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A S T U D Y  
of the  
SUSCEPTIBILITY TO DALAPON  
of  
FOUR COMMON PASTURE SPECIES.

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A Thesis presented at Massey Agricultural College  
in part fulfilment of the requirements  
for the Degree of Master of  
Agricultural Science  
in the University of New Zealand.

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by  
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1959

*Jacques*

A STUDY OF THE SUSCEPTIBILITY TO DALAPON OF FOUR COMMON PASTURE SPECIES

H.M. Lawson.

p.44 Table II. The first F ratio is  $< 1$  .

p.46 Line 2. This sentence implies that randomization overcame the effects of decreased plot area.

p.49 Line 24. In cases where bulked treatment yields were used to give common dry matter percentages, analyses should be on Greenweight if this applied to all treatments. It is assumed that this happened only on odd occasions for a single treatment.

In some of the tables of means (e.g. Table XVI p 77) d.05, d.01, d.001 are given where the analyses show no significant differences between the treatments. Where the treatments range from 31 to 41 with SEs  $\pm 6.2$  there is no point in putting in the 3"d" values.

p.80 The test "High v Low" has not been carried out on Totals, and may give the same result as that for Live Herbage. It is not necessary to have a significant F for the overall treatment comparison before carrying out such a test.

Appendix IIIb. Misprint in "O v Rest" line of Table.

*A. Blaney.*

## EXPERIMENTAL SUMMARY.

The tolerance of four pasture species to treatment with dalapon in autumn was studied on single species swards. Perennial ryegrass was found to be the most tolerant species at all rates of application, followed in order of susceptibility by white clover, cocksfoot and browntop.

2 lb. per acre caused moderate damage to perennial ryegrass and severe damage to white clover and cocksfoot during winter. Considerable mortality resulted with browntop, but all species recovered vigorously in early spring.

4 lb. per acre completely killed all browntop and left only a few survivors of cocksfoot. Perennial ryegrass and white clover were severely damaged and many plants failed to recover. Regrowth from surviving plants was less vigorous than at 2 lb. per acre.

6 and 8 lb. per acre gave equally efficient results with all species. Only a few isolated plants of perennial ryegrass and white clover survived treatment. The continued inhibition of growth of surviving white clover plants was observed.

Environmental and sward factors influencing the results are discussed. Frost damage was found to be of considerable importance in the recovery of treated plants.

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of the illustrations in the text, due to the  
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photographic paper.

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CHAPTER I.

General Introduction.

One of the more important developments of recent years in New Zealand agriculture has been the introduction of herbicides selective against grass species. Originally intended for the control of grass weeds in arable crops these herbicides have proved capable of being utilized in many other aspects of farming practice, the most spectacular of which is 'chemical ploughing'. This popular name has been coined to describe the process whereby pastures may be improved with the aid of herbicides on land which cannot successfully be cultivated by conventional means. Extension of this technique to land which is only accessible to the aeroplane is being investigated by Blackmore (1958) and the preliminary reports suggest that 'chemical ploughing' may be a useful aid to aerial top-dressing and oversowing.

Every new development, however striking, must satisfactorily blend with <sup>or</sup> replace existing practice before it becomes generally accepted. Many problems of practical application require solution before recommendations can be made to farmers and these are at present under investigation in field trials throughout the country.

At the same time a thorough knowledge of the properties of the herbicides and the factors affecting their efficiency under a wide range of field conditions is essential. Where herbicides are applied to a mixed population of plants, as in a pasture, it is desirable to know, within fairly narrow limits, the tolerance of each constituent species.

The experiments reported in this thesis were undertaken to investigate the susceptibility of some common pasture species to dalapon, \*the most important of the selective grass-killing herbicides involved in 'chemical ploughing' and associated techniques.

\* see Appendix I.

## CHAPTER II

### REVIEW OF LITERATURE

This review will be presented in three sections as follows:

PART I Aspects of the utilization of dalapon in New Zealand.

PART II Aspects of plant and species susceptibility to dalapon.

PART III The tolerance of New Zealand pasture species to dalapon.

A list of common names and chemical abbreviations of herbicides mentioned in the review of literature is presented in Appendix I.

## PART I

Comparisons of chemical and conventional methods of pasture replacement and pasture improvement in terms of economics or efficiency do not come within the scope of this thesis. Extensive trials by the New Zealand Department of Agriculture have demonstrated that, although the techniques involved are still largely in the experimental stage, chemical methods of pasture replacement and pasture improvement can be successfully used in this country.

The purpose of this section of the review is to discuss the wide range of field conditions under which the chemical may be required to function efficiently.

### A. Pasture Replacement

#### (i) Replacement with a new pasture.

This involves the complete killing of the existing sward followed by the oversowing into the decaying turf of a new pasture mixture. For this purpose, dalapon may be used alone or in conjunction with other chemicals, depending on the botanical composition of the sward.

One of the more important problems is to decide the time of year at which spraying and sowing will be most successful. In the North Island (Blackmore and Matthews, 1958) good results were obtained from both autumn and spring sowing, while in the South Island early autumn and late winter sowing have shown most promise. Much depends on the local variations in climate from one area to another.

Blackmore (1958) pointed out that if pasture was sprayed after autumn recovery in districts where February and March are dry months, little time was left for sown species to establish before winter. Spraying before the autumn rains gave a very poor grass kill and

resulted in a thick braird of volunteer weed seedlings as soon as the rains came.

Trials by Blackmore and by Thompson (1958, 1959) showed that the susceptibility of a sward to chemical treatment varies considerably at different times of the year. The sward was least resistant if sprayed in early summer or in late autumn - early winter. Results in early spring were variable. To combine the best results of spraying and sowing, Blackmore (1958) advocated spraying in mid-autumn or early winter and delaying sowing until early spring. It is not considered advisable to have a long interval between spraying and sowing because of weed colonisation (Maclean, 1956).

Aspect can be a complicating factor in hill country. Blackmore (1958) suggested that the differences between sunny and shady faces were probably as great as the average differences in climate between one district and another. He found that chemical control might be a complete success on a sunny face, while on the corresponding shady face it was a comparative failure. To add to this difference, seedling establishment on shady faces following autumn spraying and sowing was not particularly good in many of the trials carried out.

The condition of the sward at the time of spraying and sowing is another important factor. Excessive foliage in a sward may prevent broadcast seeds, especially grass seeds from reaching the soil and may cause smothering of those which do germinate. Blackmore and Matthews (1958) also reported that the slug damage to new seedlings was more severe where the sprayed foliage had been rank. On the other hand, they found that the results of oversowing on to bare ground were poor. A moderate amount of foliage was required to protect seedlings from wind, drought and exposure, especially on hill land. Thompson (1959) found that early

spring applications of dalapon were more severe on bare or short pasture than on medium length pasture. He suggested that a substantial part of the effect was caused by root absorption. However, where oversowing follows soon after spraying, it is desirable that as much of the herbicide be intercepted by the foliage as possible to reduce the chances of harmful residual effect in the soil on seedlings. Blackmore (1958) recommended that pastures should be grazed hard by sheep or cattle to allow the recovery of a short even cover for spraying. One to two inches of recovery growth in the case of a browntop dominant sward should provide suitable conditions for spraying and ensure protection without smothering of the seedlings.

Blackmore (1957) at first considered that rain soon after application reduced the effectiveness of the chemical. However, it was observed in subsequent trials (Blackmore, 1958) that moderate amounts of rain shortly after spraying did not adversely affect the degree of sward killing. This was taken to indicate that root absorption contributed substantially to the results obtained. If oversowing is to follow soon after spraying, action of dalapon through root absorption from the soil is not desirable, since the residual effects of the chemical in the soil can at times take a heavy toll of seedlings.

Ideally, to achieve a satisfactory killing of the sward with a minimum amount of damage to seedlings, there should be a short even sward to intercept the spray, fine weather immediately after spraying to facilitate leaf absorption and fairly wet weather subsequently, to flush any remaining chemical from the surface layers of the soil.

The rate of dalapon to be used depends on the season, the botanical composition of the sward and whether or not another chemical is included in the spray. Since a high degree of mortality is essential, the rates at present recommended are sufficiently high to allow a reasonable

margin of safety under most field conditions. Blackmore (1957) gave as a general recommendation for browntop dominant swards a rate of not less than 5 lb per acre of dalapon, with the addition of 1-2 lb per acre of amitrol where flatweeds are present. Where grass species such as paspalum (Paspalum dilatatum) are present, higher rates of chemical may be required.

(ii) Replacement with a crop.

When a crop is to be sown directly on to a chemically treated sward, the procedure is essentially the same as that for a new pasture, except that extra care must be taken to ensure the complete death of the old sward. The recovery of a small fraction of the sprayed sward would not prevent the establishment of a new pasture but would be an embarrassment in a crop. Numerous trials (Blackmore and Matthews, 1958; Dawes, 1958) have been reported in which cropping failed because of the recovery and subsequent competition of species such as perennial ryegrass (Lolium perenne) and cocksfoot (Dactylis glomerata) which were only minor constituents of the original sward. A rate of 10 lb per acre of dalapon and 2 lb per acre of amitrol was recommended for safety. The desirability of sowing the crop as soon as possible after spraying in order to avoid weed competition was demonstrated. Most of the trials involved spring-sown crops which necessitated spraying at a time of year when the results of chemical treatment were very variable.

