A STUDY OF THE EFFECT OF THE FREQUENCY OF SPRING CUTTING ON THE REGROWTH AND RESULTING YIELD OF LUCERNE (*Medicago sativa* L.)

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CHAPTER I

INTRODUCTION

There is abundant evidence to show that the yield, stand, chemical composition and the feeding value of lucerne may be materially affected by varying the cutting interval. Therefore, the purpose of the field experiment reported here was to determine the effect of the frequency of spring cutting on the regrowth and resulting yield of a pure stand of New Zealand certified lucerne (Chanticleer) and on weed invasion of the stand and, if possible, the reasons for this effect. It is hoped that this information will add to the existing evidence.

Lucerne is cultivated for stock feed in many parts of the world, including New Zealand. In recent years, it has become increasingly important as a forage crop because of its potential for high yields of good quality feed under a wide range of climatic and soil conditions. The long tap root of the plant affords it considerable resistance to drought. Moreover, the plant is rich in phosphates, lime and protein, all of which are essential in animal production. In common with other legumes, it possesses the power to increase the nitrogen content of the soil.

Lucerne was introduced into New Zealand during European settlement and its acreage has since increased, especially in the South Island. In 1962, there were approximately 146,000 acres cut for hay and silage. This figure would be much higher if the acreage of grazed lucerne was included. It has been reported that for many years lucerne has given profitable returns in parts of the

Auckland and Wellington Provinces of the North Island, (N.Z. Dept. of Agric. Bul. No.155, 1958).

The increased use of lucerne in New Zealand farming can be attributed to improved farming technology. The crop can now be established easily through inoculation with the right strain of bacteria and maintained at high production levels through the use of fertilisers. Weeds can be effectively controlled by mechanical means as well as weedkillers. Mechanization of hay and silage making is also a major factor influencing the spread of lucerne into areas hitherto considered unsuitable.

On the other hand, in many parts of New Zealand, particularly the North Island, improved strains of high producing grasses and clovers are on the increase at the expense of lucerne. In addition, root and fodder crops are grown in place of lucerne to supplement pastures in summer and winter. Nevertheless, lucerne has got a big potential in the drier areas and on the lighter soils where it has been shown to outyield grasses and clovers.

CHAPTER II

REVIEW OF LITERATURE

(A) GENERAL

(i) Origin

Lucerne belongs to *Leguminosae* family. *Leguminosae* is subdivided into *Mimosoideae* (*Mimosaceae*), *Caesalpiniodeae* (*Caesalpiniaceae*) and *Papilionatae* (*Papilionaceae*). Lucerne belongs to the last group, which is by far the largest and the most important agriculturally (Hector, 1938). This group comprises trees, shrubs and herbs.

Lucerne (*Medicago sativa* L), commonly known as alfalfa in North America, has been cultivated as a forage crop in some parts of the Old World for a very long time. Its introduction in the New World followed European settlement in North and South America, Australia and New Zealand. The ancient Greeks referred to it as *medicai* and the Romans *medica* and hence the generic name (Bolton, 1962). Klinkowski (1933) reports that it is known in Italy as *erba medica*. Piper (1935) suggests that the Arabs probably modified its Persian name and called it 'alfalfa' which means the best fodder. Piper (1935) also suggests that the name, lucerne, came into use for the first time in 1587. This name is assumed to have been derived from Luzern, which is a Swiss lake, or from the river valley, Lucerna, in Italy. Whatever the origin of the name, lucerne is the one commonly used in Britain, South Africa, Australia and New Zealand.

The main co-ordinating characteristic of *Leguminosae*, is the pistil, which consists of a single carpel with a superior ventral suture. The carpel is unilocular with a simple style and stigma. Ovules are usually numerous and arranged in one or two rows on the ventral suture. The fruit is typically a pod containing many seeds.

Medicago comprises a number of species. *M. lupulina* is an annual of agricultural importance in South Africa and North America. Three valuable perennials are *M. sativa*, *M. falcata* and *M. media*, all of which are grown in the Americas and Europe. Only *M. sativa* is of importance in New Zealand. *M. sativa* has evolved new varieties in the course of its spread. The winter hardy varieties evolved in climates characterised by long, cold winters. The external appearance of these varieties closely resembles each other and therefore it is hard to distinguish them from appearance alone.

Whyte, *et al* (1953) used flower colour, origin, winter hardiness, disease resistance and certain other agronomic characteristics to categorize the following groups:

1. *The Common Group*

This comprises pure *sativa* types with purple flowers and limited hardiness. This group includes the Commons of North America and the regional strains from Hungary, Italy, Spain, Argentina, South Africa, Australia and New Zealand.

2. *The Turkestan Group*

The growth habit of this group is shorter and more spreading than in the first group. They are further characterized by slow recovery after cutting, winter dormancy, low seed yield and resistance to cold and bacterial wilt. Representative varieties here are Turkestan, Hardistan, Nomastan and Nomada.

3. The Variegated Group

Strains of this group are believed to have originated as hybrids between M. falcata and M. sativa. Most of its members are winter hardy. French and German strains, including Grimm and Ladak, are typical of this group.

4. The Non-Hardy Group

This group is adapted to short days and a long growing season. Its members are erect and recover fairly quickly after cutting. They are susceptible to cold, injury and bacterial wilt. Peruvian, Indian, Egyptian and certain strains from Argentina belong to this group.

(ii) Morphology

A lucerne seedling produces a straight tap root, which under favourable soil conditions, grows vertically downwards. The depth of the soil and water table markedly affect its growth (Cottrell, 1902). Cottrell (1902) found that the length of the tap root ultimately attained was enormous where the soil is deep and free draining. Weaver (1926) found that plants, sixty-three days old, measured about three inches high, with a root length of eight feet. Most of the roots are close to the surface. Israelsen (1950) examined the roots of irrigated lucerne to a depth of six feet and found one third of the root system in the top six inches and seventy per cent in the top twenty four inches. Weaver (1926) showed that where the soil was deep, fertile and well aerated, the roots penetrated deeper and had less branching than in a soil which was shallow and poorly drained. The penetration of roots is, therefore, governed by the soil type and the depth of the water table (Bolton, 1962).

The seedling produces a slender, erect stem which branches slightly. This stem arises between the cotyledons. Leppan (1954) and other workers have shown that subsequent stems arise in the axils of the cotyledons. As these stems age, they become woody at the base and gradually form the crown during new growth. As soon as the stems commence flowering, a set of buds develops, which grow more rapidly once the older stems have been clipped or grazed. But development can be hindered by severe drought or low temperatures (Willard, *et al*, 1934). When the plant blooms, the buds at the base open up to form new shoots. In general, if the plant is not cut this second growth will develop while the first growth blooms, sets seeds and gradually decays.

(B) DEFOLIATION

(i) General

Photosynthesis is a food producing reaction which is found at the beginning of all food chains. It is a process whereby green plants absorb sun's energy and use some of it to manufacture organic compounds from inorganic materials of low energy content. Photosynthesis takes place in the presence of chlorophyll. Some of the elaborated compounds form new material (organic reserves) or add to the growth of the plant. Chlorophyll is present in the aerial parts of a plant, especially in the leaves. The leaves are responsible for the elaboration of carbohydrates, while the roots provide minerals, and maybe leaves are, therefore, vital for the survival of a plant. Frequent defoliation or removal of leaves is likely to interfere with the plant's ability to synthesize food.

Most agricultural crops grow undisturbed for a certain period. Cereals are harvested at the end of their life. For a majority of root crops, harvesting terminates their life. Herbage crops such as lucerne differ, however, in that not only is most of their photosynthesising tissue removed, but this process is normally repeated a number of times. It is therefore essential for such plants that remain after defoliation to be in good condition to be able to initiate and develop regrowth for the next harvest. Therefore, the method of harvesting, not only determines the crop obtained at the time, but also the subsequent growth and production of the plant.

Experimental work relating to the time and frequency of cutting lucerne has been extensively investigated in the United States of America. The objective of the earlier experiments was to determine the relationship of cutting practices to the yield and quality of hay. It was thought that frequent clipping stimulated growth and increased the yield. It is therefore no wonder that observations by Cottrell (1902) seemed to show that early and frequent cutting stimulated growth, thereby producing more and higher quality hay. Nelson (1925) found that premature and frequent cutting tend to stimulate bud and shoot development, but this increase is not accompanied by an increase in the yield.

American workers and others have investigated the effects of the frequency of mowing or grazing lucerne by employing various treatments such as different stages of growth, length of cutting intervals and different heights at which to cut.

It has been shown that a greater amount of herbage is harvested from hard defoliated plants than from those leniently cut. Compared with a less severe treatment, a lower production can be expected during a subsequent growth period. Increases in herbage production were found with increases in cutting height by Graber and Ream (1931), Ahlgren (1938), Juska and Hanson (1961). Brougham (1959) postulated that erect growing plants have a higher optimum height of defoliation than prostrate ones, so that the latter are able to tolerate a more severe clipping treatment. This was shown by Brougham (1959) to be dependent on the time of the year in which cutting treatments were carried out.

Some workers, notably Ridgman (1960), Van Riper and Owen (1964) have pointed out the disadvantage of leaving a long stubble. They have demonstrated that a high stubble left on the field results in reduced yields. Hildebrand and Harrison (1939) found that frequent cutting at nine or twelve inches resulted in reduced yields due to maturity and lack of vegetative growth. Harrison (1939) showed that cutting to six inches weekly interfered only slightly with the functioning of the plant in the production of top growth.

Work on lucerne has revealed that the height of cutting has no adverse effects on recovery when cutting for hay. Kust and Smith (1961) obtained higher yields by cutting three times per year at one inch than cutting five times at three inches. Therefore it would appear that with long intervals between harvests defoliation height has no effect on yields. This has been confirmed by Steinke (1963), Langer and Steinke (1965) who concluded that only by raising the height of cut and thus allowing adequate foliage to be retained could rapid regrowth be obtained with frequent defoliation.

(ii) Frequency

(a) Effect on Dry Matter Yield

The time of cutting lucerne is of great importance in the cultivation of this crop. Time and frequency of defoliation are fundamental in determining the vigour of a plant and thus they determine maintenance and production of a stand. Evidence shows that yield may be materially affected by varying the cutting time. At the Kansas Experimental Station, Ten Eyck (1908) found that the yield of lucerne increased as the stage of development progressed. Salmon *et al* (1925) showed that lucerne yields are markedly reduced by frequent cutting. Hildebrand and Harrison (1939) reported that the weekly cuttings of lucerne gave lower yields than the monthly cuttings. Other workers have found that frequent cutting has deleterious effects on the yield of lucerne (Peterson and Hagan, 1953; Murikami *et al*, 1957; Jekabsons, 1959; Kust and Smith, 1961; Whitear *et al*, 1962; Steinke, 1963; Langer and Steinke, 1965; and Keoghan, 1966). Frequent cutting at bud stage or before is uniformly disastrous in humid regions (Willard, 1950; Wilsie and Takahashi, 1937).

Willard (1930) cut lucerne five, four, three and two times per season and showed that cutting five times gave the lowest yields the following year. Tovar, (1958) harvested when lucerne was sixty centimeters tall and every three, five, seven, nine, eleven and thirteen weeks. The highest yields were obtained from six cuts at seven week intervals. Generally cutting frequency has been found to result in lower yields than infrequent cutting (Albert, 1927; Nielsen, 1955; Gross *et al*, 1958; Davies, 1960; Kust, 1960; W.E. Davies, R.O. Davies, and Harvard, 1960; Cowett and Sprague, 1962; and Bryant and Blaser, 1963).

Nelson (1925) cut lucerne at full bloom, early bud and succulent stages, taking two, three and four cuttings per season, respectively. He demonstrated that cutting frequently at immature stages of growth gave the lowest yields. In Nebraska, Kiesselbach and Anderson (1926) defoliated lucerne at the pre-bloom, initial-bloom, one-tenth bloom, new growth bloom and full bloom stages and seed stages. The new growth and half bloom stages gave the highest yields, while the seed stage yielded the least. Work done in Australia showed that when lucerne was cut at six inches high, it gave 1,687 pounds of dry matter per acre and when it was clipped in the bud stage, there was an increase of eighty four per cent as compared to six inches high (Griffith and Ramsay, 1932). Dawson et al (1940) cut lucerne at initial-bloom, half-bloom and full-bloom stages and found that the three year average yields were 8,938, 8,880 and 6,940 pounds per acre, respectively.

It has been observed by Dotzenko and Ahlgren (1951) and Erasmus (1953) that the highest yields of good quality hay are obtained when lucerne is neither cut too often nor left too long.

Near the equator, Crowder et al (1960) harvested lucerne for two years at intervals of five, seven, nine, eleven and thirteen weeks and when new shoots were about two inches high. They found that plots cut at five and seven weeks intervals produced the lowest yields, because most plants had not reached maturity in this type of environment, where growth is continuous. Cuts made at eleven weeks and thirteen weeks produced high yields but of poor quality forage. Fuess (1964) showed that lucerne cut three times per year outyielded that cut two times and the yield difference was 0.77 tons per acre, of which 0.55 tons was accounted for by leaf loss. He concluded that the rest appeared to be accounted for by higher rates of net photosynthesis in the physiologically younger plant material in the three cutting treatment.

Hutcheson (1923) suggests that when lucerne blooms freely, the time of cutting should be determined by the amount of the bloom present. He recommends that the best time to cut in order to obtain the highest amount of digestible nutrients is just after the appearance of the first blooms. Robinson (1937) and Willard (1950), support the same views.

Frequency of defoliation by the grazing animal has been found to influence lucerne production. In Australia, Moore, _et al_ (1946) employed different grazing systems which included continuous, four-week and eight-week rotation. They reported that under continuous systems of grazing, the yield was low. The eight-week rotation with close grazing, followed by seven-week spelling, gave the highest growth rate and maintained the stand in a vigorous and productive condition. Davis (1947) demonstrated that lucerne in a cocksfoot stand does not stand up to repeated close grazing with sheep. Continuous grazing is more harmful than occasional grazing of lucerne in South Africa (McKeller, 1954). The highest yield of material was obtained and the least harm was done when lucerne was grazed at the early flowering stage. Rather _et al_ (1957), grazed a lucerne-cocksfoot pasture at two, four and eight-week intervals. They concluded that defoliation at eight-week intervals maintained a good balance between the two species. Inversen (1960) found that on light land, yields of New Zealand certified lucerne under continuous grazing with sheep were only forty per cent of those obtained when managed for hay production.

Investigations have been carried out on the effects of cutting of lucerne in mixtures with other crops. Willard (1950) reports that grasses endure frequent cutting better than lucerne and that early and frequent cutting reduces the percentage of lucerne in the mixture. Comstock and Law (1948) showed that cutting forage mixtures at the hay stage results in higher forage yields than does more frequent defoliation at younger stages of growth. Dotzenko and Ahlgren (1951) indicated that frequent and early cutting reduced the yield as did delaying harvest beyond the one-half bloom stage in a lucerne-bromegrass mixture. Dennis _et al_ (1959) found that lucerne cut every four and six weeks yielded more than when clipped every one or two weeks in a sudangrass mixture. Wolf _et al_ (1962) in a greenhouse trial, found that total herbage yields of bromegrass, orchard grass and timothy, when grown in association with lucerne, were highest with long intervals between cuttings. Wolf _et al_ (1964) worked with forage mixtures which included lucerne, birdsfoot trefoil, ladino clover, bromegrass, orchard grass and timothy and showed that mixtures cut three times, outyielded those cut five times in a year. Bryant and Blaser (1963) have found similar results.

The possibility that the ill-effects of cutting treatments might be offset by applying fertilizers has been considered. Graber and Sprague (1938) and Owens and Brown (1943) are among those who investigated the interaction of clipping treatments with fertilizers. Under normal management practices, lucerne shows favourable responses to fertilizers. However, these authors have demonstrated that damage related to frequent cutting is by no means offset by heavy application of fertilizers. Gross _et al_ (1958) found that frequent cutting depressed the yield of lucerne, despite fertilization. All other observations support these findings, though plots well fertilized with minerals have had slightly better stands under all cutting treatments than those not so fertilized (Willard, 1950).

The foregoing information clearly reveals that too frequent clipping or grazing of lucerne in pure or mixed stands is generally accompanied by a decrease in production of dry matter.

(b) Effect on Botanical Composition

A number of workers have generally shown that other plants are able to encroach upon lucerne as the latter is weakened or killed by frequent mowing or grazing. This occurs because as lucerne plants die out beyond the capacity of the remaining plants to form a dense canopy by branching, there is a tendency for other species to establish in the gaps.

At the Agricultural Experiment Station of Wisconsin, Russel and Morrison (1923) report that lucerne which was normally cut in the full bloom stage, maintained a weed-free, healthy growth and yielded in two cuttings approximately four tons per acre, as against a total of only one ton from cutting four times. Clipping three or four times per year permitted heavy weed encroachment. Salmon *et al* (1925) found that the ability of lucerne to withstand weed invasion varied inversely as the frequency of cutting. The most common weeds encountered were foxtail (*Chaetochloa varidis L*), crabgrass (*Syntherisma sanguinalis L*) and Kentucky bluegrass (*Poa pratensis L*). Salmon *et al* (1925) found in Kansas, as an 8-year average that lucerne hay harvested in the bud, one tenth bloom, full bloom and seed stages consisted of 18.2, 5.9, 2.3 and

0.8 per cent of weeds, respectively.

Graber (1925) showed that lucerne cut in the full bloom stage maintained a weed free stand. Nelson (1925) found that plots cut two times in mature stages were more vigorous and less weedy than those cut three times in succulent stages. He indicated that when lucerne was cut in full bloom, early bud and succulent stages, the percentage of weeds on the basis of air-dry weights, were twenty-four, seventy-five and ninety-five, respectively. Albert (1927) found that weed encroachments were greatest in lucerne plots which had been cut more frequently. He found a correlation between frequent cutting, large amount of winter killing and weed infestation. This correlation was shown by Graber _et al_ (1927).

Dotzenko and Ahlgren (1951) came to the conclusion that although weed growth was inconsistent, it was generally greater at the earlier cutting stages than at the later.

Davies _et al_ (1953) found that the percentage combination of unsown grasses increased in a lucerne-ryegrass pasture by cutting four times as against two times per year. The same workers (1953) found an incursion of weeds and unsown grasses such as bent (_Agrostis tenuis_) and _Poa trivialis_ in plots cut four times as opposed to those cut two times a year.

Peterson and Hagan (1953) found that lucerne-ladino clover pasture, when cut every two weeks, comprised seventy-three per cent of ladino clover and six per cent of lucerne. When the cutting interval was spaced at four weeks, the lucerne consisted of sixty-seven per cent and ladino clover was twenty per cent. However, at five weekly cuts, lucerne was ninety-four per cent and ladino was practically wiped out. Dennis _et al_ (1959) showed that frequent removal of top growth of a mixture of lucerne and sudangrass

(Sorghum valgare) resulted in an encroachment of the stand by weeds.

Keoghan (1966) found that with frequent cutting of lucerne there was a marked ingress of weeds, white clover and grasses. On the other hand, he found the amount of weeds to be negligible with infrequent defoliation.

(c) Effect on Stem : Leaf Ratio

The growth curve of lucerne is sigmoid. It starts slowly, followed by a long, fairly uniform period of rapid growth and then slowing down to a much lower rate. As soon as flowering commences, the rate of growth slows down and most experiments indicate a larger yield of hay at full bloom than at any other stage (Willard, 1950). The decrease in yield after full-bloom stage has been found by a number of workers to be due to death and dropping of older leaves. Willard (1950) reports that pre-bud hay may contain fifty to sixty per cent of leaves.

Salmon et al (1925) found that there was a consistent decrease in the proportion of leaves as cutting was delayed. Thus, when plants were cut in the bud stage, fifty-three per cent of the crop consisted of leaves as compared with fifty-one, forty-eight and forty-two per cent for the tenth-bloom, full-bloom and seed stages, respectively. This is a loss in terms of nutritive value as the leaves are much richer in protein content than the stems (Dawson and Kopland, 1940).

It should be noted that percentage or proportion of leaves in a stand of lucerne at various stages of growth, differ from one locality to another. Kiesselbach and Anderson (1926) found that the proportion of leaves at time of harvest at the pre-bloom, initial-bloom, one-tenth-bloom, half-bloom, seed and new growth stages, was fifty-seven, fifty-six, fifty-three, forty-nine, thirty-three and fifty-three, respectively. Dawson and Kopland (1940) showed that the hay cut at initial and half-bloom stages, averaged forty-six per cent leaves as compared to forty-one per cent for hay harvested at the full-bloom stage.

Kiesselbach and Anderson (1926) found as an average for seven varieties of lucerne, that the first, second and third cuttings consisted of forty, forty-four and fifty-five per cent leaves and the average protein content in the hay was seventeen, nineteen and twenty per cent, respectively.

(d) Effect on Organic Reserves

As mentioned before, the assimilated organic material can be used by the plant for respiration, building new material or accumulated in storage organs. A lucerne plant stores its reserves in the crown or rhizomes, stubble and roots (Nelson, 1925; Graber et al, 1927; Reynolds and Smith, 1962). Bula and Smith (1954) found that the total available carbohydrates in the roots and crowns of lucerne were at a high level by mid-October (autumn) and they were largely starch. Most investigators have shown that maximum accumulation of carbohydrates is reached in autumn. Gains of root reserves in lucerne amounting to as much as 1,200 lb. per acre and averaging 600 lb. per acre (air dry weight) have been reported during this period (Willard, 1951).

Rather et al (1938) indicated that grazing or cutting in autumn reduced dry matter in the roots and the number and vigour of crown buds.

Changes of reserves in the storage organs of legumes in relation to season, growth and defoliation are essentially similar to those in grasses (Weinmann, 1948; Reynolds and Smith, 1962). Most work has shown that reserve depletion is followed by a steady increase to former levels by the time the plants are mature (Willard, 1951; Nielsen *et al*, 1954; Reynolds and Smith, 1962).

Graber *et al* (1927) defined reserves as 'those carbohydrate and nitrogen compounds elaborated, stored and utilised by the plant itself as food for maintenance and for the development of future top and root growth.' Their views have been challenged. May (1950), May and Davidson (1958) maintain that reserve carbohydrates are used as a respiratory substrate. Sprague (1950) concludes that after removal of top growth by cutting or grazing, new leaves are produced and the carbohydrates stored within the plant serve as a source of energy in this process.

