1 5 1	.64	2.39	.13	6.46	1.05	2.88	3.94	2.33
1 1 5 2	.38	1.83	.33	5.46	.95	2.34	3.29	2.50
1 1 5 3	1.28	6.02	.26	13.56	1.87	5.41	7.28	3.90
1 2 1 1	.17	.48	.62	6.10	1.60	3.38	4.98	12.03
1 2 1 2	.13	.48	.19	2.88	.72	1.47	2.20	8.00
1 2 1 3	.24	.66	.42	4.74	1.25	2.40	3.65	16.65
1 2 2 1	.47	1.24	.50	4.46	1.89	3.27	5.16	27.43
1 2 2 2	.29	.96	.38	4.98	1.16	2.47	3.63	12.51
1 2 2 3	.43	1.14	.44	4.49	.72	2.17	2.90	11.88
1 2 3 1	.53	1.40	.38	4.79	.90	2.11	3.01	8.43
1 2 3 2	.88	2.36	.51	8.16	2.22	3.07	5.29	17.08
1 2 3 3	.69	1.71	.29	5.34	1.01	2.31	3.32	8.16
1 3 1 1	.07	.32	.14	2.78	.68	1.63	2.32	8.33
1 3 1 2	.23	.94	.39	5.61	1.22	3.04	4.27	13.01
1 3 1 3	.11	.44	.14	3.37	.75	2.03	2.79	11.66
1 3 2 1	.40	1.28	.39	5.12	1.22	2.22	3.44	13.76
1 3 2 2	.49	1.38	.43	6.16	1.34	3.00	4.34	16.38
1 3 2 3	.34	1.21	.40	5.61	1.73	2.25	3.99	18.28
1 3 3 1	1.13	3.03	.48	8.68	1.36	3.80	5.16	14.85
1 3 3 2	.51	1.31	.25	4.67	.83	2.26	3.10	7.83
1 3 3 3	.53	1.49	.43	7.82	1.82	4.06	5.89	9.83
1 3 4 1	1.07	3.08	.13	6.76	1.06	2.47	3.54	6.98
1 3 4 2	.66	2.02	.30	5.72	1.14	2.25	3.39	3.50
1 3 4 3	1.98	5.93	.46	13.57	1.91	5.26	7.17	10.23

/3A.5.2.

Table 3A.5.2. cont.

V T H R	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHT NO
1 4 1 1	.14	.65	.62	6.84	2.53	3.67	6.20	16.43
1 4 1 2	.23	.91	.71	7.96	1.63	4.70	6.33	13.41
1 4 1 3	.40	1.41	.50	7.16	1.62	3.62	5.24	16.41
1 4 2 1	.32	1.15	.40	6.70	2.26	2.87	5.13	15.68
1 4 2 2	.37	1.28	.45	6.55	1.77	3.05	4.82	16.20
1 4 2 3	.41	1.39	.47	6.52	1.43	3.23	4.66	16.16
1 4 3 1	1.11	2.93	.34	7.62	1.69	2.63	4.33	11.36
1 4 3 2	.73	1.84	.33	5.00	.89	1.93	2.82	12.50
1 4 3 3	1.22	2.86	.43	8.34	1.61	3.42	5.03	16.81
1 4 4 1	1.15	3.14	.33	6.93	1.37	2.08	3.45	7.18
1 4 4 2	.71	2.25	.28	5.41	.89	1.99	2.88	7.00
1 4 4 3	1.68	4.91	.74	14.26	3.35	5.25	8.60	11.85
1 4 5 1	1.19	5.23	.66	15.32	1.79	5.60	7.40	4.40
1 4 5 2	2.86	10.29	.64	22.60	4.56	7.10	11.67	6.00
1 4 5 3	1.51	7.44	.48	14.45	2.17	4.35	6.52	5.73
1 4 6 1	1.12	4.07	.66	9.43	1.50	3.41	4.92	4.00
1 4 6 2	1.98	6.56	.44	16.50	2.90	6.00	8.91	4.80
1 4 6 3	2.08	7.87	1.03	14.62	1.87	4.22	6.09	7.16
2 1 1 1	.12	.56	.19	3.19	.77	1.66	2.44	16.35
2 1 1 2	.12	.76	.30	4.02	1.08	1.87	2.96	20.66
2 1 1 3	.13	.58	.32	4.17	1.05	2.22	3.27	16.33
2 1 2 1	.20	.57	.16	2.39	.61	1.04	1.66	6.33
2 1 2 2	.32	.85	.21	3.74	.94	1.73	2.67	9.26
2 1 2 3	.35	.94	.24	3.54	.83	1.52	2.35	12.16
2 1 3 1	.62	1.73	.16	5.35	1.31	2.13	3.45	5.10
2 1 3 2	.78	2.33	.23	5.99	1.03	2.39	3.43	6.33
2 1 3 3	.64	1.92	.28	4.62	.79	1.62	2.42	8.78
2 1 4 1	.78	2.30	.13	4.75	.57	1.74	2.31	4.16
2 1 4 2	.77	2.15	.25	5.04	.94	1.69	2.63	4.00
2 1 4 3	1.09	3.03	.40	7.70	1.50	2.76	4.26	6.50
2 1 5 1	.17	.74	.16	3.47	.80	1.76	2.56	1.83
2 1 5 2	.57	2.37	.10	5.09	.53	2.07	2.61	2.66
2 1 5 3	.21	1.19	.17	3.88	.70	1.80	2.50	2.38
2 4 1 1	.49	2.24	.92	10.78	2.97	4.63	7.61	52.61
2 4 1 2	.34	1.18	.50	7.81	1.96	4.16	6.12	32.81
2 4 1 3	.34	1.64	.75	11.48	3.98	5.10	9.08	50.01

/3A.5.2.

Table 3A.5.2.

V T H R	LEAF	SHOOT	STUBBLE	PLANT	CROWN	ROOT	RTCR	SHT NO
2 4 2 1	.51	2.03	.35	8.08	2.27	3.43	5.70	20.35
2 4 2 2	1.64	4.88	.75	13.10	2.47	4.99	7.46	46.36
2 4 2 3	1.11	3.90	.55	9.39	1.81	3.13	4.94	37.33
2 4 3 1	.97	3.00	.37	8.08	1.81	2.88	4.70	20.80
2 4 3 2	1.59	4.62	1.23	12.50	3.02	3.62	6.64	32.03
2 4 3 3	1.47	4.49	.91	12.10	2.90	3.77	6.68	28.95
2 4 4 1	1.29	4.09	.75	10.26	2.23	3.18	5.41	9.96
2 4 4 2	1.91	6.75	.87	14.58	2.75	4.19	6.94	18.90
2 4 4 3	1.34	4.63	.60	9.78	1.72	2.82	4.55	12.75
2 4 5 1	.94	4.84	.44	11.34	2.03	4.02	6.06	4.66
2 4 5 2	2.34	11.76	.81	20.73	2.61	5.52	8.13	8.83
2 4 5 3	.94	5.77	.60	15.54	3.44	5.71	9.16	5.43
2 4 6 1	1.56	5.59	.71	13.61	2.73	4.56	7.30	8.33
2 4 6 2	2.11	8.48	.91	16.42	3.34	5.20	8.54	10.21
2 4 6 3	2.16	9.02	1.13	18.61	3.63	4.91	8.55	13.05
2 2 1 3	.09	.34	.17	.44	.66	1.17	1.83	18.85
2 2 1 3	.19	.64	.51	.84	1.88	2.77	4.65	30.78
2 2 1 3	.13	.38	.22	.51	.83	1.65	2.48	14.88
2 3 1 3	.19	.57	.32	.77	.67	1.86	2.53	17.30
2 3 1 3	.41	1.26	.68	1.67	2.28	3.54	5.82	35.40
2 3 1 3	.36	.95	.94	1.31	1.40	2.67	4.08	31.13

Table 3A.5.3. The dry weight growth of new basal shoots in the mature lucerne crops at the H harvest. Treatments were 3R and H. Other abreviations as in table 3A.5.1.

V	T	R	P	LEAF	STEM	SHOOT	SHOOT NO
1	1	1	1	0.00	.02	.02	7.00
1	1	1	2	.03	.53	.56	17.00
1	1	1	3	.01	.11	.12	3.00
1	1	1	4	.02	.05	.07	8.00
1	1	1	5	0.00	.04	.04	4.00
1	1	1	6	.02	.12	.14	8.00
1	1	2	1	0.00	.02	.02	4.00
1	1	2	2	0.00	.02	.02	3.00
1	1	2	3	0.00	.05	.05	5.00
1	1	2	4	0.00	.16	.16	7.00
1	1	2	5	0.00	.07	.07	8.00
1	1	2	6	0.00	.04	.04	4.00
1	1	3	1	.03	.30	.33	12.00
1	1	3	2	0.00	.45	.45	19.00
1	1	3	3	.17	.80	.97	26.00
1	1	3	4	0.00	.13	.13	10.00
1	1	3	5	0.00	.05	.05	5.00
1	1	3	6	0.00	.05	.05	2.00
1	4	1	1	.50	2.09	2.59	43.00
1	4	1	2	.05	.77	.82	26.00
1	4	1	3	.04	.48	.52	28.00
1	4	1	4	.30	1.21	1.51	7.00
1	4	1	5	0.00	0.00	0.00	0.00
1	4	1	6	.03	.08	1.11	7.00
1	4	2	1	.24	.85	1.09	25.00
1	4	2	2	0.00	.47	.47	12.00
1	4	2	3	.16	.59	.75	25.00
1	4	2	4	.09	.19	.28	12.00
1	4	2	5	.13	1.19	1.32	26.00
1	4	2	6	.11	.32	.43	13.00
1	4	3	1	.20	.81	1.01	26.00
1	4	3	2	.23	.68	.91	11.00
1	4	3	3	.31	1.45	1.76	25.00
1	4	3	4	.06	.25	.31	16.00
1	4	3	5	.06	.37	.43	12.00
1	4	3	6	0.00	.03	.03	3.00

/3A.5.3.

Table 3A.5.3. cont.

V	T	R	P	LEAF	STEM	SHOOT	SHOOT NO
2	1	1	1	0.00	0.00	0.00	0.00
2	1	1	2	0.00	.04	.04	9.00
2	1	1	3	0.00	.06	.06	9.00
2	1	1	4	0.00	.20	.20	24.00
2	1	1	5	0.00	.01	.01	2.00
2	1	1	6	0.00	.02	.02	5.00
2	1	2	1	1.07	2.55	3.62	19.00
2	1	2	2	.04	.07	.11	9.00
2	1	2	3	.04	.06	.10	9.00
2	1	2	4	.03	.25	.28	24.00
2	1	2	5	.08	.15	.23	13.00
2	1	2	6	.03	.05	.08	3.00
2	1	3	1	.02	.17	.19	11.00
2	1	3	2	.04	.30	.34	21.00
2	1	3	3	.02	.10	.12	5.00
2	1	3	4	.03	.33	.36	23.00
2	1	3	5	0.00	.13	.13	6.00
2	1	3	6	0.00	0.00	0.00	0.00
2	4	1	1	.72	1.24	1.96	[illegible]00
2	4	1	2	.91	1.73	2.64	[illegible]00
2	4	1	3	.83	1.32	2.15	29.00
2	4	1	4	.07	.32	.39	27.00
2	4	1	5	.11	.48	.59	24.00
2	4	1	6	.04	.09	.13	8.00
2	4	2	1	.28	1.06	1.34	31.00
2	4	2	2	.40	.74	1.14	25.00
2	4	2	3	.27	.73	1.00	14.00
2	4	2	4	.11	.90	1.01	32.00
2	4	2	5	.08	.31	.39	17.00
2	4	2	6	0.00	0.00	0.00	0.00
2	4	3	1	.14	.84	.98	31.00
2	4	3	2	.15	.73	.88	43.00
2	4	3	3	.34	1.08	1.42	34.00
2	4	3	4	.07	.28	.35	19.00
2	4	3	5	.02	.09	.11	7.00
2	4	3	6	0.00	.05	.05	3.00

Table 3A.5.4. Field Growth Data.

1. Measured shoot height, relative shoot number, calculated relative production and time of growth (days).
T 1, 3RC; 2, 9C; 3, 15C; 4, HC.
G group - first measured, 1,15/8; 2,22/8; 3,29/8; 4,5/9; 5,12/9; 6,19/9.
D dates of measurement, weekly. 1,12/9;....
R replications.

2. Measured initial relative shoot number for each group (G)(1 to 6), and the adjusted shoot height on each date (D) (1,15/8 to 9,11/10), averaged over all groups.
** 0.0 is a non-existent value in all cases.

T	G	D	R	SHOOT HEIGHT	RELATIVE NUMBER	RELATIVE PRODUCT	TIME	T	D	R	INITIAL SHT NO	ADJ. SHT HEIGHT
									G			
1	1	1	1	8.50	0.00	0.00	35.00	1	1	0	0.0	31.0
1	1	1	2	8.50	0.00	0.00	35.00	1	1	0	0.0	29.1
1	1	1	3	9.80	0.00	0.00	35.00	1	1	0	0.0	40.0
1	1	2	1	14.80	60.00	888.00	42.00	4	1	0	0.0	37.7
1	1	2	2	13.00	10.50	137.00	42.00	4	1	0	0.0	35.2
1	1	2	3	15.30	12.90	197.00	42.00	4	1	0	0.0	35.8
1	1	3	1	18.60	0.00	0.00	49.00	1	1	1	60.0	5.1
1	1	3	2	16.70	0.00	0.00	49.00	1	1	2	10.5	5.0
1	1	3	3	19.00	0.00	0.00	49.00	1	1	3	12.9	5.0
1	1	4	1	23.10	60.00	1386.00	56.00	1	1	1	0.0	34.5
1	1	4	2	19.70	10.50	207.00	56.00	1	1	2	0.0	29.7
1	1	4	3	24.30	12.90	313.00	56.00	1	1	3	0.0	43.2
1	1	5	1	28.60	51.40	1470.00	63.00	2	1	1	24.4	6.6
1	1	5	2	28.00	6.90	193.00	63.00	2	1	2	40.4	5.1
1	1	5	3	28.70	12.90	370.00	63.00	2	1	3	20.0	6.0
1	2	1	1	7.10	0.00	0.00	35.00	3	1	1	22.8	6.4
1	2	1	2	8.60	0.00	0.00	35.00	3	1	2	30.4	5.5
1	2	1	3	8.10	0.00	0.00	35.00	3	1	3	11.9	6.3
1	2	2	1	12.40	20.00	248.00	42.00	4	1	1	40.0	6.6
1	2	2	2	15.30	31.60	484.00	42.00	4	1	2	30.6	6.0
1	2	2	3	11.40	61.30	699.00	42.00	4	1	3	15.2	7.0
1	2	3	1	17.30	0.00	0.00	49.00	4	1	1	0.0	40.0
1	2	3	2	19.60	0.00	0.00	49.00	4	1	2	0.0	37.0
1	2	3	3	14.80	0.00	0.00	49.00	4	1	3	0.0	47.8
1	2	4	1	23.30	20.00	466.00	56.00	1	2	1	20.0	5.8
1	2	4	2	23.40	31.60	740.00	56.00	1	2	2	31.6	4.9
1	2	4	3	18.30	52.50	961.00	56.00	1	2	3	61.3	5.2
1	2	5	1	26.50	20.00	530.00	63.00	2	2	1	40.0	6.1
1	2	5	2	27.00	31.60	853.00	63.00	2	2	2	28.8	5.5
1	2	5	3	24.80	35.00	868.00	63.00	2	2	3	28.9	6.7
1	3	1	1	6.50	0.00	0.00	35.00	3	2	1	15.8	6.5
1	3	1	2	6.00	0.00	0.00	35.00	3	2	2	32.1	6.2
1	3	1	3	6.80	0.00	0.00	35.00	3	2	3	40.7	5.7
1	3	2	1	10.50	4.00	42.00	42.00	4	2	1	15.0	7.0
1	3	2	2	10.30	7.90	81.00	42.00	4	2	2	38.8	5.9
1	3	2	3	12.70	12.90	164.00	42.00	4	2	3	10.9	7.8
1	3	3	1	14.00	0.00	0.00	49.00	1	3	1	4.0	6.0
1	3	3	2	16.80	0.00	0.00	49.00	1	3	2	7.9	5.6
1	3	3	3	17.00	0.00	0.00	49.00	1	3	3	12.9	5.5
1	3	4	1	18.00	4.00	72.00	56.00	2	3	1	4.4	6.8
1	3	4	2	21.30	5.20	111.00	56.00	2	3	2	9.6	6.3
1	3	4	3	24.00	12.90	310.00	56.00	2	3	3	6.7	7.7

/3A.5.4.

Table 3A.5.4. cont.

T G D R	SHOOT HEIGHT	RELATIVE NUMBER	RELATIVE PRODUCT	TIME	T D R	INITIAL SHT NO	ADJ SHT HEIGHT
1 3 5 1	22.00	4.00	88.00	63.00	3 3 1	15.8	7.2
1 3 5 2	26.00	5.20	135.00	63.00	3 3 2	8.9	6.8
1 3 5 3	29.70	12.90	383.00	63.00	3 3 3	10.2	6.2
1 4 1 1	4.50	0.00	0.00	35.00	4 3 1	15.0	7.3
1 4 1 2	4.50	0.00	0.00	35.00	4 3 2	6.2	6.3
1 4 1 3	4.80	0.00	0.00	35.00	4 3 3	6.5	8.1
1 4 2 1	7.00	4.00	28.00	42.00	1 4 1	4.0	7.9
1 4 2 2	9.20	26.30	242.00	42.00	1 4 2	26.3	6.9
1 4 2 3	9.00	9.70	87.00	42.00	1 4 3	9.7	7.8
1 4 3 1	10.00	0.00	0.00	49.00	2 4 1	26.3	8.9
1 4 3 2	12.10	0.00	0.00	49.00	2 4 2	17.3	8.9
1 4 3 3	12.30	0.00	0.00	49.00	2 4 3	28.9	8.8
1 4 4 1	15.00	4.00	60.00	56.00	3 4 1	21.1	9.4
1 4 4 2	14.20	26.30	374.00	56.00	3 4 2	16.1	9.8
1 4 4 3	16.30	9.70	158.00	56.00	3 4 3	25.4	8.9
1 4 5 1	20.00	4.00	80.00	63.00	4 4 1	25.0	8.9
1 4 5 2	16.00	26.30	421.00	63.00	4 4 2	20.4	8.2
1 4 5 3	20.00	9.70	194.00	63.00	4 4 3	56.5	7.7
1 5 2 1	5.00	4.00	20.00	42.00	1 5 1	4.0	13.3
1 5 2 2	5.70	23.70	135.00	42.00	1 5 2	23.7	10.8
1 5 2 3	6.50	3.20	21.00	42.00	1 5 3	3.2	11.7
1 5 3 1	8.00	0.00	0.00	49.00	2 5 1	4.4	15.6
1 5 3 2	8.50	0.00	0.00	49.00	2 5 2	3.8	14.0
1 5 3 3	8.50	0.00	0.00	49.00	2 5 3	15.6	15.9
1 5 4 1	14.00	4.00	56.00	56.00	3 5 1	24.6	14.1
1 5 4 2	12.30	23.70	292.00	56.00	3 5 2	12.5	15.4
1 5 4 3	9.00	3.20	29.00	56.00	3 5 3	11.9	13.0
1 5 5 1	20.00	4.00	80.00	63.00	4 5 1	3.3	15.0
1 5 5 2	20.50	26.30	421.00	63.00	4 5 2	2.0	13.9
1 5 5 3	11.00	3.20	35.00	63.00	4 5 3	10.9	14.6
2 1 1 1	20.80	24.40	508.00	42.00	1 6 1	4.0	16.9
2 1 1 2	16.90	40.40	683.00	42.00	1 6 2	.1	14.4
2 1 1 3	24.90	20.00	498.00	42.00	1 6 3	.1	15.2
2 2 1 1	16.70	40.00	668.00	42.00	2 6 1	.1	0.0
2 2 1 2	15.80	28.80	455.00	42.00	2 6 2	.1	0.0
2 2 1 3	20.80	28.90	601.00	42.00	2 6 3	.1	0.0
2 3 1 1	17.30	4.40	76.00	42.00	3 6 1	.1	18.0
2 3 1 2	9.60	13.20	127.00	42.00	3 6 2	.1	19.2
2 3 1 3	11.70	6.70	78.00	42.00	3 6 3	.1	17.6
2 4 1 1	10.50	26.80	281.00	42.00	4 6 1	1.7	21.3
2 4 1 2	7.90	17.30	137.00	42.00	4 6 2	2.0	19.1
2 4 1 3	11.00	28.90	318.00	42.00	4 6 3	.1	20.2
2 5 1 1	7.20	4.40	32.00	42.00	1 7 1	0.0	20.9
2 5 1 2	5.00	3.80	19.00	42.00	1 7 2	0.0	17.7
2 5 1 3	5.80	15.60	90.00	42.00	1 7 3	0.0	19.5
3 1 1 1	12.90	0.00	0.00	35.00	3 7 1	0.0	28.0
3 1 1 2	13.30	0.00	0.00	35.00	3 7 2	0.0	25.4
3 1 1 3	11.40	0.00	0.00	35.00	3 7 3	0.0	23.1
3 1 2 1	18.50	22.80	422.00	42.00	4 7 1	0.0	28.2
3 1 2 2	21.40	30.40	651.00	42.00	4 7 2	0.0	26.4
3 1 2 3	20.80	8.90	185.00	42.00	4 7 3	0.0	26.1
3 1 3 1	25.50	0.00	0.00	49.00	1 8 1	0.0	26.2

/3A.5.4.

Table 3A.5.4. cont.

T G D R	SHOOT HEIGHT	RELATIVE NUMBER	RELATIVE PRODUCT	TIME
3 1 3 2	26.60	0.00	0.00	49.00
3 1 3 3	24.00	0.00	0.00	49.00
3 1 4 1	33.00	13.70	452.00	56.00
3 1 4 2	35.80	25.30	1088.00	56.00
3 1 4 3	29.00	8.90	258.00	56.00
3 2 1 1	9.40	0.00	0.00	35.00
3 2 1 2	8.50	0.00	0.00	35.00
3 2 1 3	10.70	0.00	0.00	35.00
3 2 2 1	15.10	15.90	238.00	42.00
3 2 2 2	13.10	32.10	421.00	42.00
3 2 2 3	16.00	40.70	651.00	42.00
3 2 3 1	21.60	0.00	0.00	49.00
3 2 3 2	15.50	0.00	0.00	49.00
3 2 3 3	20.60	0.00	0.00	49.00
3 2 4 1	29.40	11.30	332.00	56.00
3 2 4 2	21.80	27.50	700.00	56.00
3 2 4 3	25.40	40.70	1034.00	56.00
3 3 1 1	10.30	0.00	0.00	35.00
3 3 1 2	9.00	0.00	0.00	35.00
3 3 1 3	6.50	0.00	0.00	35.00
3 3 2 1	21.00	15.80	332.00	42.00
3 3 2 2	18.00	8.90	160.00	42.00
3 3 2 3	12.10	10.20	123.00	42.00
3 3 3 1	25.70	0.00	0.00	49.00
3 3 3 2	23.90	0.00	0.00	49.00
3 3 3 3	15.60	0.00	0.00	49.00
3 3 4 1	38.50	10.50	404.00	56.00
3 3 4 2	29.00	8.90	258.00	56.00
3 3 4 3	19.40	8.20	159.00	56.00
3 4 1 1	5.10	0.00	0.00	35.00
3 4 1 2	6.20	0.00	0.00	35.00
3 4 1 3	4.90	0.00	0.00	35.00
3 4 2 1	11.90	21.10	251.00	42.00
3 4 2 2	14.10	16.10	227.00	42.00
3 4 2 3	9.60	25.40	244.00	42.00
3 4 3 1	16.40	0.00	0.00	49.00
3 4 3 2	18.80	0.00	0.00	49.00
3 4 3 3	16.00	0.00	0.00	49.00
3 4 4 1	28.80	16.90	487.00	56.00
3 4 4 2	23.80	16.10	383.00	56.00
3 4 4 3	22.00	19.00	418.00	56.00
3 5 2 1	6.70	24.60	165.00	42.00
3 5 2 2	6.70	12.50	84.00	42.00
3 5 2 3	5.30	11.90	63.00	42.00
3 5 4 1	17.30	19.70	341.00	56.00
3 5 4 2	9.00	12.50	113.00	56.00
3 5 4 3	7.50	6.00	45.00	56.00
4 1 1 1	12.20	0.00	0.00	35.00
4 1 1 2	10.10	0.00	0.00	35.00
4 1 1 3	14.50	0.00	0.00	35.00
4 1 2 1	19.90	40.00	800.00	42.00
4 1 2 2	20.80	21.80	454.00	42.00

T D R	INITIAL SHT NO	ADJ SHT HEIGHT
1 8 2	0.0	22.5
1 8 3	0.0	25.1
4 8 1	0.0	31.7
4 8 2	0.0	31.6
4 8 3	0.0	31.0
1 9 1	0.0	29.2
1 9 2	0.0	26.9
1 9 3	0.0	33.0
4 9 1	0.0	37.1
4 9 2	0.0	34.8
4 9 3	0.0	33.1

/3A.5.4.

Table 3A.5.4. cont.

T	G	D	R	SHOOT HEIGHT	RELATIVE NUMBER	RELATIVE PRODUCT	TIME
4	1	2	3	21.80	15.20	322.00	42.00
4	1	3	1	27.30	0.00	0.00	49.00
4	1	3	2	27.20	0.00	0.00	49.00
4	1	3	3	25.20	0.00	0.00	49.00
4	1	4	1	32.40	35.00	1132.00	56.00
4	1	4	2	37.30	13.10	488.00	56.00
4	1	4	3	32.00	11.40	365.00	56.00
4	1	5	1	34.60	35.00	1210.00	63.00
4	1	5	2	40.70	13.10	534.00	63.00
4	1	5	3	36.50	7.60	278.00	63.00
4	2	1	1	9.10	0.00	0.00	35.00
4	2	1	2	8.20	0.00	0.00	35.00
4	2	1	3	13.50	0.00	0.00	35.00
4	2	2	1	16.50	15.00	248.00	42.00
4	2	2	2	15.10	34.50	520.00	42.00
4	2	2	3	24.40	10.90	266.00	42.00
4	2	3	1	23.60	0.00	0.00	49.00
4	2	3	2	20.00	0.00	0.00	49.00
4	2	3	3	32.20	0.00	0.00	49.00
4	2	4	1	25.00	12.50	313.00	56.00
4	2	4	2	25.20	25.80	650.00	56.00
4	2	4	3	38.20	10.90	417.00	56.00
4	2	5	1	33.00	10.00	340.00	63.00
4	2	5	2	26.80	25.80	693.00	63.00
4	2	5	3	44.20	10.90	482.00	63.00
4	3	1	1	6.40	0.00	0.00	35.00
4	3	1	2	8.00	0.00	0.00	35.00
4	3	1	3	9.20	0.00	0.00	35.00
4	3	2	1	14.40	15.00	216.00	42.00
4	3	2	2	10.00	6.10	61.00	42.00
4	3	2	3	21.00	6.50	136.00	42.00
4	3	3	1	24.00	0.00	0.00	49.00
4	3	3	2	11.00	0.00	0.00	49.00
4	3	3	3	28.80	0.00	0.00	49.00
4	3	4	1	30.00	11.30	339.00	56.00
4	3	4	2	0.00	.10	0.00	56.00
4	3	4	3	36.00	6.50	234.00	56.00
4	3	5	1	35.00	11.30	395.00	63.00
4	3	5	2	0.00	.10	0.00	63.00
4	3	5	3	41.30	6.50	268.00	63.00
4	4	1	1	4.90	0.00	0.00	35.00
4	4	1	2	5.20	0.00	0.00	35.00
4	4	1	3	5.60	0.00	0.00	35.00
4	4	2	1	7.40	25.00	185.00	42.00
4	4	2	2	6.50	20.40	132.00	42.00
4	4	2	3	11.60	56.50	655.00	42.00
4	4	3	1	10.30	0.00	0.00	49.00
4	4	3	2	8.50	0.00	0.00	49.00
4	4	3	3	16.40	0.00	0.00	49.00
4	4	4	1	18.00	6.20	112.00	56.00

/3A.5.4.