## B. Pasture Improvement.

### (1) Control of grass in lucerne stands.

Lucerne is not completely immune to the effects of dalapon. Trials at Invermay by Meeklah (1959) indicated that the most suitable time for the control of grass species in a lucerne stand was at the onset of spring growth. Although initial suppression of the lucerne was severe at this time, recovery was very rapid. Plants sprayed earlier when the lucerne was in a dormant condition, did not recover fully that year. It was suggested that the increased lucerne damage from winter treatment was the result of the slow decomposition of dalapon in cold soils. This exposed the plant roots to the chemical for a longer period of time. Treatment at times of the year other than early spring tended to increase weed infestation because of slow lucerne recovery. It was noted that grass weed control as a result of winter application of dalapon was extremely good. Meeklah recommended rates of up to 10 lb per acre of dalapon, to be applied in late August or early September, for the optimum control of weeds under conditions which would cause the minimum damage to lucerne.

### (ii) Barley Grass control.

Barley grass (Hordeum murinum) is a troublesome weed which causes considerable damage to sheep pelts and lamb carcasses. Because it is an annual, it must be sprayed in the seedling or early vegetative stage for effective control. This necessitates spraying either in early spring or in autumn after the rain has germinated the bulk of the barley grass seed in the soil.

Merry (1959) found that chemical treatment was less effective when the young barley grass seedlings were sheltered from the spray by a canopy of taller grasses, but results were best which were obtained on a short, evenly grazed pasture. Although autumn spraying gave very

good control of barley grass, the pasture species were also extremely susceptible at this time and considerable damage to the sward resulted. Merry preferred to avoid pasture damage by spraying in spring at a time when pasture species are not as vulnerable to dalapon. Ideally, spraying should be carried out at a time of year when the specific differences in tolerance between the barley grass and the pasture species are at a maximum. Normally, spraying should be followed by oversowing with desirable species to prevent further infestation by barley grass or other weeds. 1-2 lb per acre of dalapon is the generally recommended rate for application in early spring.

(iii) Pasture renovation.

This term is used to describe the concept, introduced by Blackmore (1958), of periodically purging pastures to arrest deterioration by the removal of undesirable species and to allow the introduction of high producing species in their place. He found that species such as browntop (Agrostis tenuis) and annual meadow grass (Poa annua) could be selectively removed from a sward at rates of herbicide which caused little or no check to perennial rye grass, cocksfoot or white clover (Trifolium repens). The sward could then be overdrilled or broadcast with desirable pasture species. Trials have given variable results due to insufficient knowledge of the seasonal differences in tolerance between grass species.

PART II

Overseas work with dalapon has been mainly concerned with the removal or control of grass weeds in arable crops. American workers in particular, have carried out detailed investigations on rhizomatous and stoloniferous grass species such as quackgrass (Agropyron repens), Johnson grass (Sorghum halepense) and Bermuda grass (Cynodon dactylon). Attention has also been paid to the action of dalapon on susceptible crops including maize, cotton, sorghum and beans. Much of this work has been of a fundamental nature and has therefore a direct bearing on the use of the chemical on New Zealand pasture species. In this section, present knowledge on the movement of dalapon from the outside of the plant to the site of inhibitive action inside the plant, and the various environmental and other factors which can modify the efficiency of dalapon, are reviewed.

A. Spray Retention.

If the entry of a particular herbicide is mainly via the foliage, then the absolute amount retained by the foliage is of prime importance. Spray retention is dependent on plant characteristics such as growth habit, leaf morphology and stage of growth, and on spray properties such as droplet size, surface tension and spray volume. Blackman et al. (1958) studied the interaction of these factors on spray retention and selective toxicity. They found the greatest difference in spray retention between two species to occur when the spray consisted of large droplets with a high surface tension, and the leaf surfaces of one species repelled the droplets while those of the other did not. Their conclusion was that the optimum selectivity in a mixed population would be obtained if the lethal quantity of herbicide for the unwanted species was applied under conditions in which the specific differences in spray retention were at a maximum.

Wetting agents reduce specific differences by lowering the surface tension of the spray droplets, thus increasing spray retention on normally repellent leaves. Dow Chemical Company (1953) reported that the addition of a wetting agent to dalapon solutions increased the toxicity of the chemical. They considered that inadequate wetting ability of dilute solutions of dalapon may affect herbicidal efficiency.

When dalapon is used to give a general kill of herbage, the incorporation of a wetting agent is recommended. However, where the selective properties of the chemical are to be utilized, as for example, in the removal of undesirable species from a pasture, it may be advisable to omit the wetting agent in order to obtain maximum species selectivity.

No information regarding the effect of varying the spray volume on the toxicity of dalapon is available.

## B. Foliar penetration and absorption.

### (i) Rate and duration of penetration and absorption.

The penetration and absorption of herbicides into plant foliage has been studied by a variety of techniques. None of these is considered completely reliable and caution is needed in the interpretation of results (Woodford et al., 1958). Reports of work with dalapon, using different techniques are, however, in fairly good agreement.

Hauser and Thompson (1959) found the greatest relative absorption of dalapon by Johnson grass to occur within the first 60 minutes after treatment. Laning (1959) estimated that as much  $^{14}\text{C}$  - labelled dalapon was absorbed by maize plants within two hours as within seven days of application. Foliar uptake of dalapon was observed by Currier and Dybing (1959) within 5 minutes of application to quackgrass and a lethal quantity had entered within 30 minutes. Crafts and Foy (1959) noted the absorption of a small amount of the chemical 15-30 seconds after application to maize.

Although absorption of the herbicide takes place very rapidly following application, there are indications that the process may continue for several days. Standifer and Ennis (1956) found that absorption of dalapon by maize plants was still occurring 48 hours after treatment. Other workers have observed absorption up to two weeks after treatment. (Crafts and Foy, 1959; Hauser and Thompson, 1959).

### (ii) Variations due to plant factors.

There is considerable controversy as to whether the path of entry of herbicides into the leaf is via the cuticle, the stomata or both. (Woodford et al., 1958; Currier and Dybing, 1959). Dybing and Currier (1959) found that aqueous solutions of herbicides containing surface active agents could penetrate rapidly through open stomata. When stomata were closed or when no surface active agent was added,

absorption was much slower and occurred mainly through the cuticle. If penetration is via the cuticle, the structure of the cuticle is of importance in determining the rate of entry. Similar results with  $^{14}\text{C}$  - labelled dalapon were reported by Crafts and Foy (1959). Rapid entry also took place through cut veins of leaves. These workers found that dalapon was equally readily absorbed by tolerant and susceptible species and concluded that absorption was not a major factor in determining species selectivity to the chemical.

(iii) Variations due to environmental factors.

Warm temperatures, adequate light and relatively high humidity will promote the penetration of herbicides by encouraging stomatal opening. Wind and high temperatures combined with low humidity, by assisting the rapid evaporation of spray droplets will depress absorption (Currier and Dybing, 1959). Rain, if it occurs soon after application, can wash spray deposits off the leaf, thus reducing foliar penetration.

Hauser and Thompson (1959) found no significant difference in absorption between Johnson grass plants sprayed with dalapon at air temperatures of  $60^{\circ}\text{F}$  and  $78^{\circ}\text{F}$ . There is an indication that at higher temperatures absorption may be reduced by scorch damage to the leaves (Southwick, 1955).

Standifer and Ennis (1956) exposed corn plants to dalapon solution for varying lengths of time at relative humidities of 20 per cent and 88 per cent. With the former, only plants exposed for more than 24 hours were severely damaged, while with the latter, exposure for only 6 hours caused as much damage as exposure for any longer period.

Exposure of plants to a period of darkness before spraying with dalapon apparently had no adverse effect on absorption (Crafts and Foy, 1959; Hauser and Thompson, 1959).

(iv) Variations due to spray factors.

Investigations with many derivatives of 2,2-dichloropropionic acid have revealed none with greater biological activity than the sodium salt. This salt is readily soluble in water, and commercial dalapon is distributed for application in aqueous solution (Dow Chemical Company, 1953). Crafts and Foy (1959) considered that the formulation of dalapon influenced penetration, but gave no details.

Currier and Dybing (1959) reported that the pH of the spray solutions affects cuticular penetration of a number of herbicides. An increase in pH from 4.5 to 6.5 to 9.0 markedly decreased the absorption of dalapon solution by Johnson grass (Hauser and Thompson, 1959).

The purpose and mode of action of various additives to spray solutions has been reviewed by Currier and Dybing (1959). Some confusion exists as to the difference between a wetting agent and a surface active agent (sometimes termed surfactant). A wetting agent assists the toxicity of the chemical by reducing the surface tension of the spray droplet, thereby increasing spray retention by the foliage. A surface active agent appears to increase herbicidal efficiency mainly by assisting the actual penetration of the spray solution.