Although the exact role of organic reserves is not yet fully understood, several workers have shown that defoliation of aerial parts decreases the amount of reserves and lowers the vigour of the plant. Jenssen (1929) reports that organic reserves have an important bearing on production and longevity of plants. Graber *et al* (1927) showed that frequent cutting reduced the size of lucerne roots and lowered root reserves. Willard (1930) reports that the average loss in weight of roots per acre after two weeks cutting was one hundred and seventy-seven pounds and that the percentage of nitrogen in the roots dropped by 0.3 per cent during recovery from cutting. Hildebrand and Harrison (1939) found that cutting lucerne frequently and close to the crown resulted in depletion of the food reserves in the roots and a decrease in the vigour of plants. Bryant and Blaser (1963) propose that the lower yield of lucerne under frequent cutting compared to less frequent defoliation may be attributed in part to reduced carbohydrate reserves.

Russell and Morrison (1923) report that when lucerne is cut very early and frequently, there is a gradual exhaustion of root reserves which may cause a reduction in the ability of the plant to recover. Graber (1925) showed that plants cut three and four times per year exhausted the root reserves more than those cut at the full bloom stage. Nelson (1925) found that frequent cutting reduced the percentage of all available carbohydrates except the sugars, in lucerne roots. Plants clipped in full bloom stage were richer in dextrines, starch, hemicellulose and total available carbohydrates than those which were cut more frequently. Nielsen et al (1954) found that the weight of roots and their content of dry matter, sugars, starches and total available carbohydrates and nitrogen decreased as the number of cuts taken increased. Repeated close defoliation was shown by Langer and Steinke (1965) to prevent roots from contributing to the recovery of lucerne. They showed that reduced root weights caused regrowth to lag behind plants with higher root weights even if the plants had comparable leaf area.

Albert (1925) measured the reserve content of lucerne plants that had received different cutting treatments in the field by transplanting large numbers of such plants into pots of sand and allowing the plants to grow in dark room until no further growth was made. This top growth so obtained represented material that had been stored in the plants before transplanting into the dark room occurred. He hoped in this way to obtain a measurement of the relative amounts of reserve food present in plants grown under different conditions. Roots of plants, both before and after exhaustive growth in the dark room were analysed for total nitrogen and for reserve carbohydrates. He found that the roots of plants cut more frequently generally produced a much smaller percentage of top growth than did those which had been cut at the more mature stages.

Albert (1925) found that there was a tendency for the plants cut most frequently in the field to suffer the largest loss of dry matter by oxidation and respiration in producing a certain amount of top growth.

Smith and Graber (1948) showed that the amounts of top growth of sweet clover were directly correlated to the amounts of food stored in the roots the previous seasons.

Leukel (1927) showed that cutting lucerne more frequently in the immature stages of growth causes continuous reduction of the organic root reserve, retards the increase in the size and weight of the roots. Albert (1927) indicated that the percentage of total nitrogen and reserve carbohydrates was lowest in the roots of lucerne which had been cut in immature stages. Weir _et al_ (1960) found that plant vigour was reduced markedly by cutting intervals of three to four weeks but not at all by cuts at six week intervals.

The amount of total available carbohydrates in the crowns, rhizomes and roots of lucerne has been associated with winter hardiness. As already mentioned, a period of active growth storage of reserves in the roots is in the autumn. If lucerne is cut during this period, root storage is prevented and new growth prevents hardening of the lucerne so that it is susceptible to winter killing and yields less the following year (Willard, 1950). Dexter (1941) concluded that hardening of lucerne is favoured by conditions which tend towards the accumulation of carbohydrates and other food reserves. Kust (1960) found that the level of total available carbohydrates was reduced by autumn cutting and clipping more frequently. Plants with low levels of reserve carbohydrates were more susceptible to winter injury and winter killing (Kust, 1960). Rather *et al* (1939) proposed that starch reserves in lucerne roots are necessary to prevent winter killing. Heinricks *et al* (1960) found that winter injury is inversely proportional to the hexosan content. They showed that hardy varieties of lucerne contained a lower proportion of hexosan in the roots than the non-hardy ones. Smith *et al* (1964) found that cutting or grazing during the hardening period in the autumn or excessive frequent cutting during the growing season, can impede the development of frost hardiness. They showed that when cutting is done during the hardening period in the autumn, carbohydrates reserves are used to produce new growth if the environment is favourable and such plants go into winter with low reserves.

(e) Effect on Plant Density

The term "plant density" is used here to imply the number of plants (i.e., stems growing singly or coming from one crown) per unit area of land.

Observations by Kiesselbach (1918) revealed that when lucerne is cut frequently, a weakening of plants and a thinning of stand results. The work of Graber *et al* (1927) showed that frequent cutting reduced the number of crown buds and stems. Gross *et al* (1958) working on different varieties of lucerne, found that plants cut frequently were of smaller crown and had fewer stems per crown. They also found that plants cut more frequently were less vigorous.

Russell and Morrison (1923) reported that lucerne cut four times per year gave a yield of only one ton per acre and the stand was practically eliminated. Plots cut in the full bloom stage were vigorous in growth (Russell and Morrison, 1923). Leukel (1927) found that when lucerne was cut frequently in immature stages of growth, there was a marked decrease in the vigour and production of new top growth.

Grandfield (1934) showed that cutting lucerne in the bud stage throughout the season resulted in a depletion of the stand more rapidly than cutting it in mature stages. Sprague (1952) found that lucerne stand could be maintained by intermittent grazing followed by adequate time for recovery. He concluded that grazing for almost ten days followed by another grazing in early bloom maintained the stand satisfactorily. Baker et al (1957) showed that with each subsequent defoliation by grazing every two weeks, lucerne produced fewer and smaller shoots. Cowett and Sprague (1962) indicated that cutting lucerne high or at advanced stages of maturity increased the total number of stems per plant.

Salmon et al (1925) showed that when lucerne was cut every ten days, more than eighty per cent of the plants were killed and when it was cut every twenty days, thirty-seven per cent of them died. Salmon et al (1925) cutting lucerne at bud, tenth bloom, full bloom and seed stages, found that the respective losses in number of plants per acre from 1914 to 1922 were 77.1; 84.1; 64.4; and 53.9 per cent of the original number; that similar losses in number of stems produced per acre were 50.8; 63.8; 46.5 and 13.0 per cent. Davies et al (1956) found that four cuts had a deleterious effect on the vigour and growth of lucerne in a mixture with ryegrass. The percentage of lucerne was markedly reduced by cutting four times as opposed to two times per year.

Nelson (1926) found that frequent and early cutting of lucerne in premature stages resulted in an increase in the number of crown buds, shoots and main stems, but the total yield of the top growth was much less than with less frequent cutting at more mature stages. The increase in the number of main stems was accompanied by a depletion of root reserves which slowed the rate of growth of the main stems. Repeated frequent cutting in immature stages eventually resulted in the reduction of the number of active buds on the crown. Willard (1951) has shown that production of lucerne is increased and stands maintained longer when lucerne is allowed to come into full bloom before cutting.

(f) Effect on Stem Height

The work of many investigators has shown that under field conditions the number of main stems per plant and their length are influenced not only by thickness of stand, variety, environmental conditions, but also by defoliation practices.

Nelson (1925) found that growth of lucerne is considerably more rapid and the stems attain greater ulitmate height, when the preceding crop is cut in full bloom than after any of the earlier cutting stages. He measured lucerne plants and found that plants which were cut in full bloom were seventeen to twenty inches tall, whereas those cut in early bud stage were only seven to ten inches high.

Kiesselbach and Anderson (1928) worked on different varieties of lucerne and showed that there was a decrease in coarseness and

and length of stem with successive cuts. Average plant height for all varieties was approximately twenty-seven, twenty-five and eighteen inches for the first, second and third cutting, respectively.

(C) MOISTURE USE BY LUCERNE

The growth of a plant is a multi-conditioned response to its surroundings. If a plant is capable of growth, then the rate of growth at a particular time will depend on the relative concentrations in which the factors essential for growth are present. Light intensity and duration, temperature, carbon dioxide, water, mineral nutrients and oxygen are all essential for plant growth. Soil moisture and its extraction by lucerne will be briefly discussed in this section.

Growing plants transpire large quantities of water which they take from the soil via the root system. This water is being lost continuously through transpiration and evaporation from the surface of the leaves. The production of one ton of lucerne on the Great Plains of the United States of America may involve the transpiration of about seven hundred tons of water, depending on the evaporating power of the atmosphere (Wadleigh, 1955). Normally more water is transpired if the atmosphere is dry. It has been shown that loss of water from plants usually reaches a peak at midday and is lowest at night.

The need of lucerne for water depends, among other things, on age and vigour. The most vigourously growing plants will require more water. The total amount of water used by the plants, plus that evaporated from the soil in which the crop is growing, is known as the consumptive use of water. The daily consumptive use of water by a plant is influenced mainly by its stage of development. The stage of development will be affected by cultural practices. Defoliation and removal of the crop sharply reduces the amount of water used. When a lucerne crop is in the seedling stage or recovers from defoliation, the rate of transpiration will be low. This rate will increase as the number and size of leaves increase. The use of water levels off when reasonable foliage cover has been established. It should be borne in mind that consumptive use of water by lucerne or any other crop varies from one locality to another and also according to season (Stanberry, 1955).

The root system of lucerne is characterized by a long tap root. Small rootlets provide much of the absorbing surface for moisture and nutrients. Root distribution, which normally increases with age, is slightly affected by cultural methods. Root vigour is markedly influenced my management practices.

The three principal factors which affect the moisture extraction pattern are extent and distribution of roots, water availability and root vigour. Stanberry (1955) and other workers report that lucerne draws most of its moisture, if available, from the top four feet.

Water utilization efficiency indicates the water transpired and evaporated from the soil per unit of dry matter produced. The efficiency of water utilization of any crop depends on the growth and transpiration. Growth and transpiration are both related to plant vigour which is adversely affected by more frequent cutting in the early stages of growth.

Dennis et al (1959) found that frequent removal of top growth of lucerne and sudangrass (Sorghum vulgare) resulted in a definite lowering of dry matter production, an encroachment of the stand by weeds and an inefficient use of water in terms of dry matter production. The immature growth induced by frequent removal of top growth may use larger amounts of water per unit of dry matter produced and is likely to lead to more evaporation of moisture from the soil surface because of insufficient cover.

Efficient use of available moisture in dry matter production is not practical when plants are perpetually kept in succulent condition by frequent defoliation. Dennis et al (1959) showed that water consumed per unit of forage produced decreased as length of cutting interval increased. Lucerne cut frequently used only slightly less water than lurerne cut at four or six weeks intervals and less was used from the deeper soil horizons by plants cut more frequently.

Some work has been done on the moisture utilization by lucerne at different soil levels.

Duley (1929) found that lucerne grown continuously for four years exhausted the deep subsoil moisture to a low point which remained constant thereafter. Hobbs (1953) showed that in four years lucerne utilized subsoil moisture reserves rather completely at least to a depth of eighteen feet. In Kansas, a shallow rooted bromegrass did not seriously deplete soil moisture below four feet.

Kiesselbach et al (1935) found that lucerne drew upon the subsoil moisture supply to a depth of thirty-three feet. Lucerne is therefore capable of using subsoil moisture to lower depth than is the case with cereals. In Nebraska, it was shown that the average maximum depths of penetration of the roots of oats, winter wheat and corn were four, five and six feet, in that order, whereas under similar conditions lucerne extended its roots to more than thirty feet. Similar findings have been shown by Grandfield and Metzger (1936).

(D) LIGHT INTERCEPTION

(i) General

Light and the ability of the plant community to intercept it is of greatest importance in influencing the production of forage community under field conditions (Smith, Mott and Bula, 1964). Donald (1961) suggested that for subterranean clover maximum yields would be obtained when this species exploited the available light to the limits imposed by its own growth habit, which in turn would be determined by its genetic complex.

Spurr (1962) and Wijk (1963) have given good discussions on the physics of light and solar radiation in the plant community. The most important source of energy on this earth is solar radiation which amounts to about 10^{21} k.cal acre $^{-1}$ year $^{-1}$ (Leopold, 1964). Sun's radiation consists of electromagnetic waves which are received as photons or quanta. Trickett et al (1957) estimated that ninety-eight per cent of energy in the solar spectrum occurs between 3,000 and30,000 angstrom units ($\mathring{A}$). It has been shown that the amount of energy received depends on the wavelength as well as the number of photons.

TABLE I. The Energy Available at Various Wavelengths

(Claesson, 1964)

Wavelength	K.cal/einstein
Å	
2000	143
2500	114
3000	95
3500	82
4000	72
5000	57
6000	48
8000	36
10000	29

As the solar radiation penetrates the earth's stmosphere it is scattered, selectively absorbed and reflected by gaseous molecules, dust, clouds and impurities in the atmosphere with the result that less energy reaches the earth. Moreover the amount of energy is influenced by the length of atmospheric path over which light travels. When the sun is directly overhead the light is said to pass through an optical mass (m) of one. If the sun is thirty degrees from the horizon the optical mas (m) is equal to two.

About fifty per cent of solar radiation reaches the earth. Energy that is reflected or transmitted may be absorbed by the plant. Some radiation is absorbed by non-photosynthetic parts such as water and proteins. It has been found that about 1-3 per cent of the solar radiation reaching the plant is converted to chemical energy.

Solar radiation influences all plant processes among which are photosynthesis, seed germination, seedling morphology, seed dormancy, growth rate, pigment formation, plant movements, flowering and transpiration (Leopold, 1964 and Trickett et al, 1957).

(ii) The Measurement of Solar Radiation

The human eye has been studied intensively and found to show the most sensitivity to radiation between 4,000 and 7,600 Å. This range is commonly known as the visible spectrum. This light is normally defined as the sensation aroused by stimulation of the visual centres in the human brain and light energy as the radiant energy (luminous energy) which by its action on the organs of vision enables them to perform the function of sight. This light is measured by photometric instruments which respond to the wavelength of the radiant energy and not to the absolute energy content. Absolute energy content is measured by radiometers. Irradiance is the commonly measured radiometric flux density (in cal. cm^{-2} min^{-1}). Photometers measure illuminance in lux or footcandles (f.c.)

Photosynthesis shows spectral sensitivity over the same wavelengths as the human eye and so photometric units are often used in biological studies. Photometric units can be converted into radiometric units (Kimball, 1951) as follows:

1 cal $cm.^{-2}$ min^{-1} = ca. 6,700 F.C. (cloudless sky)

1 cal $cm.^{-2}$ min^{-1} = ca. 7,400 F.C. (overcast sky)

The difference is due to alterations in the quality of the spectrum since clouds selectively absorb the longer wavelengths to which the human eye is less sensitive. Leaves also alter spectral composition and therefore these conversion factors are not appropriate for light that has penetrated into leaf canopy (Anderson, 1964).

Radiant energy may be detected by the rise in temperature of a suitable receiving surface, the response of a photoelectric cell or by photochemical methods. Thermopiles measure energy receipt by temperature changes. These instruments give instantaneous of integrated measurements. Although thermopiles give the most accurate measurements, they are not portable and as such are not of much use in field experiments.

Photocells give instantaneous readings. There are many types in use for field experiments. One disadvantage with them is that they differ in spectral response and therefore they are not comparable. On the other hand, they are rugged, portable and relatively inexpensive. Furthermore, the f.c. readings of visible radiation may be perfectly satisfactory for studies of photosynthesis because photosynthetic process is limited to 4,000 - 7,000 range.

Photochemical methods employ light sensitive papers, light sensitive liquids and photographic techniques. These methods are cumbersome to use although some are used in forestry for studying sunfleck patterns.

Portable photometers give instantaneous readings which can be averaged to define the measured light conditions. It has been found by Anderson (1964) that the number of readings to give satisfactory results varies from twenty to a thousand. Measurements are made above the canopy and at one or several levels within the canopy to give light penetration or extinction profiles. The readings obtained are expressed as a fraction of the light above the canopy. Under clear sky conditions, light is steady enough to enable readings to be made with a one meter head (Brougham, 1958 b) whereas under cloudy conditions the amount of light arriving fluctuates so rapidly that it is advisable to take simultaneous readings with dual heads on the same meter, one above and one within the canopy (Stern, 1962).

Photometers show spectral responses. If measurements by two different meters are to be compared, it is necessary to know the spectral response of the instrument used and something about the spectral composition of the source measured. (Anderson (1964 c) discusses thoroughly the special problems of photoelectric cells.

(iii) Photosynthesis

Photosynthesis is the biological fixation of radiant energy into organic materials and the ultimate source of nearly all food. When light arrives at the leaf surface some of it is reflected, a portion is transmitted through the leaf and the rest is absorbed. Only a very small percentage of absorbed light is used in photosynthesis. The transmitted light may strike the bottom layer of canopy or bare ground. The reflected light may be lost to the atmosphere or reflected deeper into the canopy and may possibly become available to the leaves. The amount of reflection, absorption and transmission is never the same for all plant species. Species with smooth and shiny leaves reflect more light than those with rough and dark leaves. Monteith (1965) found that species with erect leaves such as grasses transmit about seventy per cent of the light they receive through a layer of one leaf area index (L A I) whereas those with horizontal leaves transmit only forty per cent of the light they receive through a layer of similar L A I.

Wit (1965) showed that erect leaves intercept less light and allow more to pass deeper into the canopy.

It has been shown that for most plants maximum photosynthesis is obtained at intensities of 2,000 to 3,000 f.c. provided other factors are not limiting. Monsi and Saeki (1953), Davidson and Phillip (1958) and other workers have found sharp reductions in light intensities from the top of the canopy downwards. Thus the top of the canopy may enjoy full sunlight while leaves lower down in the canopy may be partially or totally shaded. This explains in part the presence of dead leaves at the bottom of pastures.

The photosynthetic response in individual leaves follows the law of diminishing returns (Verhagen et al, 1963) so that photosynthetic output increases at a decreasing rate as light intensity is increased. Mitchell and Calder (1958) found that maximum efficiency of light utilization occurs at low values usually below thirty per cent of full daylight. It should be noted that not all plants become light saturated. Hesketh and Musgrave (1962) and Hesketh and Moss (1963) showed that the highest producing plants have increasing rates of photosynthesis up to maximum daylight values.

Black (1963) and Wit (1965) suggest that light saturation does not occur in canopies that have developed sufficiently so that some of the leaves are shaded and there is competition for light because increasing light intensity to maximum daylight values increases photosynthetic rate.

(iv) The Interrelationship of Light, Leaf Area and Productivity.

The leaf plays a very important role in photosynthesis and contributes a great deal to dry matter accumulation in the plant. Gregory (1921) reported that the total dry weight of a plant results almost entirely from assimilatory activity of the leaf surface. Therefore the development of the leaf surface must to a large extent determine the rate of increase in dry weight of a plant. Loomis *et al* (1963) showed that as leaf number and size increase during crop growth, light interception and the rate of dry matter production increase.

The importance of leaf area in determining yield was shown by Watson (1956) who stated that: "the main opportunity for increasing crop production and pasture yields lies in increasing leaf area." The leaf area (on one side) per unit area of land was designated as leaf area index (L A I) by Watson (1947). Smith *et al* (1964) stated that L A I or photosynthetic surface per unit area of ground is an important factor in obtaining dry matter accumulation. These workers concluded that anything which increases the photosynthetic capacity of a plant would be useful. Donald (1961) concluded that the only factor governing lucerne growth rate (i.e., grams of dry matter per day per unit area of land) appeared to be the weight of tops present.

Monsi and Saeki (1953) employed stratified clipping technique whereby the canopy was harvested in successive horizontal layers and the layers analysed separately. Since then, the method is most widely used in measuring the vertical distribution of dry matter and leaf area.

Field studies of horizontal distribution of light have also been conducted mainly in forestry. Warren Wilson (1956 b and 1960 b) reports the significance of horizontal distribution of foliage in pastures. Variation in the horizontal distribution of foliage leads to patchiness in the efficiency of light utilization.

Watson (1932) demonstrated from a study of a large number of field crops that the L A I of most crops normally rises slowly from zero to a peak and then starts to decline with senescence of leaves. This decline was shown to be slower in some crops than others. Donald (1961) has illustrated the relationship between L A I, leaf position in the canopy and the total amount of net energy fixation in photosynthesis. As L A I increases mutual shading will eventually cause some of the lower leaves in the canopy to be non-productive. Thus a limit is set on the maximum productivity obtainable by increasing L A I. Leaves with photosynthetic rate less than respiratory rate die eventually as they cannot sustain themselves.

Donald (1961) found that when death at the bottom of the canopy equals new leaf production at the top of the canopy ceiling L A I is reached. At optimum L A I crop growth rate and net assimilation rate are maximum and all the leaves are at or above compensation point. It should be noted that this is only approximately true on a daily basis. The maximum growth rate and the L A I at which it occurred was shown to be dependent on the amount of sunlight being received (Brougham, 1959; Black, 1963).

Brougham (1956) introduced the concept of critical L A I which is the L A I at which ninety-five per cent of incident light is intercepted by a plant's canopy before it reaches the ground. He showed that crop growth rate tends to plateau above this L A I.

However, it should be borne in mind that it is not the amount of light intercepted which is so important but the intensity of radiation at various levels of the canopy. For instance, ninety-five per cent of 3,000 f.c. would not leave enough energy for photosynthesis at the bottom of a well developed dense canopy, whereas ninety-five per cent of 10,000 f.c. would do so. Brougham (1958 b), Davidson and Donald (1958) have shown that the L A I increases above its optimum or critical value in some crops, to reach a ceiling L A I determined by the amount of sunlight being received under field conditions.

Plant species differ in the L A I they attain and maximum growth rate which is related to the efficiency of energy fixation. Brougham (1960) reports that the proportion of dry matter is ultimately limited by the amount of chlorophyll per unit land area exposed to levels above the compensation point (see Table 2).

TABLE 2. Growth-rates per Unit Leaf Area and Chlorophyll

Plant Species	Critical LAI	Maxim.Growth Rate (d.m.) lb/ac/day	g/m^2	Chlorophyll mg/ft^2
White Clover	3.0	121	1.3	129
Kale	3.1	127	1.4	133
Red Clover	4.8	188	1.9	199
Italian Ryegrass	6.0	156	2.2	209
Short Rot. Ryegrass	6.45	169	2.5	229
Maize	7.35	261	2.9	281

It can thus be concluded that L A I is a factor of energy fixation efficiency. L A I tells us the size of the photosynthetic system. Chlorophyll content is another factor that L A I tells us something of the size of the photosynthetic area and thus its potential for using more of the incoming radiation. Bray (1960) found a highly significant correlation between dry weight of the above crop of annual herbaceous stands and their chlorophyll content.