Table 3A.5.4. cont.

T G D R	SHOOT HEIGHT	RELATIVE NUMBER	RELATIVE PRODUCT	TIME
4 4 4 2	11.00	5.10	56.00	56.00
4 4 4 3	22.30	39.60	884.00	56.00
4 4 5 1	18.00	6.20	112.00	63.00
4 4 5 2	0.00	.10	0.00	63.00
4 4 5 3	28.00	33.90	951.00	63.00
4 5 2 1	6.50	3.30	21.00	42.00
4 5 2 2	5.00	2.00	10.00	42.00
4 5 2 3	8.00	10.90	88.00	42.00
4 5 3 1	9.30	0.00	0.00	49.00
4 5 3 2	5.00	0.00	0.00	49.00
4 5 3 3	12.30	0.00	0.00	49.00
4 5 4 1	10.00	3.30	33.00	56.00
4 5 4 2	0.00	.10	0.00	56.00
4 5 4 3	15.30	10.90	168.00	56.00
4 5 5 1	10.50	3.30	35.00	63.00
4 5 5 2	0.00	.10	0.00	63.00
4 5 5 3	16.70	10.90	183.00	63.00
0 0 0 0	0.00	0.00	0.00	0.00
0 0 0 0	0.00	0.00	0.00	0.00

Table 3A.5.5. New basal shoots stem/leaf ratio and average shoot weight (gm/shoot).

V T R	S/L	AV. WT.
1 1 1	11.1	0.0202
1 1 2	10.0	0.0116
1 1 3	9.0	0.0267
1 2 1	5.0	0.0590
1 2 2	5.0	0.0384
1 2 3	4.2.	0.0480
2 1 1	5.9	0.0068
2 1 2	2.4	0.0575
2 1 3	9.4	0.0173
2 2 1	1.9	0.0562
2 2 2	3.8	0.0406
2 2 3	4.2	0.0276

Table 3A.6.1. Data for the leaf canopy dimensions.
D day of measurement, weekly.
1, day 35; 2, day 42; .....
Treatments 1, 3RC; 2, HC.

D T R	CANOPY DEPTH	BASE HEIGHT	D T R	CANOPY DEPTH	BASE HEIGHT
1 1 1	18.5	0.0	4 2 1	18.2	20.6
1 1 2	18.6	0.0	4 2 2	18.0	22.0
1 1 3	15.3	2.9	4 2 3	19.5	21.6
1 2 1	19.1	1.7	5 1 1	19.3	15.7
1 2 2	19.4	2.4	5 1 2	18.6	16.6
1 2 3	19.1	3.5	5 1 3	17.3	22.7
2 1 1	20.6	2.3	5 2 1	16.6	23.4
2 1 2	17.6	5.1	5 2 2	16.7	25.6
2 1 3	17.6	4.7	5 2 3	18.3	21.6
2 2 1	23.5	6.0	6 1 1	20.0	17.7
2 2 2	18.2	8.2	6 1 2	17.5	19.4
2 2 3	22.4	7.1	6 1 3	20.0	22.2
3 1 1	20.0	7.6	6 2 1	17.8	25.6
3 1 2	17.1	9.0	6 2 2	18.8	26.2
3 1 3	16.2	8.8	6 2 3	18.5	27.7
3 2 1	19.0	14.5	7 1 1	18.5	19.2
3 2 2	17.3	15.4	7 1 2	20.0	20.0
3 2 3	16.2	15.5	7 1 3	21.2	23.8
4 1 1	21.5	10.0	7 2 1	20.0	27.5
4 1 2	21.0	10.0	7 2 2	15.7	30.0
4 1 3	17.1	14.3	7 2 3	16.7	36.6

Table 3A.6.2. Relative leaf area and relative light intensity data for 4 cm height intervals.

Treatments:	1	2	3	4	5	6	N, the height interval number
RLA	3RC	9C	15C	HC	3RW	HW	
RLI	-	9C	15C	HC	15W	HW	

** 0.0 is a non-exist value for that variable.

T	R	N	RLA	RLI	T	R	N	RLA	RLI
1	1	1	.90	0.00	4	1	1	9.50	17.30
1	1	2	4.70	0.00	4	1	2	23.60	33.90
1	1	3	21.00	0.00	4	1	3	40.60	55.20
1	1	4	35.80	0.00	4	1	4	62.80	69.50
1	1	5	70.80	0.00	4	1	5	72.60	73.10
1	1	6	94.00	0.00	4	1	6	83.80	88.30
1	1	7	100.00	0.00	4	1	7	96.50	97.90
1	2	1	1.00	0.00	4	1	8	100.00	100.00
1	2	2	4.80	0.00	4	2	1	13.60	11.70
1	2	3	13.90	0.00	4	2	2	33.20	24.60
1	2	4	28.80	0.00	4	2	3	45.20	36.40
1	2	5	59.50	0.00	4	2	4	67.40	52.70
1	2	6	80.30	0.00	4	2	5	93.70	80.60
1	2	7	100.00	0.00	4	2	6	98.40	93.10
1	3	1	3.70	0.00	4	2	7	100.00	100.00
1	3	2	7.70	0.00	4	3	1	9.20	13.60
1	3	3	19.50	0.00	4	3	2	24.20	18.20
1	3	4	36.80	0.00	4	3	3	38.80	32.10
1	3	5	64.70	0.00	4	3	4	70.10	63.80
1	3	6	86.00	0.00	4	3	5	88.70	91.30
1	3	7	96.30	0.00	4	3	6	95.00	99.40
1	3	8	100.00	0.00	4	3	7	100.00	100.00
2	1	1	0.00	3.90	5	1	1	.40	1.40
2	1	2	1.60	8.40	5	1	2	1.80	3.90
0	0	0	6.30	17.50	5	1	3	8.10	12.50
2	1	4	15.20	27.40	5	1	4	25.20	22.90
2	1	5	29.10	37.40	5	1	5	51.80	52.60
2	1	6	57.00	76.70	5	1	6	84.30	78.80
2	1	7	83.60	88.60	5	1	7	100.00	89.90
2	1	8	96.40	99.20	5	1	8	0.00	98.80
2	1	9	100.00	100.00	5	1	9	0.00	100.00
2	2	1	0.00	4.30	5	2	1	0.00	5.80
2	2	2	4.50	9.70	5	2	2	.20	6.20
2	2	3	11.50	15.70	5	2	3	2.30	18.30
2	2	4	24.80	45.70	5	2	4	10.00	46.00
2	2	5	37.30	71.40	5	2	5	26.10	61.50
2	2	6	54.20	92.00	5	2	6	46.00	84.60
2	2	7	75.00	95.90	5	2	7	72.40	94.90
2	2	8	77.50	97.40	5	2	8	97.00	98.60
2	2	9	97.00	100.00	5	2	9	100.00	100.00
2	2	0	100.00	0.00	5	3	1	0.00	3.40
2	3	1	5.40	0.00	5	3	2	1.00	7.70
2	3	2	13.70	0.00	5	3	3	2.80	18.40
2	3	3	24.20	0.00	5	3	4	8.80	43.60
2	3	4	42.90	0.00	5	3	5	27.80	84.40
2	3	5	68.80	0.00	5	3	6	54.30	94.40

/3A.6.2.

Table 3A.6.2. cont.

T R N	RLA	RLI
2 3 6	83.70	0.00
2 3 7	98.90	0.00
2 3 8	100.00	0.00
3 1 1	0.00	3.80
3 1 2	9.00	7.70
3 1 3	21.60	28.20
3 1 4	34.00	44.30
3 1 5	53.50	55.30
3 1 6	75.00	73.30
3 1 7	85.40	79.90
3 1 8	94.20	91.80
3 1 9	100.00	100.00
3 2 1	0.00	5.80
3 2 2	6.30	16.20
3 2 3	18.60	24.10
3 2 4	38.20	46.10
3 2 5	52.70	62.30
3 2 6	66.60	79.40
3 2 7	79.00	90.40
3 2 8	96.40	97.90
3 2 9	100.00	100.00
3 3 1	0.00	10.90
3 3 2	15.[illegible]	32.30
3 3 3	3.[illegible]	48.30
3 3 4	54.40	66.40
3 3 5	81.30	92.70
3 3 6	90.50	97.30
3 3 7	96.00	100.00
3 3 8	98.00	0.00
3 3 9	100.00	0.00

T R N	RLA	RLI
5 3 7	82.70	98.20
5 3 8	97.00	100.00
5 3 9	100.00	0.00
6 1 1	0.00	1.50
6 1 2	4.70	10.60
6 1 3	10.30	20.00
6 1 4	20.20	37.60
0 0 0	35.10	53.10
6 1 6	44.10	86.30
6 1 7	62.30	97.90
6 1 8	79.20	100.00
6 1 9	88.80	0.00
6 1 0	100.00	0.00
6 2 1	0.00	1.60
6 2 2	5.50	5.70
0 0 0	6.60	14.50
6 2 4	28.50	38.30
6 2 5	36.50	70.60
6 2 6	45.50	96.40
6 2 7	53.70	100.00
6 2 8	88.60	0.00
6 2 9	97.40	0.00
6 2 0	100.00	0.00
6 3 1	0.00	.20
6 3 2	7.40	2.80
6 3 3	16.90	9.10
6 3 4	24.[illegible]	30.80
6 3 5	40.[illegible]	53.30
6 3 6	53.00	87.70
6 3 7	76.10	96.20
6 3 8	89.40	100.00
6 3 9	100.00	90.00

Table 3A.7.1. The mid-winter organic reserve data. (One harvest only)
T Treatments, 3R and H

H	V	T	R	ROOT TNC PERCENT	CROWN TNC PERCENT	ROOT TN PERCENT	CROWN TN PERCENT	ROOT WEIGHT	CROWN WEIGHT
1	1	1	1	24.50	14.50	1.98	1.81	8.60	3.80
1	1	1	2	22.50	15.50	2.07	1.80	13.80	4.37
1	1	1	3	21.50	13.50	2.08	1.74	14.31	6.10
1	1	2	1	25.00	13.50	2.82	1.70	34.00	10.46
1	1	2	2	26.00	16.00	2.35	2.38	29.20	11.68
1	1	2	3	24.00	16.50	2.22	2.34	21.74	6.90
1	2	1	1	22.00	12.50	1.92	1.83	11.12	5.90
1	2	1	2	22.00	16.50	2.20	1.92	12.19	5.10
1	2	1	3	25.00	16.50	2.16	1.85	10.21	3.68
1	2	2	1	21.50	12.00	2.07	1.78	15.60	6.46
1	2	2	2	27.50	16.00	2.33	1.94	29.50	12.40
1	2	2	3	23.00	15.00	2.08	2.16	42.30	15.80

H	V	T	R	RTCR WEIGHT	TOTAL TNC PERCENT	TOTAL TN PERCENT	CROWN TNC WEIGHT	ROOT TNC WEIGHT	RTCR TNC WEIGHT
1	1	1	1	12.40	21.43	1.92	2.10	.55	2.65
1	1	1	2	18.17	20.81	2.00	3.10	.67	3.78
1	1	1	3	20.41	19.10	1.97	3.07	.82	3.90
1	1	2	1	44.46	22.29	2.55	8.50	1.41	9.91
1	1	2	2	40.88	23.14	2.35	7.59	1.86	9.46
1	1	2	3	28.64	22.19	2.24	5.21	1.13	6.35
1	2	1	1	17.02	18.70	1.88	2.44	.73	3.18
1	2	1	2	17.29	20.37	2.11	2.68	.84	3.52
1	2	1	3	13.89	22.74	2.07	2.55	.60	3.15
1	2	2	1	22.06	18.71	1.98	3.35	.77	4.12
1	2	2	2	41.90	24.09	2.21	8.11	1.98	10.09
1	2	2	3	58.10	20.82	2.10	9.72	2.37	12.09

H	V	T	R	CROWN TN WEIGHT	ROOT TN WEIGHT	RTCR TN WEIGHT	CROWN C/N RATIO	ROOT C/N RATIO	RTCR C/N RATIO
1	1	1	1	.28	.07	.36	10.86	8.61	10.38
1	1	1	2	.17	.06	.23	12.37	8.01	11.11
1	1	1	3	.29	.10	.40	10.33	7.75	9.65
1	1	2	1	.68	.27	.96	11.06	6.72	9.81
1	1	2	2	.95	.17	1.13	8.86	7.94	8.72
1	1	2	3	.48	.16	.64	10.81	7.05	9.86

/3A.7.1.

Table 3A.7.1. cont.

1 2 1 1	.26	.09	.36	10.00	8.59	9.62
1 2 1 2	.21	.10	.32	11.45	6.83	9.90
1 2 1 3	.22	.06	.28	11.57	8.91	10.94
1 2 2 1	.68	.24	.92	11.80	8.24	10.88
1 2 2 2	.32	.11	.43	10.38	6.74	9.42
1 2 2 3	.87	.34	1.22	11.05	6.94	9.90

Table 3A.7.2. Organic reserve data from weekly harvests during the spring.

Treatments 3R and H Harvests 1 to 9

H V T R	ROOT TNC PERCENT	CROWN TNC PERCENT	ROOT TN PERCENT	CROWN TN PERCENT	ROOT WEIGHT	CROWN WEIGHT
2 1 1 1	25.50	13.00	2.22	2.42	12.10	5.40
2 1 1 2	20.00	11.00	1.97	2.48	12.45	6.10
2 1 1 3	21.50	13.00	1.94	2.46	13.15	5.30
2 1 2 1	22.00	13.00	2.94	3.02	17.00	8.75
2 1 2 2	21.50	13.00	2.84	2.92	29.85	13.40
2 1 2 3	23.00	13.00	2.95	2.44	17.60	6.60
2 2 1 1	21.00	11.50	2.36	2.67	8.65	4.40
2 2 1 2	15.00	10.00	1.77	2.26	14.70	6.30
2 2 1 3	21.00	12.00	2.06	2.50	15.80	8.40
2 2 2 1	18.50	11.50	2.68	3.22	30.45	28.15
2 2 2 2	22.00	12.00	2.27	2.74	55.15	31.10
2 2 2 3	21.00	12.00	3.02	2.92	23.10	13.60
3 1 1 1	20.50	9.80	1.71	2.45	8.15	4.05
3 1 1 2	19.50	9.80	1.80	2.45	8.00	4.10
3 1 1 3	20.50	9.80	1.57	2.45	16.00	7.73
3 1 2 1	18.00	10.90	2.82	2.71	19.40	11.00
3 1 2 2	25.00	10.90	2.62	2.71	22.10	11.25
3 1 2 3	20.00	10.90	2.58	2.71	25.60	16.35
3 2 1 1	18.00	9.80	1.76	2.49	10.25	7.80
3 2 1 2	17.50	9.80	1.62	2.49	9.60	4.55
3 2 1 3	17.50	9.80	1.96	2.49	15.35	10.20
3 2 2 1	22.50	10.50	2.34	2.70	19.40	24.20
3 2 2 2	23.50	10.50	2.58	2.70	22.10	23.00
3 2 2 3	22.00	10.50	2.72	2.70	25.60	19.10
4 1 1 1	17.00	8.50	1.82	2.42	12.50	7.40
4 1 1 2	16.50	8.50	1.37	2.16	13.20	6.25
4 1 1 3	20.00	10.00	1.90	2.26	11.05	6.75

/3A.7.2.

Table 3A.7.2. cont.

H V T R	ROOT TNC PERCENT	CROWN TNC PERCENT	ROOT TN PERCENT	CROWN TN PERCENT	ROOT WEIGHT	CROWN WEIGHT
4 1 2 1	12.00	10.00	2.60	2.47	24.60	18.75
4 1 2 2	19.00	10.50	2.22	2.24	20.05	15.00
4 1 2 3	17.00	11.00	2.72	2.64	34.10	31.45
4 2 1 1	18.50	10.00	1.94	2.45	9.05	6.20
4 2 1 2	15.00	10.50	1.85	2.32	6.25	4.40
4 2 1 3	17.00	10.00	1.78	2.26	17.60	12.20
4 2 2 1	19.50	9.50	2.02	2.38	2.10	7.45
4 2 2 2	14.00	9.00	1.77	2.04	23.70	13.80
4 2 2 3	17.50	10.50	2.30	2.35	19.65	11.70
5 1 1 1	12.00	9.00	1.77	2.28	13.60	7.65
5 1 1 2	12.50	10.00	1.58	2.12	10.00	7.30
5 1 1 3	18.50	9.25	1.67	2.38	12.30	6.70
5 1 2 1	17.00	9.50	2.18	2.46	26.45	23.70
5 1 2 2	14.00	10.00	2.23	2.48	23.85	17.05
5 1 2 3	16.00	10.00	2.56	2.45	21.65	14.50
5 2 1 1	14.00	10.00	1.52	1.92	15.10	9.70
5 2 1 2	15.50	10.50	1.66	2.24	11.70	8.20
5 2 1 3	9.50	9.50	2.16	2.46	12.70	5.80
5 2 2 1	14.50	10.00	2.22	2.58	16.40	16.10
5 2 2 2	19.00	11.50	2.44	2.62	16.10	11.20
5 2 2 3	14.00	10.50	1.97	2.78	12.50	14.20
6 1 1 1	15.00	10.50	1.78	2.12	14.00	7.40
6 1 1 2	13.50	9.00	1.60	1.96	13.75	9.40
6 1 1 3	15.50	11.00	1.55	1.94	13.15	7.25
6 1 2 1	10.50	9.50	2.30	2.32	23.30	29.50
6 1 2 2	13.50	13.50	2.34	2.32	23.10	13.70
6 1 2 3	14.00	10.50	2.64	2.50	34.15	24.10
6 2 1 1	13.50	9.50	1.57	1.94	11.45	8.60
6 2 1 2	13.00	9.00	1.26	2.28	12.60	9.30
6 2 1 3	14.00	9.50	1.40	2.02	9.55	6.50
6 2 2 1	15.00	9.50	2.13	2.44	24.50	18.75
6 2 2 2	16.00	11.00	2.06	2.54	32.40	29.75
6 2 2 3	15.50	9.50	2.16	2.22	22.90	19.00
7 1 1 1	19.50	12.50	1.64	1.92	11.00	6.30
7 1 1 2	16.00	10.00	1.25	1.32	10.55	7.50
7 1 1 3	24.00	14.00	1.38	1.72	13.20	7.75

/3A.7.2.

Table 3A.7.2. cont.

H V T R	ROOT TNC PERCENT	CROWN TNC PERCENT	ROOT TN PERCENT	CROWN TN PERCENT	ROOT WEIGHT	CROWN WEIGHT
7 1 2 1	13.00	8.50	2.36	2.36	13.65	10.10
7 1 2 2	19.00	9.50	2.58	2.38	30.70	27.45
7 1 2 3	19.00	9.50	2.60	2.37	24.10	14.90
7 2 1 1	16.50	11.50	1.55	1.80	6.90	5.60
7 2 1 2	12.00	8.50	1.30	1.85	12.75	7.75
7 2 1 3	16.00	9.00	1.59	2.05	12.50	9.55
7 2 2 1	15.00	8.00	2.50	2.40	17.75	15.65
7 2 2 2	13.00	8.00	2.10	2.06	26.90	28.15
7 2 2 3	17.00	9.50	1.90	2.28	22.14	13.44
8 1 1 1	23.00	15.00	1.48	1.82	9.00	3.10
8 1 1 2	23.00	11.00	1.20	1.76	13.50	6.70
8 1 1 3	23.00	15.00	1.48	1.72	11.70	6.00
8 1 2 1	13.00	10.50	2.02	2.30	19.90	12.25
8 1 2 2	14.50	7.50	2.40	2.02	22.00	17.15
8 1 2 3	15.50	13.00	2.33	2.36	26.90	16.00
8 2 1 1	19.50	12.00	1.13	1.53	10.50	6.00
8 2 1 2	17.00	11.00	1.24	1.82	10.90	6.85
8 2 1 3	11.50	11.50	1.24	1.74	12.00	9.00
8 2 2 1	17.50	11.00	2.00	2.06	24.40	18.10
8 2 2 2	13.00	12.00	2.10	2.37	32.40	36.80
8 2 2 3	16.50	9.50	1.98	2.40	19.50	17.30
9 1 1 1	23.50	12.50	1.70	1.82	12.75	6.90
9 1 1 2	23.00	16.00	1.18	1.60	12.20	6.20
9 1 1 3	23.50	16.50	1.36	1.85	13.00	7.00
9 1 2 1	17.50	11.00	2.06	2.24	16.60	7.60
9 1 2 2	16.50	9.00	1.94	2.12	30.65	19.90
9 1 2 3	18.00	10.50	2.36	2.32	31.30	24.50
9 2 1 1	19.50	16.50	1.40	1.74	13.20	7.50
9 2 1 2	15.00	12.50	1.28	1.72	15.10	10.05
9 2 1 3	18.00	14.00	1.45	1.98	11.10	6.40
9 2 2 1	15.00	12.50	2.34	2.28	16.20	14.45
9 2 2 2	14.50	10.00	1.83	2.00	40.20	29.00
9 2 2 3	18.50	9.50	1.78	2.02	26.45	15.55

/3A.7.2.

Table 3A.7.2. cont.

H V T R	RTCR WEIGHT	TOTAL TNC PERCENT	TOTAL TN PERCENT	ROOT TNC WEIGHT	CROWN TNC WEIGHT	TOTAL TNC WEIGHT
2 1 1 1	17.50	21.64	2.28	3.08	.70	3.78
2 1 1 2	18.55	17.04	2.13	2.49	.67	3.16
2 1 1 3	18.45	19.05	2.08	2.82	.68	3.51
2 1 2 1	25.75	18.94	2.96	3.74	1.13	4.87
2 1 2 2	43.25	18.86	2.86	6.41	1.74	8.15
2 1 2 3	24.20	20.27	2.81	4.04	.85	4.90
2 2 1 1	13.05	17.79	2.46	1.81	.50	2.32
2 2 1 2	21.00	13.50	1.91	2.20	.63	2.83
2 2 1 3	24.20	17.87	2.21	3.31	1.00	4.32
2 2 2 1	58.60	15.13	2.93	5.63	3.23	8.87
2 2 2 2	86.25	18.39	2.43	12.13	3.73	15.86
2 2 2 3	36.70	17.66	2.98	4.85	1.63	6.48
3 1 1 1	12.20	16.95	1.96	1.67	.39	2.06
3 1 1 2	12.10	16.21	2.02	1.56	.40	1.96
3 1 1 3	23.73	17.01	1.85	3.28	.75	4.03
3 1 2 1	30.40	15.43	2.78	3.49	1.19	4.69
3 1 2 2	33.[illegible]	20.24	2.65	5.52	1.22	6.75
3 1 2 3	41.95	16.45	2.63	5.12	1.78	6.90
3 2 1 1	18.05	14.45	2.07	1.84	.76	2.60
3 2 1 2	14.15	15.02	1.89	1.68	.44	2.12
3 2 1 3	25.55	14.42	2.17	2.68	.99	3.68
3 2 2 1	43.60	15.83	2.53	4.36	2.54	6.90
3 2 2 2	45.10	16.87	2.64	5.19	2.41	7.60
3 2 2 3	44.70	17.08	2.71	5.63	2.00	7.63
4 1 1 1	19.90	13.83	2.04	2.12	.62	2.75
4 1 1 2	19.45	13.92	1.62	2.17	.53	2.70
4 1 1 3	17.80	16.20	2.03	2.21	.67	2.88
4 1 2 1	43.35	11.13	2.54	2.95	1.87	4.82
4 1 2 2	35.05	15.36	2.22	3.80	1.57	5.38
4 1 2 3	65.55	14.12	2.68	5.79	3.45	9.25
4 2 1 1	15.25	15.04	2.14	1.67	.62	2.29
4 2 1 2	10.65	13.14	2.04	.93	.46	1.39
4 2 1 3	29.80	14.13	1.97	2.99	1.22	4.21
4 2 2 1	9.55	11.69	2.30	.40	.70	1.11
4 2 2 2	37.50	12.16	1.86	3.31	1.24	4.56
4 2 2 3	31.35	14.88	2.31	3.43	1.22	4.66
5 1 1 1	21.25	10.92	1.95	1.63	.68	2.32
5 1 1 2	17.30	11.44	1.80	1.25	.73	1.98
5 1 1 3	19.00	15.23	1.92	2.27	.61	2.89

/3A.7.2.

Table 3A.7.2. cont.