The two terms are interchanged quite often in the literature and part of the confusion arises because some additives apparently act both as wetting agents and as surface active agents. There is no evidence that wetting agents per se affect penetration and absorption.

Dybing and Currier (1959) investigated the effects of the addition of surface active agents to herbicides. They were found to enhance cuticular penetration and were apparently necessary for the penetration of herbicides through open stomata. Similar results with dalapon are reported by Crafts and Foy (1959).

High rates of dalapon have been observed to decrease absorption and translocation by scorching the leaf tissue (Southwick, 1955; Hauser

and Thompson, 1959), whereas repeated applications of smaller quantities gave better results with very little scorching. This point is of particular importance where rhizomatous or stoloniferous species are involved. These require relatively large amounts of the herbicide to be absorbed and translocated throughout the stem for efficient control.

(v) Variations due to mixing herbicides.

Little detailed information is available about the effect of mixtures of other chemicals with dalapon in the spray solutions. Several workers have reported that the addition of contact herbicides such as P.C.P. scorched herbage and reduced the absorption and translocation of dalapon (Dow Chemical Company, 1953; Coulter, 1954; Southwick, 1955; Dawes, 1958), but the position requires clarification.

Dalapon is often used in conjunction with amitrol for herbage control where dicotyledonous weeds are present. Sheets and Leonard (1958) investigated reports of herbicidal synergism between these two chemicals. In trials with a range of species, they found that the effects of various combinations of dalapon and amitrol were never more than additive and in some cases were less than additive. The typical leaf-chlorosis symptoms caused by amitrol were apparently reduced when dalapon was added. There was some indication that dalapon may aid the penetration of amitrol into the leaf, and it was suggested that the pH of the spray solution might be involved. This did not appear, however, to cause a more than additive effect. More information is required here.

Peas and various weeds growing in soil which had previously been treated with T.C.A. or dalapon showed greater susceptibility to subsequent applications of dinoseb (Dewey et al., 1956). These workers postulated that T.C.A. and dalapon, which are closely related compounds, might have some effect on the permeability of the cuticle and perhaps of the protoplasmic surface layers. Pfeiffer et al. (1957) suggested that some changes in the wax formation of the cuticle are involved.

### C. Herbicidal activity in the soil.

#### (i) Root Absorption.

Very little information is available regarding the manner of entry of herbicides into roots. Although much research has been directed to the study of the entry of inorganic ions into roots, surprisingly little attention has been paid to the entry of organic molecules. It is reported, however, that most herbicides can be absorbed by plant roots (Woodford et al., 1958). Blackman (1957) suggested that differences in root uptake might be involved in species susceptibility to 2,4-D. Tests with seedling roots dipped in dalapon solutions showed that the chemical was readily absorbed (Dow Chemical Company, 1953), but no comparison of root and foliar absorption is available.

A study of root uptake of a herbicide in the field is complicated by the fact that application is not to the root, but to the soil mass. Some knowledge of the availability of the chemical for root uptake under a variety of soil conditions is therefore of importance.

#### (ii) Inactivation of dalapon in the soil.

One or more of four processes are usually considered to be involved in the inactivation of herbicides in the soil. These are decomposition, leaching, adsorption and volatilisation.

##### (a) Decomposition.

Several factors combine to influence the rate of herbicidal decomposition in the soil. Controlled greenhouse experiments have been conducted to determine the separate and cumulative effects of these factors on dalapon. Two main methods of measuring the quantity of herbicide in the soil are available. Detailed chemical analysis of the soil may be carried out, or a susceptible plant species may be used as an indicator - the bioassay method.

Thiegs (1955) treated a group of moist loam soils with

dalapon and stored them at three temperatures for a period of eight weeks. Chemical analysis demonstrated that little decomposition took place in soils maintained at 40°F., while considerable decomposition occurred in the 60°F. treatment during the second four week period and at 80°F. dalapon had disappeared from all soils within three or four weeks after treatment. This agrees with results in a similar experiment by Holstun and Loomis (1956) in which bioassay techniques involving several plant species were used. In loam soil stored at 0.5°C. (approximately 33°F.) very little decomposition of dalapon had occurred by the end of sixteen weeks after treatment.

These workers also investigated the rate of breakdown of dalapon applied to a silt loam soil stored at 27°C (80.6°F.) and four levels of soil moisture. At 0.25 field capacity there was no significant decomposition by the end of sixteen weeks. Decomposition at field capacity and 0.75 field capacity was essentially complete at both levels in eight weeks. At 0.5 field capacity, breakdown was much slower, but was complete by the end of sixteen weeks.

Trials with different soil types showed wide variations in rate of decomposition of dalapon. Soil reaction differences appeared to be important and experiments indicated that raising the pH of an acid soil from 5.1 to 7.5 increased the rate of breakdown of the chemical. Results from the addition of organic matter to soils were variable. The highest overall rate of decomposition was observed in a medium silt loam with a low organic matter content and a pH of 6.5.

Soil sterilization was found to halt almost indefinitely the decomposition of dalapon in the soil, regardless of any of the factors already reviewed (Thiess, 1955; Holstun and Loomis, 1956). This was taken to indicate that the breakdown of the chemical in the soil is primarily due to the activity of soil micro-organisms. Similar

conclusions have been arrived at concerning several other herbicides (Hernandez and Warren, 1950; Harvey and Crafts, 1952; Aldrich, 1953; Hill et al., 1955).

It has been suggested that different soil types and soil environmental conditions influence the breakdown of dalapon indirectly by their effect on the appropriate section of the soil microflora. If conditions favour the activity and multiplication of the micro-organisms which are involved in the decomposition of dalapon, the rate of disappearance of the chemical from the soil will be rapid. In unfavourable conditions; on the other hand, breakdown will be much slower or may even cease entirely. Soil temperature and moisture levels appear to be the most critical of the indirect factors involved.

Thiags (1955) interpreted the rapid disappearance of dalapon from soil under favourable conditions after an initial "lag" period of a weeks or more, and the more rapid breakdown of fresh additions of the chemical, as indicative of a gradual build-up in the soil after treatment of a bacterial population capable of utilising dalapon. It is thought that some micro-organisms detoxify dalapon by removing and utilizing the pyruvic acid resulting from hydrolysis of the chemical in the soil. Other bacteria may be able to utilize the chemical direct (Holstun and Loomis, 1956).

Worsham and Giddens (1957) reported that rates of dalapon up to 68 lb per acre had no adverse effect on soil micro-organisms. No effect on nodulation was observed and any adverse effect of dalapon on the symbiotic relationship of rhizobia on soyabeans was concluded to be a result of the action of the herbicide through the medium of the plant and not by direct action on the bacteria.

(b) Leaching.

Upchurch and Pierce (1957) have pointed out that a number

of environmental factors are involved in the process of leaching of herbicides from the soil. Leaching experiments have been mainly devoted to the effectiveness of a given amount of water in transporting a herbicide into and through a given soil. Factors such as intensity and frequency of rainfall, soil temperature, soil density, soil moisture content and rate of herbicidal application have received inadequate attention in comparison with the volume of investigation carried out on decomposition.

It is also difficult to isolate the effect of leaching from the combined effects of leaching and decomposition in the soil. There are, however, many reports that dalapon can be readily leached from the soil under normal environmental and conditions (Dow Chemical Company, 1953; Warren, 1954; Thiels, 1955; Holstun and Loomis, 1956).

(c) Adsorption.

This has been found to be of little, if any importance, in the detoxification of dalapon in the soil (Warren, 1954; Holstun and Loomis, 1956).

(d) Volatilisation.

Dow Chemical Company (1953) and Kutschinski (1954) observed some volatilisation of dalapon breakdown products in the soil, but the quantity was too small to make this process of more than minor importance in the detoxification of the chemical under field conditions.

#### D. Translocation.

Reservations made about interpretation of the results of absorption experiments apply equally to translocation experiments. In addition, there are very few experiments in which translocation differences can be separated from absorption differences. The use of radioactive isotopes has provided workers with much new evidence about the movement and accumulation of herbicides in plants. Many workers have shown that herbicides undergo chemical changes within the plant (Woodford et al., 1958). The distribution of the labelled element, therefore, need not necessarily indicate the distribution of the molecule in which it was originally incorporated. Detailed studies on the movement of dalapon within the plant have been made by Crafts and Foy (1959) using  $^{14}\text{C}$  and  $^{36}\text{Cl}$  - labelled herbicide. Their findings are presented below, corroborated where possible by the reports of other workers using different techniques.

##### (i) Mechanism of translocation.

There are two main mechanisms by which herbicides may move in plants (van Overbeek, 1956). These are with the transpiration stream in the xylem and with the photosynthates in the phloem. Santelmann and Willard (1954) and Crafts and Foy (1959) have reported the translocation of dalapon following either foliar or root application by both these methods. Woodford et al. (1958) stated that any chemical which could enter plant roots could probably be translocated in the xylem. Crafts and Foy (1954) found that upward translocation of dalapon in the plant occurred mainly in the xylem and downward translocation in the phloem. There was also appreciable lateral interchange between the two, when sufficient time was allowed. Indications were that dalapon is absorbed, translocated and accumulated as the original molecule or the dissociated salt thereof. Dow Chemical Company (1959) gave the same opinion.