Another factor affecting the efficiency of energy fixation is leaf area duration (LAD). This is a measure of LAI over a whole growth period or seasonal cycles (Donald, 1961). The longer the photosynthesizing surface is maintained the more dry matter is produced if other factors are not limiting to plant growth.

Westlake (1963) defined the amount of biological material produced by photosynthesis per unit area per unit time as primary productivity. One of the aims of scientists is to produce high rates of useful forms of productivity for human and animal consumption.

Productivity for a given plant canopy is influenced by:

(i) The amount of light energy actually absorbed by each leaf.
(ii) The total amount of chlorophyll exposed to light energy.
(iii) The rate at which the necessary carbon dioxide water and mineral nutrients arrive at the site of photosynthesis.
(iv) The capacity of photosynthetic process of each leaf to use the quantity and quality of energy absorbed.

Bula et al (1959) showed that dry matter yields were proportional to light intensity when they grew lucerne under 750, 1,500 and 3,000 f.c. in a 15-hour photoperiod. They demonstrated that a high light intensity period followed by a low intensity period did not give increased yields. Ludwig (1960), working on creeping lucerne, found that the increase in weight of tops was proportional to the increase in light intensity with a photoperiod of sixteen hours. Rhykerd et al (1960) using light intensities from 1,200 to 38,400 f.c. showed that dry wright of tops increased with increases in light intensity. Other investigators, notably Pritchett and Nelson (1951); Gist and Mott (1958) and Steinke (1963) have found similar results.

(v) Effect of Frequency of Defoliation on Light Interception.

The foregoing review does not mention the effect of frequency of defoliation of lucerne on light interception.

It would appear that defoliation would influence the efficiency of light utilization. Stanhill (1962) working on lucerne in Israel, found that only thirty-three per cent of the incident light during the growing season was ever intercepted by plants. The rest was lost by penetration through the canopy. These losses were shown to be greatest immediately after defoliation. He allowed forty-eight days instead of thirty-one days between cuttings and left a stubble twenty-five centimeters high instead of fifteen centimetres and found that the proportion of light intercepted increased from thirty-three to forty-five per cent. The actual yield rose from thirty-six to fifty-four per cent.

CHAPTER III

THE FIELD EXPERIMENT

(a) The Site

The trial was sited on a paddock adjacent to Massey University, three miles from Palmerston North. Previously the paddock had been under a rye-grass-white clover dominant pasture with some browntop and sweet vernal, for nearly twenty years. It was broken up and following suitable cultivation, pure New Zealand certified Chanticleer lucerne seed was sown in November, 1965. A ton of lime and 4 cwt. of potassic superphosphate per acre were applied at the time of sowing. This was followed by another application of potassic superphosphate in September, 1966.

The soil on the site is Ashhurst shallow silt loam, formed on the Intermediate Terrace (Pollok, 1967). The top soil is 3" to 5" deep, which is made of free draining silt loam. The subsoil consists of gravelly loam, which extends to a depth of about 16". Ferruginous loamy coarse gravel occurs from 16" to 60" or more. The drainage of this last group is slightly imperfect, due to the presence of cement. It is also considered to be deficient in available phosphates (Pollok, 1967).

(b) Climatic Conditions

Climatic data were obtained from Massey University Meteorological Station, which is about 400 yards from the site. Temperature figures were obtained from the records of Grasslands Division Meteorological Station, approximately one mile away.

The temperature regime was normal for the period. The rainfall pattern followed the usual even distribution for most part of 1966, except for December, which was unusually wet, with a record rainfall of 8.54". A slight drought was experienced in March and part of April, 1967.

(c) Treatments

The field experiment described here was carried out to obtain some information regarding the production of lucerne and the ingress of volunteer species under different frequencies of defoliation. Cutting treatments ranged from more frequent (2 weeks) through intermediate ones to less frequent (6 weeks) and extended over a period of 12 weeks.

The experiment was laid out on four blocks, each measuring 48 feet by 18 feet. There were eight treatments. The treatments were allocated at random to the plots in each of the four blocks in a completely randomized block design. This layout gave a total of 32 plots, each measuring 18 feet by 6 feet.

On 1st November, 1966, the whole experimental area was mowed with a Graveley mower as close to the ground as possible. All the forage material was removed to initiate the first growth period. The blocks were then measured off and plots were marked out by wooden pegs.

Treatments were started on 15th November, 1966, and continued until 24th January, 1967. The mowing schedule is shown below and in Table 3. Treatments are numbered from 1 to 8.

(1) 15th Nov., 29th Nov., 13th Dec., 27th Dec., 10th Jan., and 24th Jan., i.e., 14 day intervals.

(2) 29th Nov., 13th Dec,, 27th Dec., 10th Jan., and 24th Jan., i.e., 28 day interval and 14 day intervals thereafter.

(3) 22nd Nov., 13th Dec., 3rd Jan., and 24th Jan., i.e., 21 day intervals.

(4) 29th Nov., 27th Dec., and 24th Jan., i.e., 28 day intervals.

(5) 13th Dec., and 24th Jan., i.e., 42 day intervals.

(6) 13th Dec., 27th Dec., 10th Jan., and 24th Jan., i.e., 42 day interval and 14 day intervals thereafter.

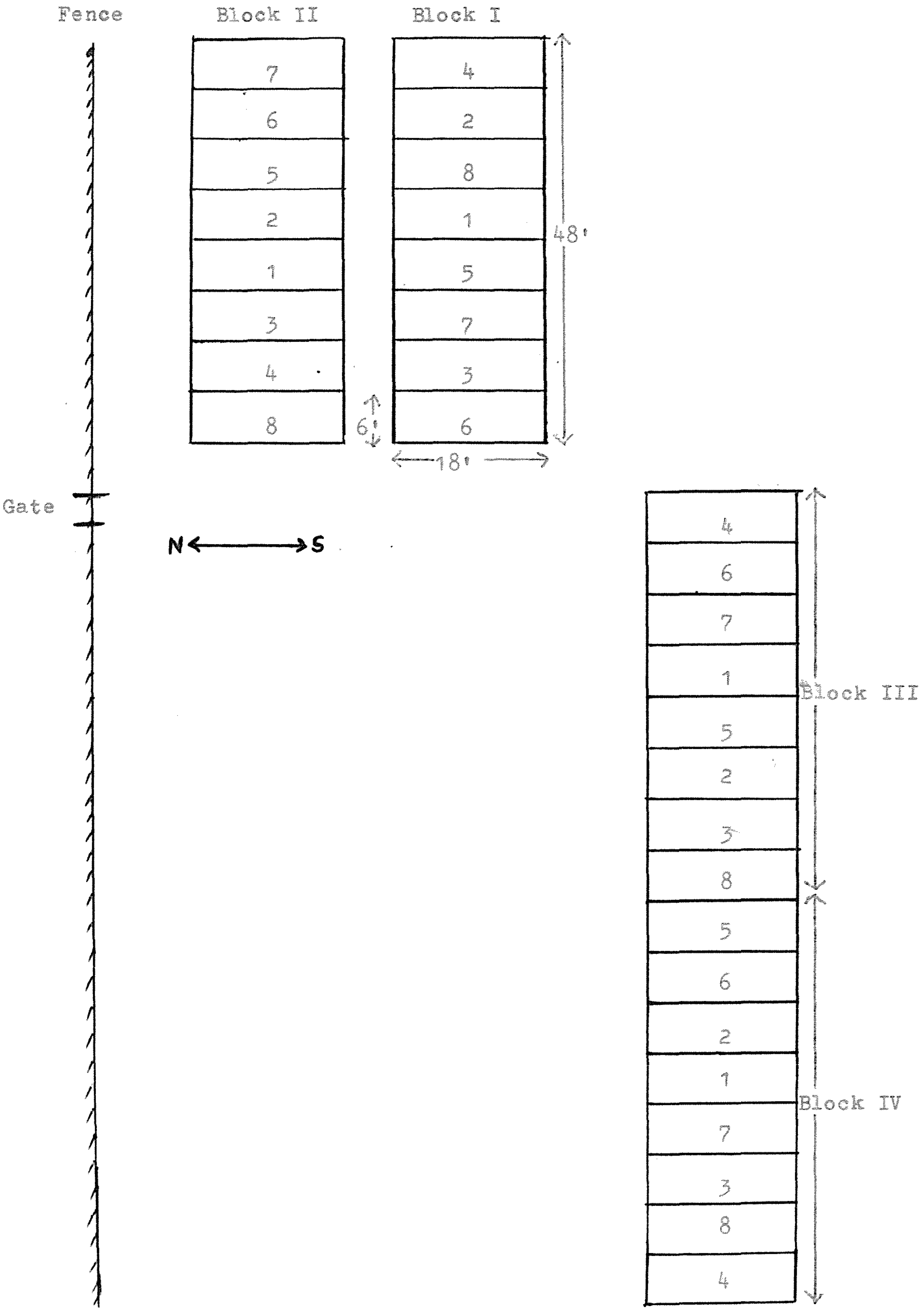
(7) 29th Nov., 13th Dec., 10th Jan., 24th Jan., i.e., 28 day interval and 14 day interval, followed by a repeat of the same procedure.

(8) 29th Nov., 13th Dec., 27th Dec., and 24th Jan., i.e., 28 day interval, then 2 x 14 day intervals, and finally 28 day interval.

TABLE 3. Treatments, Cutting Intervals and Dates

Treatment No.	1966					1967		
	15.11	22.11	29.11	13.12	27.12	3.1	10.1	24.1
1	14		14	14	14		14	14
2			28	14	14		14	14
3		21		21		21		21
4			28		28			28
5				42				42
6				42	14		14	14
7			28	14			28	14
8			28	14	14			28

DIAG. I. PLAN OF EXPERIMENTAL AREA



NOTE: Numbers 1 to 8 stand for treatments

Scale: 1 mm represents 8 inches

(d) Methods

(i) Dry Matter Yields

At the time of each treatment cut, three quadrats (each measuring 2 feet by 1 foot) totalling 6 square feet per plot, were harvested between 15th November, 1966, and 24th January, 1967, with hand shears, as close to the ground as possible. The green matter from the three quadrats was combined and all material which was not lucerne was removed by hand picking. The lucerne green material was then weighed. If the sample was more than 200 gm, a subsample of approximately 50 gm. was taken by the grab method and then weighed accurately on a K7 Mettler balance. The material was placed in a wire-mesh tray for drying overnight in a forced-draught oven at 85° C before weighing again for dry matter determination.

The same procedure was employed except that four instead of three quadrats were taken per plot of lucerne harvested on 8th March and 18th April, 1967. The dry matter yield was one of the criteria used in measuring the effects of treatments (see Chapter IV).

(ii) Botanical Composition

This was carried out to determine the effect of cutting frequency on weed ingress. Any plant species found growing in the lucerne area was classified as a weed.

On 18th April, 1967, four quadrats, each measuring 2 feet by 1 foot, were harvested per plot with hand shears. The material was separated into lucerne and weeds and weighed green in the laboratory. It was intended to dry the two lots separately and calculate the percentage of weeds on a dry weight basis. This was not possible due to lack of drying space in the oven.

The percentage productivity method of botanical analysis was employed. It is objective and gives an estimation of the intensity of representation of species in a sward. Since it was found that the method was time consuming, it was decided that each sample should be dissected into two components. Therefore samples were weighed for total fresh weight and then dissected into lucerne and weeds. Fresh weight of lucerne and weeds was used for calculation of percentage productivity (see Table 8).

(iii) Point Analysis

A point analysis was done on 4th April on all the 32 plots to determine the percentage cover of each species. It was also possible to identify different weed species by this method.

The apparatus employed was locally manufactured. It consisted of a steel frame mounted on legs, pointed to facilitate pushing into the soil. It carried three needles 4 inches apart and held in such a way that they could slide easily in a set course.

A number of points were taken at random between and within the rows. At least twenty-four points between the rows and the same number within the rows were taken for each plot. All the vegetation which was hit as the needles descended vertically was recorded. If any of the needles hit bare ground, this was included in the records. The relative frequency of each species was then calculated according to the following formula by Levy and Madden (1933):

$$\text{Relative frequency} = \frac{\text{No. of times a species is hit}}{\text{Total times vegetation is hit}}$$

(iv) Leaf Area Index and Stem : Leaf Ratio

In order to determine the distribution of leaf area with height, herbage in each 3" layer was sampled from 1' x 1' quadrat per plot on 7th March, 1967. The material was cut at ground level with hand shears. It was weighed green in the laboratory. A sub-sample was taken and cut at 3" intervals; a technique used by Black (1958, 1960). Each lot was then separated into leaf and stem petioles and floral organs being included with the latter. The leaves were then arranged into several groups, from the smallest leaves to the largest ones. A single leaf was taken from each group and its outline was traced on a graph paper. The number of squares within each outline was counted as representing the area of one leaf. The leaf area was calculated by multiplying the number of leaves with the area of the corresponding outline. The leaf area index was compiled from the information.

The leaf and stem portions were dried in the oven at 85° C. These were weighed for the calculation of stem:leaf ratio.

(v) Organic Reserves

The method employed was proposed by Prof. B.R. Watkin of the Agronomy Department of Massey University. The aim was to determine the effect of cutting frequency, on organic reserve accumulation in lucerne which had been cut every two, three, four and six weeks. The method is based on the hypothesis that organic reserves initiate regrowth and aid in the development of plants after the removal of the top growth. Therefore on a restricted number of plots that had been mowed on 8th March, 1967, with a Graveley Mower, as previously described, wooden domes were placed over the defoliated plants to exclude practically all light from reaching the cut plants. Air

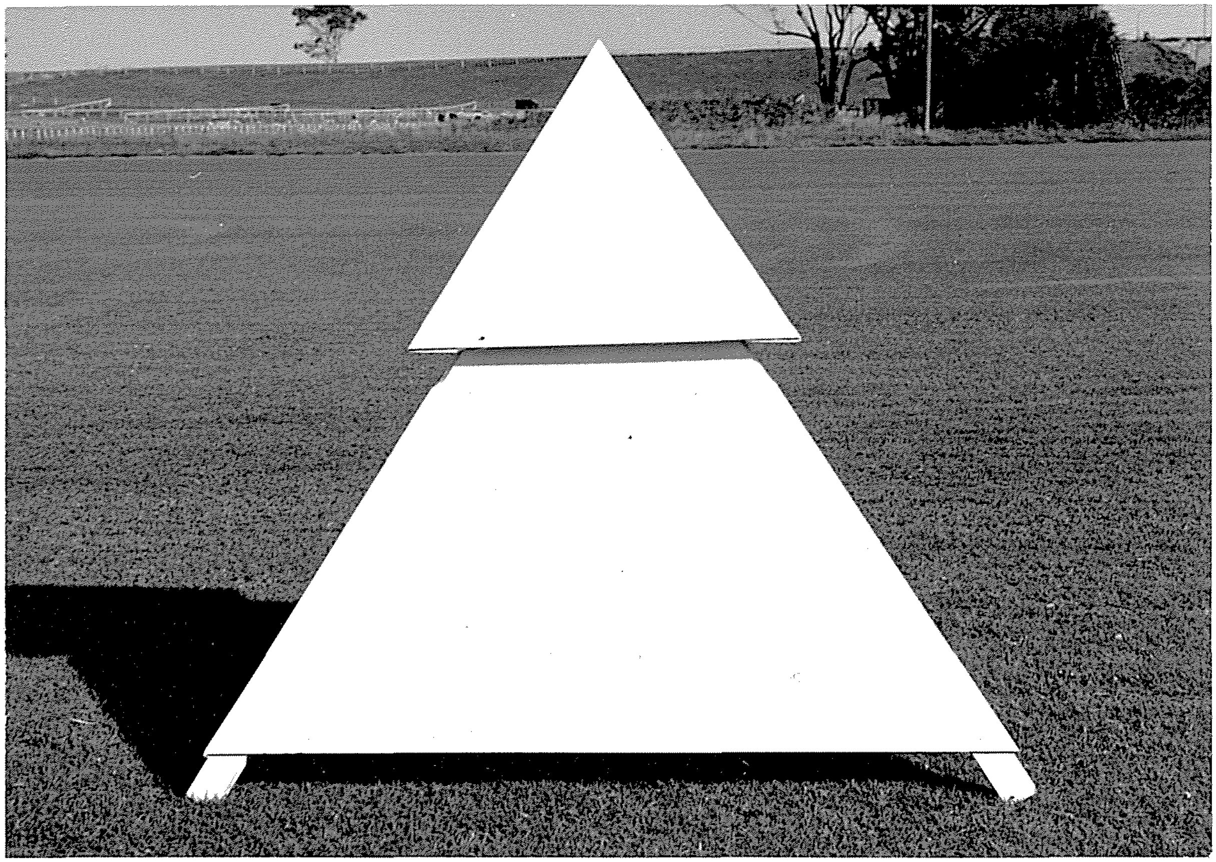
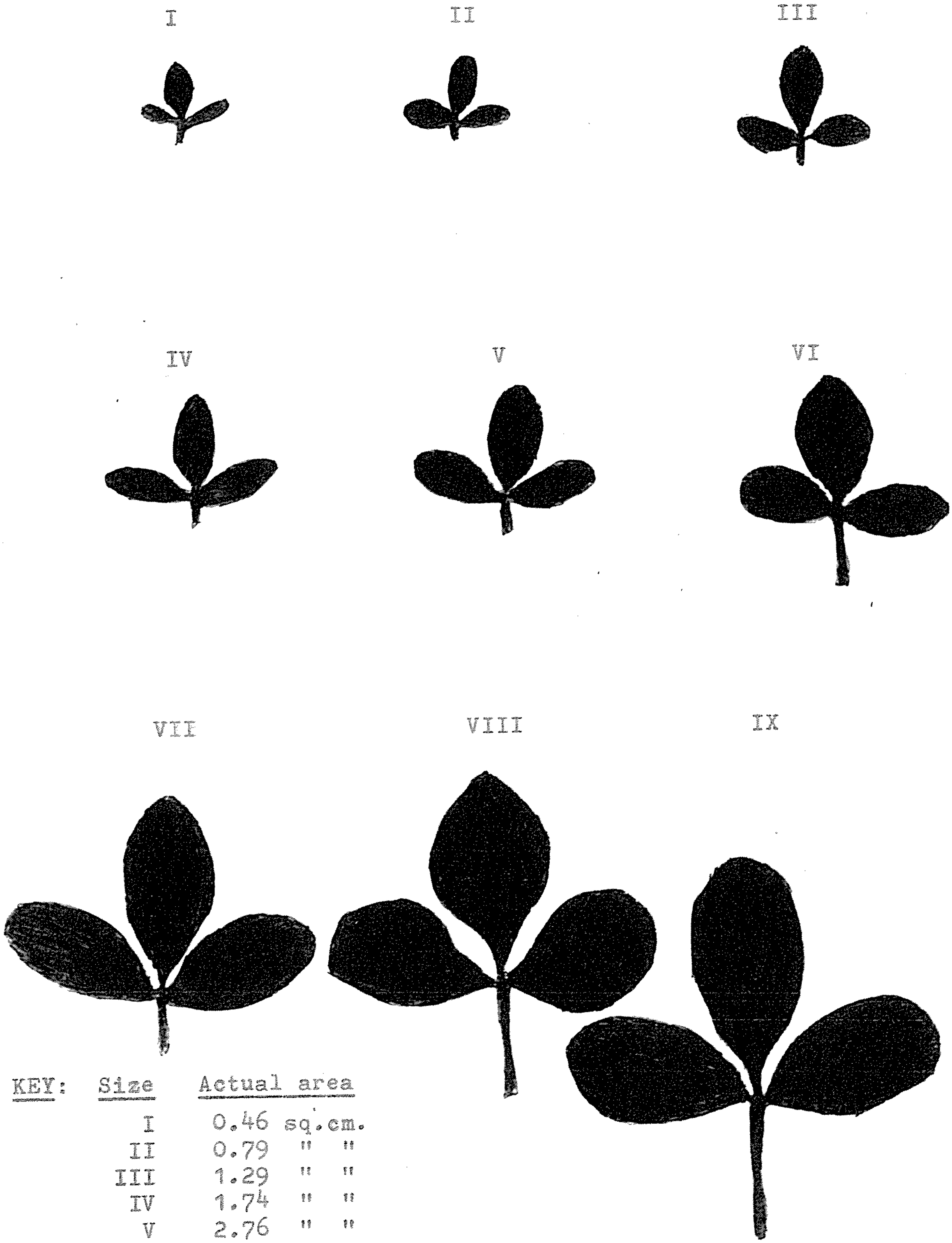


Plate 2. One of the wooden domes used in this study.

DIAGRAM 2. Different sizes of leaves used in determining leaf area index of lucerne harvested on 7/3/67. (i.e., after six weeks growth)



KEY:

Size	Actual area
I	0.46 sq.cm.
II	0.79 " "
III	1.29 " "
IV	1.74 " "
V	2.76 " "
VI	3.84 " "
VII	9.01 " "
VIII	11.94 " "
IX	14.27 " "

was allowed to circulate through the domes. In addition, the plants were watered regularly, care being taken not to remove the covers (domes). The inside temperature was read every two days.

The covers were taken off after three weeks and the lucerne underneath was harvested with hand shears. It was dried in the oven at 85° C and weighed. The dry weight yields were then compared with those obtained from the normal yield determination.

(vi) Plant Density

All the plant material within a 1' x 1' quadrat per plot was cut close to the ground with hand shears on 7th March, and 18th April, 1967. Lucerne portion was separated from the rest and the stems were counted.

(vii) Stem Height

Stem height in centimeters was measured every two weeks, starting on 7th February to 8th March (i.e., 6 weeks' growth).

An imaginery line running along the middle of each plot and at right angles with the rows, was marked. The height of all plants along the line was measured. From the measurements the average height of plants was computed.

(viii) Soil Moisture

On 24th January and 8th March, 1967, five random soil samples per plot were taken with a soil sampler, to a depth of 4". All the samples per plot were combined and stones were removed by hand picking, The two sub-samples were taken from each main sample and weighed in pre-weighed containers and dried at 100° C until a constant weight was maintained.

(ix) Light Measurement

A light meter manufactured by the Plant Physiology Division of the D.S.I.R., Palmerston North, was employed. The instrument is portable and non-directional. It is calibrated in simple numbers which range from zero to one hundred. It is relatively quick and easy to use.