H	V	T	R	RTCR WEIGHT	TOTAL TNC PERCENT	TOTAL TN PERCENT	ROOT TNC WEIGHT	CROWN TNC WEIGHT	TOTAL TNC WEIGHT
5	1	2	1	50.15	13.45	2.31	4.49	2.25	6.74
5	1	2	2	40.90	12.33	2.33	3.33	1.70	5.04
5	1	2	3	36.15	13.59	2.51	3.46	1.45	4.91
5	2	1	1	24.80	12.43	1.67	2.11	.97	3.08
5	2	1	2	17.90	13.76	1.87	1.81	.65	2.46
5	2	1	3	18.50	9.50	2.26	1.20	.55	1.75
5	2	2	1	32.50	12.27	2.39	2.37	1.61	3.98
5	2	2	2	27.30	15.92	2.51	3.05	1.28	4.34
5	2	2	3	26.70	12.13	2.40	1.75	1.49	3.24
6	1	1	1	21.40	13.44	1.89	2.10	.77	2.87
6	1	1	2	23.15	11.67	1.74	1.85	.84	2.70
6	1	1	3	20.40	13.90	1.68	2.03	.79	2.83
6	1	2	1	52.80	9.94	2.31	2.44	2.80	5.24
6	1	2	2	36.80	13.50	2.33	3.11	1.84	4.96
6	1	2	3	58.25	12.55	2.58	4.78	2.53	7.31
6	2	1	1	20.05	11.78	1.72	1.54	.81	2.36
6	2	1	2	21.90	11.30	1.69	1.63	.83	2.47
6	2	1	3	16.05	12.17	1.65	1.33	.61	1.95
6	2	2	1	43.25	12.61	2.26	3.67	1.78	5.45
6	2	2	2	62.15	13.60	2.28	5.18	3.27	8.45
6	2	2	3	41.90	12.77	2.18	3.54	1.80	5.35
7	1	1	1	17.30	16.95	1.74	2.14	.78	2.93
7	1	1	2	18.05	13.50	1.27	1.68	.75	2.43
7	1	1	3	20.95	20.30	1.50	3.16	1.08	4.25
7	1	2	1	23.75	11.08	2.36	1.77	.85	2.63
7	1	2	2	58.15	14.51	2.48	5.83	2.60	8.44
7	1	2	3	39.00	15.37	2.51	4.57	1.41	5.99
7	2	1	1	12.50	14.26	1.66	1.13	.64	1.78
7	2	1	2	20.50	10.67	1.50	1.53	.65	2.18
7	2	1	3	22.05	12.96	1.78	2.00	.85	2.85
7	2	2	1	33.40	11.72	2.45	2.66	1.25	3.91
7	2	2	2	55.05	10.44	2.07	3.49	2.25	5.74
7	2	2	3	35.58	14.16	2.04	3.76	1.27	5.04
8	1	1	1	12.10	20.95	1.56	2.07	.46	2.53
8	1	1	2	20.20	19.01	1.38	3.10	.73	3.84
8	1	1	3	17.70	20.28	1.56	2.69	.90	3.59
8	1	2	1	32.15	12.04	2.12	2.58	1.28	3.87
8	1	2	2	39.15	11.43	2.23	3.19	1.28	4.47
8	1	2	3	42.90	14.56	2.34	4.16	2.08	6.24

/3A.7.2.

Table 3A.7.2. cont.

H V T R	RTCR WEIGHT	TOTAL TNC PERCENT	TOTAL TN PERCENT	ROOT TNC WEIGHT	CROWN TNC WEIGHT	TOTAL TNC WEIGHT
8 2 1 1	16.50	16.77	1.27	2.04	.72	2.76
8 2 1 2	17.75	14.68	1.46	1.85	.75	2.60
8 2 1 3	21.00	11.50	1.45	1.38	1.03	2.41
8 2 2 1	42.50	14.73	2.02	4.27	1.99	6.26
8 2 2 2	69.20	12.46	2.24	4.21	4.41	8.62
8 2 2 3	36.80	13.20	2.17	3.21	1.64	4.86
9 1 1 1	19.65	19.63	1.74	2.99	.86	3.85
9 1 1 2	18.40	20.64	1.32	2.80	.99	3.79
9 1 1 3	20.00	21.05	1.53	3.05	1.15	4.21
9 1 2 1	24.20	15.45	2.11	2.90	.83	3.74
9 1 2 2	50.55	13.54	2.01	5.05	1.79	6.84
9 1 2 3	55.80	14.70	2.34	5.63	2.57	8.20
9 2 1 1	20.70	18.41	1.52	2.57	1.23	3.81
9 2 1 2	25.15	14.00	1.45	2.26	1.25	3.52
9 2 1 3	17.50	16.53	1.64	1.99	.89	2.89
9 2 2 1	30.65	13.82	2.31	2.43	1.80	4.23
9 2 2 2	69.20	12.61	1.90	5.82	2.90	8.72
9 2 2 3	42.00	15.16	1.86	4.89	1.47	6.37

H V T R	ROOT TN WEIGHT	CROWN TN WEIGHT	TOTAL TN WEIGHT	ROOT C/N RATIO	CROWN C/N RATIO	TOTAL C/N RATIO
2 1 1 1	.24	.15	.39	10.15	4.43	7.97
2 1 1 2	.26	.13	.39	11.48	5.37	9.48
2 1 1 3	.25	.13	.38	11.08	5.28	9.12
2 1 2 1	.84	.39	1.23	7.57	4.45	6.58
2 1 2 2	.49	.26	.76	7.48	4.30	6.38
2 1 2 3	.51	.16	.68	7.79	5.32	7.21
2 2 1 1	.26	.14	.40	8.47	4.42	7.04
2 2 1 2	.20	.11	.32	8.89	4.30	7.22
2 2 1 3	.32	.21	.53	10.19	4.80	8.07
2 2 2 1	1.25	.85	2.10	9.69	4.37	7.54
2 2 2 2	.81	.90	1.72	6.90	3.57	5.14
2 2 2 3	.69	.39	1.09	6.95	4.10	5.92
3 1 1 1	.13	.10	.23	11.95	4.00	8.66
3 1 1 2	.17	.09	.27	18.98	4.00	13.53
3 1 1 3	.25	.18	.44	13.05	4.00	9.16

/3A.7.2.

Table 3A.7.2.

H	V	T	R	ROOT TN WEIGHT	CROWN TN WEIGHT	TOTAL TN WEIGHT	ROOT C/N RATIO	CROWN C/N RATIO	TOTAL C/N RATIO
3	1	2	1	.57	.30	.88	9.54	4.02	7.63
3	1	2	2	.54	.29	.84	6.38	4.02	5.55
3	1	2	3	.66	.44	1.10	7.75	4.02	6.25
3	2	1	1	.15	.11	.26	10.80	3.93	7.90
3	2	1	2	.18	.19	.37	10.22	3.93	6.96
3	2	1	3	.30	.25	.55	8.92	3.93	6.64
3	2	2	1	.57	.62	1.19	9.10	3.88	6.38
3	2	2	2	.45	.65	1.10	9.61	3.88	6.23
3	2	2	3	.69	.51	1.21	8.08	3.88	6.30
4	1	1	1	.18	.13	.31	12.04	3.93	8.57
4	1	1	2	.22	.17	.40	9.34	3.51	6.77
4	1	1	3	.20	.15	.36	10.52	4.42	7.95
4	1	2	1	.44	.33	.78	8.55	4.68	6.89
4	1	2	2	.63	.46	1.10	4.61	4.04	4.37
4	1	2	3	.92	.83	1.75	6.25	4.16	5.26
4	2	1	1	.11	.10	.21	8.10	4.52	6.42
4	2	1	2	.17	.15	.32	9.53	4.08	7.00
4	2	1	3	.31	.27	.58	9.55	4.42	7.15
4	2	2	1	.41	.28	.70	7.90	4.41	6.50
4	2	2	2	.04	.17	.21	9.65	3.99	5.08
4	2	2	3	.45	.27	.72	7.60	4.46	6.42
5	1	1	1	.15	.15	.31	7.91	4.71	6.33
5	1	1	2	.24	.17	.41	6.77	3.94	5.58
5	1	1	3	.20	.15	.36	11.07	3.88	7.93
5	1	2	1	.53	.42	.95	6.27	4.03	5.28
5	1	2	2	.57	.58	1.15	7.79	3.86	5.81
5	1	2	3	.55	.35	.90	6.25	4.08	5.40
5	2	1	1	.19	.13	.33	9.22	4.68	7.34
5	2	1	2	.22	.18	.41	9.21	5.20	7.41
5	2	1	3	.27	.14	.41	4.39	3.83	4.20
5	2	2	1	.39	.29	.68	7.78	4.38	6.33
5	2	2	2	.36	.41	.77	6.53	3.87	5.11
5	2	2	3	.24	.39	.64	7.10	3.77	5.05
6	1	1	1	.22	.18	.40	8.43	4.59	6.68
6	1	1	2	.24	.15	.40	8.42	4.95	7.08
6	1	1	3	.20	.14	.34	10.00	5.67	8.23
6	1	2	1	.54	.31	.85	5.76	5.81	5.78
6	1	2	2	.53	.68	1.22	4.56	4.09	4.30
6	1	2	3	.90	.60	1.50	5.30	4.20	4.86

/3A.7.2.

Table 3A.7.2. cont.

H V T R	ROOT TN WEIGHT	CROWN TN WEIGHT	TOTAL TN WEIGHT	ROOT C/N RATIO	CROWN C/N RATIO	TOTAL C/N RATIO
6 2 1 1	.15	.21	.37	10.31	3.94	6.67
6 2 1 2	.17	.16	.34	8.59	4.89	6.81
6 2 1 3	.13	.13	.26	10.00	4.70	7.37
6 2 2 1	.66	.75	1.42	7.76	4.33	5.94
6 2 2 2	.52	.45	.97	7.04	3.89	5.57
6 2 2 3	.49	.42	.91	7.17	4.27	5.84
7 1 1 1	.13	.09	.23	12.80	7.57	10.55
7 1 1 2	.18	.12	.30	11.89	6.51	9.73
7 1 1 3	.18	.13	.31	17.39	8.13	13.48
7 1 2 1	.79	.65	1.44	7.36	3.99	5.83
7 1 2 2	.32	.23	.56	5.50	3.60	4.69
7 1 2 3	.62	.35	.97	7.30	4.00	6.11
7 2 1 1	.16	.14	.30	9.23	4.59	7.08
7 2 1 2	.10	.10	.20	10.64	6.38	8.58
7 2 1 3	.19	.19	.39	10.06	4.39	7.24
7 2 2 1	.58	.57	1.14	8.19	3.88	5.02
7 2 2 2	.44	.37	.81	8.00	3.33	4.77
7 2 2 3	.42	.30	.72	8.94	4.16	6.93
8 1 1 1	.16	.11	.27	19.16	6.25	13.72
8 1 1 2	.13	.05	.18	15.54	8.24	13.36
8 1 1 3	.17	.10	.27	15.54	8.72	12.99
8 1 2 1	.52	.34	.87	6.04	3.71	5.11
8 1 2 2	.40	.28	.68	6.43	4.56	5.66
8 1 2 3	.62	.37	1.00	6.65	5.50	6.22
8 2 1 1	.13	.12	.25	13.70	6.04	10.03
8 2 1 2	.11	.09	.21	17.25	7.84	13.15
8 2 1 3	.14	.15	.30	9.27	6.60	7.90
8 2 2 1	.68	.87	1.55	6.19	5.06	5.55
8 2 2 2	.48	.37	.86	8.75	5.33	7.27
8 2 2 3	.38	.41	.80	8.33	3.95	6.06
9 1 1 1	.14	.09	.24	19.49	10.00	15.61
9 1 1 2	.21	.12	.34	13.82	6.86	11.27
9 1 1 3	.17	.12	.30	17.27	8.91	13.74
9 1 2 1	.59	.42	1.01	8.50	4.24	6.73
9 1 2 2	.34	.17	.51	8.49	4.91	7.30
9 1 2 3	.73	.56	1.30	7.62	4.52	6.27
9 2 1 1	.19	.17	.36	11.71	7.26	9.61
9 2 1 2	.18	.13	.31	13.92	9.48	12.08
9 2 1 3	.16	.12	.28	12.41	7.07	10.06

Table 3A.7.3. The treatment comparison organic reserve data.

Treatments

1, 2,

3, 4,

3" and H treatments are part of table 3A.7.4.

H V T R	ROOT TNC PERCENT	CROWN TNC PERCENT	ROOT TN PERCENT	CROWN TN PERCENT	ROOT WEIGHT	CROWN WEIGHT
0 1 1 1	16.00	8.00	1.64	2.00	7.60	4.60
0 1 1 2	16.00	9.00	1.54	2.08	23.25	14.20
0 1 1 3	22.00	9.50	1.80	2.16	10.55	4.60
0 [illegible]	24.00	10.00	2.00	2.32	19.70	13.00
0 1 2 2	24.50	9.50	1.95	2.30	15.90	7.60
0 1 2 3	17.50	8.00	2.11	2.26	30.60	15.80
0 1 4 1	18.13	10.14	1.66	2.14	9.85	9.38
0 1 4 2	18.13	10.14	1.66	2.14	9.85	9.38
0 1 4 3	18.13	10.14	1.66	2.14	9.85	9.38
0 1 3 1	27.00	11.50	1.99	2.27	12.90	9.50
0 1 3 2	20.00	9.50	2.77	2.42	16.65	12.90
0 1 3 3	21.00	11.00	2.02	2.42	17.55	14.15

H V T R	RTCR WEIGHT	TOTAL TNC PERCENT	TOTAL TN PERCENT	ROOT TNC WEIGHT	CROWN TNC WEIGHT	TOTAL TNC WEIGHT
021 1 1	12.20	12.98	1.77	1.21	.36	1.58
021 1 2	37.45	13.34	1.74	3.72	1.27	4.99
021 1 3	15.15	18.20	1.90	2.32	.43	2.75
021 2 1	32.70	18.43	2.12	4.72	1.30	6.02
021 2 2	23.50	19.64	2.06	3.89	.72	4.61
021 2 3	46.40	14.26	2.16	5.35	1.26	6.61
021 4 1	19.23	14.20	1.90	1.78	.95	2.73
021 4 2	19.23	14.20	1.90	1.78	.95	2.73
021 4 3	19.23	14.20	1.90	1.78	.95	2.73
021 3 1	22.40	20.42	2.10	3.48	1.09	4.57
021 3 2	29.55	15.41	2.61	3.33	1.22	4.55
021 3 3	31.70	16.53	2.19	3.68	1.55	5.24

/3A.7.3.

Table 3A.7.3. cont.

H V T R	ROOT TN WEIGHT	CROWN TN WEIGHT	TOTAL TN WEIGHT	ROOT C/N RATIO	CROWN C/N RATIO	TOTAL C/N RATIO
021 1 1	.35	.29	.65	10.38	4.32	7.64
021 1 2	.12	.09	.21	9.75	4.00	7.31
021 1 3	.18	.09	.28	12.22	4.39	9.53
021 2 1	.31	.17	.48	12.56	4.13	9.52
021 2 2	.39	.30	.69	12.00	4.31	8.66
021 2 3	.64	.35	1.00	8.29	3.53	6.60
021 3 1	.46	.31	.77	7.22	3.92	5.89
021 3 2	.25	.21	.47	13.56	5.06	9.68
021 3 3	.35	.34	.69	10.39	4.54	7.52
021 4 1	.16	.20	.36	10.75	4.73	7.50
021 4 2	.16	.20	.36	10.75	4.73	7.50
021 4 3	.16	.20	.36	10.75	4.73	7.50

Table 3A.7.4. The organic reserve data of the plants sampled from beneath the dark covers.

Treatments 1, 3R
2, H

V T R	TNC	TN	PLANT
1 1 1	10.00	2.22	15.30
1 1 2	13.00	2.20	18.40
1 1 3	11.50	1.94	16.25
1 2 1	9.50	2.82	26.20
1 2 2	16.00	2.74	30.20
1 2 3	12.00	2.54	23.60
2 1 1	10.00	2.00	11.20
2 1 2	10.50	2.20	20.55
2 1 3	12.00	2.26	26.75
2 2 1	7.50	2.26	24.65
2 2 2	12.00	2.78	32.10
2 2 3	11.50	2.96	49.90

Table 3A.8.1. Data used for the growth/temperature relationship.
Shoot height growth increment per week for the 15/8 Group on the weekly dates (N), 2, 22/8; 3, 29/8;.....7,26/9.
Initial relative shoot number for groups (N), 1, 15/8; 2, 22/8; 3, 29/8; 4, 5/9.
Temperatures as in text with weekly mean values repeated for each replication.
Treatments, 1, 3RC; 2, 9C; 3, 15C; 4, HC.

T	R	N	SHOOT HT	SHOOT NO	FIELD SUM	FIELD AV	DSIR AV
1	1	1	0.00	15.00	18.70	18.10	20.50
1	1	2	0.00	4.00	18.70	18.10	20.50
1	1	3	0.00	4.00	18.70	18.10	20.50
1	1	4	.90	5.00	18.40	18.10	20.40
1	1	5	.30	1.00	14.90	15.80	16.10
1	1	6	2.70	1.00	19.50	21.60	22.40
1	1	7	6.30	0.00	23.80	25.70	27.70
1	2	1	3.30	0.00	19.90	21.40	22.60
1	2	2	4.50	0.00	21.30	22.90	24.50
1	2	3	.70	12.00	18.40	18.10	20.40
1	2	4	.60	3.00	14.90	15.80	16.10
1	2	5	2.70	10.00	19.50	21.60	22.40
1	2	6	4.30	0.00	23.80	25.70	27.70
1	2	7	3.70	0.00	19.90	21.40	22.60
1	3	1	3.00	0.00	21.30	22.90	24.50
1	3	2	1.20	19.00	18.40	18.10	20.40
1	3	3	.30	4.00	14.90	15.80	16.10
1	3	4	3.30	3.00	19.50	21.60	22.40
1	3	5	5.50	0.00	23.80	25.70	27.70
1	3	6	3.70	0.00	19.90	21.40	22.60
1	3	7	5.30	0.00	21.30	22.90	24.50

T	R	N	SHOOT HT	SHOOT NO	FIELD SUM	FIELD AV	DSIR AV
2	1	1	0.00	11.00	18.70	18.10	20.00
2	1	2	0.00	21.00	18.70	18.10	20.50
2	1	3	0.00	9.00	18.70	18.10	20.50
2	1	4	1.00	18.00	18.40	18.10	20.40
2	1	5	.80	2.00	14.90	15.80	16.10
2	2	1	3.50	12.00	19.50	21.60	22.40
2	2	2	8.90	0.00	23.80	25.70	27.70
2	2	3	1.30	15.00	18.40	18.10	20.40
2	2	4	.70	5.00	14.90	15.80	16.10
2	2	5	3.50	9.00	19.50	21.60	22.40
2	3	1	6.30	0.00	23.80	25.70	27.70
2	3	2	2.30	13.00	18.40	18.10	20.40
2	3	3	1.90	3.00	14.90	15.80	16.10
2	3	4	5.70	13.00	19.50	21.60	22.40
2	3	5	9.00	0.00	23.80	25.70	27.70

/3A.8.1.

Table 3A.8.1. cont.

T	R	N	SHOOT HT	SHOOT NO	FIELD SUM	FIELD AV	DSIR AV
3	1	1	0.00	13.00	18.70	18.10	20.50
3	1	2	0.00	17.00	18.70	18.10	20.50
3	1	3	0.00	7.00	18.70	18.10	20.50
3	1	4	1.40	9.00	18.40	18.10	20.40
3	1	5	1.60	9.00	14.90	15.80	16.10
3	1	6	3.50	12.00	19.50	21.60	22.40
3	1	7	5.60	0.00	23.80	25.70	27.70
3	2	1	7.00	0.00	19.90	21.40	22.60
3	2	2	8.50	0.00	21.30	22.90	24.50
3	2	3	2.50	18.00	18.40	18.10	20.40
3	2	4	.90	5.00	14.90	15.80	16.10
3	2	5	4.40	9.00	19.50	21.60	22.40
3	2	6	8.10	0.00	23.80	25.70	27.70
3	2	7	5.20	0.00	19.90	21.40	22.60
3	3	1	9.20	0.00	21.30	22.90	24.40
3	3	2	1.60	24.00	18.40	18.10	20.40
3	3	3	.70	6.00	14.90	15.80	16.10
3	3	4	2.80	15.00	19.50	21.60	22.40
3	3	5	8.40	0.00	23.80	25.70	27.70
3	3	6	3.20	0.00	19.90	21.40	22.60
3	3	7	5.70	0.00	21.30	22.90	24.40

T	R	N	SHOOT HT	SHOOT NO	FIELD SUM	FIELD AV	DSIR AV
4	1	1	0.00	24.00	18.70	18.10	20.50
4	1	2	0.00	15.00	18.70	18.10	20.50
4	1	3	0.00	7.00	18.70	18.10	20.50
4	1	4	1.30	9.00	18.40	18.10	20.40
4	1	5	1.00	9.00	14.90	15.80	16.10
4	1	6	3.30	15.00	19.50	21.60	22.40
4	1	7	7.70	0.00	23.80	25.70	27.70
4	2	1	7.40	0.00	19.90	21.40	22.60
4	2	2	5.10	0.00	21.30	22.90	24.50
4	2	3	1.30	19.00	18.40	18.10	20.40
4	2	4	.50	1.00	14.90	15.80	16.10
4	2	5	2.30	10.00	19.50	21.60	22.40
4	2	6	10.70	0.00	23.80	25.70	27.70
4	2	7	6.40	0.00	19.90	21.40	22.60
4	3	1	10.10	5.00	21.30	22.90	24.50
4	3	2	2.20	3.00	18.40	18.10	20.40
4	3	3	1.00	26.00	14.90	15.80	16.10
4	3	4	4.30	0.00	19.50	21.60	22.40
4	3	5	7.30	0.00	23.80	25.70	27.70
4	3	6	3.40	0.00	19.90	21.40	22.60
4	3	7	6.80	0.00	21.30	22.90	24.50

Table 3A.9.1. The reversal experiment crop yield and lucerne growth and composition data.

Treatments 1, 3" 2, 3R 3, HR 4, H

V	T	H	R	LUCERNE	OTHER SPECIES	TOTAL	SHOOT	STUBBLE	SHOOT NUMBER	STEM	LEAF
1	1	1	1	4.40	132.58	136.98	1.56	2.84	119.00	1.01	.55
1	1	1	2	5.81	195.10	200.91	1.62	4.19	95.00	.95	.67
1	1	1	3	5.62	151.74	157.36	1.76	3.86	72.00	1.24	.52
1	1	2	1	2.72	148.30	151.02	1.03	1.69	27.00	.67	.36
1	1	2	2	2.92	168.63	171.55	1.97	.95	58.00	.73	1.24
1	1	2	3	8.00	136.96	144.96	4.82	3.18	118.00	2.41	2.41
1	1	3	1	7.44	92.75	100.19	4.90	2.54	121.00	1.78	3.12
1	1	3	2	3.40	127.43	130.83	2.50	.90	50.00	1.05	1.45
1	1	3	3	6.25	115.20	121.45	4.62	1.63	125.00	1.90	2.72
1	2	1	1	5.70	170.36	176.06	1.13	3.44	75.00	.94	.19
1	2	1	2	11.87	129.71	149.58	2.25	7.37	122.00	1.28	.97
1	2	1	3	11.24	138.87	150.11	2.24	9.00	158.00	1.75	.49
1	2	2	1	24.10	170.54	194.64	6.92	17.18	139.00	4.43	2.49
1	2	2	2	13.94	177.07	191.01	6.35	7.59	168.00	3.53	2.82
1	2	2	3	23.87	136.59	160.46	13.69	10.18	262.00	8.27	5.42
1	2	3	1	30.74	112.02	142.76	26.95	3.79	179.00	14.34	12.61
1	2	3	2	23.90	130.48	154.38	20.43	3.47	232.00	10.42	10.01
1	2	3	3	45.86	110.65	156.52	35.92	9.94	281.00	21.73	14.19
1	3	1	1	25.00	123.90	148.90	2.46	22.54	112.00	1.12	1.34
1	3	1	2	15.06	114.93	129.98	3.51	11.55	164.00	2.98	.53
1	3	1	3	6.58	137.09	143.67	2.24	4.34	102.00	1.09	1.15
1	3	2	1	11.39	140.10	151.49	6.28	5.11	100.00	3.06	3.22
1	3	2	2	12.65	136.18	148.83	6.36	6.29	152.00	3.18	3.18
1	3	2	3	10.97	147.87	158.84	5.92	5.05	140.00	2.69	3.23
1	3	3	1	15.59	106.43	122.02	13.32	2.27	254.00	5.84	7.48
1	3	3	2	16.15	115.26	131.40	12.72	3.43	289.00	5.20	7.52
1	3	3	3	29.66	114.70	141.14	22.35	7.31	311.00	9.87	12.48
1	4	1	1	43.71	65.96	109.67	6.63	37.08	307.00	4.35	2.28
1	4	1	2	17.81	61.38	79.19	3.97	13.84	156.00	3.30	.67
1	4	1	3	39.02	69.46	108.48	6.01	33.01	434.00	5.32	.69
1	4	2	1	71.03	89.24	160.28	49.08	21.95	904.00	28.38	20.70
1	4	2	2	64.38	95.17	159.55	34.99	29.39	658.00	19.73	15.26
1	4	2	3	41.37	92.00	133.37	22.97	18.40	472.00	12.88	10.09
1	4	3	1	86.43	64.73	151.16	76.87	9.56	874.00	36.78	40.09
1	4	3	2	75.92	58.97	134.89	65.61	10.31	648.00	33.81	31.80
1	4	3	3	111.08	67.32	178.40	82.93	28.15	1500.00	45.90	37.03

/3A.9.1.

Table 3A.9.1. cont.

V	T	H	R	LUCERNE	OTHER SPECIES	TOTAL	SHOOT	STUBBLE	SHOOT NUMBER	STEM	LEAF
2	1	1	1	6.22	153.36	159.58	1.79	4.43	104.00	1.04	.75
2	1	1	2	8.52	138.22	146.74	3.07	5.45	180.00	2.02	1.05
2	1	1	3	16.91	150.04	166.95	5.30	11.61	391.00	3.28	2.02
2	1	2	1	8.99	153.55	162.53	3.10	5.89	128.00	1.52	1.58
2	1	2	2	7.37	155.22	162.59	4.38	2.99	155.00	2.01	2.37
2	1	2	3	13.53	154.84	168.37	6.92	6.61	238.00	2.89	4.03
2	1	3	1	4.79	133.62	138.41	2.84	1.95	95.00	1.21	1.63
2	1	3	2	13.69	93.28	106.98	10.48	3.21	321.00	4.17	6.31
2	1	3	3	8.92	150.02	158.94	6.23	2.69	180.00	2.40	3.83
2	2	1	1	12.35	221.32	233.68	.52	11.83	46.00	.46	.06
2	2	1	2	34.91	113.64	148.55	4.31	30.60	253.00	3.57	.74
2	2	1	3	61.32	111.46	172.78	8.55	52.77	573.00	7.28	1.27
2	2	2	1	14.80	164.41	179.21	6.28	8.52	208.00	3.88	2.40
2	2	2	2	28.31	146.23	174.54	11.17	17.14	310.00	6.96	4.21
2	2	2	3	43.86	104.89	148.83	22.12	21.74	527.00	11.71	10.41
2	2	3	1	30.35	133.23	163.58	22.95	7.40	370.00	12.40	10.55
2	2	3	2	26.91	174.10	198.89	22.24	4.68	456.00	11.52	10.41
2	2	3	3	36.50	112.86	146.82	28.08	8.42	491.00	11.62	16.46
2	3	1	1	16.51	119.51	136.08	8.72	7.75	401.00	5.30	3.49
2	3	1	2	24.95	89.29	114.24	5.42	19.53	358.00	3.90	1.52
2	3	1	3	24.45	99.60	124.01	13.38	11.07	585.00	7.72	5.66
2	3	2	1	40.52	105.88	146.40	21.46	19.06	754.00	10.73	10.73
2	3	2	2	28.99	134.63	163.62	14.84	14.15	809.00	7.42	7.42
2	3	2	3	33.63	111.93	145.56	20.02	13.61	720.00	9.29	10.73
2	3	3	1	25.88	143.00	168.88	21.34	4.54	580.00	8.17	13.17
2	3	3	2	33.82	134.31	168.13	26.58	7.24	641.00	11.83	14.75
2	3	3	3	35.47	114.53	150.00	27.49	7.98	709.00	11.23	16.26
2	4	1	1	45.78	53.73	99.51	8.81	36.97	398.00	5.48	3.33
2	4	1	2	31.02	78.44	109.46	2.88	28.14	202.00	2.16	.72
2	4	1	3	60.82	69.98	130.80	6.20	54.62	319.00	4.16	2.04
2	4	2	1	27.99	149.86	177.85	11.44	16.55	397.00	6.44	5.00
2	4	2	2	62.72	131.41	194.13	38.71	24.01	969.00	20.03	18.68
2	4	2	3	72.86	138.92	211.78	38.90	33.96	895.00	19.45	19.45
2	4	3	1	67.22	64.25	131.47	54.05	13.17	532.00	27.63	26.42
2	4	3	2	108.33	67.42	175.74	78.68	29.65	874.00	38.23	40.45
2	4	3	3	76.70	143.22	219.92	66.64	10.06	617.00	33.32	33.32

Table 3A.9.2. The reversal experiment organic reserve data.