Translocation from treated leaves is dependent on the movement of food materials (Crafts and Foy, 1959). It was found that the amount of dalapon translocated was directly related to the age of the leaf and its photosynthate - exporting ability. Distribution following root uptake was rapid. Dalapon was traced in all parts of cotton and sorghum plants within one hour of application to the root. It was noted that during the process of translocation from one part of the plant to another, some of the chemical was retained by the tissues through which it passed.

These workers observed, as did Laning (1958), that translocation in both susceptible and tolerant species was primarily towards regions of young active growth. However, in dormant or quiescent tissues dalapon could remain unmetabolised for long periods. There was also retranslocation of dalapon in response to changes in the site of metabolic activity. Dalapon sometimes appeared in tissues or organs of the cotton plant which were not yet formed at the time of treatment.

(ii) Rate and duration of translocation.

Standifer and Ennis (1954) cut treated leaves from maize plants at various intervals of time after treatment. Measurement in terms of subsequent plant growth showed that the maximum amount of translocation had not occurred within 24 hours, and that some translocation still continued after 48 hours. Although less than 2 per cent of the chemical was translocated out of the maize leaves within 8 hours, 20-30 per cent had moved out after 2 weeks.

The total amount of dalapon translocated increases in direct proportion to the rate of application where there is no acute toxicity (Crafts and Foy, 1959).

(iii) Variations due to plant factors.

Those plant factors which influence the absorption of

herbicides indirectly affect translocation also. For the optimum translocation of an herbicide, active photosyntheses to provide assimilates for phloem transport, a favourable water balance in the plant to encourage rapid xylem transport, and centres of active growth in both root and shoot, are necessary (Woodford et al., 1958; Currier and Dybing, 1959).

(iv) Variations due to environmental factors.

Light intensity, temperature and wind, influence both photosynthesis and transpiration and through them the translocation of herbicides (Woodford et al., 1958). However, the limited information available concerning the effect of environmental factors on dalapon translocation does not always fall into line with that concerning other herbicides. More detailed investigations are required to clarify the situation.

Hauser and Thompson (1958) subjected one group of Johnson grass plants to continuous sub-irrigation and another to the absolute minimum of moisture required for survival. There was little or no effect on the movement of dalapon or amitrol. These workers also found that translocation of amitrol was significantly reduced by a 60 per cent reduction in light intensity to treated plants. Little effect was observed with dalapon. The conditions under which these experiments were carried out are not very clear from the text.

Santelmann and Willard (1954) reported that quackgrass plants exposed to 48 hours darkness to exhaust the leaves of photosynthates showed greatly decreased translocation of dalapon compared to plants kept in full light. A 10 per cent sucrose solution added to the dalapon in an attempt to increase translocation from depleted leaves had no effect. In a similar experiment with etiolated bean seedlings (Jaworski et al., 1955) transport of 2, 4 - D from treated

leaves was promoted by the addition of sucrose or glucose, but not by a variety of other compounds.

(v) Variations due to spray factors.

A foliar herbicide if it is to be translocated must not destroy the leaf tissue by contact toxicity. This is a major reason for the poor translocation of T.C.A. after foliar application (Woodford et al., 1958). Dalapon has little contact toxicity under normal conditions. However, at very high rates of application or where air temperature is high and humidity low, some scorching of tissue may occur. Crafts and Foy (1959) found that contact injury from any source greatly diminished or even prevented translocation of dalapon. The herbicide cannot be translocated through dead herbage.

Hauser and Thompson (1959) did not observe any appreciable increase in translocation per se with the addition of a surface active agent to a dalapon solution.

E. The effect on plants.

Dalapon has been found to be more toxic to monocotyledonous plants than to dicotyledonous plants. New growth of established perennial grasses is often malformed after the application of the chemical and there is frequently some proliferation of tissue. At suitable rates, old foliage gradually becomes yellow and dies. The chemical also appears to induce crown and rhizome bud dormancy for varying periods of time depending on the rate applied and on environmental conditions. If the rate of application is sufficiently high, these buds fail to recover and the plant dies. The toxic symptoms are not unlike those produced by T.C.A. (Dow Chemical Company, 1953; Woodford et al., 1958). Dewey et al., (1956) reported that dalapon induced changes in the chemical composition of leaves.

Grass seedlings of many species are often stunted for some considerable period after absorption of dalapon via the foliage or the soil. There are indications that the chemical has less effect on seedling root growth than on shoot growth at sub-lethal rates (Dow Chemical Company, 1953). Andersen and Helgesen (1956) found that dalapon caused no effective reduction in the germination of seeds collected from plants of wild oat (Avena fatua) treated at the "boot" stage. It did, however, cause an initial retardation of growth for a few days after germination. Direct application of dalapon to cultivated oat and beet seeds did inhibit germination (Olssen and Salisbury, 1957). Seeds were found to absorb effective amounts of herbicide in the first few hours of contact. Dalapon-treated oat or beet seeds germinated in the dark gave only slightly stunted plants as compared with control, while treated oats brought into the light almost ceased to grow after one day. Treated beet seeds brought into the light continued to grow normally.

Corns (1956) and Miller(1957) demonstrated that dalapon or

T.C.A. at rates of application below those which caused growth inhibition were capable of improving the cold resistance of the seedling shoots of sugar beet. Severed shoots were exposed for 6 minutes to a temperature of  $-10^{\circ}\text{C}$ . Untreated plants showed 18 per cent survival, those treated with dalapon at 4 p.p.m. showed 50 per cent survival and at 8 p.p.m. there was 71 per cent survival. 12 p.p.m. caused some inhibition of growth. It was thought that observed increases in the sugar and dry matter contents of the shoot were involved in the greater resistance to low temperature of shoots treated with dalapon.

#### F. Mechanism of action.

Very little is known about the exact mechanism of action of herbicides in plants. Woodford et al. (1958) attribute this to the present limited information about the physiological and biochemical processes in the plant. Until there is greater knowledge about the growth of plants, an understanding of the action of herbicides in inhibiting growth cannot be expected.

Grigsby et al. (1955) studied the effect of dalapon on mitosis in seedlings. At a concentration of 1,000 p.p.m. of dalapon, mitosis was upset at the prophase stage and the affected nuclei reverted to a pseudo-resting stage instead of proceeding normally through metaphase, anaphase and telophase. Dalapon caused a scattering of chromosomes superficially resembling that which follows treatment with colchicine. The chemical caused a marked retardation of growth of the seedlings and retarded or killed the primary root. However, extensive development of apparently normal secondary roots was observed.

Salisbury (1957) concluded that the effect of dalapon in causing flowering inhibition was due to a general inhibitive effect and not to interference with the flowering mechanism itself.

Dalapon and T.C.A. have been shown to be protein precipitants (Redemann and Hamaker, 1954).

It has been suggested that dalapon might be expected to act as an anti-metabolite to pyruvic acid and to inhibit enzyme systems using pyruvic acid as a substrate. Redemann and Meikle (1955) tested this hypothesis with pyruvate oxidase and carboxylase, but their results did not clearly demonstrate that this was indeed the primary cause of the action of dalapon. Similar experiments with germinating

Hilton et al. (1957) reported that dalapon inhibited the growth of yeast, and that this inhibition could be partially reversed by high concentrations of beta-alanine. Similar experiments with germinating

seeds were less decisive, but the utilization of beta-alanine was affected. It was thought that beta-alanine metabolism might be involved in the mechanism of action of dalapon. This evidence has been substantiated by Dow Chemical Company (1959) who concluded that dalapon interfered with an enzymatic process in which beta-alanine and pantoate were changed to pantothenic acid. This acid is essential for plant growth and it was suggested that it is through the disruption of the formation of pantothenic acid that dalapon has its effect on plants.

PART III

Perhaps the most important prerequisite to the successful use of dalapon on pastures is a thorough understanding of the tolerance of the constituent species. The previous sections of this review illustrate that the effect of the herbicide on pasture species will vary considerably with the stage of growth of the plants and the environmental conditions at the time of treatment.

Detailed information on the effects of various rates of dalapon at different seasons and under different management practices is therefore essential before the use of the chemical can be recommended to farmers.

This section reviews what little information there is at present on the subject with regard to some of the commoner pasture species.

(i) Perennial ryegrass (*Lolium perenne*).

Matthews (1956) in a series of pasture renovation trials found that 5 lb per acre of dalapon was required to kill this species in spring, while in summer 15-20 lb per acre might be necessary.