Percentage light was recorded at 3" intervals in the canopy. Measurements were taken between and within the rows to give an indication of light transmission in the sward.

The probe was placed above the canopy to record the total incident light as one hundred per cent. This was immediately followed by recording readings at every 3" in the canopy. Since the method was time consuming, only eight samples per plot were taken on 17th and 18th April, 1967.

CHAPTER IV

RESULTS

(i) Dry Matter Yields

To facilitate the analysis of results, the data for dry matter yields are presented as dry matter production per week for each treatment. Therefore a six-week period was chosen to cover dates between 13th December, 1966, and 24th January, 1967. This was a preliminary period aimed at showing the immediate effect of frequency of defoliation on dry matter yields as presented in Table 4.

TABLE 4. Dry weight yields (g/3 quadrats/week) in response to cutting frequency.
(From 13th December, 1966, to 24th January, 1967)

Treatment	Rep.1	Rep.2	Rep.3	Rep.4	Treatment Totals	Treatment Means
(1)	18.32	20.88	12.15	13.01	64.36	16.90
(2)	27.51	28.49	19.49	18.40	93.89	23.47
(3)	26.89	25.11	17.41	13.64	83.05	20.76
(4)	26.70	32.30	24.90	19.07	102.97	25.74
(5)	67.73	52.07	55.15	44.80	219.75	54.74
(6)	31.40	28.18	22.22	18.86	100.66	25.17
(7)	35.89	36.07	30.19	27.94	130.09	32.53
(8)	31.86	31.96	21.80	19.29	104.91	26.23
Block Totals	266.30	255.06	203.31	175.01	899.68	

Fig.I. Effect of cutting intervals on dry matter yield (gm/6ft²/week). Production between 13th Dec.1966 and 24th Jan.1967.

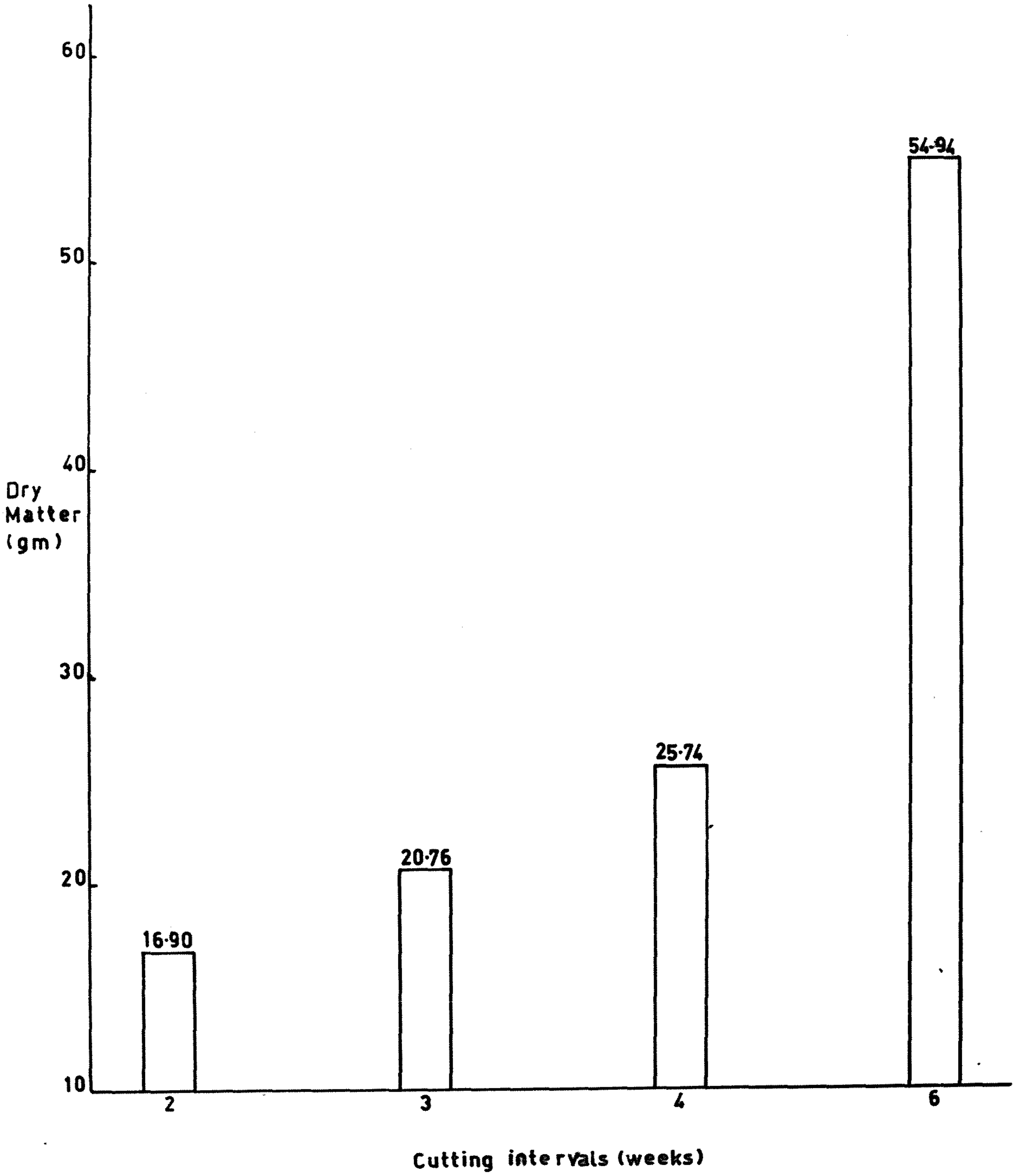


TABLE 5. Analysis of variance on dry matter yield per week as g/3 quadrats

Source of Variation	S.S.	d.f.	M.s.	F Ratio	F Required		Result
					5%	1%	
Reps.	232.466	3					
Treatments	1302.638	7	186.98	58.63	2.49	3.65	P < 0.01**
Error 1 (Plots)	66.661	21	3.174				
Error 2 (Samples)		64					
Total		95					

** Significant at the 1% level.

S.E. ± 0.89.

Cutting frequency was significant at the 1% level. As there were eight treatments, further tests were carried out to establish their differences both at 1% and 5% levels. Thus Duncan's Multiple Range Test was applied (see Appendix). Treatment means are arranged in increasing order of magnitude as follows:

Treat-ment	1	3	2	6	4	8	7	5	
Mean	16.90	20.76	23.47	25.17	25.74	26.23	32.52	54.94	1%

Treat-ment	1	3	2	6	4	8	7	5	
Mean	16.90	20.76	23.47	25.17	25.74	26.23	32.52	54.94	5%

Comments on Table 4

1. Treatment 5 gave the highest yield of dry matter.
2. Treatment 7 produced the next highest yield.
3. There were no significant differences in the yields of 2, 6, 4 and 8 at the 1% level, although yields increased in that order.
4. The yield in 3 was significantly greater than that of 1.

5. Treatment 1 produced the lowest yield.
6. The yields of 3 and 2 were not significantly different at the 1% level.
7. The yield of treatment 6 was significantly greater than that of 2 at the 5% level.
8. The yield of 2 was significantly greater than that of 3 at the 5% level.

(ii) Main Dry Matter Yields

Analysis of variance was conducted on the main dry matter yields harvested at 2 x 6 weekly intervals. The first lot of dry matter was clipped on 8th March, 1967, and the second on 18th April, 1967. The purpose was to obtain information on the residual effect of different frequencies of cutting on the yield of lucerne. Table 6 shows dry weight yields (g/4 quadrats) per week per treatment in response to cutting frequency.

TABLE 6. Dry weight yields (g/4 quadrats per week) in response to cutting frequency (harvested on 8/3/67 and 18/4/67)

Treatment	Rep.1	Rep.2	Rep.3	Rep.4	Treatment Totals	Treatment Means
(1)	11.41	12.59	7.29	3.78	35.07	8.77
(2)	14.44	14.80	0.03	6.63	44.90	11.23
(3)	13.71	12.25	10.87	5.62	42.45	10.61
(4)	15.06	15.25	17.67	10.15	58.13	14.53
(5)	25.76	22.11	21.83	19.71	89.41	22.35
(6)	16.24	15.38	18.09	10.15	59.86	14.97
(7)	17.92	13.89	17.27	10.96	60.04	15.01
(8)	16.76	16.04	12.36	11.52	56.68	14.17
Block Totals	131.30	122.31	114.41	78.52	446.54	

TABLE 7. Analysis of variance on dry matter yield per week as g/4 quadrats

Source of Variation	S.S.	d.f.	M.s.	F Ratio	F Required		Result
					5%	1%	
Reps.	50.1554	3					
Treatments	118.7966	7	16.9709	20.481	2.49	3.65	0.01**
Error 1 (Plots)	17.4000	21	0.8286				
Error 2 (Samples)		96					
Total:	228.7096	127					

** Significant at the 1% level.

S.E. ± 0.45

Duncan's Multiple Range Test gave the following results:

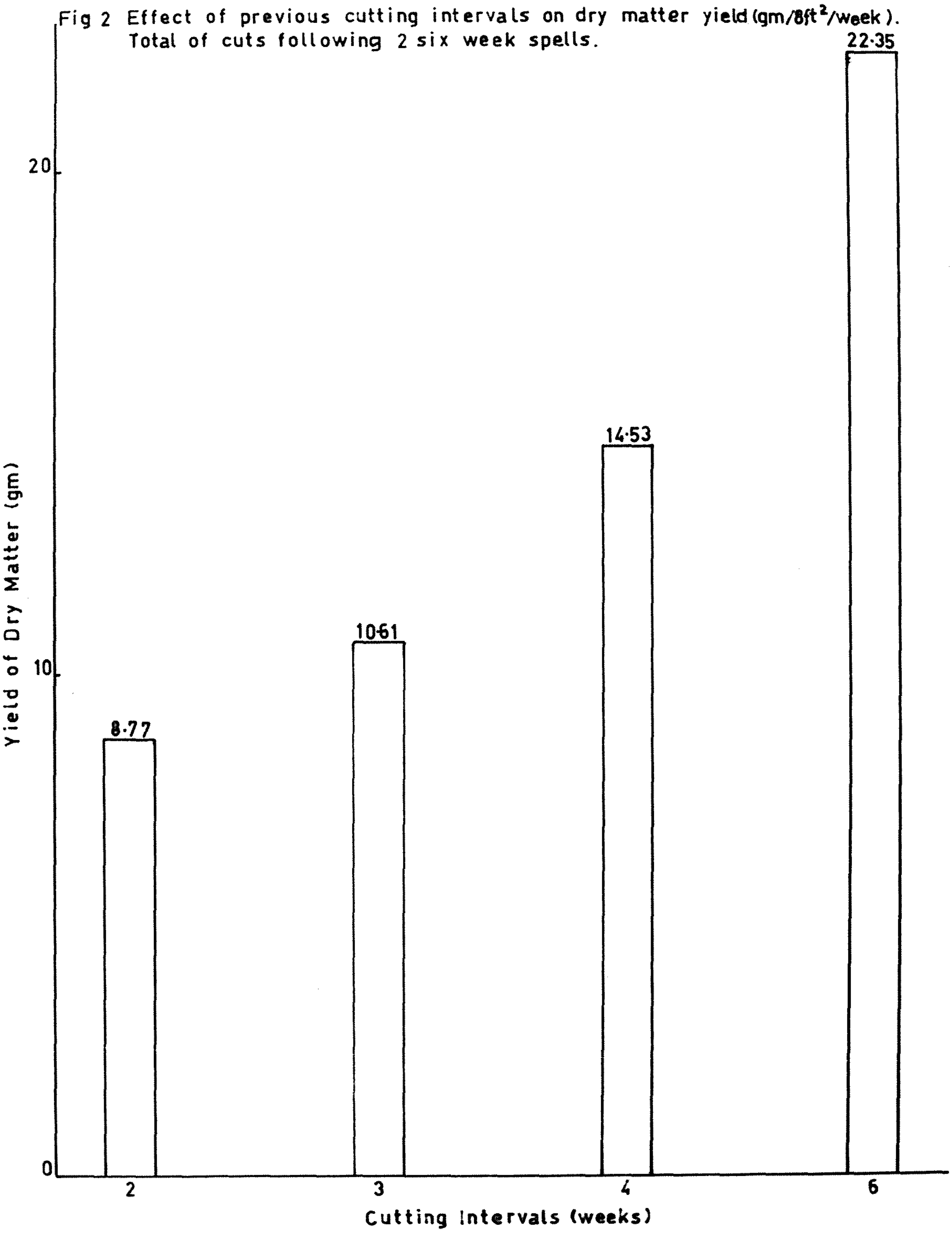
Treat-ment	1	3	2	8	4	6	7	5	
Mean	8.77	10.61	11.23	14.17	14.53	14.97	15.01	22.35	1%

Treat-ment	1	3	2	8	4	6	7	5	
Mean	8.77	10.61	11.23	14.17	14.53	14.97	15.01	22.35	5%

Comments on Table 6

1. Treatment 5 out yielded the rest.
2. Treatments 8, 4, 6 and 7 were not significantly different at both 1% and 5% levels, although yields increased in that order.
3. Treatments 8, 4, 6 and 7 were significantly different (at 1% and 5% levels) from treatments 1, 3 and 2.
4. Treatments 3 and 2 were not significantly different but they were significantly different from treatment 1.
5. Treatment 1 produced the lowest dry matter.

Fig 2 Effect of previous cutting intervals on dry matter yield (gm/8ft²/week). Total of cuts following 2 six week spells.



(iii) Botanical Composition

It was not possible to carry out analysis of variance as dry weight data of weeds were not available. (See Chapter III). However, the percentage productivity method of botanical analysis (after Brown, 1954) was applied and gave the following results;

TABLE 8. Percentage contribution of lucerne

Treat-ment	Rep.1	Rep.2	Rep.3	Rep.4	Treatment Means
(1)	57.7	80.7	57.5	25.5	55.3
(2)	78.2	96.3	59.5	65.9	75.0
(3)	92.4	79.8	78.2	40.0	72.6
(4)	97.9	100.0	100.0	64.4	90.6
(5)	100.0	100.0	100.0	100.0	100.0
(6)	100.0	88.2	100.0	89.3	94.4
(7)	100.0	94.1	100.0	82.2	94.1
(8)	100.0	100.0	92.8	71.9	91.2

Comments on Table 8

1. The highest recorded value of lucerne was 100 per cent in treatment 5. This indicated that the sward was virtually weed free.

2. The lowest recorded value was 55.3 per cent in treatment 1. This showed that with frequent cutting (2 weeks) there was a considerable increase in weeds.

3. The percentage contribution of lucerne increased as the length of cutting interval increased. Thus cutting every 2, 3, 4 and 6 weeks, the percentage contribution of lucerne was 55.3, 72.6, 90.6 and 100.0, respectively.

(iv) Point Analysis

The results are presented as relative frequency (average number of times each species was hit per plot per 48 points) of

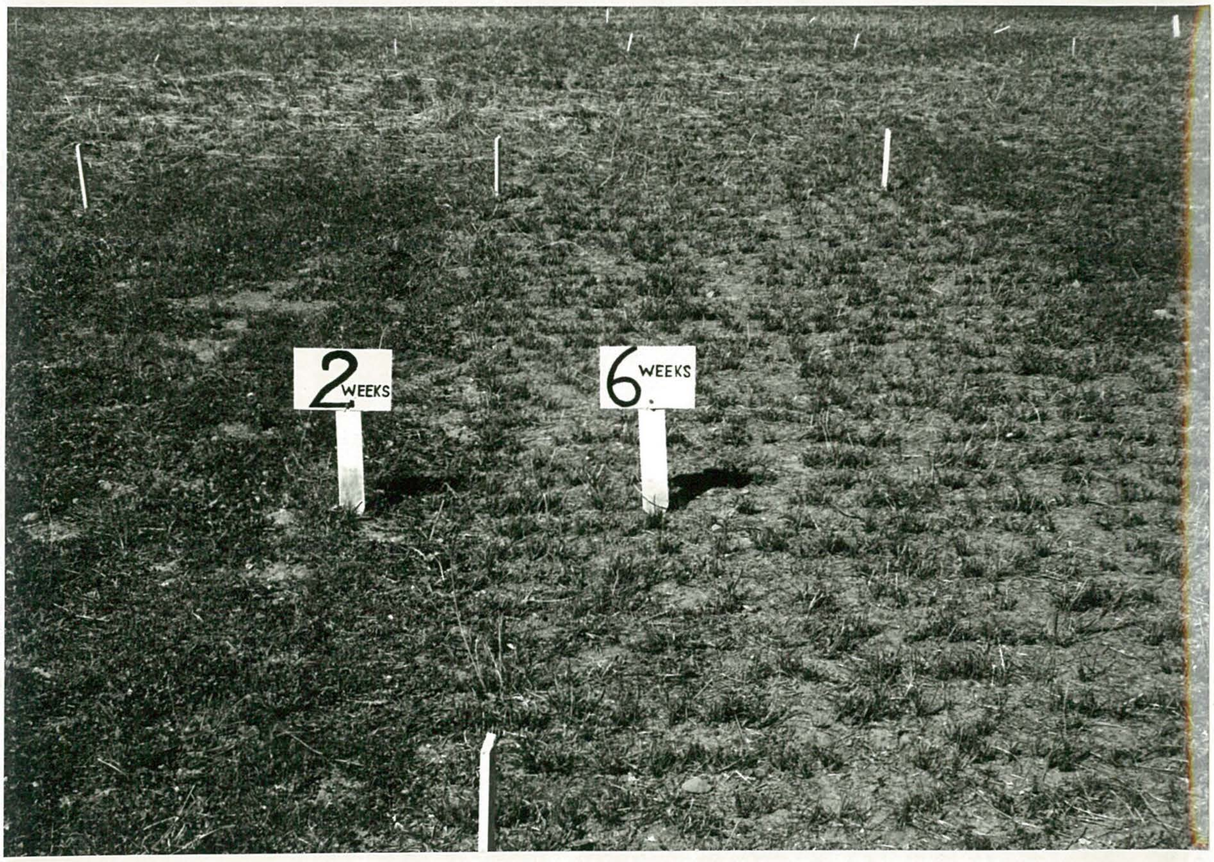


Plate 3. Treatment 1 plot (cut every 2 weeks) has got more weeds covering the ground than treatment 5 plot (cut every 6 weeks), which has got more bare ground and is virtually weed free. Therefore it appears that frequent cutting of lucerne weakens the plants and makes them susceptible to weed invasion.

each species in the cover. (See Table 9).

TABLE 9. Relative frequency of each species in the cover

Treat-ment	Lucerne	Flat Weeds	Clovers	Oxalis	Bare Ground	Misc
(1)	23	6	36	14	5	4
(2)	36	6	12	11	10	5
(3)	28	4	17	6	14	3
(4)	33	8	9	4	16	2
(5)	56	1	1	0	23	0
(6)	43	4	6	1	15	5
(7)	35	10	5	2	18	2
(8)	41	4	5	1	18	0

Comments on Table 9

1. The relative frequency of lucerne increased as the length of cutting interval increased. This cutting every 2, 3, 4 and 6 weeks, the relative frequency of lucerne was 23, 28, 33 and 56, respectively.

2. Clovers (mainly white clover) were the most common and their frequency decreased as the length of cutting interval increased. Thus cutting every 2, 3, 4 and 6 weeks, the relative frequency of clovers was 36, 17, 9 and 1, in that order.

3. The relative frequency of bare ground increased as the length of spelling increased. This showed that plots cut less frequently (6 weeks) were weed-free.

4. The relative frequency of oxalis decreased as cutting intervals increased. The most common oxalis encountered in the plots was Oxalis corniculata.

5. Generally flat weeds and miscellaneous weeds (scarlet pimpernel, moss, etc.), decreased as cutting interval increased.

(v) Stem : Leaf Ratio

The stem:leaf ratio data are presented in Table 10 overleaf.

Plate 4. Treatment 1 plot (cut every 2 weeks) showing a dense mat of weeds which came in as lucerne stand was weakened by repeated frequent cutting.

Plate 5. Treatment 5 plot (cut every 2 weeks), showing patches of bare ground, is practically weed free, an advantage gained from less frequent defoliation. It would appear that when lucerne is infrequently defoliated, it grows vigorously and prevents weeds from making a start.

Fig 3 Effect of previous cutting intervals on relative frequency of each species and bare ground in the cover as determined by point analysis on 4th April,1967.

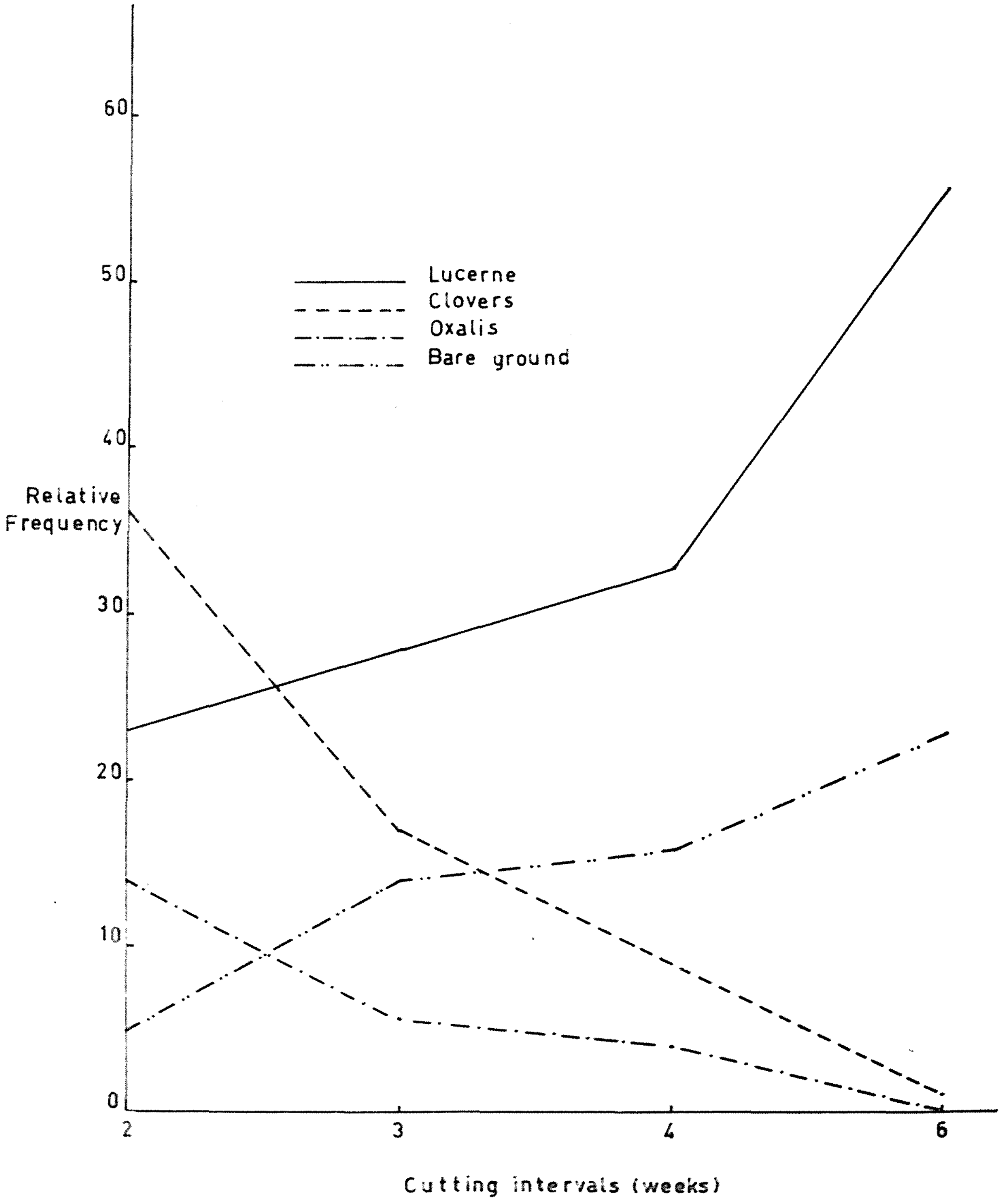


TABLE 10. Stem:leaf ratio measurements taken on 7th March, 1967.