Treatments 1, 3" 2, 3R
3, HR 4, H

H	V	T	R	ROOT TNC PERCENT	CROWN TNC PERCENT	ROOT TN PERCENT	CROWN TN PERCENT	ROOT WEIGHT	CROWN WEIGHT
0	1	1	1	10.00	8.50	1.45	1.86	9.70	6.25
0	1	1	2	13.00	7.00	1.71	2.04	4.90	3.00
0	1	1	3	11.00	7.50	1.62	1.95	13.50	8.55
0	1	2	1	36.00	20.00	1.78	2.17	23.45	7.00
0	1	2	2	28.00	17.00	1.72	2.12	12.70	5.70
0	1	2	3	36.00	22.00	1.84	2.12	22.90	7.50
0	1	3	1	9.00	9.00	2.33	2.29	11.45	10.80
0	1	3	2	9.00	6.50	2.17	2.46	15.55	10.25
0	1	3	3	8.50	6.50	2.49	2.44	15.00	10.75
0	1	4	1	27.00	11.50	2.79	3.13	23.00	13.20
0	1	4	2	29.50	13.50	2.29	2.68	32.35	16.75
0	1	4	3	27.00	15.50	2.68	2.68	29.70	18.55
0	2	1	1	15.00	10.50	1.54	1.90	5.15	3.50
0	2	1	2	12.50	9.00	1.44	1.92	9.30	5.80
0	2	1	3	12.50	8.50	1.46	1.84	9.50	7.05
0	2	2	1	22.50	14.00	1.56	2.21	17.50	10.35
0	2	2	2	29.50	16.00	1.96	2.44	12.10	5.85
0	2	2	3	30.00	16.00	2.02	2.54	25.30	14.30
0	2	3	1	11.00	7.50	2.10	2.17	25.00	27.55
0	2	3	2	13.50	8.50	1.74	2.10	18.10	16.40
0	2	3	3	11.00	7.00	2.12	1.98	18.30	21.60
0	2	4	1	25.50	16.50	2.47	2.98	17.55	15.00
0	2	4	2	25.50	12.50	2.44	2.71	27.70	26.40
0	2	4	3	25.50	14.00	2.50	3.12	27.70	22.50

/3A.9.2.

Table 3A.9.2. cont.

H V T R	RTCR WEIGHT	TOTAL TNC PERCENT	TOTAL TN PERCENT	ROOT TNC WEIGHT	CROWN TNC WEIGHT	TOTAL TNC WEIGHT
011 1 1	15.95	9.41	1.61	.97	.53	1.50
011 1 2	7.90	10.72	1.83	.63	.21	.84
011 1 3	22.05	9.64	1.74	1.48	.64	2.12
011 2 1	30.45	32.32	1.86	8.44	1.40	9.84
011 2 2	18.40	24.59	1.84	3.55	.96	4.52
011 2 3	30.40	32.54	1.90	8.24	1.65	9.89
011 3 1	22.25	9.00	2.31	1.03	.97	2.00
011 3 2	25.80	8.00	2.28	1.39	.66	2.06
011 3 3	25.75	7.66	2.46	1.27	.69	1.97
011 4 1	36.20	21.34	2.91	6.21	1.51	7.72
011 4 2	49.10	24.04	2.41	9.54	2.26	11.80
011 4 3	48.25	22.57	2.68	8.01	2.87	10.89
012 1 1	8.65	13.17	1.68	.77	.36	1.14
012 1 2	15.10	11.15	1.62	1.16	.52	1.68
012 1 3	16.85	10.79	1.62	1.18	.59	1.78
012 2 1	27.85	19.34	1.80	3.93	1.44	5.38
012 2 2	17.95	25.10	2.11	3.56	.93	4.50
012 2 3	39.60	24.94	2.20	7.59	2.28	9.87
012 3 1	52.55	9.16	2.13	2.75	2.06	4.81
012 3 2	34.50	11.12	1.91	2.44	1.39	3.83
012 3 3	39.90	8.83	2.04	2.01	1.51	3.52
012 4 1	32.55	21.35	2.70	4.47	2.47	6.95
012 4 2	54.10	19.15	2.57	7.06	3.30	10.36
012 4 3	50.20	20.34	2.77	7.06	3.15	10.21

/3A.9.2.

Table 3A.9.2. cont.

H V T R	ROOT TN WEIGHT	CROWN TN WEIGHT	TOTAL TN WEIGHT	ROOT C/N RATIO	CROWN C/N RATIO	TOTAL C/N RATIO
011 1 1	.08	.06	.14	7.60	3.43	5.84
011 1 2	.14	.11	.25	6.89	4.56	5.84
011 1 3	.21	.16	.38	6.79	3.84	5.51
011 2 1	.21	.12	.33	16.27	8.01	13.33
011 2 2	.41	.15	.56	20.22	9.21	17.28
011 2 3	.42	.15	.58	19.56	10.37	17.04
011 3 1	.33	.25	.58	4.14	2.64	3.50
011 3 2	.26	.24	.51	3.86	3.93	3.89
011 3 3	.37	.26	.63	3.41	2.66	3.10
011 4 1	.74	.44	1.18	12.38	5.07	9.95
011 4 2	.64	.41	1.05	9.67	3.67	7.32
011 4 3	.79	.49	1.29	10.07	5.78	8.42
012 1 1	.13	.11	.24	8.68	4.68	6.86
012 1 2	.07	.06	.14	9.74	5.52	7.81
012 1 3	.13	.12	.26	8.56	4.61	6.65
012 2 1	.23	.14	.37	15.05	6.55	11.85
012 2 2	.27	.22	.50	14.42	6.33	10.73
012 2 3	.51	.36	.87	14.85	6.29	11.29
012 3 1	.31	.34	.65	7.75	4.04	5.82
012 3 2	.52	.59	1.12	5.23	3.45	4.28
012 3 3	.38	.42	.81	5.18	3.53	4.32
012 4 1	.67	.71	1.39	10.45	4.61	7.44
012 4 2	.43	.44	.88	10.32	5.53	7.89
012 4 3	.69	.70	1.39	10.20	4.48	7.32

Table 3A.9.3. Reversal experiment plant population count.
(No./1 sq ft)

1 1 1	5.16	2 1 1	4.33
1 1 2	6.83	2 1 2	10.33
1 1 3	6.00	2 1 3	8.00
1 2 1	7.33	2 2 1	7.50
1 2 2	8.50	2 2 2	6.50
1 2 3	9.16	2 2 3	7.30

APPENDIX 4A

STATISTICAL ANALYSES

Table 4A.4.1. ANOVA* of the cumulative crop production of the total and other species growth (gm

Variation	df	Total			Other Species		
		M.S.	F.**	Sig.	M.S.	F.	Sig.
Variety (V)	1	1140.9	0.3	NS	1733.1	0.7	NS
Treatment (T)	5	6928.2	1.8	NS	28195.1	11.1	1%
Replication	2	4839.9	1.3	NS	2221.6	0.9	NS
V x T	5	4928.8	1.3	NS	4738.7	1.8	NS
Error	22	3752.8			2531.3		

Table 4A.4.2. ANOVA of the cumulative lucerne crop production (gm lucerne percentage.

Variation	df	Lucerne			Lucerne Percentage***		
		M.S.	F.	Sig.	M.S.	F.	Sig.
Replication	2	1243.0	0.6	NS	0.0030	0.1	NS
Variety (V)	1	5686.4	3.0	NS	0.0231	0.9	NS
Treatment (T)	5	31949.4	16.9	1%	0.4774	19.1	1%
V x T	5	2552.3	1.3	NS	0.0503	2.0	NS
Error	22	1890.0			0.0250		

Table 4A.4.3. ANOVA of the point analysis records for lucerne, other species and bare ground.

Variation	df	Lucerne			Other Species			Bare Ground		
		M.S.	F.	Sig.	M.S.	F.	Sig	M.S.	F.	Sig.
Replication	2	26.54	2.2	NS	7.04	0.4	NS	26.00	1.5	NS
Variety (V)	1	155.04	12.7	1%	0.37	0.0	NS	170.66	9.8	1%
Treatment (T)	3	184.48	15.2	1%	581.48	37.4	1%	156.11	9.0	1%
V x T	3	21.04	1.7	NS	36.70	2.4	NS	40.11	2.3	NS
Error	14	12.16			15.56			17.33		

* ANOVA, Analysis of Variance

** Where F is less than 0.1 a value of 0.0 is entered.

*** Data transformed to arcsin values before analysis.

Table 4A.4.4. ANOVA of the point analysis records for grass, clover and other weeds.

Variation	df	Grass			Clover			Other Weeds		
		M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	91.54	2.6	NS	3.16	0.3	NS	44.04	1.1	NS
Variety (V)	1	22.04	0.6	NS	6.00	0.5	NS	2.66	0.0	NS
Treatment (T)	3	448.48	13.0	1%	41.16	3.3	5%	22.72	0.6	NS
V x T	3	5.48	0.2	NS	28.55	2.3	NS	52.11	1.3	NS
Error	14	34.49			12.31			39.04		

Table 4A.4.5. ANOVA of 1. First plant number count (No./1 sq ft).
2. Initial root + crown dry weights (gm/plant).
3. 3R and H treatment lucerne CGR comparison.

Variation	df	Plant number			Root + Crown			df	CGR		
		M.S.	F	Sig	M.S.	F	Sig		M.S.	F	Sig
Replication	2	3.32	0.9	NS	1.31	0.9	NS	2	0.231	0.7	NS
Variety (V)	1	43.55	12.6	1%	18.32	12.7	1%		0.004	0.0	NS
Treatment (T)	3	6.74	1.9	NS	0.83	0.6	NS		6.487	19.6	1%
V x T	3	20.67	6.0	1%	1.70	1.2	NS		0.105	0.3	NS
Error	14	3.44			1.45				0.329		

Table 4A.4.6. ANOVA of the first and second plant number count comparison (No./1 sq ft)

Variation	df	M.S.	F	Sig
Replication	2	7.72	2.3	NS
Count (C)	1	43.28	12.7	1%
Variety (V)	1	13.06	3.8	NS
Treatment (T)	1	0.25	0.0	NS
C x V	1	10.33	3.0	NS
C x T	1	7.90	2.3	NS
V x T	1	50.14	14.8	1%
C x V x T	1	13.45	3.9	NS
Error	14	3.39		

Table 4A.5.1. ANOVA of the dry weights of plant parts (gm/plant) and shoot number per plant by stages of growth.

The data for plant parts was transformed to logarithims and for shoot number to square root before analysis.

		Leaf			Shoot			Plant		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
RD harvest	(Treatments 3RC, 9C, 15C, HC, 3RW and HW.)									
Replication	2	1.99	0.3	NS	3.12	0.0	NS	0.37	0.0	NS
Treatment	5	36.42	4.9	3%	263.36	5.8	1%	689.60	7.5	1%
Error	10	7.36			45.10			92.18		
3" harvest	(Treatments 3RC, 9C, 15C, HC, 3RW and HW)									
Replication	2	25.43	0.9	NS	65.29	1.7	NS	88.43	3.7	NS
Treatment	5	143.41	5.5	1%	551.51	14.5	1%	602.65	25.0	1%
Error	10	26.04			38.06			24.08		
9" harvest	(Treatments 3RC, 9C, 15C, HC, 3RW and HW)									
Replication	2	6.54	0.2	NS	16.02	0.2	NS	51.39	0.4	NS
Treatments	5	110.77	3.1	5%	326.24	3.7	5%	410.54	3.4	5%
Error	10	35.29			86.91			120.67		
15" harvest	(Treatments 3RC, 15C, HC, 3RW and HW)									
Replication	2	189.81	3.7	NS	471.75	3.9	NS	676.00	5.0	5%
Treatments	4	129.39	2.5	10%	476.95	3.9	5%	489.03	3.6	5%
Error	8	51.63			120.33			134.12		
H harvest	(Treatments 3RC, HC, 3RW and HW)									
Replication	2	166.46	1.6	NS	424.79	1.9	NS	170.38	1.0	NS
Treatments	3	558.09	5.4	5%	1979.0	8.8	3%	1925.7	12.3	1%
Error	6	103.71			223.06			157.01		

		Crown			Root			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
RD harvest										
Replication	2	5.13	0.0	NS	0.22	0.0	NS	0.14	0.0	NS
Treatments*	5	421.63	5.7	1%	433.41	7.3	1%	603.92	7.3	1%
Error	10	73.25			59.62			82.74		
3" harvest										
Replication	2	12.68	0.3	NS	37.78	1.1	NS	22.49	0.5	NS
Treatments	5	218.27	4.9	3%	298.24	8.6	1%	395.01	8.1	1%
Error		44.72			34.47			48.58		
9" harvest										
Replication	2	20.34	0.2	NS	40.27	0.6	NS	43.73	0.4	NS
Treatments	5	247.06	2.9	10%	192.29	2.7	10%	292.65	2.7	10%
Error	10	83.63			69.24			106.72		

/4A.5.1.

Table 4A.5.1. cont.

		Crown			Root			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
15" harvest										
Replication	2	282.18	3.3	NS	440.69	5.0	5%	553.88	4.8	5%
Treatment	4	241.37	2.8	10%	155.64	1.7	NS	265.71	2.3	NS
Error	8	85.58			87.59			115.65		
H harvest										
Replication	2	79.43	0.7	NS	42.71	0.4	NS	69.26	0.6	NS
Treatment	3	776.04	7.4	2%	763.28	7.6	2%	1081.9	9.2	2%
Error	6	105.17			99.72			117.97		

		Stubble			Shoot number		
Variation	df	M.S.	FF	Sig	M.S.	F	Sig
RD harvest							
Replication	2	6.85	0.4	NS	12.27	0.4	NS
Treatments	5	104.24	5.5	1%	449.11	14.52	1%
Error	10	18.76			30.92		
3" harvest							
Replication	2	5.95	1.0	NS	17.20	0.4	NS
Treatment	5	40.03	6.9	1%	278.19	5.7	1%
Error	10	5.78			49.25		
9" harvest							
Replication	2	22.62	1.0	NS	21.65	0.9	NS
Treatment	5	120.09	5.3	3%	308.52	13.3	1%
Error	10	22.80			23.16		
15" harvest							
Replication	2	41.13	2.5	NS	55.31	2.9	NS
Treatment	4	127.79	7.8	1%	118.47	6.4	2%
Error	8	16.42			18.55		
H treatment							
Replication	2	10.88	1.1	NS	12.19	2.9	NS
Treatment	3	149.85	14.9	1%	53.23	12.7	1%
Error	6	10.05			4.21		

Table 4A.5.2. Multiple statistical comparison of leaf dry weight (gm/plant) between treatments for selected times of growth.

LEAF WEIGHT LOG. DAY 0

DF 74. POOLED S.E. = .238 DF = 74. , 12.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC LEA - 9C LEA	.222	.201	.267	5%	1.864	5%
3RC LEA - 15C LEA	.061	.184	.245	NS	.119	NS
3RC LEA - HC LEA	.332	.166	.221	1%	2.851	1%
3RC LEA - 3RW LEA	.089	.174	.231	NS	.223	NS
3RC LEA - HW LEA	.553	.166	.221	1%	7.910	1%
9C LEA - 15C LEA	-.161	.210	.279	NS	1.070	NS
9C LEA - HC LEA	.109	.194	.258	NS	.421	NS
9C LEA - 3RW LEA	-.133	.201	.267	NS	.671	NS
9C LEA - HW LEA	.330	.194	.258	1%	3.850	1%
15C LEA - HC LEA	.270	.177	.236	1%	2.153	5%
15C LEA - 3RW LEA	.027	.184	.245	NS	.024	NS
15C LEA - HW LEA	.492	.177	.236	1%	7.105	1%
HC LEA - 3RW LEA	-.243	.166	.221	1%	1.527	NS
HC LEA - HW LEA	.221	.158	.211	1%	1.142	NS
3RW LEA - HW LEA	.464	.166	.221	1%	5.569	1%

LEAF WEIGHT LOG. DAY 14

DF 74. POOLED S.E. = .189 DF = 74. , 12.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC LEA - 9C LEA	.158	.160	.212	NS	1.483	NS
3RC LEA - 15C LEA	.189	.146	.195	5%	1.786	5%
3RC LEA - HC LEA	.342	.132	.176	1%	4.780	1%
3RC LEA - 3RW LEA	-.108	.138	.184	NS	.522	NS
3RC LEA - HW LEA	.537	.132	.176	1%	11.776	1%
9C LEA - 15C LEA	.030	.167	.222	NS	.061	NS
9C LEA - HC LEA	.184	.154	.206	5%	1.887	5%
9C LEA - 3RW LEA	-.266	.160	.212	1%	4.214	1%
9C LEA - HW LEA	.379	.154	.206	1%	7.997	1%
15C LEA - HC LEA	.153	.141	.188	5%	1.090	NS
15C LEA - 3RW LEA	-.297	.146	.195	1%	4.424	1%
15C LEA - HW LEA	.348	.141	.188	1%	5.626	1%
HC LEA - 3RW LEA	-.451	.132	.176	1%	8.286	1%
HC LEA - HW LEA	.195	.126	.168	1%	1.409	NS
3RW LEA - HW LEA	.646	.132	.176	1%	17.006	1%

/4A.5.2.

Table 4A.5.2. cont.

LEAF WEIGHT LOG. DAY 28

DF 74. POOLED S.E. = .176 DF = 74. , 12.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC LEA - 9C LEA	.168	.148	.197	5%	1.958	5%
3RC LEA - 15C LEA	.265	.136	.181	1%	4.098	1%
3RC LEA - HC LEA	.352	.123	.163	1%	5.881	1%
3RC LEA - 3RW LEA	-.095	.128	.170	NS	.473	NS
3RC LEA - HW LEA	.512	.123	.163	1%	12.441	1%
9C LEA - 15C LEA	.096	.155	.206	NS	.707	NS
9C LEA - HC LEA	.183	.143	.191	5%	2.180	5%
9C LEA - 3RW LEA	-.264	.148	.197	1%	4.815	1%
9C LEA - HW LEA	.344	.143	.191	1%	7.638	1%
15C LEA - HC LEA	.086	.131	.174	NS	.405	NS
15C LEA - 3RW LEA	-.361	.136	.181	1%	7.588	1%
15C LEA - HW LEA	.247	.131	.174	1%	3.283	1%
HC LEA - 3RW LEA	-.448	.123	.163	1%	9.511	1%
HC LEA - HW LEA	.160	.117	.156	1%	1.104	NS
3RW LEA - HW LEA	.608	.123	.163	1%	17.525	1%

LEAF WEIGHT LOG. DAY 42

DF 74. POOLED S.E. = .187 DF = 74. , 12.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC LEA - 9C LEA	.254	.158	.210	1%	3.904	1%
3RC LEA - 15C LEA	.291	.145	.193	1%	4.322	1%
3RC LEA - HC LEA	.362	.131	.174	1%	5.450	1%
3RC LEA - 3RW LEA	.016	.137	.182	NS	.012	NS
3RC LEA - HW LEA	.479	.131	.174	1%	9.525	1%
9C LEA - 15C LEA	.037	.165	.220	NS	.090	NS
9C LEA - HC LEA	.108	.153	.204	NS	.661	NS
9C LEA - 3RW LEA	-.237	.158	.210	1%	3.403	1%
9C LEA - HW LEA	.224	.153	.204	1%	2.858	1%
15C LEA - HC LEA	.071	.140	.186	NS	.238	NS
15C LEA - 3RW LEA	-.274	.145	.193	1%	3.836	1%
15C LEA - HW LEA	.187	.140	.186	1%	1.662	5%
HC LEA - 3RW LEA	-.345	.131	.174	1%	4.954	1%
HC LEA - HW LEA	.116	.125	.166	NS	.513	NS
3RW LEA - HW LEA	.462	.131	.174	1%	8.865	1%

/4A.5.2.

Table 44.5.2. cont.

LEAF WEIGHT LOG. DAY 56

DF 67. POOLED S.E. = .202 DF = 67. , 10.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC LEA - 15C LEA	.265	.156	.208	1%	2.594	1%
3RC LEA - HC LEA	.372	.141	.188	1%	4.136	1%
3RC LEA - 3RW LEA	.119	.147	.196	NS	.465	NS
3RC LEA - HW LEA	.436	.141	.188	1%	5.694	1%
15C LEA - HC LEA	.106	.150	.200	NS	.382	NS
15C LEA - 3RW LEA	-.146	.156	.208	NS	.787	NS
15C LEA - HW LEA	.170	.150	.200	5%	.987	NS
HC LEA - 3RW LEA	-.252	.141	.188	1%	1.906	1%
HC LEA - HW LEA	.064	.134	.179	NS	.112	NS
3RW LEA - HW LEA	.317	.141	.188	1%	3.004	1%

LEAF WEIGHT LOG. DAY 70

DF 57. POOLED S.E. = .188 DF = 57. , 8.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC LEA - HC LEA	.381	.132	.175	1%	3.986	1%
3RC LEA - 3RW LEA	.101	.138	.183	NS	.308	NS
3RC LEA - HW LEA	.385	.132	.175	1%	4.061	1%
HC LEA - 3RW LEA	-.279	.132	.175	1%	2.144	1%
HC LEA - HW LEA	.003	.125	.167	NS	0.000	NS
3RW LEA - HW LEA	.283	.132	.175	1%	2.199	1%

LEAF WEIGHT LOG. DAY 84

DF 57. POOLED S.E. = .184 DF = 57. , 8.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC LEA - HC LEA	.390	.129	.171	1%	4.369	1%
3RC LEA - 3RW LEA	-.146	.135	.179	NS	.669	NS
3RC LEA - HW LEA	.324	.129	.171	1%	3.018	1%
HC LEA - 3RW LEA	-.537	.129	.171	1%	8.256	1%
HC LEA - HW LEA	-.066	.123	.163	NS	.113	NS
3RW LEA - HW LEA	.471	.129	.171	1%	6.353	1%

Table 4A.5.3. Multiple statistical comparison of shoot dry weight (gm/plant) between treatments at selected times of growth.

SHOOT WEIGHT LOG. DAY 0

DF 77. POOLED S.E. = .204 DF = 77. , 9.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 9C SHO	.006	.172	.229	NS	.001	NS
3RC SHO - 15C SHO	.033	.158	.210	NS	.036	NS
3RC SHO - HC SHO	.233	.143	.190	1%	1.431	NS
3RC SHO - 3RW SHO	.095	.149	.198	NS	.259	NS
3RC SHO - HW SHO	.485	.143	.190	1%	6.186	1%
9C SHO - 15C SHO	.026	.180	.240	NS	.030	NS
9C SHO - HC SHO	.226	.167	.222	1%	1.838	
9C SHO - 3RW SHO	.088	.172	.229	NS	.297	NS
9C SHO - HW SHO	.478	.167	.222	1%	8.199	1%
15C SHO - HC SHO	.199	.152	.202	5%	1.189	NS
15C SHO - 3RW SHO	.061	.158	.210	NS	.120	NS
15C SHO - HW SHO	.451	.152	.202	1%	6.083	1%
HC SHO - 3RW SHO	-.138	.143	.190	NS	.502	NS
HC SHO - HW SHO	.251	.136	.181	1%	1.514	NS
3RW SHO - HW SHO	.390	.143	.190	1%	3.999	1%

SHOOT WEIGHT LOG. DAY 14

DF 77. POOLED S.E. = .177 DF = 77. , 9.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 9C SHO	.090	.149	.199	NS	.411	NS
3RC SHO - 15C SHO	.134	.137	.183	NS	.771	NS
3RC SHO - HC SHO	.316	.124	.165	1%	3.492	1%
3RC SHO - 3RW SHO	-.087	.129	.172	NS	.291	NS
3RC SHO - HW SHO	.555	.124	.165	1%	10.740	1%
9C SHO - 15C SHO	.044	.156	.208	NS	.108	NS
9C SHO - HC SHO	.226	.145	.192	1%	2.437	5%
9C SHO - 3RW SHO	-.177	.149	.199	5%	1.599	NS
9C SHO - HW SHO	.465	.145	.192	1%	10.277	1%
15C SHO - HC SHO	.182	.132	.176	1%	1.315	NS
15C SHO - 3RW SHO	-.221	.137	.183	1%	2.105	5%
15C SHO - HW SHO	.420	.132	.176	1%	7.014	1%
HC SHO - 3RW SHO	-.404	.124	.165	1%	5.692	1%
HC SHO - HW SHO	.238	.118	.157	1%	1.803	10%
3RW SHO - HW SHO	.642	.124	.165	1%	14.395	1%

/4A.5.3.

Table 4A.5.3. cont.