Thompson (1958, 1959) began a series of experiments to study the seasonal tolerance of a number of grass species to various rates of dalapon. The following results deal with the ryegrass fraction of the sward.  $1\frac{1}{4}$  and  $2\frac{1}{2}$  lb per acre applied in September gave an initial depression in yield of 30 per cent, whereas 5 lb per acre caused a 70 per cent reduction. Recovery at all rates was, however, complete by early November when all treated plots were yielding more than control, due partly to the removal of competition from other species. In a November trial the effects were more severe, while treatment in December was quite drastic. 5 lb per acre had little effect when applied in February, but in April this rate caused severe damage which persisted throughout

the winter. Lower rates gave moderate damage.  $2\frac{1}{2}$  lb per acre applied in June had almost as much effect as 5 lb per acre applied in April. 5 lb per acre applied in June removed practically all the herbage during winter, but slow recovery commenced in spring. Dalapon at 10 lb per acre killed nearly all ryegrass plants at all times of year except in February.

It was concluded that treatment of ryegrass early in a period of active growth had a relatively slight effect, whereas treatment before or at the beginning of a decline in growth was much more effective. In general, autumn treatments were more severe than spring treatments.

In another experiment the effects of the height of pasture and its degree of maturity on susceptibility were investigated. Dalapon was applied to a ryegrass dominant sward at the beginning of the spring growth period or during the full spring flush period. No significant effects due to pasture height or maturity were observed on spring flush growth. In early spring, however, 5 lb per acre gave significantly less control of ryegrass of medium height (6-7 inches, representing 12 days' growth) than of short (2 inches, representing 7 days' growth) or bare ( $\frac{1}{2}$  inch, mown the same day) pasture. The similarity of the effect on short and bare pasture was striking, since the latter had little or no foliage available for leaf absorption of the spray. It was concluded that root absorption must have contributed substantially to the effect of the chemical on the bare pasture.

(ii) Cocksfoot (*Dactylis glomerata*).

Lynch (1955) reported that 40 lb per acre of dalapon killed cocksfoot. Matthews (1956) mentioned that cocksfoot could be killed with 10 lb per acre of dalapon plus 5 lb per acre of amitrol. Reports such as these gave rise to the belief that this species was

very resistant to herbicides. Subsequent information, however, has indicated that the resistance of cocksfoot can vary considerably. The results reported by Thompson (1958,1959) in his seasonal tolerance and stage of growth trials illustrate this point.

$1\frac{1}{4}$  lb per acre of dalapon applied in September to a mixed pasture caused no change in the level of production of cocksfoot.  $2\frac{1}{2}$  lb per acre gave a slight check, but 5 lb per acre was drastic. This rate caused an initial reduction of 80 per cent in production with eventual recovery to 50 per cent of control yield. November treatments were more severe, especially at the  $2\frac{1}{2}$  lb per acre rate.

A trial was laid down on separate pure swards of cocksfoot and ryegrass. 5 lb per acre of dalapon was applied at three stages of growth:

Tall	(10-12 inches)
Medium	( 6-8 inches)
Short	( 3-4 inches)

and at two times of year:

late October, and late December.

Once again the effect was more severe on the short growth, especially with the summer treatment. In spring, when short growth was treated, dalapon damaged cocksfoot more than ryegrass, but as height at treatment increased, differences between the species largely disappeared.

In a similar experiment dalapon was applied to an area of mature clumpy cocksfoot at three regrowth heights in November. Results were most severe when applied to the tall regrowth, especially at 15 lb per acre. This rate gave 83 per cent kill of plants when applied to tall growth and only 41 per cent kill on short growth. It was suggested that mature clumpy cocksfoot plants, having deep root systems are less likely to be susceptible to dalapon in the soil than younger plants in a sward. If this is the case, then the plants with the most foliage will absorb the most dalapon from a spray application. This explanation requires elaboration and confirmation.

(iii) White Clover (*Trifolium repens*).

When dalapon was first introduced, it was reported to have little effect on mature white clover plants. Lynch (1955) stated that although dalapon severely scorched young clover plants, mature plants were much more resistant. Maclean (1955) conducted a series of experiments to investigate the tolerance of clovers to a number of herbicides. 10 lb per acre of dalapon severely damaged white clover seedlings. However, no suppression of mature white clover was observed at this rate. Workers at Oxford (Elliott and Fryer, 1958) found that while 4 lb per acre of dalapon had an initial depressing effect on white clover, the plants soon returned to normal and no significant reduction in yield was obtained in cuts taken one month later.

There is no indication in either of the above two reports about the time of year at which treatment was applied.

Results from the seasonal tolerance trials by Thompson (1958) did not agree with those detailed above. Even at a rate of  $1\frac{1}{2}$  lb per acre of dalapon, applied in early September there was a noticeable check to growth, amounting over the spring period to 20 per cent of yield. Thereafter the plants returned to normal. Application of  $2\frac{1}{2}$  lb per acre and 5 lb per acre gave reductions of 55 and 75 per cent respectively over the period from treatment until the end of October. Some reduction persisted until well into the early summer period when the normal decline in ryegrass growth allowed the clover to recover. Following normal clover growth during summer there was a decline in autumn, due in part to the increasing competition from ryegrass. Both the  $2\frac{1}{2}$  lb per acre and the 5 lb per acre treatments finished the season at about 70 per cent the yield of the control plots. Treatments in November affected the clover less severely and recovery was more rapid, presumably because of reduced competition from grasses. However, total yields were again lower over the season than on control plots. The effect of dalapon on clover

in these experiments was complicated by the competition between grass and clover.

(iv) Browntop (*Agrostis tenuis*.)

This species has received more attention than any other in New Zealand because of the low rates of dalapon which are required to kill it and because of the large acres of browntop dominant pastures which it is hoped may be improved by chemical means. Matthews (1956) and Blackmore (1958) reported that dalapon at a rate of 2½ lb- 5 lb per acre successfully controlled browntop. It was suggested, however, that higher rates might be required during the dry summer and early autumn periods (Blackmore and Matthews, 1958). Thompson (1958) confirmed these rates of application to browntop. Little difference was observed between September and November applications.

(v) Other species.

No satisfactory detailed information about any of the other common pasture species is available.

The following list, taken from Elliott and Fruer (1958), gives an indication of the relative toxicity of some pasture species to dalapon. It is only an indication.

Susceptible to 5 lb per acre:

Perennial ryegrass	<u><i>Lolium perenne</i></u>
Italian ryegrass	<u><i>Lolium multiflorum</i></u>
Cocksfoot	<u><i>Dactylis glomerata</i></u>
Timothy	<u><i>Phleum pratense</i></u>
Bent grasses	<u><i>Agrostis species</i></u>
Rough stalked meadow grass	<u><i>Poa trivialis</i></u>
Creeping fescue	<u><i>Festuca rubra</i></u>
Crested dogstail	<u><i>Cynosurus cristatus</i></u>

Susceptible to 10 lb per acre:

Lucerne	<u><i>Medicago sativa</i></u>
White clover	<u><i>Trifolium repens</i></u>

Resistant to 10 lb per acre:

Most of the common decotyledonous weeds of pastures.  
Also most rushes (*Juncus species*) and sedges (*Carex species*).

C H A P T E R    I I I  
M A T E R I A L S    A N D    M E T H O D S

Four major experiments were conducted simultaneously. Each involved the application of dalapon to an established pure sward of a common pasture species at rates of :-

	<u>Code number in text</u>
2 lb per acre	2
4 lb per acre	4
6 lb per acre	6
8 lb per acre	8
Control - no dalapon	0

The species involved in the experiments were:-

Perennial ryegrass	<u>Lolium perenne</u>
Cocksfoot	<u>Dactylis glomerata</u>
Browntop	<u>Agrostis tenuis</u>
White clover	<u>Trifolium repens</u>

This chapter deals with the planning and layout of the experiments, the application of treatments and the techniques employed to measure the effects of treatment with dalapon.

A. Preliminary Investigations.

When these experiments were planned (autumn, 1958), the information available on the tolerance of pasture species to dalapon was, as can be seen from the review of literature, extremely limited and vague. It was decided, therefore, that a series of observational trials should be conducted to facilitate the choice of a suitable range of rates of the herbicide for the investigation of specific tolerance. Accordingly, small (15 inch square) observational plots on an existing sward were marked out and sprayed on 23rd April, 1958, with rates of dalapon varying from 1 to 30 lb per acre. At least three replications of each treatment were applied, to cover as wide a range of species as possible. The plots were sited on an area of rough grazing adjacent to the Crop Experimental Area. Another series of similar trials on the same field were laid down on 26th August, 1958.

The only recordings taken were of specific frequency within the plot before spraying and two months after spraying. Heddle (1933) reported that specific frequency measurements, although they do not give a quantitative analysis of the sward, are of value for preliminary surveys and introductory investigations. It was felt that such measurements would be sufficiently accurate for a preliminary experiment of this nature.

The following is a brief summary of the results obtained.

- a) Rates of 10 lb per acre and above removed all grass species from the sprayed plots and invasion by flatweeds followed.
- b) Only perennial ryegrass survived in plots treated with 8 lb per acre.
- c) No cocksfoot or crested dogstail remained on plots treated at rates above 6 lb per acre.
- d) No Yorkshire fog (Holcus lanatus) or sweet vernal (Anthoxanthum odoratum) remained on plots treated at rates above 4 lb per acre.