Treatment	Rep.1	Rep.2	Rep.3	Rep.4	Treatment Totals	Treatment Means
(1)	0.77	0.97	0.96	0.95	3.65	0.01
(2)	1.20	1.03	0.88	0.73	3.84	0.96
(3)	1.52	1.08	0.92	0.74	4.26	1.07
(4)	1.06	1.27	0.97	0.96	4.26	1.07
(5)	2.00	1.53	1.84	1.53	6.90	1.73
(6)	1.39	1.00	1.58	1.09	5.06	1.27
(7)	1.00	1.15	1.27	0.97	4.39	1.10
(8)	1.12	1.16	1.13	1.21	4.62	1.16
	10.6	9.19	9.55	8.18	36.98	

Analysis of variance was conducted on stem:leaf ratio and presented in Table 11.

TABLE 11. Analysis of variance on stem:leaf ratio

Source of Variation	S.S.	d.f.	M.s.	F Ratio	F Required 5%	F Required 1%	Result
Reps.	0.2368	3					
Treatments	1.8134	7	0.25906	6.68	2.49	3.65	$p < 0.01$**
Error	0.7520	21	0.03581				
Total	2.8022	31					

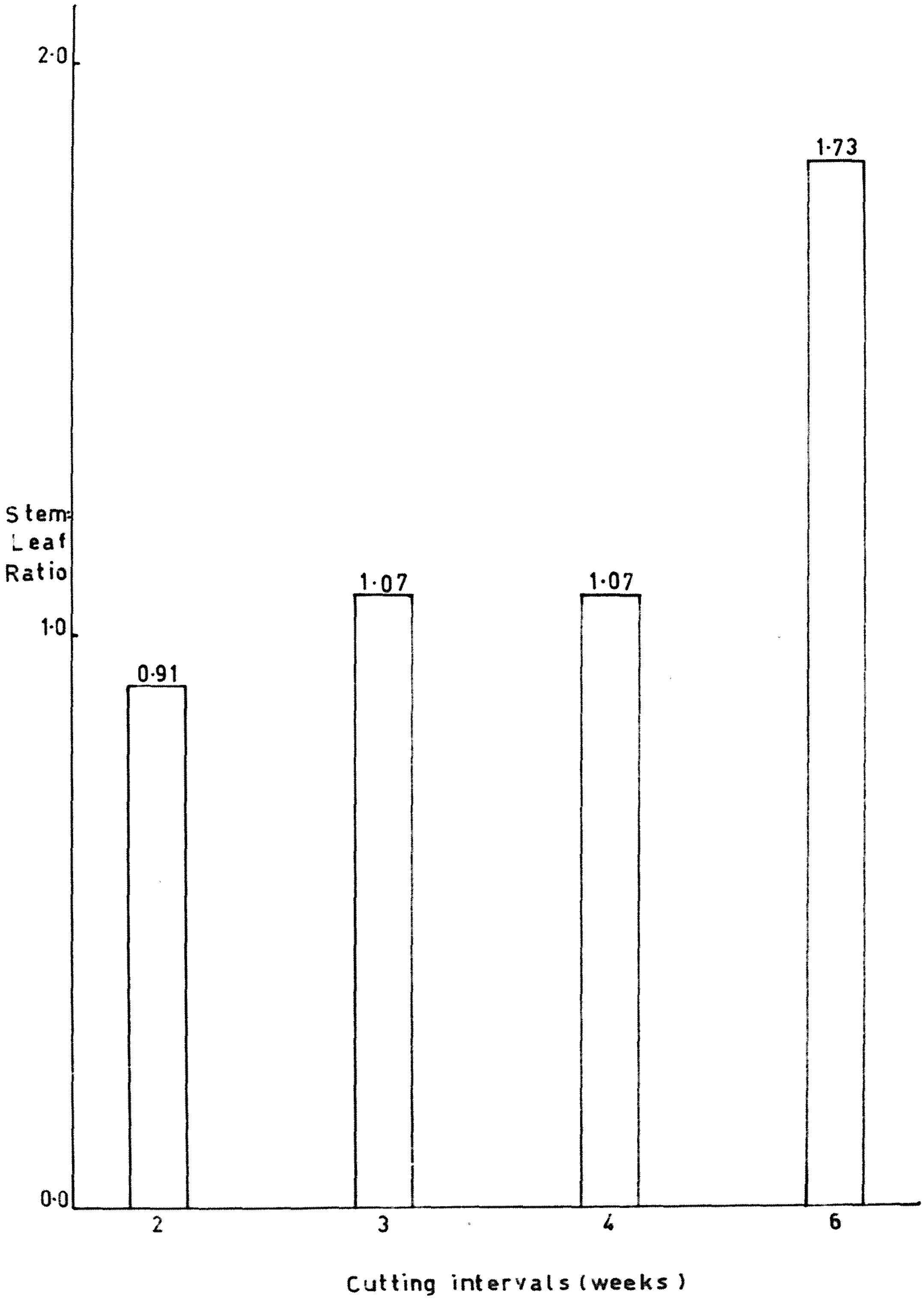
** Significant at the 1% level.

S.E. ± 0.09

Duncan's Multiple Range Test gave the following results:

Treatment	1	2	3	4	7	8	6	5	
Mean	0.91	0.96	1.07	1.07	1.10	1.16	1.27	1.73	1%

Fig.4. Effect of previous cutting intervals on stem:leaf ratio measured on 7th. March,1967. (ie.after 6 weeks growth)



Treat-ment	1	2	3	4	7	8	6	5	
Mean	0.91	0.96	1.07	1.07	1.10	1.16	1.27	1.73	5%

Comments on Table 10

1. Treatment 5 had the highest stem:leaf ratio.
2. There were no significant differences (at 1% level) among treatments 1, 2, 3, 4, 7, 8 and 6, although stem:leaf ratio increased in that order.
3. Treatment 6 was significantly different (at 5% level) from treatments 1, 2, 3, 4, 7, and 8.
4. Treatments 1, 2, 3, 4, 7 and 8 were not significantly different at the 5% level.

(vi) Organic Reserves

The dry weight yields of top growth are shown in Table 12 below.

TABLE 12. Dry weight yields of top growth per dome

Treat-ment	Rep.1	Rep.2	Rep.3	Rep.4	Treat ment Totals	Treat-ment Means
(1)	-	-	-	-	-	-
(3)	-	-	-	-	-	-
(4)	0.20	0.40	-	-	0.60	0.15
(5)	6.00	4.60	1.70	4.00	16.30	4.07

Comments on Table 12

1. Treatment 5 (cut every 6 weeks) yielded maximum top growth.
2. Treatment 4 (cut every 4 weeks) produced very little top growth.
3. Treatments 1 and 3 (cut every 2 and 3 weeks, respectively) did not produce measurable top growth.

(vii) (a) Plant Density

The results of plant density measured on 7th March, 1967, (i.e., after six weeks' growth) are presented in Table 13.

TABLE 13. Plant density measurements taken on 7th March, 1967.

Treatment	Rep.1	Rep.2	Rep.3	Rep.4	Treatment Totals	Treatment Means
(1)	50	60	41	32	183	46
(2)	68	81	48	36	233	58
(3)	59	55	48	55	217	54
(4)	50	56	43	71	220	55
(5)	99	166	158	83	506	127
(6)	60	99	62	68	289	72
(7)	70	76	71	49	266	67
(8)	60	68	55	72	255	64
Block Totals	516	661	526	466	2169	

Analysis of variance was conducted on plant density and presented in Table 14.

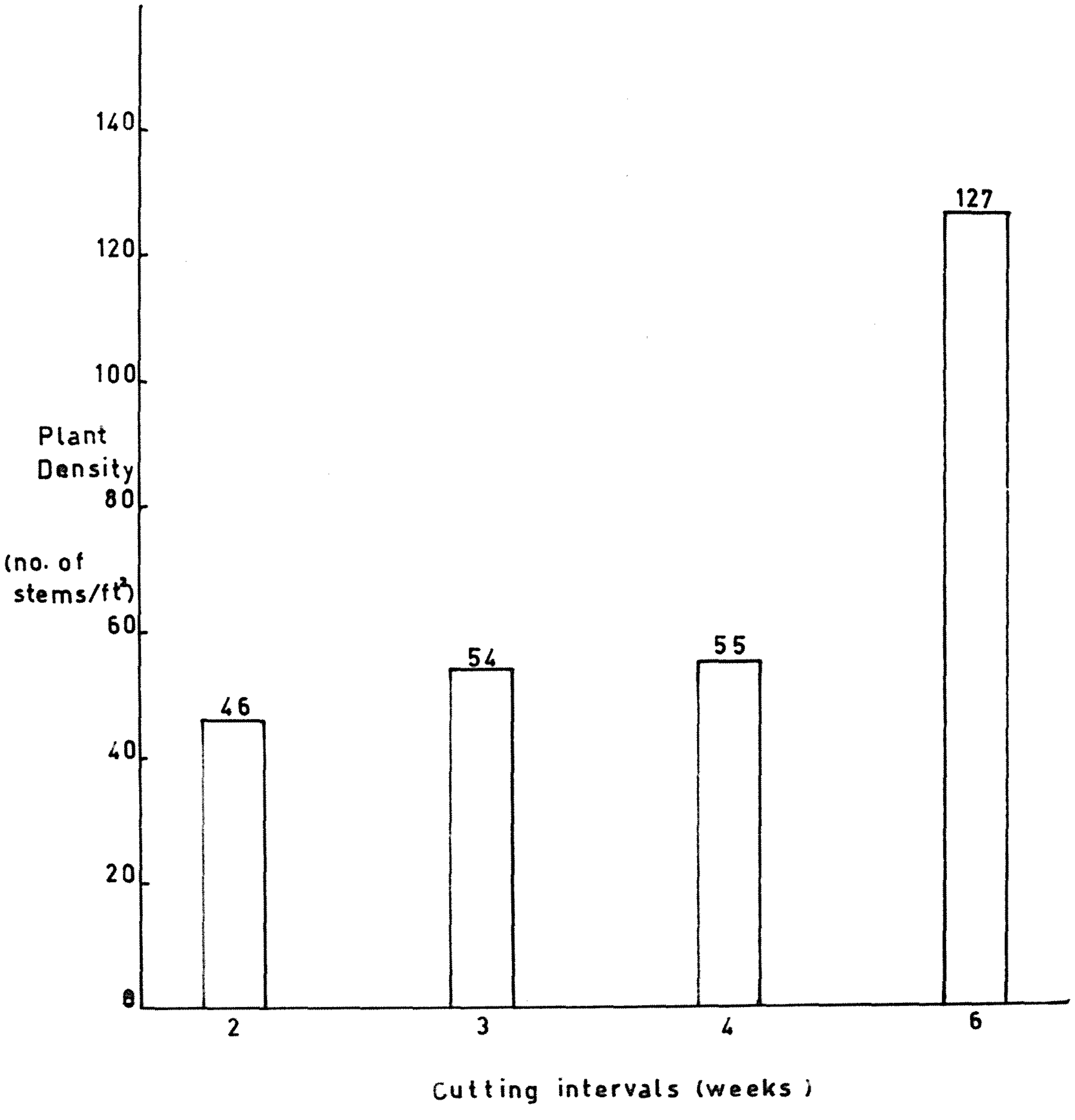
TABLE 14. Analysis of variance on plant density measured on 7/3/67.

Source of Variance	S.S.	d.f.	M.s.	F Ratio	F Required 5%	F Required 1%	Result
Reps.	2608.61	3	869.537				
Treatments	17633.73	7	2519.103	8.37	2.49	3.65	$p<.01$**
Error	6321.14	21	301.007				
Total		31					

** Significant at the 1% level

S.E. ± 8.68

Fig.5. Effect of previous cutting intervals on plant density measured on 7.th. March,1967. (ie after 6 weeks growth)



Duncan's Multiple Range Test gave the following results:

Treatment	1	3	4	2	8	7	6	5	
Mean	46	54	55	58	64	67	72	127	1%

Treatment	1	3	4	2	8	7	6	5	
Mean	46	54	55	58	64	67	72	127	5%

Comments on Table 13

1. Treatment 5 had the highest number of stems per unit area of land and was significantly greater (at 1% level) than the rest.
2. There were no significant differences (at the 1% level) among treatments 1, 3, 4, 2, 8, 7 and 6, although plant numbers increased in that order.
3. Treatment 6 was significantly greater (at the 5% level) than treatments 1, 3, 4, 2, 8 and 7.

(vii) (b) Plant Density

The results of plant density measured on 18th April, 1967, (i.e., after six weeks' growth) are presented in Table 15.

TABLE 15. Plant density measurements taken on 18th April, 1967.

Treatment	Rep.1	Rep.2	Rep.3	Rep.4	Treatment Totals	Treatment Means
(1)	41	46	40	39	166	42
(2)	62	60	75	50	247	62
(3)	57	55	64	59	235	59
(4)	63	69	67	56	255	64
(5)	60	67	66	63	256	64
(6)	66	70	98	64	298	75
(7)	51	50	58	74	233	58
(8)	70	75	88	64	297	74
Block Totals	470	492	556	469	1987	

Analysis of variance was conducted on plant density and presented in Table 16.

TABLE 16. Analysis of variance on plant density measured on 18/4/67.

Source of variation	S.S.	d.f.	M.s.	F. Ratio	F. Required		Result
					5%	1%	
Reps.	627.34	3	209.113				
Treatments	3032.97	7	433.281	6.88	2.49	3.65	$P<0.01$**
Error	1322.41	21	62.972				
Total		31					

** Significant at the 1% level.

S.E. ± 3.97

Duncan's Multiple Range Test gave the following results:

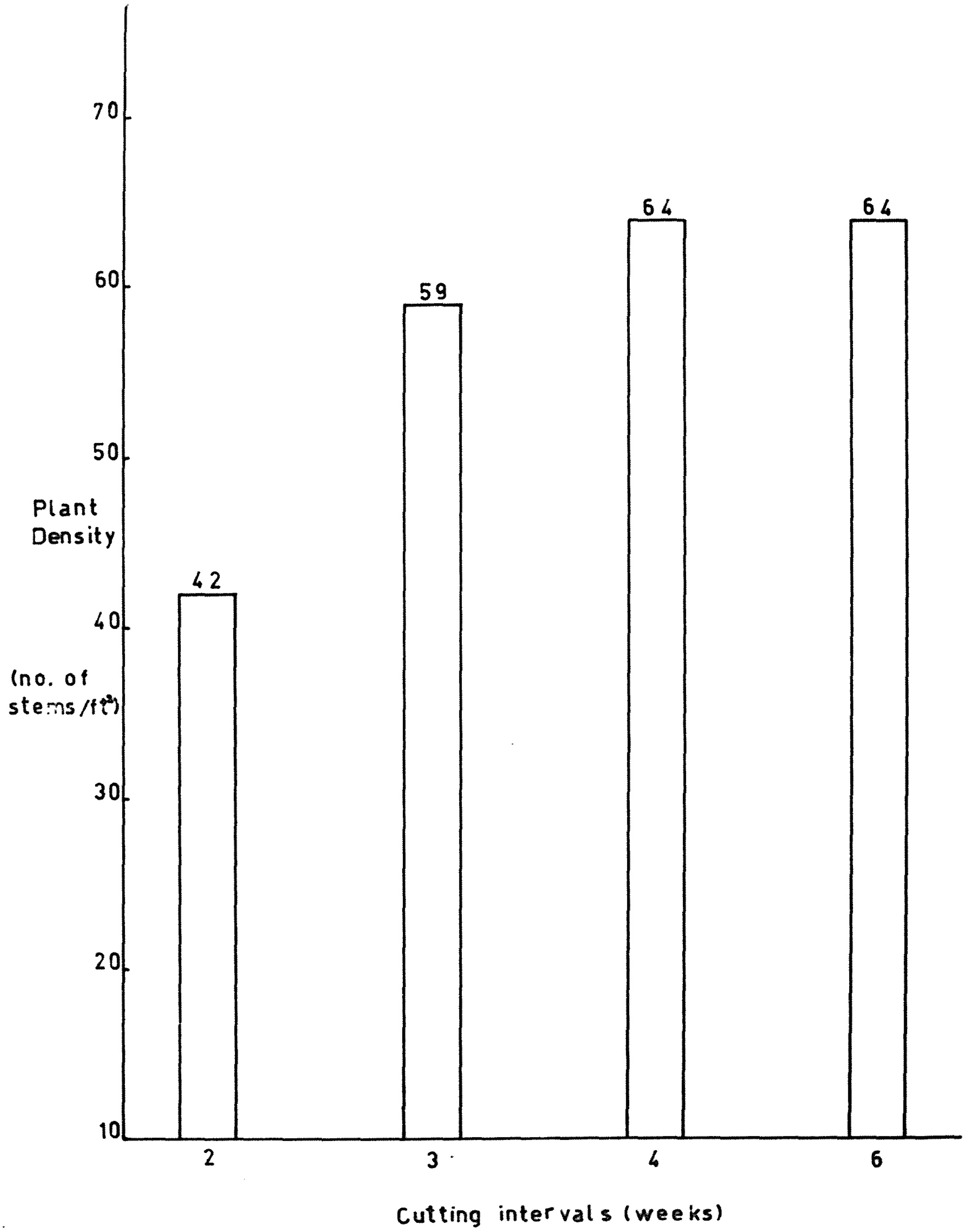
Treatment	1	7	3	2	4	5	8	6	
Mean	42	58	59	62	64	64	74	75	1%

Treatment	1	7	3	2	4	5	8	6	
Mean	42	58	59	62	64	64	74	75	5%

Comments on Table 15

1. There were no significant differences (at 1% level) among treatments 7, 3, 2, 4, 5, 8 and 6, although stem numbers increased in that order.
2. Treatment 1 had the lowest number of stems per unit area of land and was significantly less than the rest.
3. There were no significant differences (at the 5% level) among treatments 2, 4, 5, 8 and 6, although stem numbers increased in that order.
4. Treatments 8 and 6 were significantly greater (at 5% level) tran treatments 1, 7 and 3.

Fig.6. Effect of previous cutting intervals on plant density, measured on 18th. April, 1967. (i.e. after 6 weeks growth)



5. There were no significant differences (at 5% level) among treatments 7, 3, 2, 4 and 5, although stem numbers increased in that order.

(viii) Stem Height

Stem height measurements were calculated on a weekly basis and presented in Table 17.

TABLE 17. Stem height measurements in centimeters (weekly averages)

Treatment	Rep.1	Rep.2	Rep.3	Rep.4	Treatment Totals	Treatment Means
(1)	4.6	4.8	4.6	5.3	19.2	4.83
(2)	5.4	4.9	5.2	6.3	21.8	5.45
(3)	5.5	4.9	5.6	5.7	21.7	5.43
(4)	6.6	7.3	6.4	6.6	26.9	6.73
(5)	12.7	10.7	12.8	12.8	49.0	12.25
(6)	6.5	6.1	7.4	6.8	26.8	6.70
(7)	7.6	5.8	7.4	7.1	27.9	6.98
(8)	7.5	6.1	7.5	7.9	29.0	7.25
Block Totals	56.4	50.6	56.9	58.5	222.4	

Analysis of variance was conducted on stem height and presented in Table 18.

TABLE 18. Analysis of variance on average stem height in c.m. per week

Source of Variation	S.S.	d.f.	M.s.	F. Ratio	F Required		Results
					5%	1%	
Reps.	4.467	3					
Treatments	149.540	7	21.3629	77.966	2.49	3.65	$P < 0.01^{**}$
Error	5.753	21	0.2740				
Total	159.760	31					

** Significant at the 1% level

S.E. ± 0.26

Duncan's Multiple Range Test gave the following results:

Treatment	1	3	2	6	4	7	8	5	
Mean	4.83	5.43	5.45	6.70	6.73	6.98	7.25	12.25	1%

Treatment	1	3	2	6	4	7	8	5	
Mean	4.83	5.43	5.45	6.70	6.73	6.98	7.25	12.25	5%

Comments on Table 17

1. Treatment 5 had the tallest plants and was significantly taller (at 1% and 5% levels) than the rest.
2. There were no significant differences among treatments 6, 4, 7 and 8, although plant height increased in that order.
3. Plants in treatments 6, 4, 7 and 8 were significantly taller than plants in treatments 1, 3 and 2.
4. There were no significant differences among treatments 1, 3, and 2, although plant height increased in that order.

(ix) (a) Soil Moisture

The figures for soil moisture percentages are presented in Tables 19 and 20.