SHOOT WEIGHT LOG. DAY 28

DF 77. POOLED S.E. = .164 DF = 77. , 9.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 9C SHO	.173	.138	.184	5%	1.781	10%
3RC SHO - 15C SHO	.234	.127	.169	1%	2.756	1%
3RC SHO - HC SHO	.379	.114	.152	1%	5.874	1%
3RC SHO - 3RW SHO	-.063	.120	.159	NS	.180	NS
3RC SHO - HW SHO	.593	.114	.152	1%	14.365	1%
9C SHO - 15C SHO	.061	.144	.192	NS	.244	NS
9C SHO - HC SHO	.206	.134	.178	1%	2.365	5%
9C SHO - 3RW SHO	-.237	.138	.184	1%	3.329	1%
9C SHO - HW SHO	.420	.134	.178	1%	9.819	1%
15C SHO - HC SHO	.144	.122	.162	5%	.972	NS
15C SHO - 3RW SHO	-.298	.127	.169	1%	4.453	1%
15C SHO - HW SHO	.359	.122	.162	1%	5.967	1%
HC SHO - 3RW SHO	-.443	.114	.152	1%	8.009	1%
HC SHO - HW SHO	.214	.109	.145	1%	1.697	10%
3RW SHO - HW SHO	.657	.114	.152	1%	17.610	1%

SHOOT WEIGHT LOG. DAY 42

DF 77. POOLED S.E. = .167 DF = 77. , 9.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 9C SHO	.256	.141	.187	1%	3.762	1%
3RC SHO - 15C SHO	.335	.129	.172	1%	5.416	1%
3RC SHO - HC SHO	.422	.117	.155	1%	7.017	1%
3RC SHO - 3RW SHO	.055	.122	.162	NS	.132	NS
3RC SHO - HW SHO	.601	.117	.155	1%	14.185	1%
9C SHO - 15C SHO	.078	.147	.196	NS	.386	NS
9C SHO - HC SHO	.166	.136	.181	5%	1.477	NS
9C SHO - 3RW SHO	-.201	.141	.187	1%	2.307	5%
9C SHO - HW SHO	.344	.136	.181	1%	6.351	1%
15C SHO - HC SHO	.087	.124	.165	NS	.341	NS
15C SHO - 3RW SHO	-.279	.129	.172	1%	3.767	1%
15C SHO - HW SHO	.265	.124	.165	1%	3.152	1%
HC SHO - 3RW SHO	-.367	.117	.155	1%	5.291	1%
HC SHO - HW SHO	.178	.111	.148	1%	1.135	NS
3RW SHO - HW SHO	.545	.117	.155	1%	11.680	1%

/4A.5.3.

Table 4A.5.3. cont.

SHOOT WEIGHT LOG. DAY 56

DF 69. POOLED S.E. = .184 DF = 69., 8.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 15C SHO	.435	.142	.189	1%	6.721	1%
3RC SHO - HC SHO	.445	.128	.171	1%	5.729	1%
3RC SHO - 3RW SHO	.159	.134	.178	5%	.796	NS
3RC SHO - HW SHO	.577	.128	.171	1%	9.604	1%
15C SHO - HC SHO	.009	.137	.182	NS	.003	NS
15C SHO - 3RW SHO	-.276	.142	.189	1%	2.708	1%
15C SHO - HW SHO	.141	.137	.182	5%	.654	NS
HC SHO - 3RW SHO	-.286	.128	.171	1%	2.368	1%
HC SHO - HW SHO	.131	.122	.163	5%	.452	NS
3RW SHO - HW SHO	.417	.128	.171	1%	5.037	1%

SHOOT WEIGHT LOG. DAY 70

DF 58. POOLED S.E. = .177 DF = 58., 7.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - HC SHO	.448	.124	.165	1%	5.455	1%
3RC SHO - 3RW SHO	.135	.129	.172	5%	.544	NS
3RC SHO - HW SHO	.521	.124	.165	1%	7.381	1%
HC SHO - 3RW SHO	-.312	.124	.165	1%	2.655	1%
HC SHO - HW SHO	.073	.118	.157	NS	.132	NS
3RW SHO - HW SHO	.386	.124	.165	1%	4.042	6%

SHOOT WEIGHT LOG. DAY 84

DF 58. POOLED S.E. = .184 DF = 58., 7.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - HC SHO	.431	.128	.171	1%	4.688	1%
3RC SHO - 3RW SHO	-.126	.134	.178	NS	.437	NS
3RC SHO - HW SHO	.435	.128	.171	1%	4.771	1%
HC SHO - 3RW SHO	-.557	.128	.171	1%	7.830	1%
HC SHO - HW SHO	.003	.122	.163	NS	0.000	NS
3RW SHO - HW SHO	.561	.128	.171	1%	7.938	1%

Table 4A.5.4. Multiple statistical comparison of plant dry weight (gm/plant) between treatments at selected times of growth.

PLANT WEIGHT LOG. DAY 0

DF 75. POOLED S.E. = .140 DF = 75. , 11.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC PLA - 9C PLA	.087	.118	.157	NS	.760	NS
3RC PLA - 15C PLA	.061	.108	.144	NS	.311	NS
3RC PLA - HC PLA	.345	.098	.130	1%	8.108	1%
3RC PLA - 3RW PLA	.050	.102	.136	NS	.192	NS
3RC PLA - HW PLA	.470	.098	.130	1%	15.043	1%
9C PLA - 15C PLA	-.026	.123	.164	NS	.076	NS
9C PLA - HC PLA	.257	.114	.152	1%	6.156	1%
9C PLA - 3RW PLA	-.036	.118	.157	NS	.133	NS
9C PLA - HW PLA	.382	.114	.152	1%	13.579	1%
15C PLA - HC PLA	.284	.104	.139	1%	6.244	1%
15C PLA - 3RW PLA	-.010	.108	.144	NS	.008	NS
15C PLA - HW PLA	.409	.104	.139	1%	12.943	1%
HC PLA - 3RW PLA	-.294	.098	.130	1%	5.892	1%
HC PLA - HW PLA	.124	.098	.124	1%	.966	NS
3RW PLA - HW PLA	.419	.098	.130	1%	11.959	1%

PLANT WEIGHT LOG. DAY 14

DF 75. POOLED S.E. = .134 DF = 75. , 11.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC PLA - 9C PLA	.091	.113	.150	NS	.917	NS
3RC PLA - 15C PLA	.108	.103	.138	NS	1.070	NS
3RC PLA - HC PLA	.222	.093	.124	1%	3.708	1%
3RC PLA - 3RW PLA	-.101	.098	.130	5%	.835	NS
3RC PLA - HW PLA	.385	.093	.124	1%	11.116	1%
9C PLA - 15C PLA	.016	.118	.157	NS	.031	NS
9C PLA - HC PLA	.131	.109	.145	5%	1.746	10%
9C PLA - 3RW PLA	-.193	.113	.150	1%	4.053	1%
9C PLA - HW PLA	.294	.109	.145	1%	8.797	1%
15C PLA - HC PLA	.114	.100	.133	5%	1.117	NS
15C PLA - 3RW PLA	-.209	.103	.138	1%	4.017	1%
15C PLA - HW PLA	.277	.100	.133	1%	6.545	1%
HC PLA - 3RW PLA	-.324	.093	.124	1%	7.846	1%
HC PLA - HW PLA	.163	.089	.118	1%	1.802	5%
3RW PLA - HW PLA	.487	.093	.124	1%	17.719	1%

/4A.5.4.

Table 4A.5.4. cont.

PLANT WEIGHT LOG. DAY 28

DF 75. POOLED S.E. = .131 DF = 75. , 11.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC PLA - 9C PLA	.096	.111	.147	NS	1.043	NS
3RC PLA - 15C PLA	.155	.101	.135	1%	2.292	5%
3RC PLA - HC PLA	.190	.092	.122	1%	2.816	1%
3RC PLA - 3RW PLA	-.111	.096	.127	5%	1.059	NS
3RC PLA - HW PLA	.364	.092	.122	1%	10.290	1%
9C PLA - 15C PLA	.058	.116	.154	NS	.429	NS
9C PLA - HC PLA	.094	.107	.142	NS	.942	NS
9C PLA - 3RW PLA	-.208	.111	.147	1%	4.884	1%
9C PLA - HW PLA	.268	.107	.142	1%	7.599	1%
15C PLA - HC PLA	.035	.098	.130	NS	.110	NS
15C PLA - 3RW PLA	-.267	.101	.135	1%	6.789	1%
15C PLA - HW PLA	.209	.098	.130	1%	3.852	1%
HC PLA - 3RW PLA	-.302	.092	.122	1%	7.095	1%
HC PLA - HW PLA	.173	.087	.116	1%	2.126	5%
3RW PLA - HW PLA	.476	.092	.122	1%	17.583	1%

PLANT WEIGHT LOG. DAY 42

DF 75. POOLED S.E. = .129 DF = 75. , 11.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC PLA - 9C PLA	.100	.109	.145	NS	1.169	NS
3RC PLA - 15C PLA	.202	.100	.133	1%	4.000	1%
3RC PLA - HC PLA	.220	.090	.120	1%	3.884	1%
3RC PLA - 3RW PLA	-.048	.094	.126	NS	.203	NS
3RC PLA - HW PLA	.380	.090	.120	1%	11.520	1%
9C PLA - 15C PLA	.101	.114	.152	NS	1.313	NS
9C PLA - HC PLA	.120	.106	.141	5%	1.573	NS
9C PLA - 3RW PLA	-.148	.109	.145	1%	2.568	1%
9C PLA - HW PLA	.279	.106	.141	1%	8.505	1%
15C PLA - HC PLA	.018	.096	.128	NS	.031	NS
15C PLA - 3RW PLA	-.250	.100	.133	1%	6.144	1%
15C PLA - HW PLA	.177	.096	.128	1%	2.868	1%
HC PLA - 3RW PLA	-.269	.090	.120	1%	5.773	1%
HC PLA - HW PLA	.159	.086	.115	1%	1.841	5%
3RW PLA - HW PLA	.428	.090	.120	1%	14.640	1%

/4A.5.4.

Table 4A.5.4. cont.

PLANT WEIGHT LOG. DAY 56

DF 67. POOLED S.E. = .134 DF = 67. , 10.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC PLA - 15C PLA	.249	.103	.138	1%	5.183	1%
3RC PLA - HC PLA	.286	.093	.124	1%	5.561	1%
3RC PLA - 3RW PLA	.021	.097	.130	NS	.034	NS
3RC PLA - HW PLA	.408	.093	.124	1%	11.354	1%
15C PLA - HC PLA	.036	.099	.132	NS	.104	NS
15C PLA - 3RW PLA	-.227	.103	.138	NS	4.323	NS
15C PLA - HW PLA	.159	.099	.132	1%	1.963	5%
HC PLA - 3RW PLA	-.264	.093	.124	1%	4.751	1%
HC PLA - HW PLA	.122	.089	.118	1%	.930	NS
3RW PLA - HW PLA	.387	.093	.124	1%	10.184	1%

PLANT WEIGHT LOG. DAY 70

DF 56. POOLED S.E. = .133 DF = 56. , 9.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC PLA - HC PLA	.366	.093	.123	1%	7.977	1%
3RC PLA - 3RW PLA	.030	.097	.129	NS	.063	NS
3RC PLA - HW PLA	.424	.093	.123	1%	11.169	1%
HC PLA - 3RW PLA	-.328	.093	.123	1%	6.674	1%
HC PLA - HW PLA	.065	.088	.118	NS	.243	NS
3RW PLA - HW PLA	.394	.093	.123	1%	9.616	1%

PLANT WEIGHT LOG. DAY 84

DF 56. POOLED S.E. = .136 DF = 56. , 9.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC PLA - HC PLA	.412	.095	.126	1%	10.091	1%
3RC PLA - 3RW PLA	-.088	.099	.132	NS	.513	NS
3RC PLA - HW PLA	.403	.095	.126	1%	9.663	1%
HC PLA - 3RW PLA	-.501	.095	.126	1%	14.918	1%
HC PLA - HW PLA	-.008	.090	.120	NS	.004	NS
3RW PLA - HW PLA	.492	.095	.126	1%	14.397	1%

Table 4A.5.5. Multiple statistical comparison of shoot number (No./plant) between treatments at selected times of growth.

SHOOT NO. SQRTF DAY 0

DF 64. POOLED S.E. = 2.100 DF = 64. , 13.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 15C SHO	-2.230	1.688	2.245	1%	2.041	5%
3RC SHO - HC SHO	-.018	1.524	2.027	NS	0.000	NS
3RC SHO - 3RW SHO	1.351	1.592	2.117	NS	.666	NS
3RC SHO - HW SHO	8.915	1.524	2.027	1%	26.575	1%
15C SHO - HC SHO	2.211	1.624	2.161	1%	1.858	10%
15C SHO - 3RW SHO	3.582	1.688	2.245	1%	5.264	1%
15C SHO - HW SHO	11.146	1.624	2.161	1%	47.198	1%
HC SHO - 3RW SHO	1.370	1.524	2.027	NS	.627	NS
HC SHO - HW SHO	8.934	1.453	1.933	1%	24.259	1%
3RW SHO - HW SHO	7.564	1.524	2.027	1%	19.128	1%

SHOOT NO. SQRTF DAY 14

DF 64. POOLED S.E. = 1.956 DF = 64. , 13.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 15C SHO	2.289	1.515	2.015	1%	2.624	1%
3RC SHO - HC SHO	2.245	1.367	1.819	1%	2.092	5%
3RC SHO - 3RW SHO	.833	1.428	1.900	NS	.314	NS
3RC SHO - HW SHO	9.644	1.367	1.819	1%	38.609	1%
15C SHO - HC SHO	-.024	1.458	1.939	NS	0.000	ns
15C SHO - 3RW SHO	-1.436	1.515	2.015	NS	1.051	NS
15C SHO - HW SHO	7.374	1.458	1.939	1%	25.651	1%
HC SHO - 3RW SHO	-1.411	1.367	1.819	5%	.827	NS
HC SHO - HW SHO	7.399	1.304	1.734	1%	20.658	1%
3RW SHO - HW SHO	8.810	1.367	1.819	1%	32.224	1%

/4A.5.5.

Table 4A.5.5. cont.

SHOOT NO. SQRTF DAY 28

DF 64. POOLED S.E. = 1.742 DF = 64. , 13.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 15C SHO	2.408	1.349	1.795	1%	3.726	1%
3RC SHO - HC SHO	2.842	1.218	1.620	1%	4.229	1%
3RC SHO - 3RW SHO	.754	1.272	1.692	NS	.324	NS
3RC SHO - HW SHO	8.826	1.218	1.620	1%	40.772	1%
15C SHO - HC SHO	.434	1.298	1.727	NS	.112	NS
15C SHO - 3RW SHO	-1.654	1.349	1.795	5%	1.757	10%
15C SHO - HW SHO	6.417	1.298	1.727	1%	24.496	1%
HC SHO - 3RW SHO	-2.088	1.218	1.620	1%	2.282	1%
HC SHO - HW SHO	5.983	1.161	1.544	1%	17.034	1%
3RW SHO - HW SHO	8.071	1.218	1.620	1%	34.100	1%

SHOOT NO. SQRTF DAY 42

DF 64. POOLED S.E. = 1.643 DF = 64. , 13.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 15C SHO	1.181	1.273	1.693	NS	1.007	NS
3RC SHO - HC SHO	2.420	1.149	1.528	1%	3.445	1%
3RC SHO - 3RW SHO	.878	1.200	1.596	NS	.494	NS
3RC SHO - HW SHO	7.084	1.149	1.528	1%	29.509	1%
15C SHO - HC SHO	1.238	1.225	1.629	5%	1.025	NS
15C SHO - 3RW SHO	-.303	1.273	1.693	NS	.066	NS
15C SHO - HW SHO	5.902	1.225	1.629	1%	23.278	1%
HC SHO - 3RW SHO	-1.542	1.149	1.528	1%	1.399	NS
HC SHO - HW SHO	4.663	1.095	1.457	1%	11.625	1%
3RW SHO - HW SHO	6.205	1.149	1.528	1%	22.646	1%

/4A.5.5.

Table 4A.5.5. cont.

SHOOT NO. SQRTF DAY 56

DF 64. POOLED S.E. = 1.836 DF = 64. , 13.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - 15C SHO	1.586	1.422	1.892	5%	1.454	NS
3RC SHO - HC SHO	1.626	1.284	1.707	5%	1.245	NS
3RC SHO - 3RW SHO	.968	1.341	1.783	NS	.481	NS
3RC SHO - HW SHO	5.040	1.284	1.707	1%	11.966	1%
15C SHO - HC SHO	.039	1.368	1.820	NS	0.000	NS
15C SHO - 3RW SHO	-.618	1.422	1.892	NS	.220	NS
15C SHO - HW SHO	3.453	1.368	1.820	1%	6.385	1%
HC SHO - 3RW SHO	-.657	1.284	1.707	NS	.203	NS
HC SHO - HW SHO	3.413	1.224	1.628	1%	4.991	1%
3RW SHO - HW SHO	4.070	1.284	1.707	1%	7.810	1%

SHOOT NO. SQRTF DAY 70

DF 55. POOLED S.E. = 1.886 DF = 55. , 10.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - HC SHO	1.105	1.318	1.754	NS	.419	NS
3RC SHO - 3RW SHO	.787	1.377	1.831	NS	.232	NS
3RC SHO - HW SHO	5.316	1.318	1.754	1%	3.778	1%
HC SHO - 3RW SHO	-.317	1.318	1.754	NS	.034	NS
HC SHO - HW SHO	2.210	1.257	1.672	1%	1.526	NS
3RW SHO - HW SHO	2.528	1.318	1.754	1%	2.196	1%

SHOOT NO. SQRTF DAY 84

DF 55. POOLED S.E. = 1.994 DF = 55. , 10.

COMPARISON MADE	Y DIFF	LSD P = 0.05	LSD P = 0.01	SIG	SCHEFFE F	SIG
3RC SHO - HC SHO	1.505	1.394	1.855	5%	.696	NS
3RC SHO - 3RW SHO	.100	1.456	1.937	NS	.003	NS
3RC SHO - HW SHO	2.535	1.394	1.855	1%	1.973	5%
HC SHO - 3RW SHO	-1.405	1.394	1.855	5%	.606	NS
HC SHO - HW SHO	1.029	1.329	1.768	NS	.295	NS
3RW SHO - HW SHO	2.434	1.394	1.855	1%	1.820	NS

Table 4A.5.6. ANOVA of shoot average crop growth rate regressions.

(gm/plant/week)

6 treatment comparison

Source of variation	df	Mean Square	F	Sig.
Total within group	48	0.727		
Due to average regression	1	19.302	58.0	1%
Deviations from aver. regress.	47	0.332		
Between individual group regress.	5	0.596	1.9	10%
Deviations from individ. regress.	42	0.301		

3 treatment comparison

Source of variation	df	Mean Square	F	Sig
Total within group	55	1.596		
Due to average regression	1	47.384	63.31	1%
Deviations from average regress.	54	0.748		
Between individ. group regress.	4	1.899	2.89	5%
Deviations from individ. regress.	50	0.656		

4 treatment comparison

Source of variation	df	Mean Square	F	Sig
Total within group	50	3.126		
Due to average regress.	1	93.866	73.67	1%
Deviations from average regress.	49	1.274		
Between individ. group regress.	3	6.936	7.66	1%
Deviations from individ. regress.	46	0.905		

Table 4A.5.7. ANOVA of shoot average relative growth rate regressions.

(gm/gm/week)

6 treatment comparison

Source of variation	df	Mean Square	F	Sig
Total within group	48	161.805		
Due to average regression	1	5283.926	100.02	1%
Deviations from average regress.	47	52.824		
Between individ. group regress.	5	44.808	0.83	NS
Deviations from individ. regress.	42	53.778		

/4A.5.7.

Table 4A.5.7. cont./

5 treatment comparison

Source of variation	df	Mean Square	F	Sig
Total within group	55	257.292		
Due to average regression	1	9488.418	109.89	1%
Deviations from average regress.	54	86.345		
Between individual group regress.	4	143.958	1.76	NS
Deviations from individ. regress.	50	81.736		

4 treatment comparison

Source of variation	df	Mean Square	F	Sig
Total within group	50	319.177		
Due to average regress.	1	11858.755	141.72	1%
Deviations from average regress.	49	83.676		
Between individ. group regress.	3	203.622	2.76	10%
Deviations from individ. regress.	46	75.526		

Table 4A.5.8. ANOVA of the standard dry weight ratios.

Variation	df	M.S.	F	Sig
Variety (V)	1	0.657	114.9	1%
Treatment (T)	1	0.425	74.3	1%
Dates (D)	6	1.788	312.7	1%
V x T	1	0.159	27.8	1%
V x D	6	0.014	2.4	NS
T x D	6	0.290	50.7	1%
Error	6	0.008		

Table 4A.5.9. ANOVA of root + crown dry weights over harvests for each treatment for plant size variability estimations.

Variation	3RC	9C	15C	HC	3RW	HW
Replications	*9.15	5.50	12.90	9.83	2.42	7.61
Harvests	0.89	0.46	10.34	17.99	2.96	22 15
Reps. x Harv.	4.06	11.69	12.90	21.28	2.95	8.81
Error	3.36	7.78	4.76	8.82	2.80	22.86
Within grp SD.	1.83	2.79	2.18	2.97	1.67	4.78
Gen. mean	3.02	3.78	4.12	5.29	2.82	6.68
df Rep.	3	2	3	4	3	4
df Har.	2	2	2	2	2	2
df R x H	6	4	6	8	6	8
df Error	60	45	60	75	60	75

* Mean Square

Table 4A.5.10. ANOVA of the regressions of shoot height growth in the field over time (cm x 10/shoot/day).

5RC treatment

Source of variation	df	Mean Square	F	Sig.
Total within group	67	4154.15		
Due to average regress.	1	252461.06	644.16	1%
Deviations from average regress.	66	391.92		
Between individ. group regress.	4	1001.27	2.84	5%
Deviations from individ. regress.	62	352.62		

15C treatment

Source of variation	df	Mean Square	F	Sig.
Total within group	49	5797.58		
Due to average regress.	1	225693.03	185.54	1%
Deviations from average regress.	48	1216.43		
Between individ. group regress.	4	2274.14	2.01	NS
Deviations from individ. regress.	44	1120.27		

[illegible] treatment

Source of variation	df	Mean Square	F	Sig.
Total within group	67	9580.42		
Due to average regress.	1	258989.39	44.64	1%
Deviations from average regress.	66	5801.50		
Between individ. group regress.	4	11373.20	2.09	NS
Deviations from individ. regress.	62	5442.03		

Table 4A.5.11. ANOVA of lucerne field growth parameters. Shoot height (cm), relative production and shoot number measured on the 12/9.

		Shoot Height*			Relat. Product*			Shoot Number**		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	2030.6	2.9	NS	2542.2	0.0	NS	0.0003	0.0	NS
Treatment (T)	3	4080.8	6.0	1%	13966.9	0.5	NS	0.0034	0.2	NS
Group (G)	4	31790.5	46.7	1%	426976.8	14.4	1%	0.1906	8.5	1%
T x G	12	939.0	1.4	NS	15757.5	0.5	NS	0.0201	0.9	NS
Error	38	679.8			29600.0			0.0222		

* (y x 10)

** Data was transformed to the arcsin form for analysis.

Table 4A.5.12. ANOVA of lucerne field growth parameters. Shoot height (cm), relative production and shoot number measured on the 26/9.

		Shoot Height*			Relat. Product*			Shoot Number**		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	9459.3	2.1	NS	4614.5	0.0	NS	0.0032	0.1	NS
Treatment (T)	2	14781.6	3.3	NS	29303.0	0.3	NS	0.0331	1.2	NS
Group (G)	4	48543.6	10.9	1%	500932.5	5.2	1%	0.1139	3.9	5%
T x G	8	4047.8	0.9	NS	23436.7	0.2	NS	0.0119	0.4	NS
Error	28	4461.8			96486.1			0.0287		

* (y x 10)

** Data was transformed to the arcsin form for analysis.

Table 4A.5.13. ANOVA of the field growth initial relative shoot numbers.*

Variation	df	M.S.	F	Sig
Replications	2	0.0001	0.0	NS
Treatments (T)	3	0.0009	0.0	NS
Groups (G)	5	0.4459	23.5	1%
T x G	15	0.0168	0.9	NS
Error	46	0.0188		

*Data was transformed to the afcsin form for analysis.

Table 4A.5.14

Table 4A.5.14. ANOVA of the adjusted average field growth shoot heights* - 26/9.

Variation	df	M.S.	F	Sig
Replications	2	716.44	5.3	NS
Treatments	2	4816.44	35.6	1%
Error	4	135.44		

* cm

Table 4A.5.15. Correlation analysis of initial shoot number per plant with with initial root + crown weight.

Variety	df	Regress.	S.E.	SS Due Reg	Resid SSY	Correl
Chanticleer	67	0.1270	0.0221	120.3203	245.1874	0.574
Wahrau	67	0.1066	0.0089	495.2265	235.8580	0.823

Table 4A.5.16. ANOVA of basal shoot growth (gm/plant), shoot number (No./plant) and stem/leaf ratio.

		Shoot growth*			Shoot Number*			Stem/Leaf Ratio		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	1.57	0.3	NS	17.8	0.1	NS	1.96	0.4	NS
Variety (V)	1	1.56	0.3	NS	232.6	1.3	NS	23.24	5.3	5%
Treatment (T)	1	110.74	21.2	1%	2934.8	17.0	1%	46.80	10.7	2%
V x T	1	0.24	0.0	NS	24.6	0.1	NS	5.46	1.2	NS
Error	66	5.23			172.6			4.37		

* Data was transformed to the square root form for analysis.

Table 4A.6.1 . ANOVA of the field growth leaf canopy depth and base height (cm).

		Canopy Depth			Canopy Base Height		
Variation	df	M.S.	F	Sig	M.S.	F	Sig
Replication	2	7.43	3.2	5%	30.46	16.2	1%
Time (Ti)	6	3.96	1.7	NS	503.13	246.2	1%
Treatment (Tr)	1	0.48	0.2	NS	406.72	215.7	1%
Ti x Tr	6	5.02	2.1	NS	16.08	8.5	1%
Error	26	2.35			1.88		

Table 4A.7.1. ANOVA of the Organic Reserve Measurements during Growth.