- e) Browntop was severely reduced by rates of 2 lb per acre and was killed by rates of from 3 to 6 lb per acre.
- f) No conclusion as to the effect on white clover was possible because only the occasional plant was present in sprayed plots.
- g) Results from the August treatment varied much more than those from the April treatment.

### Conclusions

These results indicated that 10 lb per acre of dalapon was approximately the upper limit of tolerance for the species reported. It was concluded that a range of up to 10 lb per acre should give a satisfactory indication of the tolerance range of a number of common species and allow comparison between species regarding the effect of the herbicide on one species at rates lethal to another.

B.. Planning and layout of the experimental area.

(i) The experimental area.

This was located on the Crop Demonstration Area, Massey Agricultural College and had been utilised for spaced plant trials with Yorkshire fog (Holcus lanatus) for the previous five years. Frequent inter-plant cultivation of the area to eliminate weeds had resulted in a marked deterioration in soil structure. The soil type is classified (New Zealand Soil Bureau, 1954) as a Tokomaru silt loam. Investigations to determine the soil reaction revealed a pH varying from 4.7 to 5.3.

The experimental area measured approximately 150 feet by 70 feet, bounded on one side by a road and beyond this, a line of tall trees and on the other side by a regularly grazed pasture. The line of trees prevented the sun from reaching part of the area for most of the morning in winter, and clover from the roadside verge and from the pasture continually encroached on the edges of the experimental area. Since cutting with a motor mower was envisaged as part of the plot management, large quantities of stones had to be removed before the experiments were laid down.

(ii) Planning and Layout.

An important criticism of specific tolerance estimations based on the effect of dalapon on mixed swards is that the factor of inter-specific competition has a profound bearing on the disappearance or recovery of species within the sward. The suppression of the more susceptible species aids the recovery of the more resistant species. For this reason, and also because of the difficulty in maintaining uniformity in a mixed sward, it was decided that for a critical examination of specific tolerance to dalapon, it would be necessary to study pure swards of each species.

Two alternatives were available in the layout of the experimental area. One large experiment could be designed with plots of

individual species randomised over the whole experimental area, or the area could be split into several smaller area, each comprising a separate but similar experiment.

Since adult plants rather than seedlings were to be tested, it was planned that sowing should take place in autumn 1958 for treatment in autumn 1959.

One large integrated experiment would allow direct statistical comparison between species at all levels of treatment. Such a layout would, however, require the final decisions as to plot size, number of treatments and degree of replication to be made at sowing time. Before any assessment of the uniformity of the area could be made, and a full year before treatment. As a result there could be no manoeuvrability in experimental design in the event of pre-treatment managerial difficulties or in the light of new information which might become available before treatment. Furthermore, one large unit would be unviably from the point of view of management and would impose an impossible burden at sampling time unless the number of treatments envisaged was substantially reduced.

On the other hand, there were many factors in favour of laying down separate experiments for each species. Experimental design need not be finally formulated until just prior to treatment and could be chosen to accommodate the condition and uniformity of the areas at this time. Work at sowing time could be limited to the laying down of an area of each species, and these areas could be managed as separate large units in such a way as to favour the sown species at the expense of weeds. Sampling could be spread over a longer period since each experiment could be sampled individually. Observational, as opposed to statistical comparison could be made between species since all the experiments would be laid out in adjoining areas of the same field and the treatments as

as well as the experimental design would be identical.

In view of the factors discussed above, it was decided that separate experiments would be conducted for each species. Subsequent management and uniformity difficulties proved that this was a wise choice.

C. Establishment and routine care.

(i) General

The experimental area was not available until mid-April. It was ploughed, disced and rolled, and on the 13th April, 1958, separate areas of five species were sown by hand. Seeding rates were fairly high so that a dense and even pure sward would be obtained. Each area was then raked over to cover the seed. 2 cwt. per acre of superphosphate was applied a few days later. Each area was approximately 50 feet by 70 feet in size. (See Fig. 1)

Five species were originally selected for investigation. Perennial ryegrass and cocksfoot were chosen as representative of the desirable pasture grasses, browntop and Yorkshire fog as common constituents of run-out pasture and white clover to discover whether the rates of dalapon applied to the grass species had any harmful effect on it. The availability of seed was also taken into account in the choice of species. Table 1 shows the rates of seed sown and the source from which it was obtained.

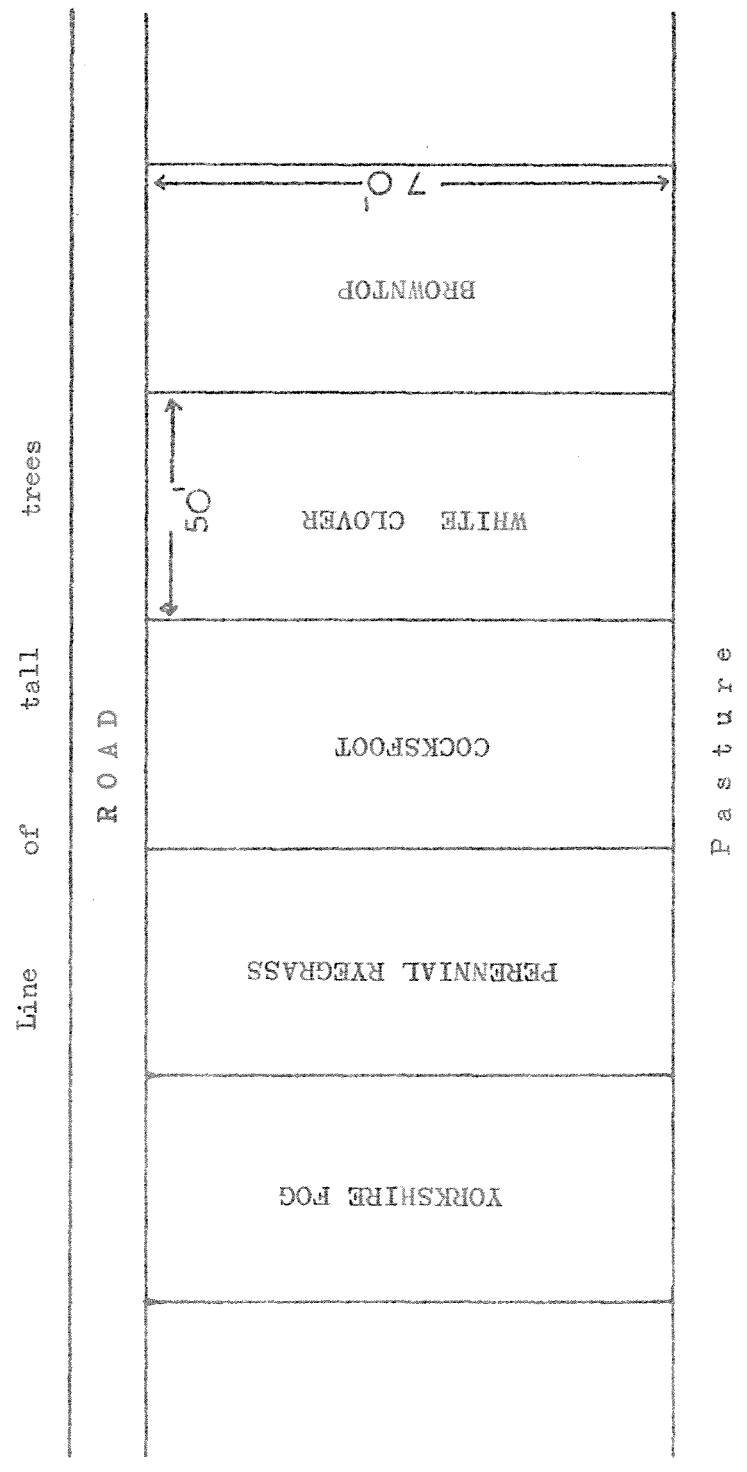
TABLE 1            Sowing rates and source of the seed used in the experiments.

Species sown	Rate	Source
Perennial ryegrass	20 lb per acre	N.Z. Certified seed
Cocksfoot	20 lb per acre	N.Z. Certified seed
Yorkshire fog	20 lb per acre	Commercial seed Cleanings
Browntop	20 lb per acre	N.Z. Certified seed
White Clover	4 lb per acre	N.Z. Certified Pedigree seed



FIG. 1

PLAN OF EXPERIMENTAL AREA



Establishment was slow and patchy, due in part to the late sowing and the variability of the experimental area. 3 cwt. per acre of nitrogenous fertilizer applied in early spring to all areas, including the clover, gave a rapid and substantial improvement; nitrogen and phosphorus were applied sparingly throughout the pre-treatment period since it was considered desirable to study the effect of dalapon on the sown species under conditions of low fertility approximating as nearly as possible to those under which it might be used on run-out pasture in farm practice.

The areas were mown at regular intervals from early spring until two weeks before treatment with a Hayter rotoscythe. This type of cutting blade did not chew the sward and could be adjusted to shave off the top growth evenly at heights of from  $\frac{1}{2}$ -6 inches above ground level.