Plate 6. Treatment 5 plot (cut every 6 weeks) has got the tallest plants, whereas treatment 1 plot (cut every 2 weeks) has got the shortest plants. Plants on both plots were allowed six weeks growth before measuring the height. It appears that repeated frequent defoliation slows down the rate of growth.

Plate 1. The Graveley mower used in this study.

Fig.7. Effect of previous cutting intervals on stem height. Weekly averages of 6 weeks measured on 7.th.Feb., 21st.Feb.,and 8th. March, 1967.

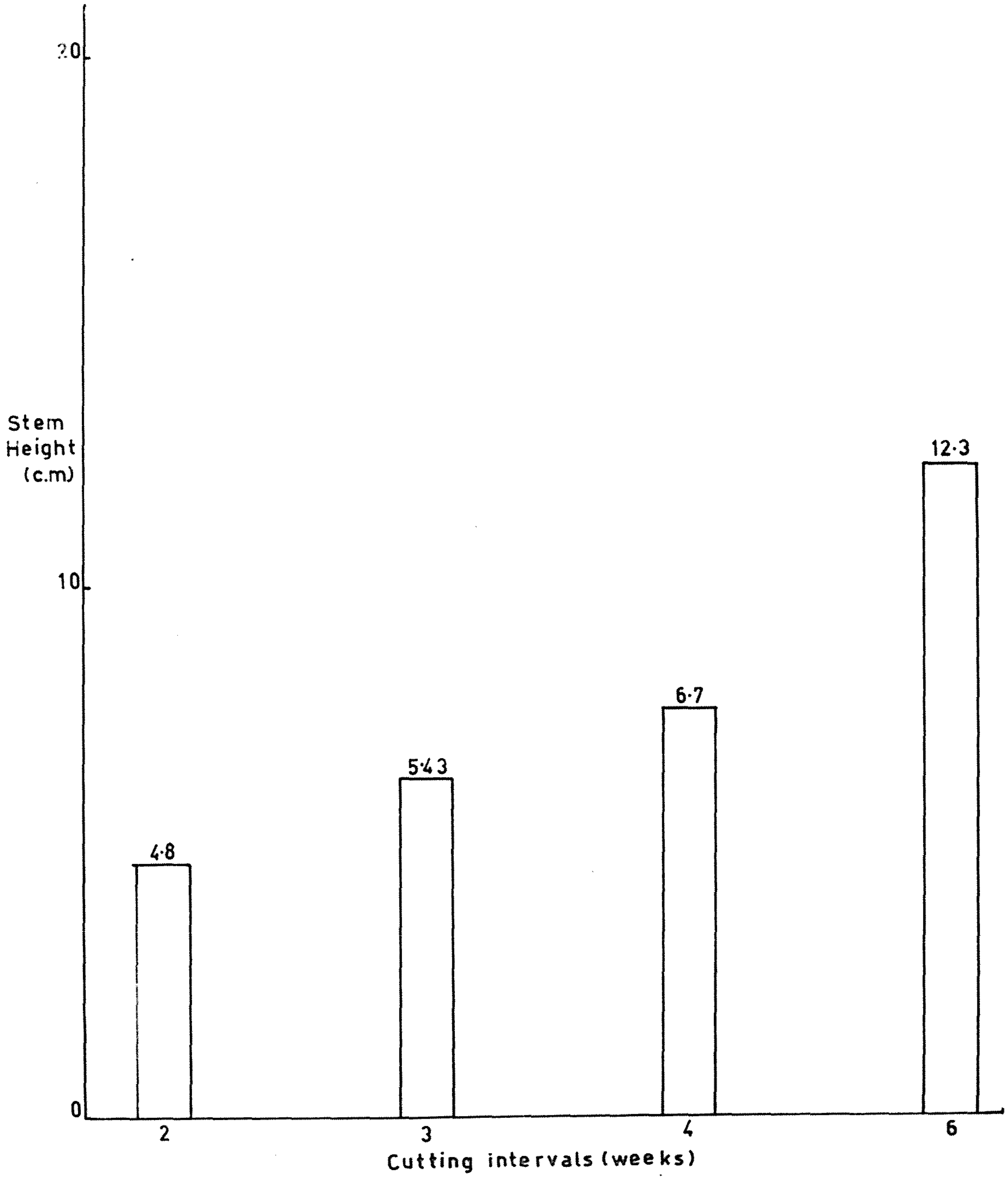


TABLE 19. Soil moisture percentage sampled to a depth of 4" on 24th January, 1967

Treatment	Rep.1	Rep.2	Rep.3	Rep.4	Treatment Totals	Treatment Means
(1)	18.6	14.9	19.4	16.8	69.7	17.4
(2)	18.6	17.1	18.1	17.1	70.9	17.7
(3)	20.9	16.1	20.7	29.6	87.2	21.8
(4)	16.4	19.0	19.1	21.7	76.2	19.1
(5)	19.2	15.1	21.1	19.6	75.0	18.7
(6)	17.6	17.5	18.0	19.8	72.9	18.2
(7)	17.5	17.4	20.3	18.9	74.1	18.5
(8)	18.1	16.7	16.6	21.2	72.6	18.2
Block Totals	146.9	133.8	153.3	164.7	598.7	

Analysis of variance was done on soil moisture percentage and presented in Table 20.

TABLE 20. Analysis of variance in soil moisture percentage

Source of Variation	S.S.	d.f.	M.s.	F Ratio	F Required 5%	F Required 1%	Result
Reps.	62.326	3					
Treatments	52.038	7	7.434	1.51	2.49	3.65	P>.05*
Error	103.504	21	4.929				
Total	217.868	31					

* Not significant at the 5% level.

Comments on Table 19

1. The differences among treatments were not significant.

(ix) (b) Soil Moisture

The figures for soil moisture percentages are presented in Tables 21 and 22.

TABLE 21. Soil moisture percentages sampled to a depth of 4" on 8th March, 1967.

Treat-ment	Rep.1	Rep.2	Rep.3	Rep.4	Treat-ment Totals	Treat-ment Means
(1)	13.4	12.0	17.0	14.5	56.9	14.2
(2)	13.8	12.6	17.0	16.5	59.9	15.0
(3)	11.5	9.7	13.4	16.8	51.4	12.9
(4)	12.9	11.9	17.1	17.9	59.8	15.0
(5)	12.8	12.2	16.3	14.4	55.7	13.7
(6)	12.6	13.5	15.8	17.3	59.2	14.8
(7)	13.2	13.5	16.0	17.0	59.7	14.9
(8)	14.7	12.6	15.0	18.6	60.9	15.2
Block Totals	104.9	98.0	127.6	133.0	463.5	

Analysis of variance was done on soil moisture percentages and presented in Table 22.

TABLE 22. Analysis of variance on soil moisture percentage

Source of Variation	S.S.	d.f.	M.s.	F Ratio	F Required 5% 1%	Result
Reps.						
Treatments	17.405	7	2.4864	2.051	2.49 3.65	P > .05*
Error	25.459	21	1.2123			
Total	151.703	31				

* Not significant at the 5% level.

Comments on Table 21

1. The differences among all treatments were not significant.

(x) Leaf Area Distribution Percentage

The data on leaf area distribution percentage are shown in Table 23.

TABLE 23. Leaf area distribution percentage in 3" layers in the canopies of lucerne harvested on 7th March, 1967, (i.e., after six weeks' growth).

Treatment	Layers	Rep.1	Rep.2	Rep.3	Rep.4
1	A - B	75.7	43.4	25.9	29.1
	B - C	24.3	42.4	43.8	70.9
	C - D		14.2	30.3	
2	A - B	23.4	60.8	39.7	16.0
	B - C	43.6	26.0	60.3	72.2
	C - D	29.3	13.2		11.8
	D - E	3.7			
3	A - B	40.1	81.3	55.8	52.9
	B - C	46.8	18.7	44.2	47.1
	C - D	13.1			
4	A - B	48.7	72.3	58.3	33.1
	B - C	36.0	27.7	32.1	39.8
	C - D	15.3		9.6	27.1
5	A - B	66.5	80.1	19.7	50.3
	B - C	26.7	15.4	28.5	20.6
	C - D	6.8	4.5	3.43	29.1
	D - E			12.9	
	E - F			4.6	
6	A - B	32.1	66.9	21.9	24.0
	B - C	46.1	29.1	38.3	28.1
	C - D	21.8	4.0	27.3	47.9
	D - E			12.5	
7	A - B	25.4	42.4	32.2	34.8
	B - C	44.6	48.6	34.0	42.5
	C - D	30.0	9.0	19.0	20.2
	D - E			14.8	2.5
8	A - B	52.6	57.4	43.9	30.5
	B - C	47.4	42.6	44.6	40.7
	C - D			11.5	18.8

Comments on Table 23

1. The data was not analysed statistically because of lack of uniformity in height of plants within replicates and treatments.
2. Most of the leaf area was found to be in A - B and B - C layers.

(xii) Leaf Area Index

The data on leaf area index are shown in Table 24.

TABLE 24. The leaf area indices of lucerne plants harvested on 7th March, 1967, (I.e., after six weeks' growth)

Treatment	Rep.1	Rep.2	Rep.3	Rep.4	Treatment Totals	Treatment Means
(1)	0.7	1.3	0.8	0.3	3.1	0.78
(2)	1.2	1.3	0.7	0.7	3.9	0.98
(3)	0.9	1.3	1.0	0.9	4.1	1.03
(4)	1.2	1.6	1.7	1.0	5.5	1.38
(5)	1.6	1.6	3.0	1.7	7.9	1.98
(6)	1.4	1.9	1.8	0.9	6.0	1.50
(7)	1.6	2.1	2.2	1.7	7.6	1.90
(8)	1.0	1.0	1.3	0.9	4.2	1.05
Block Totals	9.6	12.1	12.5	8.1		

Analysis of variance was done on leaf area indices and presented in Table 25.

TABLE 25. Analysis of variance on leaf area indices

Source of Variation	S.S.	d.f.	M.s.	F Ratio	F Required		Result
					5%	1%	
Reps.	1.639	3					
Treatments	5.508	7	0.7869	8.31	2.49	3.65	P 0.01**
Error	1.988	21	0.0947				
Total	9.135	31					

** Significant at the 1% level.

Duncan's Multiple Range Test gave the following results:

Treatment	1	2	3	8	4	6	7	5	
Mean	0.78	0.98	1.03	1.05	1.38	1.50	1.90	1.98	1%

Treatment	1	2	3	8	4	6	7	5	
Mean	0.78	0.98	1.03	1.05	1.38	1.50	1.90	1.98	5%

Comments on Table 24

1. There were no significant differences (at 1% level) among treatments 4, 6, 7 and 5, although leaf area indices increased in that order.

2. Treatments 7 and 5 were significantly greater (at 1% level) than treatments 1, 2, 3 and 8.

3. There were no significant differences (at the 1% level) among treatments 2, 3, 8, 4 and 6, although leaf area indices increased in that order.

4. Treatment 6 was significently greater (at the 1% level) than treatment 1.

5. There were no significant differences (at the 1% level among treatments 1, 2, 3, 8 and 4.

6. There were no significant differences (at the 5% level) among treatments 6, 7 and 5.

7. Treatments 7 and 5 were significantly greater (at the 5% level) than treatments 1, 2, 3, 8 and 4.

8. Treatment 6 was significantly greater (at the 5% level) than treatments 1 and 2.

9. Treatment 4 was significantly greater (at the 5% level) than treatment 1.

Fig.8. Relationship between yield L.A.I. and stem height in response to previous cutting intervals.

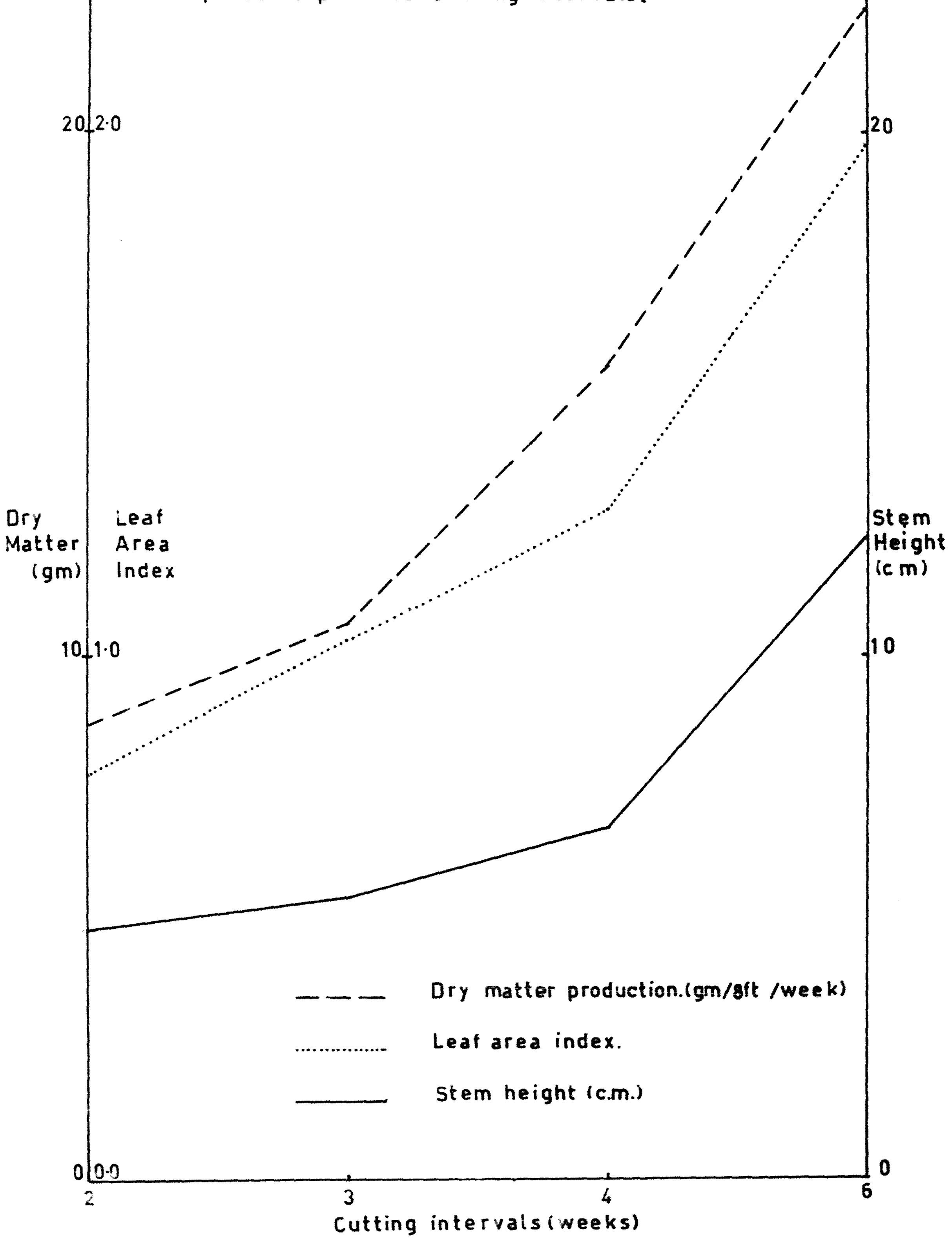
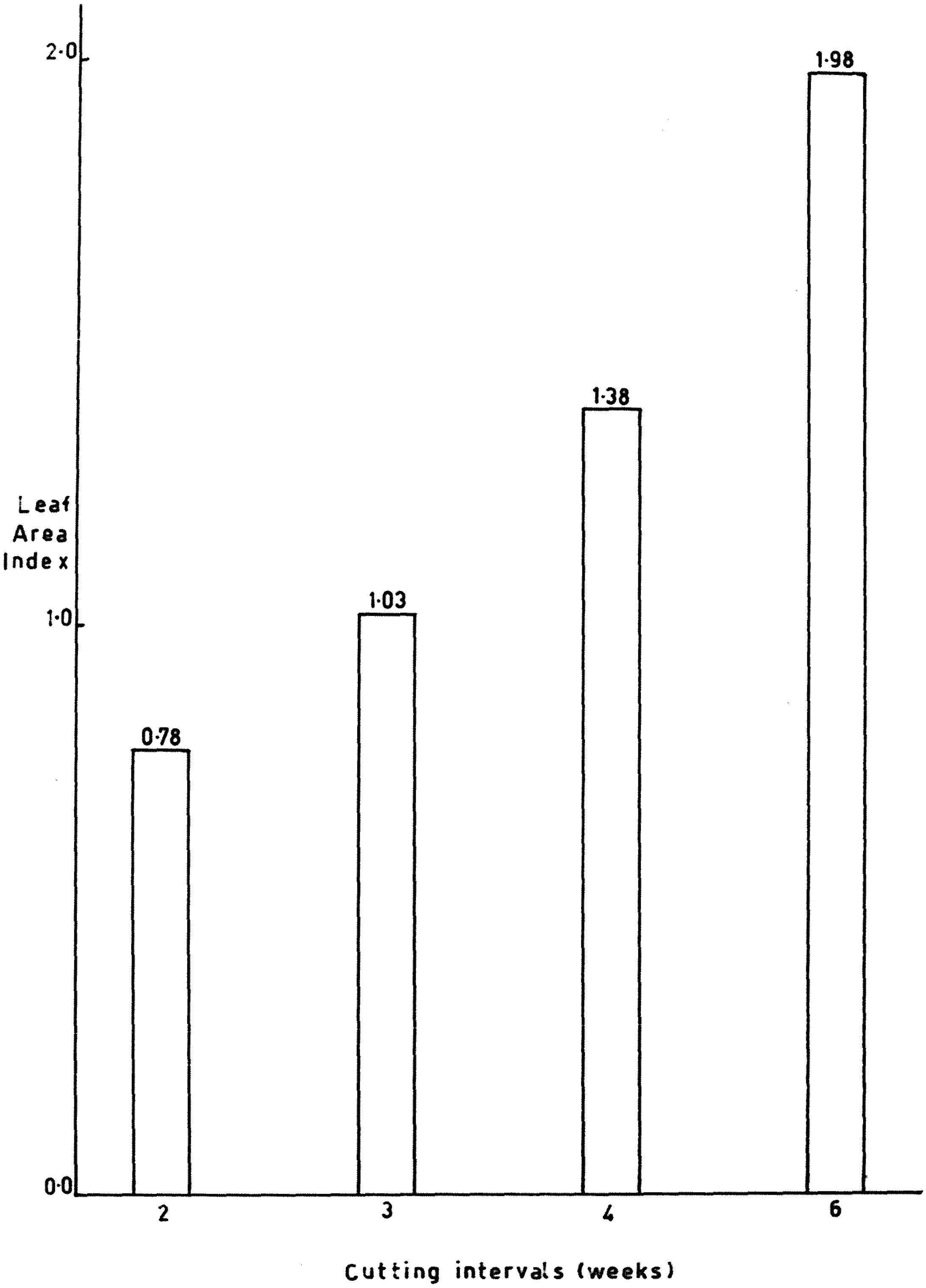


Fig.9. Effect of previous cutting intervals on leaf area index. Measured on 7th.March, 1967. (i.e. after 6 weeks growth)



(xiii) Light Penetration Percentage

The data on light penetration percentage are presented in Table 26.

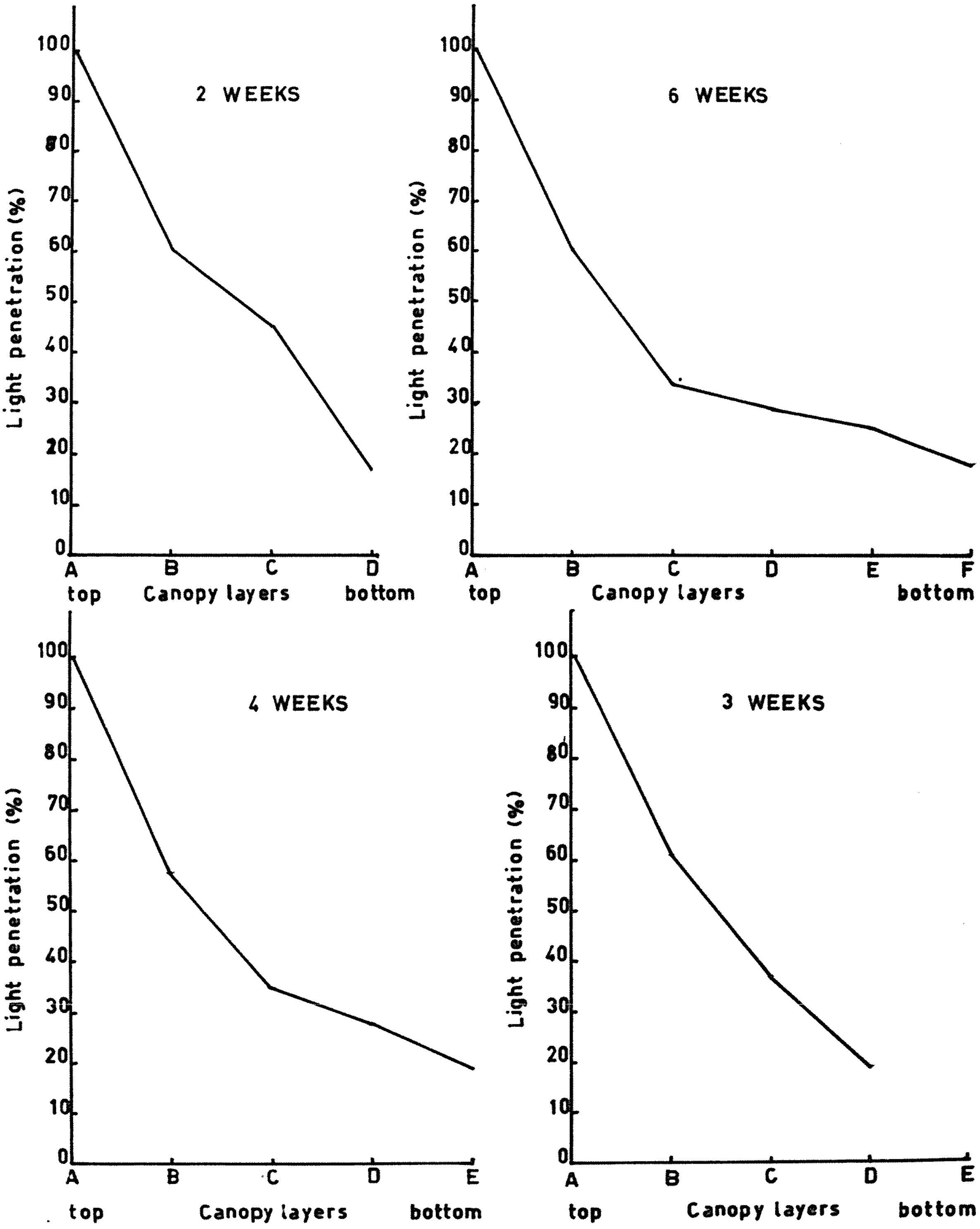
TABLE 26. Light penetration percentage at 2" intervals in the canopies of lucerne harvested on 7th March, 1967, (i.e., after six weeks' growth)

Treatment	Layers	Rep.1	Rep.2	Rep.3	Rep.4
1	A - B	62.4	57.0	56.6	65.0
	B - C	30.1	29.5	34.2	45.7
	C - D	14.1	20.4	16.6	17.3
2	A - B	55.7	43.2	45.8	56.8
	B - C	33.1	27.9	32.9	37.4
	C - D	25.9	16.2	28.3	28.9
	D - E	18.0		16.5	19.0
3	A - B	62.9	56.9	69.1	55.7
	B - C	29.4	34.8	45.9	37.1
	C - D	18.9	22.7	34.1	21.0
	D - E			12.4	
4	A - B	59.5	60.1	63.4	47.1
	B - C	33.4	41.3	34.3	31.9
	C - D	23.8	27.7	27.4	32.2
	D - E	15.7	19.4	24.1	15.2
5	A - B	50.3	69.7	60.0	63.7
	B - C	29.6	40.4	31.3	33.5
	C - D	23.6	35.0	27.5	27.9
	D - E	20.3	29.7	24.8	25.8
	E - F	13.9	17.4	22.4	19.5
	F - G			11.0	
6	A - B	54.1	57.2	53.1	55.7
	B - C	27.8	31.9	25.8	35.5
	C - D	22.1	22.2	18.4	32.1
	D - E	15.9	14.9	11.3	21.7
7	A - B	36.4	57.2	42.4	62.3
	B - C	15.5	30.2	19.9	36.3
	C - D	12.7	22.4	13.0	28.2
	D - E	8.4	17.1	8.1	17.9
8	A - B	55.5	53.1	71.2	55.2
	B - C	32.3	37.2	34.6	28.4
	C - D	16.3	35.3	26.3	27.7
		8.8	29.8	15.0	10.2

Comments on Table 26

1. The data were not analysed statistically because of lack of uniformity in heigh of plants within replicates and treatments.
2. Light penetration percentage in the bottom layer did not fall below 8% in any treatment. This means that not all light was intercepted by lucerne canopy.