Root, crown and root plus crown dry weights (gm/6 plants)

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	182.9	6.2	1%	49.4	2.0	NS	404.5	4.3	5%
Harvest (H)	7	41.5	1.4	NS	18.3	0.7	NS	78.1	0.8	NS
Variety (V)	1	1.4	0.0	NS	79.9	3.3	10%	60.2	0.6	NS
Treatment (T)	1	3443.9	117.	1%	3026.4	124.	1%	12927.0	138.	1%
H x V	7	49.6	1.7	NS	55.8	2.2	NS	201.5	2.2	5%
H x T	7	26.5	0.9	NS	10.4	0.4	NS	59.4	0.6	NS
V x T	1	0.0	0.0	NS	18.0	0.7	NS	16.6	0.2	NS
H x V x T	7	44.8	1.5	NS	45.4	1.7	NS	170.2	1.8	NS
Error	62	29.3			24.3			93.4		

Total non-structural carbohydrate percentages.*

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	0.00156	1.6	NS	0.00072	2.1	NS	0.00139	2.4	NS
Harvests (H)	7	0.01263	12.8	1%	0.00354	10.4	1%	0.00897	15.5	1%
Variety (V)	1	0.00968	9.8	1%	0.00135	4.0	5%	0.01109	19.12	1%
Treatment (T)	1	0.00530	1.3	NS	0.00203	6.0	5%	0.00489	8.4	1%
H x V	7	0.00151	1.5	NS	0.00046	1.4	NS	0.00073	1.3	NS
H x T	7	0.00337	3.4	5%	0.00268	7.9	1%	0.00267	4.6	1%
V x T	1	0.01380	14.1	1%	0.00020	0.6	NS	0.00557	9.6	1%
H x T x V	7	0.00062	0.6	NS	0.00040	1.2	NS	0.00060	1.0	NS
Error	62	0.00098			0.00034			0.00058		

Total Non-structural carbohydrate weights (gm/6 plants)

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	6.85	8.0	1%	0.48	2.4	NS	10.62	9.6	1%
Harvests (H)	7	4.99	5.9	1%	0.27	0.9	NS	5.98	2.8	5%
Variety (V)	1	0.96	1.1	NS	0.72	2.5	NS	0.01	0.0	NS
Treatments (T)	1	95.44	112.	1%	30.79	106.	1%	234.69	108.	1%
H x V	7	1.52	1.8	NS	0.66	2.3	5%	3.82	1.8	NS
H x T	7	1.82	2.2	5%	0.23	0.8	NS	2.62	1.2	NS
V x T	1	1.44	1.7	NS	0.29	2.2	NS	3.04	1.4	NS
H x T x V	7	1.72	2.0	NS	0.62	2.2	5%	4.18	1.9	NS
Error	62	0.84			0.28			2.17		

* Data was transformed to the arcsin form for analysis.

/4A.7.1.

Table 4A.7.1. cont.

Total nitrogen percentages.*

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	0.00031	7.7	1%	0.00008	4.4	5%	0.00023	9.6	1%
Harvests (H)	7	0.00084	21.0	1%	0.00097	53.8	1%	0.00897	36.3	1%
Variety (V)	1	0.00044	11.0	1%	0.00001	0.6	NS	0.01109	2.1	NS
Treatment (T)	1	0.01636	409.	1%	0.00339	188.	1%	0.00489	445.	1%
H x V	7	0.00003	0.7	NS	0.00001	0.5	NS	0.00073	0.4	NS
H x T	7	0.00009	2.2	5%	0.00010	5.5	1%	0.00267	2.9	5%
V x T	1	0.00039	9.7	1%	0.00002	1.1	NS	0.00557	7.9	1%
H x V x T	7	0.00004	1.0	NS	0.00004	2.2	5%	0.00060	1.3	NS
Error	62	0.00004			0.00002			0.00002		

Total nitrogen weight (gm/6 plants).

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	0.0638	4.4	5%	0.0149	0.9	NS	0.1265	2.4	NS
Harvests (H)	7	0.0458	3.1	1%	0.0110	0.7	NS	0.0847	1.6	NS
Variety (V)	1	0.0314	2.2	NS	0.0527	3.4	NS	0.0028	0.0	NS
Treatment (T)	1	3.2230	220.	1%	2.1690	139.	1%	10.6800	206.	1%
H x V	7	0.0636	1.9	NS	0.0149	2.7	5%	0.1266	2.6	5%
H x T	7	0.0217	1.5	NS	0.0078	0.5	NS	0.0501	0.9	NS
V x T	1	0.0236	1.6	NS	0.0134	0.9	NS	0.0015	0.0	NS
H x V x T	7	0.0280	1.9	NS	0.0369	2.4	5%	0.1253	2.4	5%
Error	62	0.0146			0.0155			0.0518		

Total non-structural carbohydrate/total nitrogen ratios.

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	0.638	0.2	NS	0.060	0.1	NS	0.207	0.1	NS
Harvests (H)	7	25.893	8.5	1%	10.163	22.2	1%	18.198	12.8	1%
Variety(V)	1	14.445	4.7	5%	2.270	4.9	5%	19.613	13.8	1%
Treatment (T)	1	395.919	130.	1%	33.848	74.1	1%	204.984	144.	1%
H x V	7	4.217	1.4	NS	0.646	1.4	NS	1.764	1.2	NS
H x T	7	16.412	5.4	1%	5.908	12.9	1%	10.189	7.2	1%
V x T	1	69.518	22.83	1%	1.144	2.5	NS	27.872	19.7	1%
H x V x T	7	2.028	0.6	NS	0.667	1.4	NS	1.367	1.0	NS
Error	62	3.146			0.457			1.414		

* Data was transformed to the arcsin form for analysis.

/4A.7.1.

Table 4A.7.1. cont.

Root and crown comparisons for the several organic reserve measurements.

		TNC Percent***			TN Percent***			RTCR Weight**		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
RT vs CR (RC)*	1	0.43524	636.	1%	0.00560	134.	1%	1387.93	46.8	1%
Harvests (H)	7	0.01180	17.3	1%	0.00177	42.3	1%	39.04	1.3	NS
Variety (V)	1	0.00914	13.4	1%	0.00015	3.6	NS	30.08	1.0	NS
Treatment (T)	1	0.00330	4.8	5%	0.01734	415.	1%	6463.52	218.	1%
RC x H	7	0.00438	6.4	1%	0.00004	1.1	NS	20.80	0.7	NS
RC x V	1	0.00189	2.8	NS	0.00030	7.4	1%	51.27	1.7	NS
RC x T	1	0.00004	0.0	NS	0.00242	58.1	1%	6.74	0.2	NS
H x V	7	0.00128	1,9	NS	0.00002	0.6	NS	100.72	3.4	1%
H x T	7	0.00547	8.0	1%	0.00017	4.2	1%	29.68	1.0	NS
V x T	1	0.00866	12.7	1%	0.00030	7.2	1%	8.32	0.3	NS
RC x H x V	7	0.00068	1.0	NS	0.00002	0.5	NS	4.69	0.2	NS
RC x H x T	7	0.00058	0.9	NS	0.00002	0.6	NS	7.28	0.2	NS
RC x V x T	1	0.00533	7.8	1%	0.00011	2.7	NS	9.71	0.3	NS
H x V x T	7	0.00082	1.2	NS	0.00006	1.5	NS	85.09	2.8	5%
RC x H x V x T	7	0.00020	0.3	NS	0.00002	0.5	NS	5.12	0.2	NS
Error	128	0.00068			0.00004			29.60		

		TNC Weight**			TN Weight**			TNC/TN Ratio		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
RT vs CR (RC)*	1	153.254	185.	1%	0.3198	20.2	1%	977.637	572.	1%
Harvests (H)	7	2.994	3.6	1%	0.0423	2.8	5%	29.744	17.4	1%
Variety (V)	1	0.008	0.0	NS	0.0013	0.0	NS	14.084	8.2	1%
Treatment (T)	1	117.359	142.	1%	5.3400	337.	1%	330.647	193.	1%
RC x H	7	2.273	2.8	5%	0.0142	0.9	NS	6.311	3.7	1%
RC x V	1	1.684	2.0	NS	0.0828	5.2	5%	2.632	1.5	NS
RC x T	1	8.904	10.8	1%	0.0520	3.3	NS	99.121	58.0	1%
H x V	7	1.914	2.3	5%	0.0678	4.3	1%	2.699	1.6	NS
H x T	7	1.313	1.6	NS	0.0251	1.6	NS	19.503	11.4	1%
V x T	1	1.521	1.8	NS	0.0007	0.0	NS	44.251	25.9	1%
RC x H x V	7	0.272	0.3	NS	0.0026	0.2	NS	2.164	1.2	NS
RC x H x T	7	0.740	0.9	NS	0.0043	0.3	NS	2.817	1.6	NS
RC x V x T	1	0.217	0.3	NS	0.0364	2.3	NS	26.410	15.5	1%
H x V x T	7	2.092	2.5	5%	0.0627	3.9	5%	1.911	1.1	NS
RC x H x V x T	7	0.254	0.3	NS	0.0022	0.1	NS	0.784	0.5	NS
Error	128	0.825			0.0158			1.707		

* Root and crown comparison

** (gm/6 plants

*** Data was transformed to the arcsin form for analysis.

Table 4A.7.2. ANOVA comparison of the Winter organic reserves with those of the first spring sampling.

Total non-structural carbohydrate percentages.*

		Root			Crown			RTCR		
Variation	df		F	Sig		F	Sig		F	Sig
Harvests (H)	1	0.00649	8.7	1%	0.00964	23.3	1%	0.00984	16.9	1%
Variety (V)	1	0.00197	2.6	NS	0.00064	1.5	NS	0.00255	4.4	NS
Treatment (T)	1	0,00113	1.5	NS	0.00016	0.4	NS	0.00072	1.2	NS
H x V	1	0.00102	1.4	NS	0.00034	0.8	NS	0.00104	1.8	NS
H x T	1	0.00013	0.2	NS	0.00016	0.4	NS	0.00017	0.3	NS
V x T	1	0.00001	0.0	NS	0.00019	0.5	NS	0.00004	0.0	NS
H x V x T	1	0.00046	0.6	NS	0.00020	0.5	NS	0.00025	0.4	NS
Error	16	0.00074			0.00041			0.00058		

Total nitrogen percentages.*

		Root			Crown			RTCR		
Variation	df		F	Sig		F	Sig		F	Sig
Harvests (H)	1	0.00030	5.7	5%	0.00360	68.1	1%	0.00095	29.8	1%
Variety (V)	1	0.00009	1.7	NS	0.00000	0.0	NS	0.00003	1.1	NS
Treatment (T)	1	0.00153	28.0	1%	0.00063	11.9	1%	0.00128	40.3	1%
H x V	1	0.00000	0.0	NS	0.00002	0.5	NS	0.00001	0.4	NS
H x T	1	0.00036	6.7	5%	0.00003	0.6	NS	0.00023	7.3	5%
V x T	1	0.00015	2.8	NS	0.00000	0.0	NS	0.00008	2.8	NS
H x V x T	1	0.00000	0.0	NS	0.00006	1.3	NS	0.00002	0.7	NS
Error	16	0.00005			0.00005			0.00003		

Total non-structural carbohydrate/total nitrogen ratios.

		Root			Crown			RTCR		
Variation	df		F	Sig		F	Sig		F	Sig
Harvests (H)	1	23.826	24.8	1%	58.919	141.	1%	44.118	76.8	1%
Variety (V)	1	0.259	0.3	NS	0.483	1.2	NS	0.909	1.6	NS
Treatments (T)	1	11.370	11.8	1%	2.377	5.7	5%	7.196	12.5	1%
H x V	1	1.715	1.8	NS	0.589	1.4	NS	2.006	3.5	NS
H x T	1	5.287	5.5	5%	0.280	0.7	NS	2.108	3.7	NS
V x T	1	3.443	2.3	NS	0.001	0.0	NS	1.111	1.9	NS
H x V x T	1	0.326	0.3	NS	0.021	0.0	NS	0.001	0.0	NS
Error	16	0.959			0.416			0.574		

* Data was transformed to the arcsin form for analysis.

Table 4A.7.3. ANOVA comparison of treatments for organic reserve measurements.

Total non-structural carbohydrates percentages.*

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replications	2	0.00027	0.3	NS	0.00033	0.9	NS	0.00014	0.1	NS
Variety (V)	1	0.00008	0.0	NS	0.00301	8.1	1%	0.00002	0.0	NS
Treatments (T)	3	0.03717	36.1	1%	0.00849	22.9	1%	0.02316	32.2	1%
V x T	3	0.00082	0.8	NS	0.00008	0.2	NS	0.00084	1.2	NS
Error	14	0.00103			0.00037			0.00072		

Total nitrogen percentages.*

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replications	2	0.00000	0.1	NS	0.00000	0.1	NS	0.00000	0.0	NS
Variety (V)	1	0.00000	0.0	NS	0.00001	0.7	NS	0.00001	0.5	NS
Treatments (T)	3	0.00158	35.9	1%	0.00110	84.5	1%	0.00135	67.5	1%
V x T	3	0.00004	0.9	NS	0.00000	0.6	NS	0.00002	1.0	NS
Error	14	0.00004			0.00001			0.00002		

Total non-structural carbohydrate/total nitrogen ratios.

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replications	2	0.931	0.3	NS	0.196	0.6	NS	0.275	0.2	NS
Variety (V)	1	0.209	0.0	NS	1.556	4.5	5%	0.277	0.2	NS
Treatment (T)	3	10.454	3.7	5%	0.388	1.1	NS	3.585	2.7	NS
V x T	3	2.040	0.7	NS	0.231	0.7	NS	1.751	1.3	NS
Error	14	2.835			0.343			1.326		

Table 4A.7.4. ANOVA of organic reserves of the plants grown under the covers.

		TNC Percent*			TN Percent*		
Variation	df	M.S.	F	Sig	M.S.	F	Sig
Replications	2	0.00348	6.9	5%	0.00002	0.3	NS
Variety (V)	1	0.00147	2.9	NS	0.00000	0.0	NS
Treatment (T)	1	0.00001	0.0	NS	0.00097	16.2	1%
V x T	1	0.00042	0.8	NS	0.00000	0.5	NS
Error	6	0.00050			0.00006		

* Data was transformed to the arcsin form for analysis.

Table 4A.9.1. ANOVA of the plant number count for the reversal experiment (No./1 sq ft).

Variation	df	M.S.	F	Sig
Replication	2	8.968		5%
Variety (V)	1	5.860		NS
Treatment (T)	3	1.005		NS
V x T	3	4.830		NS
Error	14	1.645		

Table 4A.9.2. ANOVA of the reversal experiment dry weight yields (gm/6 sq ft).

		Lucerne*			Other Species			Total		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	1120.1	4.8	5%	186.6	0.3	NS	42.8	0.2	NS
Variety (V)	1	5898.0	25.1	1%	394.4	0.7	NS	2491.3	10.0	1%
Treatment (T)	3	22212.6	94.9	1%	12194.7	22.7	1%	2244.7	9.0	1%
Harvest (H)	2	2138.8	9.1	1%	4010.6	7.5	1%	3057.0	12.3	1%
V x T	3	581.0	2.5	NS	1007.8	1.9	NS	440.9	1.8	NS
V x H	2	540.4	2.3	NS	1264.8	2.4	NS	495.8	2.0	NS
T x H	6	397.4	1.7	NS	1195.5	2.2	NS	27	11.1	1%
V x T x H	6	348.8	1.4	NS	481.6	0.9	NS	5	2.2	NS
Error	46	2	.9		5	.7		428.9		

		Shoot*			Stubble*			Shoot Number*		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	1587.6	7.1	1%	926.	3.1	NS	2392.0	7.6	1%
Variety (V)	1	3561.8	15.9	1%	6695.	22.5	1%	14330.6	45.7	1%
Treatment (T)	3	16442.3	73.4	1%	16441.	55.1	1%	13343.5	42.6	1%
Harvest (H)	2	27175.7	121.	1%	5682.7	19.1	1%	3860.5	12.3	1%
V x T	3	1272.9	5.7	1%	293.3	0.9	NS	2703.2	8.6	1%
V x H	2	309.9	1.4	NS	322.0	1.1	NS	516.4	1.6	NS
T x H	6	2007.0	8.9	1%	97.3	0.3	NS	866.5	2.7	5%
V x T x H	6	76.3	0.3	NS	515.4	1.7	NS	151.7	0.5	NS
Error	46	223.9			295.9			313.3		

* Data was transformed to logarithims for analysis.

Table 4A.9.3. ANOVA of the reversal experiment crop growth rate regressions (gm/6 sq ft/day).

Source of variation	df	Mean Square	F	Sig
Total within group	68	259.294		
Due to average regression	n 1	8331.606	60.02	1%
Deviations from average regression	67	138.812		
Between individ. group regress.	3	2202.563	52.34	
Deviations from individ. regress.	64	42.074		

Table 4A.9.4. ANOVA of the reversal experiment relative growth rate regressions (gm/gm/day).

Source of variation	df	Mean Square	F	Sig
Total within group	68	1298.931		
Due to average regression.	1	53841.300	104.60	1%
Deviations from average regress.	67	514.717		
Between individ. group regress.	3	3814.498	10.59	1%
Deviations from individ. regress.	64	360.040		

Table 4A.9.5. ANOVA of the reversal experiment organic reserve measurements.

Root, crown and root plus crown dry weights (gm/6 plants).

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	35.40	1.7	NS	15.26	1.2	NS	96.60	1.6	NS
Variety (V)	1	0.04	0.0	NS	140.16	11.3	1%	135.37	2.3	NS
Treatment (T)	3	315.64	14.9	1%	230.56	18.6	1%	979.76	16.7	1%
V x T	3	30.94	1.5	NS	35.74	2.9	NS	116.26	1.9	NS
Error	14	21.11			12.38			58.71		

Total non-structural carbohydrate percentage.*

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	0.00017	0.2	NS	0.00047	0.8	NS	0.00000	0.0	NS
Variety (V)	1	0.00005	0.0	NS	0.00002	0.0	NS	0.00095	1.2	NS
Treatment (T)	3	0.09945	110.	1%	0.03155	57.4	1%	0.07732	96.6	1%
V x T	3	0.00414	4.6	5%	0.00214	3.9	5%	0.00371	4.6	5%
Error	14	0.00090			0.00055			0.00080		

* Data was transformed to the arcsin form for analysis.

/4A.9.5.

Table 4A.9.5. cont.

Total non-structural carbohydrate weight (gm/6 plants).

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	2.617	1.2	NS	0.357	2.3	NS	4.854	1.5	NS
Variety (V)	1	1.918	0.9	NS	1.338	8.5	1%	0.052	0.0	NS
Treatment (T)	3	52.972	24.1	1%	4.623	29.4	1%	85.161	26.8	1%
V x T	3	2.998	1.4	NS	0.250	1.6	NS	3.664	1.2	NS
Error	14	2.199			0.157			3.178		

Total nitrogen percentage.*

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	0.00005	1.9	NS	0.00000	0.0	NS	0.00002	1.2	NS
Variety (V)	1	0.00011	4.2	5%	0.00000	0.0	NS	0.00002	1.2	NS
Treatment (T)	3	0.00140	53.8	1%	0.00102	60.0	1%	0.00124	72.9	1%
V x T	3	0.00005	1.9	NS	0.00013	5.9	1%	0.00007	4.1	5%
Error	14	0.000026			0.000017			0.000017		

Total nitrogen weight (gm/6 plants).

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	0.0253	3.1	NS	0.0096	1.4	NS	0.0662	2.3	NS
Variety (V)	1	0.0026	0.3	NS	0.0795	11.5	1%	0.0531	1.9	NS
Treatment (T)	3	0.2855	34.8	1%	0.2139	31.0	1%	0.9688	34.1	1%
V x T	3	0.0109	1.3	NS	0.0135	2.0	NS	0.0289	1.0	NS
Error	14	0.0082			0.0068			0.0283		

Total non-structural carbohydrate/total nitrogen ratios.

		Root			Crown			RTCR		
Variation	df	M.S.	F	Sig	M.S.	F	Sig	M.S.	F	Sig
Replication	2	0.558	0.4	NS	0.352	0.7	NS	0.063	0.0	NS
Variety (V)	1	0.037	0.0	NS	0.518	0.9	NS	3.187	2.7	NS
Treatment (T)	3	150.285	105.	1%	21.471	39.8	1%	97.099	81.6	1%
V x T	3	12.142	8.5	1%	4.443	8.2	1%	11.808	9.9	1%
Error	14	1.427			0.539			1.189		

* Data was transformed to the arcsin form for analysis.