The slow establishment over the winter period and dry early spring period encouraged the ingress of weeds. Sheep's sorrel (Rumex acetosella) in particular germinated and spread over the whole area during spring and summer. Hand weeding was able to keep other weeds fairly well under control, but this species spread rapidly by underground runners and produced new shoots within a few days of weeding. In an attempt to control this weed, 1 lb per acre of 2,4-D solution was applied on 8th December, 1958. The clover area was not sprayed in case of damage to the sown species. The weed killer appeared to have little if any effect on the sheep's sorrel although it removed several other dicotyledonous weed species. No further attempt was made to kill this weed by the use of a herbicide in case some effect on the response of the sown species to dalapon resulted.

To save the experimental area from dominance by sheep's sorrel, hand weeding using a sharp knife was resorted to. This disturbed the sown species to some extent, especially where thick patches of weed occurred.

In all, the whole experimental area was handweeded four times over the summer period.

During the weeding process, the presence of a substantial population of army worms (Pseudaletia separata) was observed. This was thought to be contributing to the patchy growth, especially on the browntop area. D.D.T.-superphosphate was therefore applied on the next manuring date

Over the latter part of the summer, sprinkler irrigation was employed as an aid to management.

(ii) Specific areas.

Perennial ryegrass was severely attacked in early summer by rust (Puccinia graminis). This, plus the virtual cessation of growth in summer, resulted in an open sward which encouraged weed ingress. Sheep's sorrel took control of patches of the area and smothered the sown species in places. Weeding left patches of bare ground and resulted in poor uniformity over the area. When growth began again in autumn however, the ryegrass sward thickened up considerably and the combination of cutting, manuring and regular weeding finally produced a virtually pure and moderately uniform stand.

Cocksfoot, due to very slow establishment had the largest weed population of all areas in spring. However, its continued growth over the summer period, combined with lenient defoliation and adequate nitrogen eliminated all weeds except sheep's sorrel. Regular weeding produced a pure and moderately uniform stand for treatment.

Yorkshire fog showed the best establishment of all species, resulting in a dense and relatively weed-free sward in spring. Unfortunately the whole area completely died out in early summer. The reason for this is unknown, but reports of similar occurrences at Grasslands Division, Palmerston North and at the Grassland substation at Lincoln (Edmond, 1959) together with personal observations over the Massey College area showed that it was not an isolated phenomenon. The Yorkshire fog trial had to

be abandoned.

The browntop area opened up considerably during summer. The remaining herbage turned brown and growth virtually ceased. The area was rapidly colonised by weeds, especially sheep's sorrel, mouse-eared chickweed (Cerastium glomeratum) and Cotula species. Removal of these weeds left large patches of bare ground, which were soon covered with weeds again. The weed problem was so acute on this area, that it was contemplated abandoning this trial also. However, since browntop showed some recovery in autumn, weeding was persisted with and the sward at treatment time although browntop dominant was very uneven and patchy.

Little weeding was possible on the clover area. After slow initial establishment, clover spread rapidly over the area. The major weeds were browntop and sheep's sorrel, both of which it was found impossible to remove without severely upsetting clover growth. The active growth of the clover over the summer period allowed a reasonable degree of weed control by cutting management. Complete weed control was impossible but clover dominance was maintained.

Emphasis was placed on obtaining as pure a sward as possible so that the competition factor would not interfere with results due to dalapon, and the rapidity of weed ingress into the sward after treatment could be studied.

Plot maintenance was a full-time occupation over the summer and early autumn period. This prohibited a series of greenhouse trials which had been planned to furnish information on the effect of dalapon on seedlings of the species used in the field trials.

D. Experimental design and sampling arrangements.

(1) Experimental design.

During the summer trial, cuts were taken when the areas were mown and an estimate of the degree of uniformity obtained. Results indicated that considerable variability was present. It was considered necessary to include in the experimental design as many replications as possible, subject to the limitations imposed by convenient plot size for sampling and the area available for the trial.

An experimental design was therefore planned incorporating five treatments replicated six times in a simple randomised block layout (after Cochran and Cox, 1957). This layout gave a total of 30 plots per species, each measuring 11 feet by 5½ feet and involved an actual experimental area for each species of 68 feet by 28 feet, leaving a small discard area of the sown species around the perimeter. Replications were laid out in a direction calculated to minimise variations due to fertility trends or to shading effects of the trees. The areas were measured off and plots marked out by wooden pegs.

The final layout for the white clover trial is seen in Fig. II. The layout for the other three species was similar. The five treatments were allocated at random within each block of each experiment.

To test whether the proposed layout was satisfactory or would require modification, uniformity trials were conducted on the cocksfoot and white clover areas on 6th March, 1959. Perennial ryegrass and browntop were producing very little herbage at that time and mowing was not considered advisable. Sample areas of approximately 7 feet by 2 feet were mown up the centre of each plot and the cut herbage collected for fresh weight yield determination. After correction to unit area, the results were statistically analysed. Table III indicates that while no significant trends appeared between blocks or treatments, the individual

FIG. II



BLOCKS

	I	II	III	IV	V	VI
T	2	4	8	0	6	0
R	4	8	4	2	4	2
E	0	2	6	6	8	6
A	8	6	0	8	2	4
T	6	0	2	4	0	8
M						
E						
N						
T						
S						

Experimental design for the white clover area illustrating the layout  
of blocks and the randomisation of treatments  
within blocks.

TABLE II

Uniformity trials conducted on 6th March, 1959.

Cocksfoot.

Analysis of Variance.

Variation due to	d.F.	S.S.	M.S.	F.	Result
Blocks	5	0.4087	0.0817	< 1 2.5 (2.87)	N.S.
Treatments	4	3.4035	0.8509		N.S.
Error	20	8.3149	0.4157		
<b>Total</b>	<b>29</b>	<b>12.1271</b>			
				Mean	4.32

Standard error of the mean = 0.26  
 Estimated detectable difference  
 between treatments required for  
 significance at 0.05 level = 18 per cent.

White Clover.

Analysis of Variance.

Variation due to	d.F.	S.S.	M.S.	F.	Result
Blocks	5	1.7793	0.3559	1.80 (2.71) 1.97 (2.87)	N.S.
Treatments	4	1.5610	0.3903		N.S.
Error	20	3.9632	0.1982		
<b>Total</b>	<b>29</b>	<b>7.3035</b>			
				Mean	2.28

Standard error of the mean = 0.18  
 Estimated detectable difference  
 between treatments required for  
 significance at 0.05 level = 24 per cent.

plot variation was considerable. In view of the large differences between treatments which it was estimated would be required for statistical significance, it was decided that a wider interval between treatment rates, namely 2 lb per acre, than had been originally planned should be employed. Otherwise the proposed layout appeared to be as satisfactory as could be obtained under the circumstances.

(ii) Sampling arrangements.

The taking of field measurements posed several problems. Herbage yield from the treated plots appeared to offer the most reliable measure of the effect of dalapon on sown species. It provided an objective method of comparison in experiments where the results of treatment might be difficult to assess by other methods of pasture measurement. It also allowed field work to be reduced to a minimum - an important point from the weather aspect during late autumn and winter, considering the large number of plots - 120 in all to be sampled.

The simplest sampling method would be to cut the whole plot (less discard areas) by motor mower and measure total plot yield. Regrowth, if any, could then be cut at intervals, to measure recovery. However, it was not known to what extent cutting and treatment with dalapon might interact in suppressing plant growth, and also, such a sampling method would not allow continued measurement of the decline and recovery if any, of the treated foliage. It was decided that each plot should be divided into sections and that one of these sections would be cut at each sampling date, throughout the course of the experiment. This method provided for measurement of the effect of dalapon on sprayed uncut herbage at regular intervals and also allowed observation of the effect of removing treated herbage at various times after treatment on subsequent regrowth.

Such a procedure was most likely to cause greater

experimental error because of the decreased plot area to be sampled at each cut. This was avoided to some extent by random allocation of the section to be cut at one particular sampling date on one particular plot. As a further safeguard, each plot was divided into six sections. At the first sampling date, one of these sections would be cut and the resulting yields analysed as rapidly as possible to find whether the sampling area was sufficiently large. If it was not, then another one or, if necessary, two sections could be cut and the yields bulked to give an adequate sampling area per plot. Such an arrangement allowed for a provisional six, three, or two sampling dates depending on the sample size required for experimental efficiency. As it happened, the single section sample proved sufficiently accurate on the first species sampled (white clover). It was therefore decided that up to six sampling dates could be used if desired.