Fig.10. Light penetration percentages in canopies of lucerne which had previously been cut every 2,3,4 and 6 weeks.



CHAPTER V

INTERPRETATION OF RESULTS

The design and the layout of the experiment proved to be satisfactory in facilitating handling of the material and examination of results. The number of replicates was adequate to permit treatment differences to be established as statistically significant at the 1% and 5% levels.

Numerous investigations have shown that dry matter production of green plants during early growth is exponential. At this time the number of leaves and stems or branches is on the increase, thereby reducing the area occupied by bare ground. (Ibanez, 1963). Brougham (1959) showed that when the vegetation covers the soil in such a way that the light is completely intercepted, dry matter becomes linear with time until other factors interfere. Some of these factors are discussed in this chapter.

(i) Dry matter yields

The results obtained from lucerne which was cut between 13th December, 1966, and 24th January, 1967, confirmed the importance of infrequent defoliation in order to achieve the highest yields from lucerne.

Perhaps the relation between frequency of cutting and yield can be seen more clearly if presented graphically. This has been done in Figure 1, which the abscissa represents the number of weeks between cuttings and the ordinate the dry matter yields of pure lucerne. A comparison between the dry matter production of frequently cut plants and those infrequently defoliated, shows that the amount of dry matter was reduced by cutting more frequently. In other words, production of dry matter increased with delaying cutting. The time lag immediately after cutting caused a delay in the re-establishment of production, especially of those plants which had been cut more frequently. This increased the subsequent differences in dry weight between more frequently cut plants and those infrequently cut.

Treatment 1 was shown to have produced the lowest dry matter yields. A glance at Table 3 reveals that this was the treatment with the shortest cutting interval (i.e., 14 days) and consequently the plants had not been given ample time in which to recover and attain a reasonable size. It should be remembered that the rate of production of dry matter by plants normally increases with time during early growth or following recovery from defoliation. Figure 1 shows clearly this relationship of increasing cutting interval and dry matter production. Figure 1 represents treatments 1, 3, 4 and 5, with corresponding cutting intervals of two, three, four and six weeks. Thus frequent cutting at 2 and 3 weeks has weakened the plants and reduced the yields, while infrequent cutting (i.e., six weeks) has produced the highest yields of any treatment.

Treatment 2 was highly significantly different from treatment 1. The results of treatment 2 suggest that the detrimental effect of cutting every 14 days as in treatment 1 was masked by initially including a rest period of 28 days interval (see Table 3). Once more these results emphasize the deleterious effect of frequent cutting on dry matter production of lucerne.

It should be noted that treatments 2, 6, 7 and 8 were a combination of 1, 4 and 5. The former were employed to study the effect of alternating long and short cutting intervals on the production of lucerne and weed ingress. As previously mentioned, analysis of variance was conducted on dry matter gains per week by lucerne which was harvested between 13th December, 1966, and 24th January, 1967, (i.e., six weeks period). Although this method of calculating yields on a weekly basis proved satisfactory for statistical analysis, it was assumed that the rate of dry matter gains per week was constant. This is unlikely to be the case as the experiment was carried out under variable field conditions. Brougham (1959) showed that under field conditions the growth rate of pasture responds fairly rapidly to changes in environmental conditions. Mitchell and Coles (1955) found that the rate and pattern of tissue formation of pasture species are dependant on current rather than previous environmental conditions. Therefore it is possible that such daily changes in the environment may have accounted for the failure to detect any significant differences at the 1% level among treatments 2, 6, 4 and 8. The results thus demonstrate the detrimental effect of consecutive frequent defoliation on dry matter production.

Although treatment 8 had one 28-day rest period, it was not highly significantly different from treatments 2 and 6. This indicated that harmful effect of two consecutive 14-day cutting intervals reduced the vigour of the plants with the result that even with a subsequent 28-day rest period, the plants were not capable of recovering sufficiently to compensate for previous losses.

Treatment 7 was highly significantly greater than the rest, except treatment 5. This treatment was thus distinguished because of the advantage gained from alternate 28-day and 14-day cutting intervals. Thus the plants were able to recover from the deleterious effects of repeated defoliation during the 28-day rest period.

The yield of treatment 6 was significantly greater than that of treatment 2 at the 5% level. The former treatment had an initial rest period of 42 days as against the 28-day rest period for treatment 2 (see Table 3). This emphasizes the advantage of allowing a long rest period before cutting or between cuttings. This probably explains why production of dry matter in treatment 2 was significantly more than that of treatment 3. These two treatments had an initial rest period of 28 and 21 days, respectively.

These results agree with other research (Nelson, 1925; Wolfe, 1926; Albert, 1927; Hildebrand and Harrison, 1939; Brown and Munsell, 1942; Graber and Ream, 1950; and Gaumann _et al_, 1954) that has also reported an association between increasing yields as recovery periods are lengthened.

(ii) Main Dry Matter Yields

As has already been mentioned, all plots were harvested at the same time on 8th March and 18th April, 1967, in order to determine the residual effect of cutting frequency.

The results were consistent with those already discussed in showing the bad effect of frequent cutting. It was observed that this effect was still detectable even after allowing 2 six-week growth periods for all treatments. Highest yields were obtained from plants which had been cut less frequently (i.e., six weeks

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spelling). On the other hand, lowest yields of forage occurred with the most frequent cutting (i.e., every 2 weeks) as shown in Figure 2.

Treatment 7 was not significantly different (at 1% and 5% levels) from treatments 2, 8, 4 and 6, although previously it had been significantly greater than each of the treatments. The gap in yield differences was presumably narrowed by the six weeks growth. This period enabled those plants which had previously been cut less frequently to reach maturity earlier and shed some of the leaves. This loss of old leaves probably explains the failure of infrequently cut plants to produce as large yields as might have been expected.

It is perhaps also significant that the effect of frequent cutting on yield was most apparent during the active growth in December and January, when there was no apparent injury to the plants. Brougham (1959) working with a short rotation ryegrass and white clover pasture, showed that the maximum daily rate of growth of total herbage changed markedly with season. This ranged from approximately ten pounds per acre in July (winter) to one hundred and twenty pounds per acre in the early spring and by October a growth rate of a hundred pounds per acre was reached. The decline in growth rate was more gradual over the summer and autumn. Robinson (1967), working with lucerne (Chanticleer) found that dry matter production per acre per day was forty-four pounds in March (autumn), thirteen pounds in May (winter) and eighty-two pounds in January (summer). Thus growth conditions in March and April (autumn) were not as good and no doubt this factor reduced the differences in yield that might have been expected between treatments.

(iii) Botanical Composition

For the purpose of statistical analysis, dry matter yields must be used in perference to fresh weight yields. This is because of the possible variations in fresh weight yields caused by weather conditions (Greenhill, 1936). Therefore no attempt was made to analyse statistically the data in Table 8. The data represent percentage contribution of lucerne on a fresh weight yield basis. Furthermore, the data somewhat show the effect of previous cutting intervals on the percentage contribution of lucerne in the sward. It should be noted that before the commencement of the experiment (i.e., 1st November, 1966), the plots were practically weed-free.

The amount of weeds in treatment 5 was too small to be weighed by this method. However, it is interesting to note that weeds were present in every treatment; the amount varying from 44.7% in treatment 1 to negligible in treatment 5. This led to the conclusion that weed infestation is caused by a number of factors, among which are climatic conditions and management practices. One aspect of the latter, namely frequency of cutting, will be briefly discussed in this section.

Treatment 1 as shown in Table 8, had the lowest percentage of lucerne, 55.3, as against 100 in treatment 5. The former treatment was the most frequently cut (i.e., every 14 days). It appears that this repeated 2-weekly cutting did not permit the canopy to attain maximum size to completely cover the ground. It should be remembered that in general, after cutting, a recovery period soon begins in which the aerial parts of a plant increase in size and number. Provided the recovery period is long enough and growth conditions are favourable, this increase in size can reach maximum and completely cover the ground. On the other hand, if the cutting interval is too short, the opposite may happen and other plant species may invade the area. It is therefore likely that too frequent cutting as in treatment 1, resulted in weed encroachment.

The data in Table 8 show that the percentage contribution of lucerne in the sward increased as cutting interval increased. Thus treatments 1, 3, 4 and 5 with corresponding cutting intervals of 2, 3, 4 and 6 weeks had percentage contribution of lucerne of 55.3, 72.6, 90.6 and 100, respectively.

(iv) Point Analysis

The results obtained by plant analysis indicated that the weakening effect of cutting lucerne frequently shows itself in a natural decrease of the vigour of the plant and at the same time makes the crop susceptible to weed ingress.

The ingress of clovers (mainly white clover), oxalis and other weeds, was particularly noticeable in treatment 1 plots which had been previously cut more frequently. The predominance of white clover was probably due to the fact that the paddock on which the experiment was located had been previously under a ryegrass-white clover dominant pasture. White clover seed is known to remain dormant in the ground for a long period (Hilgendorf, 1960). It is therefore possible that some of these dormant seeds germinated in plots of lucerne which had been cut more frequently. The relative frequency of lucerne in treatment 1 plots was the lowest of any treatment. The relative frequency of lucerne increased in treatments 1, 3, 4 and 5 (in that order) which had been previously cut every 2, 3, 4 and 6 weeks, respectively. (See Figure 3). On the other hand, relative frequency of white clover, Oxalis cornuculata decreased in the same order. Oxalis cornuculata is a common pasture weed and a native of New Zealand. Therefore its presence in lucerne plots which had been previously mown frequently was not surprising.

The results showed that the amount of bare ground increased in plots which had been previously mown less frequently. Treatment 5 plots had the highest amount of bare ground. This is because the vigourous growth of lucerne in treatment 5 plots prevented weeds from getting a start. The weeds concerned tended to cover the ground more completely than did lucerne plants.

In general, it appears that weeds were able to encroach upon lucerne as the latter was weakened by previous repeated frequent mowing. It should also be borne in mind that the lack of uniformity in the distribution of weed seeds in the soil and many other factors may also cause variations in the presence of weeds in lucerne.

(v) Stem : Leaf Ratio

The data on stem:leaf ratio as given in Table 10, were obtained from lucerne which had been left to grow for six weeks after treatments had ceased. This information showed that the amount of stems on a dry weight basis was reduced by previous frequent cutting.

There was a tendency for the amount of stems to increase in lucerne plots which had been previously clipped less frequently (see Figure 4). In other words, there was a decrease in the proportion of leaves in plots which had been previously cut less frequently. It would appear that plants which had been frequently clipped were weakened and were slow to recover from defoliation, with the result that they were still immature, succulent and leafy at harvesting time. This supports the work of most investigators. Widtsoe (quoted by Piper, 1924), determined the relative percentage of leaves, stems and flowers at nearly every stage of growth for the first, second and third cuttings and found that percentage of leaves decreased as plants grow older and that the second crop was less stemmy than the first.

Treatment 5 plots had the highest amount of stems of any treatment. Lucerne in treatment 5 plot was vigorous in growth and matured earlier than the rest, with the result that there was death and dropping of old leaves before harvesting. This shedding of old leaves partly accounted for an increase in the ratio of stem to leaf. Another reason for the increase in the ratio may be due to the fact that dry matter accumulation (mainly lignin) in stems, normally increases with age. Meyer and Jones (1962) found that as lucerne matures, lignin increases during the prebud and bud stages.

There was no significant difference between treatment 3 and 4, which had been previously defoliated every 3 and 4 weeks, respectively. Probably this was due to the fact that the six weeks growth period for both treatments, enabled the plants to recover sufficiently and mask any differences in the ratio that might have otherwise occurred. The same explanation applies to treatments 1, 2, 7 and 8.

Treatment 6, which had an initial rest period of 42 days, was significantly greater (at 5% level) than treatment 1. This was probably due to the long rest period, the longest of any treatment except for treatment 5. As has already been mentioned, a long rest period enables defoliated plants to recover fully when growth conditions are favourable.

(vi) Organic Reserves

The figures in Table 12 represent dry weight yields of topgrowth of lucerne which had grown for 3 weeks in darkness under wooden domes (Chapter III). The yields were harvested from treatment 1, 3, 4 and 5 plots (previously cut every 2, 3, 4 and 6 weeks) for comparison with yields of the same treatments as presented in the last column of Table 4. Work by Graber *et al* (1931) and Hildebrand *et al* (1939) showed that the amount of top growth after cutting and the frequency of cutting as well as carbohydrate reserves influence rate of regrowth.

A comparison of the data in both tables showed that the yields were lowest in treatment 1 and highest in treatment 5. Therefore it would appear that as cutting interval increased so did recovery from reserves.

Treatments 1 and 3 did not produce any measurable topgrowth (Table 12). Plants like lucerne, when cut frequently, are almost totally defoliated and usually do not synthesize adequate carbohydrate reserves which may be used for fast initiation of new top-growth between cuttings. It should be borne in mind that the harmful effect of frequent defoliation is enhanced by adverse growth conditions. This probably explains why plants in treatment 1 and 3 plots which had already been exhausted by frequent cutting, did not produce measurable top-growth in the dark. It has also been shown by Albert (1925) that plants cut most frequently in the field tend to suffer the largest loss of dry matter by oxidation and respiration in producing a certain amount of top-growth. Probably this is what happened to the plants in treatment 1 and 3 plots with the result that no measurable top-growth was produced.

Graber _et al_ (1939) stressed that photosynthetic parts of plants remaining after cutting are potential sources of reserve foods. In the experiment carried out by the writer, lucerne was cut at ground level, leaving practically no sutbble. Therefore, this may also have accounted for the lack of measurable top-growth in treatment 1 and 3 plots, in which severe cutting, combined with frequent cutting, exhausted reserve foods.

The area covered by the domes was small and gave a measurable plot of 0.975 sq.ft. It would have been more satisfactory if this area could have been greater.

(vii) Plant Density

The data in Table 13 represent the average number of stems per one foot square as counted on 7th March, 1967, which was approximately 6 weeks growth from the time treatments ceased.

A number of investigators have shown that after cutting a recovery period soon begins in which tiller numbers increase rapidly (Ibanez, 1963). In general, if the interval is long enough the number of tillers will increase to the maximum with successive cuts if conditions are favourable for growth. Probably this is why treatment 5 plots (cut every 6 weeks) had the highest number of stems. Treatment 6, which had an initial rest period of 42 days, was the next one with the highest number of stems.

There were no significant differences (5% level) among treatments 1, 3, 4, 2, 8 and 7 (Table 13). The six weeks growth period was probably sufficient for the plants which had been treated differently to recover from defoliation and thus minimise any differences in density. The lack of significant differences (1% level) among treatments 7, 3, 2, 4, 5, 8 and 6 (Table 15) may be accounted for by the same reason.

The data in Tables 13 and 15 represent the number of stems per unit area. Perhaps the result would have been different if plants per unit area had been determined, since most workers have shown that the number of individual plants generally decreases as cutting interval decreases. Ibanez (1963) reported that in vegetative plants the tillering potential is not reduced by cutting. Salmon _et al_ (1925) found that although there was a heavy mortality of lucerne plants in plots cut more frequently, the loss was made up to some extent by greater production of stems per plant. This would seem to be a logical explanation for the lack of significant differences among most treatments in Tables 13 and 15.

(viii) Stem Height

The data in Table 17 represent stem height measurements in

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centimeters as weekly averages. These were taken to determine the immediate effects of different cutting intervals (Table 3) on the subsequent growth of lucerne.

The growth measurements demonstrate the wide differences especially between treatments 1 and 5 in the comparative recovery of lucerne after various cutting treatments. Growth was considerably more rapid in treatment 5, which had been previously cut every 6 weeks. The plants in treatment 5 plots gained a weekly average height of about 12 centimeters, whereas those cut more frequently as in treatment 1, gained roughly 5 centimeters (see Figure 7). The initial growth of the next crop in treatment 1 plots tended to become slow and sluggish and the plants appeared undernourished as indicated by a stunted top growth. These results agree with those of Nelson (1925) who showed that the length of lucerne stems is influenced among other things, by cutting procedure. Troughton (1957) stated that the total quantity of shoot produced by a plant which is defoliated once or more during a period suitable for growth, is normally lower than the quantity produced by a similar plant not defoliated and the difference varies directly with the intensity of defoliation.

It would appear from the results that repeated frequent cutting reduces the capacity of the plants to recover, whereas less frequent defoliation permits plants to recover quickly and maintain normal growth. The results (Table 17) show that there was no significant difference between treatments 1 and 3, which had been previously cut every 2 and 3 weeks, respectively. The reason why there was a lack of significant difference is probably due to the difficulty in accurately measuring the height of lucerne growing in the field.

(ix) Soil Moisture

The data on soil moisture are presented in Tables 19 and 21. Those in Table 19 were compiled from samples taken on 24th January, 1967. The results in Table 21 were obtained from samples taken on 8th March, 1967 (i.e., six weeks after treatments ceased).

The results in both tables were not statistically significant. All the samples were taken within a depth of 4 inches. Most investigators have shown that lucerne roots draw water from greater depth than this. Probably this is why there were no significant differences among the treatments.

When the results are interpreted from the point of view of water evaporation from the soil, they show that there were no significant differences among the treatments. One explanation is that there was a cover of vegetation (weeds) on plots that had been weakened by frequent cutting, thereby minimizing water evaporation from the soil. On the other hand, those plants that were less frequently cut had a greater leaf area most of the time, which prevented loss of soil moisture. It would also appear that loss of soil moisture through evaporation is small in this temperate climate, where summer temperatures are mild and rainfall evenly distributed and relatively high.

(x) Leaf Area Index

The results obtained from lucerne which was sampled on 7th March, 1967, (i.e., approximately 6 weeks growth) are presented in Tables 22 and 23.

As previously mentioned, stratified clips were carried out on 7th March, 1967, which was approximately six weeks after treatments ceased. Analysis of variance was not conducted on the data in Table 22 because of lack of uniformity in height, which made comparisons not valid. The height of lucerne in treatment 5 plots which had been previously cut less frequently was greater than that of lucerne in other treatments which had been previously defoliated more frequently. Most of the leaf area (more than 75%) was in A - B and B - C layers (see Table 22).

The results in Table 23, which represent total LAI values, show that treatment 5 (previously cut every 6 weeks) possesses significantly greater LAI (at the 5% level), than treatments 1, 3 and 4, which had been previously cut every 2, 3 and 4 weeks, respectively. This was probably due to the long cutting interval for treatment 5, during which the plants grew without interruption, thereby reaching a relatively greater LAI than the rest of the treatments. It is also possible that LAI of those plants which had been cut less frequently could have been much greater had it not been for the death and dropping of old leaves due primarily to maturity.

On the whole the results do not reveal striking differences in LAI among the treatments. For instance, treatment 4 was not significantly different (at the 1% level) from treatments 1 and 3. It is possible that during the six weeks growth period, practically all plants made sufficient recovery with the results that the differences in LAI were slight.

(xi) Light Measurements

The data on percentage light penetration as presented in Figure 10, were not statistically analysed due to lack of uniformity in plant height.

However, the results showed that there was a considerable reduction in the light as it penetrated deeper into the canopy regardless of the treatment. (See Table 26). This was probably because the measurements were taken at the end of six weeks, during which most plants had made sufficient recovery in leaf area to intercept the light.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The effect of cutting treatments (frequency) on lucerne production and weed ingress was studied. All cutting was done at ground level.

The immediate effect of cutting treatments on the dry yields of lucerne showed that dry matter production increased as cutting interval increased.

The residual effect of cutting treatments revealed that those plants which had previously been cut more frequently, yielded significantly less than those which had been cut less frequently.

Determination of the percentage productivity showed that lucerne was weakened and killed by previous frequent cutting.

Point analysis on all treatments indicated that white clover, oxalis and other weeds encroached into plots which had been mown more frequently.

There was a tendency for the amount of stems, determined as stem:leaf ratio, to increase in plots which had been previously cut less frequently.

Top growth dry weight yields produced in the dark (under wooden domes) was greatest in plants which had been cut less frequently. These plants were therefore assumed to have accumulated more reserve foods.