APPENDIX 5A

COMPUTER PROGRAMS

5A.1. Multiple Linear Regression with sequential removal of the highest variable.
Controls used: program switch (PS) 1 off, PS 3 off - no plot back; PS 1 on, PS 3 on - plotback after each regression analysis.
Header cards and data input control: PS 2 on, PS 4 on - read in a. parameter card*, b. 5 hedder cards using C.C. 1-72 each, c. t-values, d. data - format 7F10.0.
* NUM - number of observations; M - number of variables including the dependent variable.

```
C     PROG. NO. 0211206210          MLR -MULTIPLE LINEAR REGRESSION 1      DWT
C
C       MULTIPLE LINEAR REGRESSION
C
        DIMENSION SUMX2(26),SUMX(26),SUMXY(26),XBAR(26),SX(26)
        DIMENSION A(26,26),B(26),X(26),BETA(26)
        DIMENSION R(26),SB(26),T(26),IDEL(26),TTV(26),ALPHA(78)
        COMMON SUMX2,SUMX,SUMXY,XBAR,SX,A,B,BETA,R,SB,T,IDEL,M,N,NUM,ANM,A
       1M,KON,AO,L1,KOUNT,X,TTV,ALPHA,TITLE,LZ,XX,XS
        DEFINE DISK (10,2000)
C
C       ZERO THE ACCUMULATORS
C
 1111   READ 1,NUM,M,NTRAN
        MP=M+1
        DO 12 I=1,MP
        IDEL(I)=I
        BETA(I)=0.
        SUMX2(I)=0.
        SUMX(I)=0.
        SUMXY(I)=0.
        XBAR(I)=0.
        SX(I)=0.
        SB(I)=0.
   12   X(I)=0.
        DO 13 I=1,MP
        DO 14 J=1,MP
   14   A(I,J)=0.
   13   CONTINUE
        KN=3*M
        KM=3*M+3
        DO 1229 I=1,KM
 1229   ALPHA(I)=0.
        IF (SENSE SWITCH 2)249,229
  249   IF(SENSE SWITCH 4)219,15
  219   DO 220 I=1,5
        READ 3
  220   PRINT 3
        GO TO 15
  229   IF(SENSE SWITCH 4)16,15
   16   READ 93,(ALPHA(J),J=1,KN)
   15   MA=M-1
        READ 2000,(TTV(I),I=1,MA)
C
C       THE FIRST PART OF THE PROGRAM GENERATES THE COEFFICIENT
C       MATRIX,CALCULATES THE VARIABLE MEANS AND STANDARD DEVIATIONS,
C       AND ADJUSTS THE ELEMENTS OF THE COEFFICIENT MATRIX.
C
        MA=M-1
        KON=M
        AN=NUM
        IMAX=1
        DO 1000 MAX=1,NUM
        READ 2000,(X(I),I=1,M)
        IF(NTRAN)301,300,301
  301   DO 302 II=1,M
  302   X(II)=(LOGF(X(II)))*.43429448
  300   RECORD (IMAX) (X(I),I=1,M)
        DO 22 I=1,M
        SUMX2(I)=SUMX2(I)+X(I)*X(I)
```

```
      N=N-1
      M=M-1
      MA=MA-1
      DO 512 J=L,N
      DO 513 I=1,N
513   A(I,J)=A(I,J&1)
512   CONTINUE
      PRINT 29
   29 FORMAT (1H0,15H INVERSE MATRIX/16H ----------------)
      DO 160 I=1,N
  160 PRINT 162,(A(I,J),J=1,N)
  162 FORMAT (1H,8F18.5)
      DO 6149 I=L,N
      TTV(I)=TTV(I&1)
      XBAR(I)=XBAR(I&1)
6149  SX(I)=SX(I&1)
      PRINT 92
      PRINT 8885,XBAR(1),SX(1),ALPHA(1),ALPHA(2),ALPHA(3)
      K=4
      DO 7645 I=2,M
      IK=I-1
      PRINT 4,IK,XBAR(I),IK,SX(I),ALPHA(K),ALPHA(K&1),ALPHA(K&2)
 7645 K=K&3
      KOUNT =0
      DO 2040 J=1,KON
      IF(IDEL(J)) 2050,2040,2050
 2050 KOUNT=KOUNT & 1
      IF (KOUNT - L ) 2040,2060, 2040
 2040 CONTINUE
 2060 IDEL (J)=0
      GO TO 69
4999  CALL EXIT
C
C     FORMAT STATEMENTS.
C
6110  FORMAT(20H ALL VARIABLES SIGNIFICANT)
6116  FORMAT(50H THE NUMBER OF VARIABLES ... LESS THAN 2)
6117  FORMAT(////27H THE VARIABLE ELIMINATED IS ,I3,////)
79    FORMAT(/37H THE PARTIAL REGRESSION COEFFICIENTS./)
5     FORMAT(6H B(,I3,2H)=,F20.8)
74    FORMAT(17H THE Y-INTERCEPT.,/)
6     FORMAT(7H ALPHA=,F20.8,/)
76    FORMAT(46H THE STANDARD ERRORS OF THE REGRESSION COEFS.,/)
   61 FORMAT(4H SB(,I3,2H)=,F20.8)
76    FORMAT(23H THE BETA COEFFICIENTS.,/)
7     FORMAT(6H BETA(,I3,2H)=,F14.3)
77    FORMAT(/43H THE COEFFICIENT OF MULTIPLE DETERMINATION.,/)
9     FORMAT(5H RHO=,F14.3,/)
78    FORMAT(41H THE COEFFICIENT OF MULTIPLE CORRELATION.,/)
10    FORMAT(3H R=,F14.3,/)
79    FORMAT(32H THE STANDARD ERROR OF ESTIMATE.,/)
8     FORMAT(13H S(1.23...M)=,F14.3,/)
91    FORMAT(/38HTHE PARTIAL CORRELATION COEFFICIENTS     )
62    FORMAT(3H R(,I3,2H)=,F20.8)
98    FORMAT(3H T(,I3,2H)=,F20.8)
95    FORMAT(/12H THE F-TEST.,/)
96    FORMAT(3H F=,F12.4,/)
97    FORMAT(12H THE T-TEST.,/)
8000  FORMAT(7F10.0)
   11 FORMAT (1H ,I4,5X,F14.3,5X,F14.3,5X,F14.3)
71    FORMAT(I2)
199   FORMAT(6HOBS.NO,15X,1HY,15X,5HY-EST,18X,1HE)
8885  FORMAT(7H YBAR =,F14.6,20H          SIGMA(Y) = ,F14.6 ,4X,3A4)
92    FORMAT(44H THE VARIABLE MEANS AND STANDARD DEVIATIONS.,/)
 1044 FORMAT (1H,66HCOMPARING THE EQUATION WITH THE PREVIOUS AND PREVIOUO
     1S &1 EQUATIONS)
 1046 FORMAT (1H,7HF(1-2)=,F12.4,10X,4HDF  ,I2,2H, ,I2)
 1048 FORMAT (1H,7HF(1-3)=,F12.4,10X,4HDF  ,I2,2H, ,I2)
  4   FORMAT (6H XBAR(,I3,2H)=,F14.3,5X,7H SIGMA(,I3,2H)=,F14.3,4X,3A4)
      END
```

```
      TDF=M&1-MA
      BDF=NUM-(M&1)-1
      PRINT 1048,F2,TDF,BDF
 1050 RHE=RHA
 1040 RHA=RHO
C
C     THIS PART OF THE PROGRAM CALCULATES THE PARTIAL
C     CORRELATION COEFFICIENTS.
C
      PRINT 91
      DO 52 J=2,M
      AR=SQRT(A(1,J)*A(1,J)/(A(1,1)*A(J,J)))
      K=J-1
   52 PRINT 62,K,AR
C
C     THIS PART OF THE PROGRAM CALCULATES THE F RATIO
C
      PRINT 95
      F=RHO*ANM/(AT*(1.-RHO))
      PRINT 96,F
C
C     THIS PART OF THE PROGRAM CALCULATES THE T VALUES FOR THE
C     PARTIAL REGRESSION COEFFICIENTS.
C
      PRINT 97
      DO 120 I=1,MA
      T(I)=B(I)/SS(I)
      IF(T(I))130,120,120
  130 T(I)=-1.*T(I)
  120 PRINT 98,I,T(I)
C
C     THIS PART OF THE PROGRAM PUNCHES THE DEGREES OF FREEDOM FOR
C     THE REGRESSION PROBLEM.
C
      PRINT 8111,ANM
 8111 FORMAT(/28H T-T DEGREES OF FREEDOM //7H N-M-1=,F10.0)
C
C     THIS PART OF THE PROGRAM PERMITS THE USER TO OBTAIN
C     A PLOTBACK OF THE OBSERVATION NUMBER,T  VALUE OF
C     THE DEPENDENT VARIABLE,THE ESTIMATED  VARIABLE,AND THE
C     DEVIATION FROM REGRESSION.
C
      IF(SENSE SWITCH 3)41,642
 41   IF(SENSE SWITCH 1)641,8160
 8151 TYPE 8116
      CALL LINK (MLR)
  642 IF(SENSE SWITCH 1)189,8160
  641 CONTINUE
C
C     THIS PART OF THE PROGRAM GIVES THE USER THE OPPORTUNITY TO
C     ELIMINATE ONE VARIABLE FROM THE REGRESSION ANALYSIS.
C
  189 IF(LAST)186,8160,186
 8160 J=1
 8150 L=MA&1
      IF(N-3)8151,8152,8152
 8152 PRINT 8117,MA
      GO TO 779
 8149 CONTINUE
  183 PRINT 8118
  187 IF(SENSE SWITCH 1)184,186
  184 IF(SENSE SWITCH 3)186,185
  185 LAST=1
      GO TO 641
  186 CALL LINK (MLR)
  779 DO 80 I=1,N
      DO 81 J=1,N
      IF(J-L)82,81,82
   82 IF(I-L)83,81,83
   83 A(I,J)=(A(I,J)*A(L,L)-A(I,L)*A(J,L))/A(L,L)
   81 CONTINUE
   80 CONTINUE
      DO 510 I=L,N
      DO 511 J=1,N
  511 A(I,J)=A(I&1,J)
  510 CONTINUE
      LK=3*L-2
      LT=3*M&3
      DO 6339 I=LK,LT
 6339 ALPHA(I)=ALPHA(I&3)
```

```
C     PROG. NO. 0211306210          MLRS -MULTIPLE LINEAR REGRESSION 2     DWT
      DIMENSION SUMX2(26),SUMX(26),SUMXY(26),XBAR(26),SX(26)
      DIMENSION A(26,26),B(26),X(26),BETA(26)
      DIMENSION R(26),SB(26),T(26),IDEL(26),TTV(26),ALPHA(78)
      COMMON SUMX2,SUMX,SUMXY,XBAR,SX,A,B,BETA,R,SB,T,IDEL,M,N,NUM,ANM,A
     1M,KON,AO,L1,KOUNT,X,TTV,ALPHA,TITLE,LZ,XX,XS
      DEFINE DISK (10,200))
C
CCC   THIS PART OF THE PROGRAM CALCULATES THE PARTIAL
C     REGRESSION COEFFICIENTS.
C
      LAST=0
      KON=M
      AN=NUM
      MA=M-1
      MIN=0
   69 PRINT 73
      DO 36 J=2,M
36    B(J-1)=-A(1,J)/A(1,1)
      DO 37 J=1,MA
   37 PRINT 5,J,B(J)
C
CCC   THIS PART OF THE PROGRAM CALCULATES THE Y-INTERCEPT.
C
      SUM=0.
      DO 38 I=2,M
38    SUM=SUM+B(I-1)*XBAR(I)
      AO=XBAR(1)-SUM
      PRINT 74
      PRINT 6,AO
C
CCC   THIS PART OF THE PROGRAM CALCULATES THE STANDARD ERRORS
C     OF THE REGRESSION COEFFICIENTS.
C
      PRINT 75
      ANM=NUM-M
      AT=M-1
      DO 51 J=2,M
      SB(J-1)=SQRT((A(1,1)*A(J,J)-A(1,J)*A(1,J))/(ANM*A(1,1)*A(1,1)))
      K=J-1
   51 PRINT 61,K,SB(J-1)
C
CCC   THIS PART OF THE PROGRAM CALCULATES THE STANDARD
C     PARTIAL REGRESSION COEFFICIENTS.
C
      PRINT 76
      DO 39 I=2,M
      BETA(I-1)=B(I-1)*SX(I)/SX(1)
      K=I-1
   39 PRINT 7,K,BETA(K)
C
CCC   THIS PART OF THE PROGRAM CALCULATES THE MULTIPLE CORRELATION
C     COEFFICIENT,THE STANDARD ERROR OF ESTIMATE,AND THE COEFFICIENT
C     OF MULTIPLE DETERMINATION.
C
      PRINT 77
      RHO=(A(1,1)*AM-1.)/(A(1,1)*AM)
      PRINT 9,RHO
      PRINT 78
      RA=SQRT(RHO)
      PRINT 10,RA
      PRINT 79
      SXX=SQRT(SX(1)*SX(1)*(1.-RHO))
      SXX=SXX*SQRT(AN/ANM)
      PRINT 8,SXX
C     COMPARING WITH PREVIOUS EQUATIONS
      MIN=MIN&1
      IF (MIN-1)1040,1040,1042
 1042 F1=((RHA-RHO)/((AT&1.)- AT       ))/((1.-RHA)/(AN-(AT&1.)-1.))
      TDF=M-MA
      BDF=NUM-M-1
      PRINT 1044
      PRINT 1046,F1,TDF,BDF
      IF (MIN-2)1050,1050,1052
 1052 F2=((RHE-RHO)/((AT&2.)-AT))/((1.-RHE)/(AN-(AT&2.)-1.))
```

```
22      SUMX(I)=SUMX(I)&X(I)
        DO 23 I=1,M
        DO 24 J=I,M
24      A(I,J)=A(I,J)&X(I)*X(J)
23      CONTINUE
1000    CONTINUE
        PRINT 9
     9  FORMAT(1HO,22H SUM OF SQUARES MATRIX/23H ----------------------)
        DO 20 I=1,M
    20  PRINT 79,(A(I,J),J=1,M)
        DO 25 I=1,M
        DO 26 J=I,M
26      A(I,J)=(AN*A(I,J)-SUMX(I)*SUMX(J))/AN
25      CONTINUE
        PRINT 19
    19  FORMAT(1HO,22H PRODUCT MOMENT MATRIX/23H ----------------------)
        DO 30 I=1,M
    30  PRINT 79,(A(I,J),J=1,M)
     3  FORMAT(50H1                                                  30H
      1                                  )
        AM=A(1,1)
        DO 50 J=1,M
        JP=J&1
        DO 51 I=JP,M
51      A(I,J)=A(J,I)
50      SUMXY(J)=A(J,1)
        PRINT 92
8885    FORMAT(6H YBAR = ,F14.6,20H          SIGMA(Y) = ,F14.6,4X,3A4)
        DO 27 I=1,M
        XBAR(I)=SUMX(I)/AN
27      SX(I)=SQRT((SUMX2(I)-AN*XBAR(I)*XBAR(I))/AN)
        PRINT 8885,XBAR(1),SX(1),ALPHA(1),ALPHA(2),ALPHA(3)
        K=4
        DO 7654 I=2,M
        II=I-1
        PRINT 4,II,XBAR(I),II,SX(I),ALPHA(K),ALPHA(K&1),ALPHA(K&2)
 7654   K=K&3
C
C       FORMAT STATEMENTS
C
        FORMAT(I5,2I2)
2000    FORMAT(F12.4)
92      FORMAT(44H THE VARIABLE MEANS AND STANDARD DEVIATIONS.)
2       FORMAT(F20.8)
4       FORMAT(6H XBAR(,I3,2H)=,F14.3,5X,7H SIGMA(,I3,2H)=,F14.3,4X,3A4)
   93   FORMAT(6(3A4))
C
C     THIS PART OF THE PROGRAM INVERTS THE MATRIX OF COEFFICIENTS.
C
        N=M
        MA=M-1
        NK=M
        K=M-1
        DO 105 L=1,NK
        DO 106 J=1,NK
106     R(J)=A(1,J)
        R(NK&1)=1.
        DO 107 I=1,K
        DO 108 J=1,NK
        IF(J-NK)109,110,109
109     A(I,J)=A(I&1,J&1)-(A(I&1,1)*R(J&1)/R(1))
        GO TO 108
110     A(I,J)=-A(I&1,1)/R(1)
108     CONTINUE
107     CONTINUE
        DO 111 J=1,NK
111     A(NK,J)=R(J&1)/R(1)
105     CONTINUE
        PRINT 29
    29  FORMAT(1HO,15H INVERSE MATRIX/16H ---------------)
        DO 40 I=1,M
    40  PRINT 79,(A(I,J),J=1,M)
    79  FORMAT(1H ,8F18.3)
132     L1=0
        KOUNT=0
        CALL LINK (MLRS)
        END
```

5A.2. Multiple regression for a selected number of variables.
Control program switches are as for 5A.1. PS 1 on, PS 3 on,
PS 2 on, PS 4 on.
It further reads the title of the curve, an LZ control of the maximum selected X*value to plot back and an AZ control for antilogging calculated Y values and SE's when applicable.
The program plots back for the read X values, for selected X values and determines the SE of each calculated Y value
* X the independent variable; Y the dependent variable.

```
C     PROG. NO. 0211206210          MLE -MULTIPLE LINEAR REGRESSION 1      DWT
C
C       MULTIPLE LINEAR REGRESSION
C
        DIMENSION SUMX2(26),SUMX(26),SUMXY(26),XBAR(26),SX(26)
        DIMENSION A(26,26),B(26),X(26),BETA(26)
        DIMENSION R(26),SB(26),T(26),IDEL(26),TTV(26),ALPHA(78)
        DIMENSION XX(8),XS(8),TITLE(20)
        COMMON SUMX2,SUMX,SUMXY,XBAR,SX,A,B,BETA,R,SB,T,IDEL,M,N,NUM,ANM,A
       1N,KON,AO,L1,KOUNT,X,TTV,ALPHA,TITLE,LZ,XX,XS,AZ
        DEFINE DISK (10,2000)
C
C       ZERO THE ACCUMULATORS
C
  1111  READ 1,NUM,M,NTRAN
        ANM=NUM
        DO 12 I=1,26
        SUMX2(I)=0.
        SUMX(I)=0.
        BETA(I)=0.
        SUMXY(I)=0.
        XBAR(I)=0.
        SX(I)=0.
        SB(I)=0.
   12   X(I)=0.
        DO 13 I=1,MP
        DO 14 J=1,MP
   14   A(I,J)=0.
   13   CONTINUE
        KM=3*M
        KN=3*M&3
        DO 1229 I=1,KM
 1229   ALPHA(I)=0.
        IF (SENSE SWITCH 2)249,229
  249   IF(SENSE SWITCH 4)219,15
  219   DO 220 I=1,5
        READ 3
  220   PRINT 3
        GO TO 15
  229   IF(SENSE SWITCH 4)16,15
   16   READ 93,(ALPHA(J),J=1,KN)
   15   MA=M-1
        READ 2000,(TTV(I),I=1,MA)
        READ 94,(TITLE(J),J=1,5),LZ,AZ
   94   FORMAT (5A4,2I2)
C
C       THE FIRST PART OF THE PROGRAM GENERATES THE COEFFICIENT
C       MATRIX,CALCULATES THE VARIABLE MEANS AND STANDARD DEVIATIONS,
C       AND ADJUSTS THE ELEMENTS OF THE COEFFICIENT MATRIX.
C
        MA=M-1
        KON=M
        AN=NUM
        IMAX=1
        DO 1000 MAX=1,NUM
        READ 2000,(X(I),I=1,M)
        IF(NTRAN)301,300,301
  301   DO 302 II=1,M
  302   X(II)=(LOGF(X(II)))*.43429448
```

```
  300 RECORD (IMAX) (X(I),I=1,M)
      DO 22 I=1,M
      SUMX2(I)=SUMX2(I)&X(I)*X(I)
22    SUMX(I)=SUMX(I)&X(I)
      DO 23 I=1,M
      DO 24 J=I,M
24    A(I,J)=A(I,J)&X(I)*X(J)
23    CONTINUE
1000  CONTINUE
      PRINT 9
    9 FORMAT(1H0,22H SUM OF SQUARES MATRIX/23H ----------------------)
      DO 20 I=1,M
   20 PRINT 79,(A(I,J),J=1,M)
      DO 25 I=1,M
      DO 26 J=I,M
26    A(I,J)=(AN*A(I,J)-SUMX(I)*SUMX(J))/AN
25    CONTINUE
      PRINT 19
   19 FORMAT(1H0,22H PRODUCT MOMENT MATRIX/23H ----------------------)
      DO 30 I=1,M
   30 PRINT 79,(A(I,J),J=1,M)
    3 FORMAT(50H1                                                  30H
     1                              )
      AM=A(1,1)
      DO 50 J=1,M
      JP=J&1
      DO 51 I=JP,M
51    A(I,J)=A(J,I)
50    SUMXY(J)=A(J,1)
      PRINT 92
8885  FORMAT(8H YBAR = ,F14.6,20H          SIGMA(Y) = ,F14.6,4X,3A4)
      DO 27 I=1,M
      XBAR(I)=SUMX(I)/AN
27    SX(I)=SQRT((SUMX2(I)-AN*XBAR(I)*XBAR(I))/AN)
      PRINT 8885,XBAR(1),SX(1),ALPHA(1),ALPHA(2),ALPHA(3)
      K=4
      DO 7584 I=2,M
      II=I-1
      PRINT 4,II,XBAR(I),II,SX(I),ALPHA(K),ALPHA(K&1),ALPHA(K&2)
7584  K=K&3
C
C     FORMAT STATEMENTS.
C
1     FORMAT(I5,2I2)
2000  FORMAT(7F10.0)
92    FORMAT(44H THE VARIABLE MEANS AND STANDARD DEVIATIONS.)
2     FORMAT(F20.8)
4     FORMAT(6H XBAR(,I3,2H)=,F14.3,5X,7H SIGMA(,I3,2H)=,F14.3,4X,3A4)
   93 FORMAT(6(3A4))
C
C     THIS PART OF THE PROGRAM INVERTS THE MATRIX OF COEFFICIENTS.
C
      N=M
      MA=M-1
      NK=M
      K=M-1
      DO 105 L=1,NK
      DO 106 J=1,NK
106   R(J)=A(1,J)
      R(NK&1)=1.
      DO 107 I=1,K
      DO 108 J=1,NK
      IF(J-NK)109,110,109
109   A(I,J)=A(I&1,J&1)-(A(I&1,1)*R(J&1)/R(1))
      GO TO 108
110   A(I,J)=-A(I&1,1)/R(1)
108   CONTINUE
107   CONTINUE
      DO 111 J=1,NK
111   A(NK,J)=R(J&1)/R(1)
105   CONTINUE
      PRINT 29
   29 FORMAT(1H0,15H INVERSE MATRIX/16H ----------------)
      DO 40 I=1,M
   40 PRINT 79,(A(I,J),J=1,M)
   79 FORMAT(1H ,8F18.3)
132   L1=0
      KOUNT=0
      CALL LINK (MLRE)
      END
```

```
C     PROG. NO. 0211306210          MLRE -MULTIPLE LINEAR REGRESSION 2     DWT
      DIMENSION SUMX2(26),SUMX(26),SUMXY(26),XBAR(26),SX(26)
      DIMENSION A(26,26),B(26),X(26),BETA(26)
      DIMENSION R(26),SB(26),T(26),IDEL(26),TTV(26),ALPHA(78)
      DIMENSION XX(6),XS(6),TITLE(20)
      COMMON SUMX2,SUMX,SUMXY,XBAR,SX,A,B,BETA,R,SB,T,IDEL,M,N,NUM,ANM,A
     1M,KON,A0,L1,KOUNT,X,TTV,ALPHA,TITLE,LZ,XX,XS,AZ
      DEFINE DISK (10,2000)
      TYPE 1031
 1031 FORMAT (33HSENSE SWITCHES 1 AND 3 MUST BE ON)
C
C     THIS PART OF THE PROGRAM CALCULATES THE PARTIAL
C     REGRESSION COEFFICIENTS.
C
      LAST=0
      KON=M
      AN=NUM
      MA=M-1
   69 PRINT 73
      DO 36 J=2,M
36    B(J-1)=-A(1,J)/A(1,1)
      DO 37 J=1,MA
   37 PRINT 5,J,B(J)
C
C     THIS PART OF THE PROGRAM CALCULATES THE Y-INTERCEPT.
C
      SUM=0.
      DO 38 I=2,M
38    SUM=SUM+B(I-1)*XBAR(I)
      A0=XBAR(1)-SUM
      PRINT 74
      PRINT 6,A0
C
C     THIS PART OF THE PROGRAM CALCULATES THE STANDARD ERRORS
C     OF THE REGRESSION COEFFICIENTS.
C
      PRINT 75
      ANM=NUM-M
      AT=M-1
      DO 51 J=2,M
      SB(J-1)=SQRT((A(1,1)*A(J,J)-A(1,J)*A(1,J))/(ANM*A(1,1)*A(1,1)))
      K=J-1
   51 PRINT 61,K,SB(J-1)
C
C     THIS PART OF THE PROGRAM CALCULATES THE STANDARD
C     PARTIAL REGRESSION COEFFICIENTS.
C
      PRINT 76
      DO 39 I=2,M
      BETA(I-1)=B(I-1)*SX(I)/SX(1)
      K=I-1
   39 PRINT 7,K,BETA(K)
C
C     THIS PART OF THE PROGRAM CALCULATES THE MULTIPLE CORRELATION
C     COEFFICIENT,THE STANDARD ERROR OF ESTIMATE,AND THE COEFFICIENT
C     OF MULTIPLE DETERMINATION.
C
      PRINT 77
      RHO=(A(1,1)*AM-1.)/(A(1,1)*AM)
      PRINT 9,RHO
      PRINT 78
      RA=SQRT(RHO)
      PRINT 10,RA
      PRINT 79
      SXX=SQRT(SX(1)*SX(1)*(1.-RHO))
      SXX=SXX*SQRT(AN/ANM)
      PRINT 8,SXX
C
C     THIS PART OF THE PROGRAM CALCULATES THE F RATIO
C
      PRINT 95
      F=RHO*ANM/(AT*(1.-RHO))
      PRINT 96,F
```

```
C
C       THIS PART OF THE PROGRAM PUNCHES THE DEGREES OF FREEDOM FOR
C       THE REGRESSION PROBLEM.
C
        PRINT 8111,ANM
8111    FORMAT(/23H THE DEGREES OF FREEDOM //7H N-M-1=,F10.0)
C
C       THIS PART OF THE PROGRAM PERMITS THE USER TO OBTAIN
C       A PLOTBACK OF THE OBSERVATION NUMBER,THE VALUE OF
C       THE DEPENDENT VARIABLE,THE ESTIMATED VARIABLE,AND THE
C       DEVIATION FROM REGRESSION.
C
        IF(SENSE SWITCH 3)41,642
41      IF(SENSE SWITCH 1)641,8160
 8151   TYPE 8116
        CALL LINK (MLR)
642     IF(SENSE SWITCH 1)189,8160
  641   PRINT 99
99      FORMAT(//32H THE DEVIATIONS FROM REGRESSION.,//,6HOBS.NO,15X,1HY,1
       15X,5HY-EST,18X,1HE,6X,13HS.E. OF Y-EST,15X,10HANTI-LOG Y,12X,3HX
       2,/)
        IMAX=1
49      DO 48 LI=1,NUM
        YEST=AO*1.
        FETCH (IMAX) (X(I),I=1,KON)
2011    KT=2
        DO 45 J=2,M
146     IF(IDEL(KT))55,145,55
145     KT=KT&1
        GO TO 146
55      YEST=YEST&B(J-1)*X(KT)
45      KT=KT&1
        E=X(1)-YEST
        DO 1016 J=1,MA
 1016   XS(J)=X(J)-XBAR(J&1)
        LH=1
        GO TO 666
  777   SYY=SXX*SQRTF((1./AN)&FSUM)
        IF (AZ)  43,  43,1030
 1030   AX=EXPF(X(2)/.43429167)/10.
   43   PRINT 11,LI,X(1),YEST,E,SYY,AX,X(2)
48      CONTINUE
        PUNCH 198,NUM,MA,SXX,AO,(B(J),J=1,MA)
C       ESTIMATING Y AND ITS STANDARD ERROR FOR SELECTED X VALUES
        PRINT 1022,NUM,MA
        LH=LH&1
        XX(1)=0.
        XL=1.
        DO 1010 LX=1,LZ
C       DEVELOPES EXTENDED VALUES OF X
        IF (M-2)555,555,560
  560   DO 1012 J=2,MA
 1012   XX(J)=XX(J-1)*XX(1)
C       CALCULATES THE ESTIMATE OF Y
  555   YES=AO
        DO 1014 J=1,MA
 1014   YES=YES&B(J)*XX(J)
        IF (AZ)1027,1027,1028
 1058   BYES=YES/0.43429167
 1028   AYES=EXPF(YES/0.43429167)/10.
C       CALCULATE TH E X VALUE FOR THE STANDARD ERROR
 1027   DO 1015J=1,MA
 1015   XS(J)=XX(J)-XBAR(J&1)
C       CALCULATE THE STANDARD ERROR OF THE Y ESTUMATE
  666   FSUM=0.
        NI =1
        DO 1018 I=2,M
        NI =NI&1
        DO 1018 J= NI,M
        IF(I-J)1017,1019,1017
 1017   FSUM=FSUM&(2.*A(I,J)*XS(I-1)*XS(J-1))
        GO TO 1018
 1019   FSUM=FSUM&(A(I,J)*XS(I-1)*XS(J-1))
 1018   CONTINUE
        GO TO (777,787),LH
  787   SYX=SXX*SQRTF(1.&(1./AN)&FSUM)
        IF (AZ) 1054,1054,1055
 1055   ASYX=EXPF(SYX/0.43429167)
 1054   CONTINUE
C       OUTPUT OF RESULTS
```

```
      IF(XL-2.)835,836,836
  835 PUNCH 1020,XX(1),YES,SYX,NUM,MA,BYES,(TITLE(J),J=1,5)
      XL=XL&1.
      GO TO 837
  836 XL=1.
  837 PRINT 1024,XX(1),YES,SYX,AYES,ASYX,BYES
      XX(1)=XX(1)&0.7
 1010 CONTINUE
  189 GO TO 186
 8160 GO TO 186
  186 CALL LINK (MLE)
 4999 CALL EXIT
C
C     FORMAT STATEMENTS.
C
8118  FORMAT(26H ALL VARIABLES SIGNIFICANT)
8116  FORMAT(39H THE NUMBER OF VARIABLES IS LESS THAN 2)
73    FORMAT(/37H THE PARTIAL REGRESSION COEFFICIENTS./)
5     FORMAT(3H B(,I3,2H)=,F20.8)
74    FORMAT(17H THE Y-INTERCEPT.,/)
6     FORMAT(7H ALPHA=,F20.8,/)
75    FORMAT(45H THE STANDARD ERRORS OF THE REGRESSION COEFS.,/)
   61 FORMAT(4H SB(,I3,2H)=,F20.8)
76    FORMAT(23H THE BETA COEFFICIENTS.,/)
7     FORMAT(6H BETA(,I3,2H)=,F14.3)
77    FORMAT(/43H THE COEFFICIENT OF MULTIPLE DETERMINATION.,/)
9     FORMAT(5H RHO=,F14.3,/)
78    FORMAT(41H THE COEFFICIENT OF MULTIPLE CORRELATION.,/)
10    FORMAT(3H R=,F14.3,/)
79    FORMAT(32H THE STANDARD ERROR OF ESTIMATE.,/)
8     FORMAT(13H S(1.23...M)=,F14.3,/)
95    FORMAT(/12H THE F-TEST.,/)
96    FORMAT(3H F=,F12.4,/)
[illegible] FORMAT (1H ,I4,5X,F14.3,5X,F14.3,5X,F14.3,5X,F14.3,10X,2F15.3)
[illegible] FORMAT (4F10.3,2F8.1,5A4,9X,1H2)
[illegible] FORMAT (2F5.1,6F8.5,5X,1H5)
[illegible] FORMAT (F5.2,[illegible]F15.5,2F5.1,F14.5,5A4,[illegible])
 1022 FORMAT (1H,/,//[illegible]SELECT. VALUE,10X,[illegible]EST,11X,4HS.E.,5X,14HANTI-
     [illegible] Y-EST,5X,[illegible] S.E.,16HNO. OBSERVATIONS,I3,10X,22HNO. IN
     [illegible] VARIABLES = [illegible]
 [illegible] FORMAT (1H,F13.[illegible])
 [illegible] FORMAT (1H [illegible]COMPA[illegible]ION WITH THE PREVIOUS AND PREVIOUS
     1 &1 EQUATIONS)
 1046 FORMAT (1H,7HF(1-2)=,F12.4,10X,4HDF  ,I2,2H, ,I2)
 1040 FORMAT (1H,7HF(1-2)=,F12.4,10X,4HDF  ,I2,2H, ,I2)
      END
```

5A.3. A program for the multiple statistical comparison of comparable values for which the Standard Errors are available. Both a Least Significant Difference and Scheffe F-test are used using a pooled Standard Error.

```
C       MULTIPLE COMPARISONS OF ESTIMATED Y VALUES FROM MLR EQUATIONS
        DIMENSION YEST(10),SE(10),FNUM(10) ,FMA(10),TITLE(40,10),SSD(5),
       1T(5)
    4   PAUSE
C
CC      READ TITLE OF ANALYSIS
C
        READ 2
        PRINT 2
        IF (SENSE SWITCH 3)40,41
C
CC      ACCEPT NUMBER OF COMPARISONS
C
   40   TYPE 140
        ACCEPT 303,N
        CN=N*1
   41   SW=0.
        SD=0.
        FN=0.
        FM=0.
C
C       READ DATA
C
        DO 141 K=1,N
        READ 10,K,YEST(K),SE(K),FNUM(K),FMA(K),(TITLE(K,J),J=1,2)
C
C       CALCULATES POOLED SE AND DF
C
        SW=SW&((FNUM(K)-FMA(K))*SE(K)**2)
        SD=SD&(FNUM(K)-FMA(K))
        FN=FN&FNUM(K)
  141   FM=FM&FMA(K)
        PSE=SQRTF(SW/SD)
        DF=FN-FM
        RN=FM-1.
        IF(SENSE SWITCH 3)42,43
C
CC      ACCEPTS T TEST VALUES
C
   42   TYPE 142,DF
        ACCEPT 160,    (T(I),I=1,3 )
   43   PRINT 167,DF,PSE,DF,RN
        PRINT 20
C
CC      CALCULATES LSD SIGNIFICANT DIFFERENCES
C
        NI=1
        NN=N-1
        DO 12 J=1,NN
        NI=NI&1
        DO 12 I=NI,N
        YDIFF=YEST(I)-YEST(J)
        SDIFF=PSE*SQRTF(1./FNUM(J)&1./FNUM(I))
        DO 5 IK=1,3
    5   SSD(IK)=T(IK)*SDIFF
C
CC      CALCULATES SCHEFFE TEST
C
        QDIFF=YDIFF**2
        SCEF=QDIFF/(PSE**2)*(1./FNUM(J)&1./FNUM(I))*RN
C
CC      PRINT RESULTS
C
   12   PRINT 22,(TITLE(J,K),K=1,2),(TITLE(I,K),K=1,2),  YDIFF,(SSD(K),K=1
       1, 2),SCEF
        PRINT 604
```

```
      IF (SENSE SWITCH 1)4,30
   30 IF (SENSE SWITCH 2)32,6
   32 CALL EXIT
    2 FORMAT (54H1                                                          )
  140 FORMAT (26HLOAD NUMBER OF COMPARISOMS)
  303 FORMAT (3I2)
   10 FORMAT (F5.2,2F15.8,2F5.1,14X,5A4,1X)
  160 FORMAT (3F6.3)
  166 FORMAT (1H,20X,10H  T VALUES,3(F6.3,5X))
  164 FORMAT (1H,//)
  142 FORMAT  (5HDF = ,I3,14HFORMAT = F10.3)
   22 FORMAT (1H,2A4,3H - ,2A4,  5X,F 7.3,   2F10.3,6X,F10.3,6X)
   20 FORMAT (1H,/5X,15HCOMPARISON MADE,5H     ,   7H Y DIFF,   22H
     1P = 0.05  P = 0.01,2X,3HSIG   ,2X,9HSCHEFFE F,2X,3HSIG   /)
  167 FORMAT(1H,/12X,3H  DF ,F4.0,8X,14HPOOLED S.E. = ,F8.3,10X,5HDF = ,
     1F4.0,2H ,,F4.0)
  604 FORMAT (1H,////)
      END
```

5.4 Frequency distribution program.

```
C       PROGRAM FOR DETERMINING DATA FREQUENCY DISTRIBUTIONS
C
        DIMENSION R(1,530),H(1),S(1),RG(1),D(1,20),FNS(1,20),V(50),
       1FT(1,20),PP(1,20),FOR(20),TITLE(10),P(1,530),A(1),B(1)
     28 PAUSE
        IF (SENSE SWITCH 2)1,3
C
CC      READ DATA
C
      1  READ 404, IM,IN
         READ 400,(FOR(IK),IK=1,10)
         PRINT 405,IM,IN,(FOR(IK),IK=1,10)
      3 DO 2 K=1,IM
      2 READ FOR,(R(K,I),I=1,IN)
C
CC      DETERMINES MAX AND MIN VALUES
C
         IL=IN-1
         DO 11 K=1,IM
         DO 3 I=1,IL
         DO 12 I=1,IL
         IF (R(K,I)-R(K,I+1))10,12,12
     10  Z=Z
         Z=R(K,I+1)
         R(K,I+1)=X
     12  CONTINUE
         S(K)=(Z+R(K,1))/2.
         R(K,1)=Z
     25  DO 9 K=1,IM
         Z=R(K,1)
         DO 4 I=1,IL
         IF (Z-R(K,I+1))4,4,6
      6  X=Z
         Z=R(K,I+1)
         R(K,I+1)=X
      4  CONTINUE
         S(K) =(Z*2.)/2.
      9  R(K,1)=Z
         LL=0.
         DO 25 K=1,IM
         READ 601,(TITLE(IJ),IJ=1,4)
C
CC      CALCULATES CLASS INTERVAL
C
         DO 34 I=1,IN
     34  P(K,I)=R(K,I)*1.
         H(K)=A(K)*1.
         S(K)=B(K)*1.
     40  RG(K)=H(K)-S(K)
         TA    =RG(K)/2).
         LL=LL+1
         GO TO (50,51,52),LL
C
CC      PRINTS DIMENSIONAL DATA
C
     50  PRINT 610,(TITLE(IJ),IJ=1,4)
         GO TO 53
     51  PRINT 611,(TITLE(IJ),IJ=1,4)
         GO TO 53
     52  PRINT 612,(TITLE(IJ),IJ=1,4)
         GO TO 53
     53  PRINT 604
         PRINT402, H(K),S(K),RG(K),TA
         PRINT 604
C
C       CALCULATES DISTRIBUTION
```

```
C
      D(K,1)=DS(K)
      DO 14 J=2,20
   14 D(K,J)=D(K,J-1)&TA
      DO 17 J=1,20
   17 FNS(K,J)=0.
      J=1
      FT(K,1)=0.
      DO 19 I=1,IN
      DO 18 J=1,20
        IF (P(K,I)-D(K,J))16,16,18
   16 FNS(K,J)=FNS(K,J)&1.
      GO TO 19
   18 CONTINUE
   19 CONTINUE
CCC
CCC   PREPARES AND PRINTS DISTRIBUTION HISTOGRAM
CCC
      PN =(IN*1)/1
      FT(K,1)=FT(K,1)&FNS(K,1)
      DO 32 J=2,20
   32 FT(K,J)=FT(K,J-1)&FNS(K,J)
      DO 33 J=1,20
   33 PP(K,J)=(FT(K,J)*100.)/PN
      PRINT 406
      PRINT 407
      PRINT 408, (FNS(K,J),J=1,20)
      PRINT 409, (PP(K,J),J=1,20)
C
CCC   TRANSFORMS ALL VALUES TO SQUARE ROOTS AND THEN LOGS IN SEQUENCE
C
      WW=0.
      DO 22 L=1,20
      LN=FNS(K,J)
      WW=WW&1.
      IF (LN)80,80,81
   81 DO 21 L=1,LN
   21 V(L)=R(K,L)
      IF (SENSE SWITCH 1)90,91
   90 PRINT 200,WW,(V(L),L=1,LN)
      GO TO 92
   91 PRINT 201,WW,(V(L),L=1,LN)
   92 GO TO 22
   80 PRINT 605,WW
   22 CONTINUE
      GO TO (80,82,81),LL
   80 PRINT 606
      PRINT 606
      GO TO 81
   82 PRINT 606
   81 CONTINUE
      IF(LL-2)47,48,25
   47 DO 41 I=1,IN
   41 P(K,I)=SQRTF(R(K,I)*1.)
      H(K)=SQRTF(A(K)*1.)
      S(K)=SQRTF(B(K)*1.)
      GO TO 40
   48 DO 42 I=1,IN
   42 P(K,I)=LOGF(R(K,I)&1.1)
      H(K)=LOGF(A(K)&1.1)
      S(K)=LOGF(B(K)&1.1)
      GO TO 40
   25 CONTINUE
      IF (SENSE SWITCH 3)28,30
   30 CALL EXIT
  400 FORMAT (10A4)
  604 FORMAT (1H )
  402 FORMAT  (1H,F10.5,1H-,F10.5,3H = ,10HTHE RANGE ,F10.5,26H
     1CLASS INTERVAL = ,F10.5///)
  200 FORMAT(1H,I4,4X,47I2)
  201 FORMAT (1H,I4,4X,96I1,30I1)
  404 FORMAT ( 2I5)
  606 FORMAT (1H0////)
  406 FORMAT (1H,85HCLASS    1    2    3    4    5    6    7    8    9   10   11   1
     12   13   14   15   16   17   18   19   20)
  407 FORMAT (1H,85H-------------------------------------------------
     1--------------------------------)
  408 FORMAT (1H,5HFREQU,20I4)
  409 FORMAT (1H,5HPERCT,20I4,//)
  405 FORMAT (1H,2F5.0,10X,10A4)
```

```
501 FORMAT ( 4A4)
601 FORMAT (1H,          30HWITHOUT TRANSFORMATION          ,4A4)
611 FORMAT (1H,          30HSQUARE ROOT TRANSFORMATION      ,4A4)
612 FORMAT (1H,          30HLOGARITHMIC TRANSFORMATION      ,4A4)
450 FORMAT (1H,I4,4HFNS ,20I4/)
451 FORMAT (1H,2I4)
500 FORMAT (1H,I4,1X,20I4/5X,20I4/5X,20I4/)
503 FORMAT (1H,I4)
700 FORMAT (1HD)
701 FORMAT(1H1)
    END
```

APPENDIX 6A.

LIGHT METER DESCRIPTION

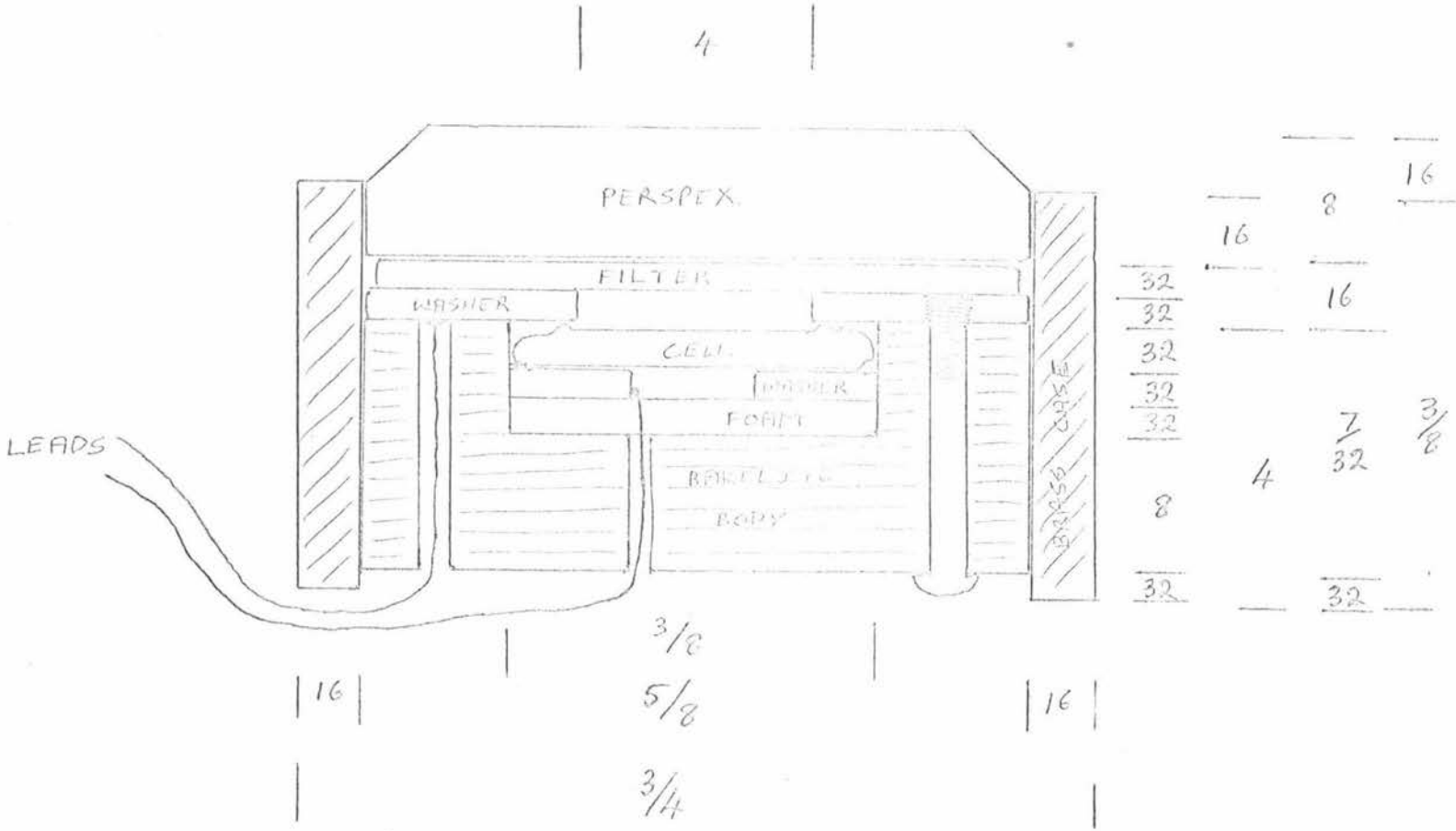
Two sensors, each fitted with selenium photocells were wired to a 10μA moving coil meter with a 6" scale through a multi-range switch.

The photocells with an output of 18 μamp. at 100 fc. were mounted in a ½" diameter head with a Wratten gelatin filter - Kodak (N.D. = 1.0, % transmission 10% ± 5%) and a cover of perspex diffusing plastic - ICI (diamond opal 040, thickness 3.2 mm. % transmission 55 ± 3%). This gave an approximate reduction of 10,000 fc. to 55 fc. at the photocell with a current output of 9.9 μamp.

The switch system was wired so that each sensor had two contacts with a 10x current output difference giving high and low sensitivity positions for each sensor. The current output was modified to give full range deflection with a current of 10 μamp for the low sensitivity switch positions. The meter was suitably damped.

The meter and switch system were mounted in a suitable metal box. One sensor had a 2' long 1/4" diameter handle and was used for canopy measurements. The other was mounted above the canopy and used to measure the incident light intensity. The multi-stage switch enabled very close readings to be taken from each sensor for relative light intensity measurements (canopy light intensity relative to incident light intensity). This was satisfactory providing cloud conditions were reasonably stable and there was little wind.

Diagram of [illegible] Head (in.)



Appendix 7A.

Organic Reserves Analyses.

7A.1. Total Non-structural Carbohydrates (TNC).

7A.1.1. Extraction:

A 0.5 gm dried sample was extracted with 75 ml of 0.5% ammonium oxalate by boiling in a 250 ml reflux condenser for 2 hours. Eight drops of silicon were added to stop frothing.

The extract was filtered through a No.41 Whatman filter paper. A 75 ml aliquot of the final filtrate was stored in a sealed plastic container under refrigeration until the TNC determinations were made.

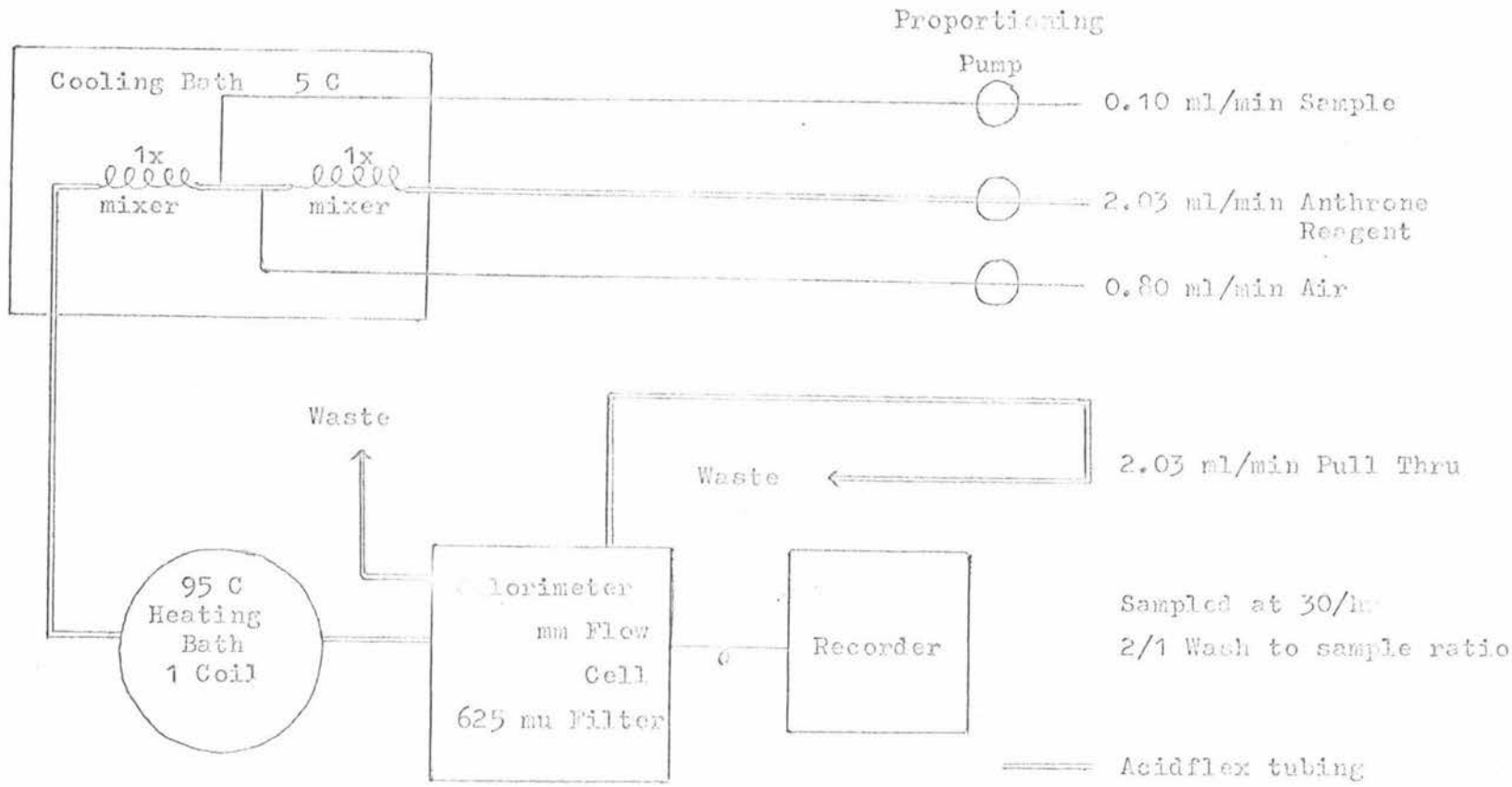
This method, a derivation of that used by Deriaz (1961) as suggested by Bailey (1970a), was used as it reduced the probability of structural material being broken down while at the same time extracting the starch. The use of a heated concentrated acid anthrone reagent ensured that all the extracted polysaccharides were hydrolysed to glucose. An $0.2\ N\ H_2SO_4$ hydrolysis, as first thought to be suitable (Smith et al., 1964) has since been shown to extract some structural carbohydrates and to give an inaccurate starch extraction (Grotelueschen and Smith, 1967). The more accurate takadiastase enzyme method (Grotelueschen and Smith, l.c., Smith, 1969b) took too long to be considered in the current experimental circumstances.

7A.1.2. Determination:

The determinations were made with the aid of an Auto-Analyser, using an anthrone reagent method based on the manifold and method reported by Burt (1964), although this was somewhat modified to meet the immediated requirements. The manifold is illustrated in Fig. 7A.1.

An 0.1% solution of anthrone in 76% (v/v) sulphuric acid was used. The anthrone reagent was cooled, segmented and mixed with the sample under cooling conditions, the reaction mixture then being reheated to 95 C through a single coil of the heating bath. A 625 mu filter was used for the colorimetric determination, this filter being chosen after making a manual determination of the maximum optical density wavelengths of several developed anthrone/glucose solutions. "Acid flex" tubing was used for all pump and transmission lines carrying the anthrone reagent. The samples were introduced at 30 per hour with a 2 to 1, wash to sample

Figure 7A.1. Total Non-structural Carbohydrate Determination Manifold



ratio. Calibrations were made by using glucose solutions in 0.5% ammonium oxalate. Concentration ranges were 0.005% to 0.04%. These were calculated to cover the expected sample TNC percentage range.

An important practical aspect is that the "acid flex" must be "primed" with 76% sulphuric acid and is similarly "flushed" out after the determinations so that the anthrone reagent does not come into contact with water in the lines. The risk of blockage is high with the very water insoluble anthrone reagent.

The very viscous nature of the reagent was responsible for the slow speed and also for a poor inter-sample wash condition. This was improved by having a large air flow (0.80 cc/min) to improve scouring and the pull-through such that most of the solution passed through the flow cuvet of the colorimeter. It was further found that single large samples gave better results than several small samples. The poor inter-sample wash of the latter resulted in sample results running together, contrary to the findings of Burt (l.c.).

It was found that if the anthrone reagent was mixed too quickly it developed a dark colour unsuitable for use. This was due to overheating from the mixing heat of the water and acid. It was found best to mix the acid and water first, allow to partially cool, adding the anthrone and then slowly heating to the point when the anthrone dissolved, and then cooling. The reagent then remained the expected clear yellow colour.

7A.2. Total Nitrogen (TN).

7A.2.1. Extraction:

The TN was extracted by a standard Micro-Kjeldahl procedure. The digestion mixture consisted of 1gm selenium powder, and 100 gm K_2SO_4 in 1 litre of concentrated H_2SO_4. This mixture was strongly heated until it gained a clear light green colour (1 to 2 Hours) (Clements, 1970).

A 0.5gm sample was digested in 5 ml of digestion mixture for 1 hr. 45 min. The digestate was diluted to 100 ml with distilled water. 50ml aliquots were stored in sealed plastic containers to await TN% determinations.

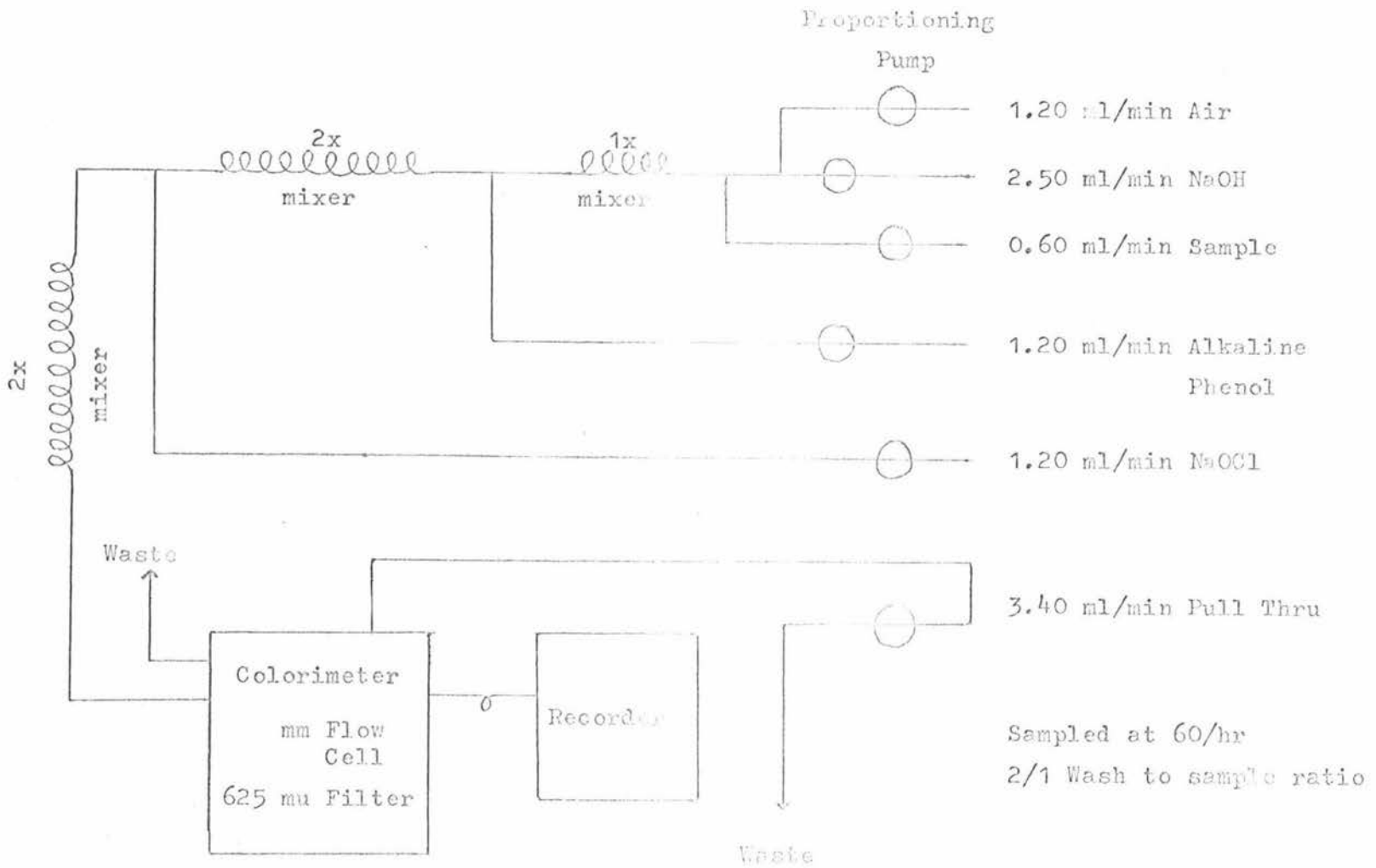
7A.2.2. Determination:

An Auto-analyser was used, using the Berthelot method and based on the manifold of Warner and Benton Jones (1967). The ammoniun con-

tent of the extract was determined directly. The manifold used is illustrated in fig 7A.2.

A segmented solution of 35% NaOH was mixed with the sample, this mixture in turn being mixed with an alkaline phenol solution of 25% phenol in 20% NaOH. This extended mixture was further mixed with full commercial strength (5%) sodium hypochlorite. The volume ratio of these components is indicated by the respective pipe line capacities (fig.7A.2). The resultant developed solution was read with a 625 mu filter in the colorimeter. The samples were introduced at 60 per hour with a two to one, wash to sample ratio. Ammonium sulphate standard solutions were used for calibration. It was found that the sample size had to be reduced to decrease the colour intensity of the developed solution and hence the response range on the chart.

Figure 7A.2. Total Nitrogen Determination Manifold



APPENDIX 8A.

The adjustment of root weights for the plant size distribution analysis.

For each treatment :-

$$\bar{X} - \bar{H}_i = \pm d_i$$

where:

$\bar{X}$ = the general treatment mean over all harvests

$\bar{H}_i$ = the ith harvest mean

d_i = the ith difference, negative or positive.

$$r_{ij} \pm d_i = rd_{ij}$$

where:

r_{ij} = the jth replication mean value of the ith harvest

rd_{ij} = the adjusted jth replication mean value for the ith harvest.