Plants which had been previously cut less frequently produced the greatest number of stems per unit area (Table 13).

Plants which had been previously mown less frequently were significantly taller than the rest.

There were no significant differences among all treatments in soil moisture percentages.

Leaf area measurements indicated that there was a tendency for LAI to increase in lucerne plants which had been previously less defoliated.

From the foregoing, it would appear that a farmer cannot afford to cut his lucerne too frequently if he has to maintain the stand, longevity and high production of dry matter.

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APPENDIX I. Rainfall figures for 1966

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		0.67	0.04	0.06	0.37							
2	0.96		0.28	0.26	0.40	0.04						
3			0.18	0.06	0.01	0.31					0.29	
4				0.12		0.17		0.12			0.08	0.01
5				0.31		0.12	0.45	0.14	Trace	0.10	0.29	1.72
6	1.22			0.01		0.04	1.54	0.07		0.28	0.16	0.95
7	0.06		0.04	0.03			0.54	0.08		0.03	0.16	
8						0.01	0.65	1.07	0.23	0.02	0.13	0.34
9	0.46			0.30			0.25	0.01	0.45	0.03	Trace	0.60
10							0.26		0.01	0.06		0.21
11	0.06				0.01	0.01	0.05			0.19		0.22
12							Trace			0.10		0.03
13					0.03	0.24				0.07		0.02
14	0.06					0.31		0.07				
15						Trace		0.01			0.26	
16		0.02			0.45						0.31	
17				0.12	0.12		0.13	0.05			0.33	
18		0.02		0.17	0.02		0.23		0.09	Trace	0.13	
19		0.12	0.01				0.14		0.17	0.15	0.02	
20	0.03	0.32					0.03		0.22		0.06	
21	0.06	0.09				0.17			0.03	Trace	0.60	
22	0.53	1.04			0.23	0.41			0.47	0.08	0.09	0.03
23	0.69	2.58			0.41	0.49			0.15	0.20		1.29
24	0.16	0.35			0.15	0.02		0.24	0.08		0.05	0.66
25		0.06		0.79				0.02				0.21
26		0.01		0.26				0.05				0.08
27					0.16	0.20	0.01					
28		0.18				0.67	0.08				0.04	0.68
29			0.56	0.63		0.04	0.85					0.92
30			0.81				0.46			0.12		0.10
31												0.47
Totals:	4.29	5.46	1.92	4.12	2.36	3.25	5.67	1.93	1.90	1.43	3.00	8.54
Rain Days	11	12	7	13	12	16	15	12	10	13	16	18

Total for Year: 43.87 inches. No. of rain days: 155.

APPENDIX II. Rainfall figures for 1967

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.04	0.31	0.12	0.04				0.02	Trace			0.35
2		3.16		0.01		0.09	0.19	0.44	0.01			0.76
3		0.05				Trace	Trace	0.36	Trace	0.85	0.56	
4	0.19						0.44	0.69	0.01		0.13	0.40
5	0.11						0.01	Trace	0.02	0.04	0.08	1.00
6	0.49				0.02						0.39	0.87
7	0.04				0.15					0.09		0.58
8				0.01	0.20				0.05	0.62	0.14	0.11
9		0.04	0.09	0.14	0.15			Trace	0.04	0.02	0.37	0.03
10			0.05	0.65	0.20			0.03	0.26		0.26	
11	0.10		0.31	0.05	0.07			1.98	0.24		0.01	
12		0.01					0.26		0.26	Trace		
13	0.08	0.01			Trace				Trace		Trace	
14	0.62	0.03	0.13				Trace	0.94		0.15		0.04
15		0.19			0.25			0.84		0.04		0.28
16		0.01							0.03			Trace
17						0.06	0.06				0.71	
18	0.46					0.40	0.22		0.01		0.16	
19	Trace					0.03	0.50		0.20			
20				0.09		0.79		0.02	Trace	0.22	0.04	
21			Trace			0.18				Trace		
22								0.02			Trace	0.03
23			0.20	0.75	0.13			0.67			0.95	
24	0.06		1.85	0.02	0.63	Trace		0.07			0.08	0.75
25	1.08		0.04	0.03	0.16	0.06		0.61				
26				0.44	0.58	0.09		0.40	0.02			0.03
27				0.05	0.27			Trace	0.02			0.06
28		0.06			Trace			0.15	0.08			0.74
29								0.03			0.01	0.13
30			0.01		0.04			0.01	0.01	0.60		
31	0.17		0.06		0.08		0.06	0.02		Trace		
Totals:	3.44	3.87	2.73	2.28	3.06	1.70	1.74	7.30	1.26	2.63	3.89	6.16
Rain Days	12	10	9	12	15	8	8	18	15	9	14	16

Total for Year: 40.06 inches. No. ofrain days: 146.

APPENDIX III. Mean temperature figures for 1966 and part of 1967

Month	1966	1967
January	63.0	62.0
February	67.3	62.1
March	63.0	62.5
April	56.9	57.1
May	49.7	51.6
June	47.5	
July	45.7	
August	46.1	
September	15.3	
October	53.6	
November	56.0	
December	59.5	

APPENDIX IV. Dry matter yields (gm/2 sq.ft.) of lucerne harvested between 15/11/66 and 24/1/67.

Tmt.		Rep.1			Rep.2			Rep.3			Rep.4		
	Date												
1.	15/11/66	23.80	24.30	19.80	28.10	21.60	19.00	13.40	18.50	15.40	18.10	16.00	16.30
	29/11/66	10.20	9.40	13.80	16.80	15.40	14.90	13.50	12.20	10.50	8.10	9.40	9.40
	14/12/66	11.60	12.78	11.00	14.21	12.75	14.40	4.50	5.10	7.70	6.98	4.75	6.80
	27/12/66	23.13	14.20	18.61	26.13	25.52	23.51	20.45	10.40	14.65	19.80	14.45	14.80
	10/ 1/67	4.90	4.85	3.75	5.55	4.80	4.90	4.30	3.05	3.60	2.80	3.70	2.90
	24/ 1/67	10.50	12.40	17.60	6.90	8.70	19.30	5.00	6.45	5.00	6.95	5.80	6.85
2.	29/11/66	55.85	53.10	67.30	64.05	73.10	53.50	48.20	59.20	58.60	55.50	48.85	57.50
	14/12/66	5.00	5.05	5.55	6.70	5.00	5.20	5.20	3.80	3.55	4.45	3.00	4.50
	27/12/66	26.16	38.86	27.23	36.36	32.46	31.40	20.52	23.65	22.92	29.90	22.60	25.20
	10/ 1/67	3.70	5.70	3.60	4.15	4.20	3.90	4.15	3.80	5.00	3.35	3.80	3.60
	24/ 1/67	14.30	16.15	29.35	19.30	17.60	21.60	10.20	9.60	17.10	11.00	4.30	6.60
3.	22/11/66	40.90	33.15	37.35	29.25	30.75	35.90	35.30	39.15	37.75	35.25	36.75	45.06
	14/12/66	25.68	30.70	26.96	28.06	33.14	24.20	18.91	20.49	15.90	19.21	22.22	17.17
	3/ 1/67	34.10	29.80	33.45	33.80	31.70	29.70	16.35	18.20	21.30	19.80	20.20	16.00
	24/ 1/67	21.90	17.00	25.10	19.25	18.20	18.00	17.00	15.85	15.70	8.60	9.55	7.70
4.	29/11/66	55.12	56.78	55.24	61.40	69.30	66.65	55.90	58.05	51.40	38.60	46.10	40.70
	27/12/66	42.33	46.82	37.60	47.44	47.09	51.60	37.58	40.20	34.45	32.20	45.23	36.75
	24/ 1/67	26.20	41.70	28.90	40.60	39.40	40.75	27.50	32.80	32.90	22.85	16.40	18.10

(Continued overleaf)

APPENDIX IV. (Continued)

Tmt.	Rep.1				Rep.2		Rep.3			Rep.4		
Date												
5. 14/12/66	75.26	73.88	69.71	72.03	60.58	59.87	86.92	66.35	75.17	63.27	58.20	54.23
24/ 1/67	125.75	121.48	159.12	98.40	98.81	115.21	124.43	105.84	100.59	84.16	88.91	95.72
6. 14/12/66	62.75	57.60	63.71	91.26	57.61	73.80	85.72	97.68	88.02	58.68	87.43	56.56
27/12/66	33.85	27.96	36.55	29.63	32.19	33.65	27.20	19.80	23.90	20.00	22.70	16.85
10/ 1/67	9.45	8.90	9.85	6.55	6.60	11.15	5.30	5.40	5.75	5.40	5.00	6.00
24/ 1/67	22.50	18.20	21.10	13.70	20.60	15.05	23.30	11.75	10.90	14.35	11.90	10.90
7. 14/12/66	59.05	60.10	64.12	59.86	74.82	50.09	65.25	60.13	65.23	55.28	51.24	63.04
27/12/66	6.20	4.70	4.90	4.05	4.70	5.10	3.80	3.60	3.20	5.70	5.40	5.20
10/ 1/67	63.30	57.60	56.90	69.40	50.30	51.20	62.20	36.30	47.20	48.30	38.10	49.60
24/ 1/67	15.70	12.30	9.50	14.10	15.50	15.90	10.05	12.90	12.50	11.05	10.20	10.40
8. 29/11/66	64.84	60.79	61.22	62.20	62.00	61.90	45.26	49.58	51.52	58.56	54.35	45.53
14/12/66	5.90	6.35	3.70	4.90	6.55	5.10	5.40	2.95	4.40	4.35	5.30	3.90
27/12/66	24.87	30.22	31.40	22.91	34.84	31.05	24.30	21.15	13.05	18.85	17.40	18.70
24/ 1/67	33.80	37.90	33.00	30.70	36.90	35.30	26.00	28.70	17.60	22.20	17.20	21.35

APPENDIX V. Dry matter yields (gm/2 sq.ft./week) of lucerne harvested between 13/12/66 and 24/1/67.

Tmt.	Rep.1			Rep.2			Rep.3			Rep.4		
1	6.42	5.24	6.66	6.43	6.50	7.95	4.96	3.31	3.88	4.93	3.99	4.09
2	7.36	10.12	10.03	9.97	9.04	9.48	5.81	6.18	7.50	7.38	5.12	5.90
3	9.33	7.80	9.76	8.84	8.32	7.95	5.56	5.68	6.17	4.73	4.96	3.95
4	7.90	10.85	7.95	10.72	10.49	11.09	7.72	8.82	8.36	6.49	6.50	6.08
5	20.96	20.25	26.52	16.40	16.47	19.20	20.74	17.64	16.77	14.03	14.82	15.95
6	10.97	9.18	11.25	8.31	9.90	9.97	9.30	6.16	6.76	6.63	6.60	5.63
7	13.17	11.65	11.07	13.92	10.97	11.18	12.04	8.20	9.95	9.89	8.05	10.00
8	9.78	11.35	10.73	8.94	11.96	11.06	8.31	8.31	5.11	6.84	5.77	6.68

Mean separation using Duncan's Multiple Range Test

Treatment means arranged in increasing order of magnitude.

	1	3	2	6	4	8	7	5
Mean	16.90	20.76	23.47	25.17	25.74	26.23	32.52	54.94

The S.E. of a mean = $\sqrt{\frac{s^2}{n}} = \sqrt{\frac{3.173}{4}}$ = 0.7935 = 0.8908

Table of shortest significant range values (1%)

p	2	3	4	5	6	7	8
rp	4.01	4.20	4.30	4.38	4.44	4.50	4.55
Rp	3.57	3.74	3.83	3.90	3.96	4.01	4.05

(Continued overleaf)

APPENDIX V. (Continued)

Table of Grouped Means

E-A	p = 8	54.94-16.90 = 38.04	4.05**	H-C	p = 5	26.23-20.76 = 5.47	3.90**
E-C	p = 7	54.94-20.76 = 34.18	4.01**	H-B	p = 4	26.23-23.47 = 2.76	3.83
E-B	p = 6	54.94-23.47 = 31.47	3.96**	H-F	p = 3	26.23-25.17 = 1.06	3.74
E-F	p = 5	54.94-25.17 = 29.77	3.90**	H-D	p = 2	26.23-25.74 = 0.49	3.57
E-D	p = 4	54.94-25.74 = 29.20	3.83**	D-A	p = 5	25.74-16.90 = 8.84	3.92**
E-H	p = 3	54.94-26.23 = 28.71	3.74**	D-C	p = 4	25.74-20.76 = 4.98	3.83**
E-G	p = 2	54.94-32.52 = 22.42	3.57**	D-B	p = 3	25.74-23.47 = 2.27	3.74
G-A	p = 7	32.52-16.90 = 15.62	4.01**	D-F	p = 2	25.74-25.17 = 0.57	3.59
G-C	p = 6	32.52-20.76 = 11.76	3.96**	F-A	p = 4	25.17-16.90 = 8.27	3.83**
G-B	p = 5	32.52-23.47 = 9.05	3.90**	F-C	p = 3	25.17-20.76 = 4.41	3.74**
G-F	p = 4	32.52-25.17 = 7.35	3.83**	F-B	p = 2	25.17-23.47 = 2.70	3.57**
G-D	p = 3	32.52-25.74 = 6.78	3.74**	B-A	p = 3	23.47-16.90 = 6.57	3.74**
G-H	p = 2	32.52-26.23 = 5.29	3.57**	B-C	p = 2	23.47-20.76 = 2.71	3.57
H-A	p = 6	26.23-16.90 = 9.33	3.96**	C-A	p = 2	20.76-16.90 = 3.86	3.57**

NOTE:

The asterisks indicate that those differences exceed the value of the shortest significant range for the respective values of the significant studentized ranges (rp) at the 1% level of significance. Thus the mean difference of 38.04 for E-A, which represents a studentized range of p = 8, exceeds the value of the shortest significant range of 4.05. Therefore, H-B, H-F, H-D, D-B, D-F and F-B are non-significant at the 1% level.

Treatment	1	3	2	6	4	8	7	5
Mean	16.90	20.76	23.47	25.17	25.74	26.23	32.52	54.94

APPENDIX VI. Dry weights of stems and leaves of lucerne harvested on 7th March, 1967, (i.e., after 6 weeks growth).

Treatment	Rep.1		Rep.2		Rep.3		Rep.4	
	Stems	Leaves	Stems	Leaves	Stems	Leaves	Stems	Leaves
1.	2.62	3.40	3.20	3.30	2.40	2.50	0.95	1.00
2.	8.40	7.00	3.40	3.30	1.50	1.70	0.95	1.30
3.	2.90	1.90	2.80	2.60	2.20	2.40	1.70	2.30
4.	2.50	2.35	3.30	2.60	3.40	3.50	2.40	2.50
5.	8.80	4.40	4.90	3.20	8.10	4.40	5.20	3.40
6.	3.90	2.80	3.20	3.20	4.10	2.60	2.50	2.30
7.	2.90	2.90	3.90	3.40	4.20	3.30	3.30	3.40
8.	2.80	2.50	2.90	2.50	2.70	2.40	2.90	2.40

APPENDIX VII. Yield of dry matter harvested on 8/3/67 (6 weeks growth)

Tmt.	Rep.1				Rep.2				Rep.3				Rep.4			
1	20.80	12.50	16.50	30.60	16.40	16.30	17.50	24.20	20.50	8.20	4.20	9.60	4.30	3.20	6.20	8.80
2	19.20	25.50	14.90	22.70	25.60	27.00	24.20	23.70	22.30	21.80	6.60	8.00	7.30	9.30	13.90	13.70
3	32.20	26.70	22.60	21.60	22.80	12.70	19.00	15.80	25.30	28.80	10.50	16.90	10.70	9.10	5.20	9.60
4	22.40	19.40	26.10	23.40	26.30	28.20	22.20	27.00	29.43	44.80	30.20	31.70	16.50	16.70	25.40	17.17
5	34.70	42.70	60.20	53.48	35.80	45.00	42.80	42.70	51.15	34.82	41.02	48.87	42.71	38.83	39.95	45.21
6	33.90	31.20	25.50	26.60	48.90	31.52	18.60	18.20	44.75	29.50	38.80	27.43	23.50	19.40	11.10	14.90
7	35.00	35.20	27.10	30.10	32.24	27.19	14.80	23.50	39.66	28.84	26.75	32.50	20.80	14.40	17.60	27.40
8	22.80	23.80	55.60	29.10	30.08	25.33	27.50	32.00	21.50	28.30	25.50	18.00	16.10	15.00	29.50	24.90

Yield of dry matter harvested on 18/4/67 (6 weeks growth)

Tmt.	Rep.1				Rep.2				Rep.3				Rep.4			
1	16.50	14.60	12.70	12.70	19.80	17.30	19.70	19.80	8.20	14.00	13.50	9.20	6.20	4.60	7.80	4.20
2	17.80	30.10	26.20	16.50	18.70	20.20	20.90	17.30	15.20	13.00	12.60	8.80	7.00	5.90	10.60	11.80
3	18.80	17.40	14.20	10.90	18.40	24.00	17.30	16.90	16.00	15.20	8.70	9.00	9.10	5.30	5.30	13.10
4	34.40	20.00	16.70	18.30	19.20	24.70	19.70	15.70	20.60	21.10	16.40	17.90	11.70	10.10	12.80	11.60
5	33.20	28.00	30.70	27.00	27.50	23.70	25.80	21.90	25.10	22.30	20.10	18.70	18.30	19.80	15.40	16.40
6	16.10	26.50	18.60	16.30	21.30	15.60	14.90	15.50	20.00	17.10	18.30	21.20	13.50	16.60	12.50	10.30
7	25.60	22.90	15.60	23.50	17.60	18.10	18.00	15.40	20.30	22.30	21.11	15.70	16.20	15.20	11.90	8.00
8	18.30	15.00	19.70	16.70	18.80	16.40	19.60	22.70	18.30	12.00	10.20	14.40	9.30	11.10	17.50	14.70

Yield of dry matter calculated as growth rate per week from 8/3/67 to 18/4/67

Tmt.	Rep.1				Rep.2				Rep.3				Rep.4			
1	3.11	2.26	2.43	3.61	3.02	2.80	3.10	3.67	2.39	1.85	1.48	1.57	0.88	0.65	1.17	1.08
2	3.08	4.63	3.46	3.27	3.69	3.93	3.76	3.42	3.13	2.90	1.60	1.40	1.19	1.27	2.04	2.13
3	4.25	3.68	3.07	2.71	3.43	3.06	3.03	2.73	3.44	3.67	1.60	2.16	1.65	1.20	0.88	1.89
4	4.73	3.28	3.57	3.48	3.79	4.41	3.49	3.56	4.17	5.49	3.88	4.13	2.35	2.23	3.18	2.39
5	5.58	5.59	7.58	6.71	5.28	5.73	5.72	5.38	6.35	4.76	5.09	5.63	5.08	4.89	4.61	5.13
6	4.17	4.81	3.68	3.58	5.85	3.93	2.79	2.81	5.40	3.88	4.76	4.05	3.08	3.00	1.97	2.10
7	5.05	4.84	3.56	4.47	4.15	3.77	2.73	3.24	5.00	4.26	3.99	4.02	3.08	2.47	2.46	2.95
8	3.43	3.23	6.28	3.82	4.07	3.48	3.93	4.56	3.32	3.36	2.98	2.70	2.12	2.18	3.92	3.30
	33.40	32.62	33.63	31.65	33.28	31.11	28.55	29.37	33.20	30.17	25.38	25.68	19.43	17.89	20.23	20.97

<u>NOTE</u>: All yields are presented as dry matter in gm/2 sq. ft.

APPENDIX VIII. Fresh weight yields of total vegetation and lucerne harvested on 8/3/67

	Rep.1				Rep.2				Rep.3				Rep.4			
Tmt.	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L
1A	89.60	71.20	105.10	57.60	93.10	53.70	51.40	51.40	90.10	71.70	36.80	14.00	65.00	13.20	82.50	19.50
1B	136.50	41.00	100.30	81.40	87.90	57.20	76.00	76.00	50.20	32.30	80.40	38.70	65.20	10.20	71.40	30.40
2A	63.00	58.20	77.70	46.60	100.20	85.40	71.80	71.80	74.20	65.40	52.70	24.30	39.00	22.70	77.00	52.70
2B	100.30	81.60	100.50	81.50	88.50	88.50	76.40	76.40	85.20	63.60	88.00	25.70	38.50	30.70	94.00	53.80
3A	145.00	128.50	66.90	66.90	92.40	68.70	45.00	45.00	79.00	79.00	64.20	34.60	98.80	34.70	51.50	17.10
3B	124.00	100.60	60.40	61.60	76.00	34.20	40.00	40.00	76.30	76.30	99.50	58.50	58.50	29.10	76.80	32.50
4A	86.50	79.40	76.00	76.00	81.90	81.90	56.60	56.60	106.50	106.50	89.90	89.90	86.60	57.20	112.60	85.90
4B	113.10	73.00	61.60	61.60	88.70	88.70	80.80	80.80	92.40	92.40	112.30	112.30	91.10	54.30	124.10	63.00
5A	117.75	117.75	158.70	158.70	114.80	114.80	102.50	102.50	142.90	142.90	141.50	141.50	120.50	120.50	137.10	137.10
5B	122.40	122.40	139.20	139.20	92.70	92.70	110.50	110.50	150.60	150.60	169.00	169.00	107.70	107.70	147.30	147.30
6A	108.40	108.40	65.80	65.80	96.00	96.00	85.30	72.00	127.10	127.10	144.80	144.80	68.90	68.90	53.00	40.40
6B	103.40	103.40	88.20	88.20	116.10	116.10	94.50	64.80	114.60	114.60	120.00	120.00	74.90	67.50	55.60	50.70
7A	135.50	135.50	82.20	82.20	110.20	110.20	59.00	45.00	132.40	132.40	112.10	112.10	88.00	70.40	91.90	59.60
7B	137.20	137.20	94.90	94.90	94.90	94.90	75.20	75.20	146.20	146.20	131.40	131.40	48.10	41.70	101.70	96.60
8A	78.30	78.30	107.40	107.40	97.70	97.70	74.40	74.40	63.00	63.00	83.30	83.30	82.00	47.80	112.70	85.20
8B	77.40	77.40	96.80	96.80	80.30	80.30	91.20	91.20	80.00	80.00	92.60	66.10	69.20	47.10	103.10	88.10

<u>KEY</u>:

Tmt. = Treatment
Rep. = Replicate
T = Total
L = Lucerne