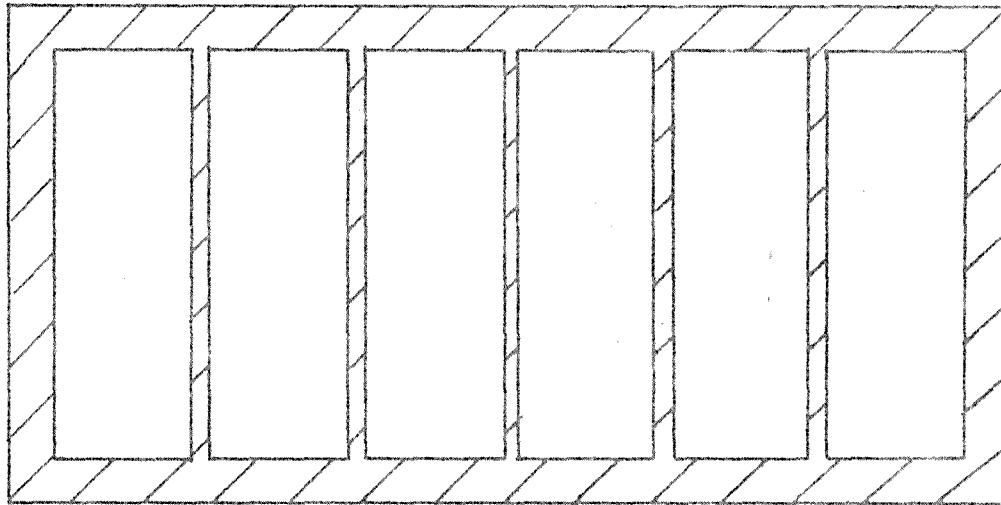
A plan of the plot subdivision into six sections together with discard areas is seen in Fig. III. The size of each section was  $4\frac{1}{2}$  feet by  $1\frac{1}{2}$  feet, giving a sampling area of 0.75 square yards per plot per cut. The random allocation of plot sample sections is illustrated in Appendix 11.

A wooden frame  $4\frac{1}{2}$  feet by  $1\frac{1}{2}$  feet was constructed to facilitate sampling, which was carried out with the aid of a pair of Wilkinson hedge shears. (See Fig. IV).

FIG. III

Plan of plot sampling sections.

Scale (1 m.m. = 1 inch)



Plot size	11 ft. by $5\frac{1}{2}$ ft.
Section size	$4\frac{1}{2}$ ft. by $1\frac{1}{2}$ ft.
Perimeter discard	6 inches.
Between section discard	$2-2\frac{1}{2}$ inches.

Fig.IV.

Sampling equipment and  
technique.



E. Treatment.

The experimental areas were mown for the last time 17 days before treatment. This produced a dense foliage cover on all but the browntop area for the interception of the spray. The height of the swards at treatment was:-

Perennial ryegrass	2½ inches
Cocksfoot	4 inches
Browntop	1 inch
White Clover	2½ inches

Dalapon was applied in the form of the normal commercial preparation, containing 85 per cent of 2,2 - Dichloropropionic acid, sodium salt. No wetting agent or surface active agent was added, so that specific differences in tolerance would be at a maximum.

The quantities of the chemical applied to the treated plots were:-

<u>Grams per plot</u>	<u>lb per acre</u>
1.26	2
2.52	4
3.78	6
5.04	8

The method of application of these small quantities required some consideration. None of the spray pumps available could deliver the spray with sufficient accuracy on a small area and a small residual amount was always left in the container. The most suitable piece of equipment available was a watering-can with a very fine rose. This delivered a fine spray, the distribution of which could be fairly well controlled. An area the size of one of the experimental plots was pegged out on a lawn and spray delivery was practised with various volumes of water to determine the least volume which would give adequate cover of the area at a reasonable walking speed. Two pints was found to suit these requirements best and some time was spent practising with this quantity of water until an even and accurate distribution of the whole amount over the plot area was obtained.

Treatments were applied on the 4th April, 1959 in <sup>at</sup> dry, sunny weather.

F. Field and laboratory sampling techniques and analysis.

(i) Field sampling.

It was found convenient to sample the individual experiments on separate days. Every endeavour was made to keep the sampling dates for each species as close as possible for comparative purposes, but the weather did not always permit this. The longest interval between sampling the first and the last species at any one period was fifteen days. The shortest was six days. The experiments were always cut in the order - white clover, browntop, cocksfoot, ryegrass, since this was the order in which treatment responses first appeared. The sampled area was cut to within half an inch of ground level and all cut herbage removed. Samples were put into polythene bags, numbered, and taken to the laboratory for analysis.

(ii) Laboratory analysis.

Samples were weighed for total fresh weight and then dissected into sown species, monocotyledonous weeds and dicotyledonous weeds. The separate constituents were then weighed and percentage by weight contribution to yield estimated. In general, the complete sample was dissected. The virtual absence of weeds in the ryegrass and cocksfoot swards in the early stages of the experiment made dissection fairly simple. Separation of clover samples took longer and very weedy samples were halved or quartered for dissection after thorough mixing. Some of the browntop samples which had a large weed content were similarly treated. The average time required for complete dissection was 20 minutes. Because of the large number of samples to be dissected, subdivision in the cases mentioned was necessary for efficiency. To test whether subdivision caused a loss of accuracy, one such weedy sample was dissected completely after thorough mixing and sub-division into four equal parts. Total dissection took three hours while dissection of one fourth of the sample took approximately 45 minutes. The small variation caused by subsampling

was considered of little consequence compared with the time saved and the number of samples involved.

As the experiments progressed, the volume of herbage for dissection became much less and complete dissection of almost all samples was possible. At the last two cuts for each species, it was also possible to separate the dead and living tissue from the sown species constituent.

The percentage productivity method of botanical analysis (after Brown, 1954) was the most suited to these experiments. It is objective and gives an estimation of the intensity of representation of species in a sward.

Fresh weight of the separate constituents was used for calculation of percentage productivity, for the sake of convenience and because several constituents, including the sown species at the high rates of application of dalapon were too small in fresh yield for satisfactory individual dry matter analysis.

All weights recorded during the experiments were in grams and weighing was carried out on an E.T.A. Triple Beam Balance which could be read to an accuracy of 0.1 gm.

After botanical dissection, subsamples of the constituents (or bulked treatment yields where individual samples were too small) were dried in a Wilco oven at 100<sup>o</sup>F. for 24 hours for the determination of dry matter percentage.

For the purposes of statistical analysis dry weight yields were used in preference to fresh weight yields because of the possible variations in fresh weight caused by weather conditions. Greenhill (1936) suggested that dry weight yield allowed the most accurate comparisons to be made within and between species at different dates.

All results are given in terms of yield in grams per

0.75 square yards.

At the last two sampling dates, where dissection of sown species into dead and live tissue was carried out, an element of personal bias was unavoidably introduced in the separation of the live and dead material. An arbitrary demarcation between the two was decided upon and adhered to as closely as possible.

In addition to plot sampling, regular detailed plot notes were taken and photographic evidence was collected to augment the information obtained from sampling and yield analysis.

## CHAPTER IV

### RESULTS

#### A. Introduction.

The four experiments are treated separately in the presentation of results. For convenience, each experiment is divided into five sections the first of which covers the period from treatment until the first sampling date, while the remainder correspond to the intervals between successive sampling dates.

Statistical analyses have been carried out on the dry matter yield of sown species in grams per 0.75 square yard. Since all other measurements taken contributed to these data, no separate statistical analyses for other measurements were considered necessary.

The following is a list of conventional abbreviations used in the presentation of statistical results and their full meaning.

d.f.	=	Degrees of freedom.
S.S.	=	Corrected sums of squares.
M.S.	=	Mean square.
F.	=	The variance ratio, for specified conditions.
p	=	Probability level.
Mean	=	The mean value, for specified characters of six plots in any one experiment at any sampling date.
General Mean	=	The mean value, for specified characters, of the thirty plots in any one experiment at any sampling date.
S.E. $\bar{x}$	=	The standard error, or the standard deviation of the mean as defined above.
N.S.	=	Result not statistically significant.
*	=	Result statistically significant at the 0.05 (5%) level.
**	=	Result statistically significant at the 0.01 (1%) level.
***	=	Result statistically significant at the 0.001 (0.1%) level.
$d_{0.05}$	=	The difference required between two means for significance at the

$d_{0.01}$  = The difference required between two means for significance at the 0.01 level.

$d_{0.001}$  = The difference required between two means for significance at the 0.001 level.

B. Meteorological data.

Figures for rainfall, soil temperature at four inches depth and grass minimum temperature over the experimental period were obtained from the records of Grasslands Division Meteorological Station, situated approximately half-a-mile from the experimental area. These figures are presented in Fig.V. They serve to give an indication of the climatic conditions influencing plant growth and the persistence of dalapon in the soil over the period from treatment until early spring. The daily rainfall figures for the first fortnight after treatment are given separately in Table III.

Table III. Daily rainfall during the first fortnight after spraying.

Days after treatment	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Rainfall (Inches)	-	0.02	1.38	0.01	0.18	0.74	-	0.14	0.01	-	-	-	0.06	0.16	0.04	2.74

Treatment was applied on a warm sunny calm day. There was no rain that day and virtually none the next day, but prolonged heavy rain fell on the following day.

Grass minimum frost days figures have been compiled to augment observational notes on the effect of frosts on treated herbage. The intensity and frequency of frosts are illustrated in Fig. V.

FIG. V.

WEATHER DATA. GRASSLANDS DIVISION METEOROLOGICAL STATION.

Temperature, Scale (5m.m. = 1°F).

4 inch soil temperature (weekly mean).

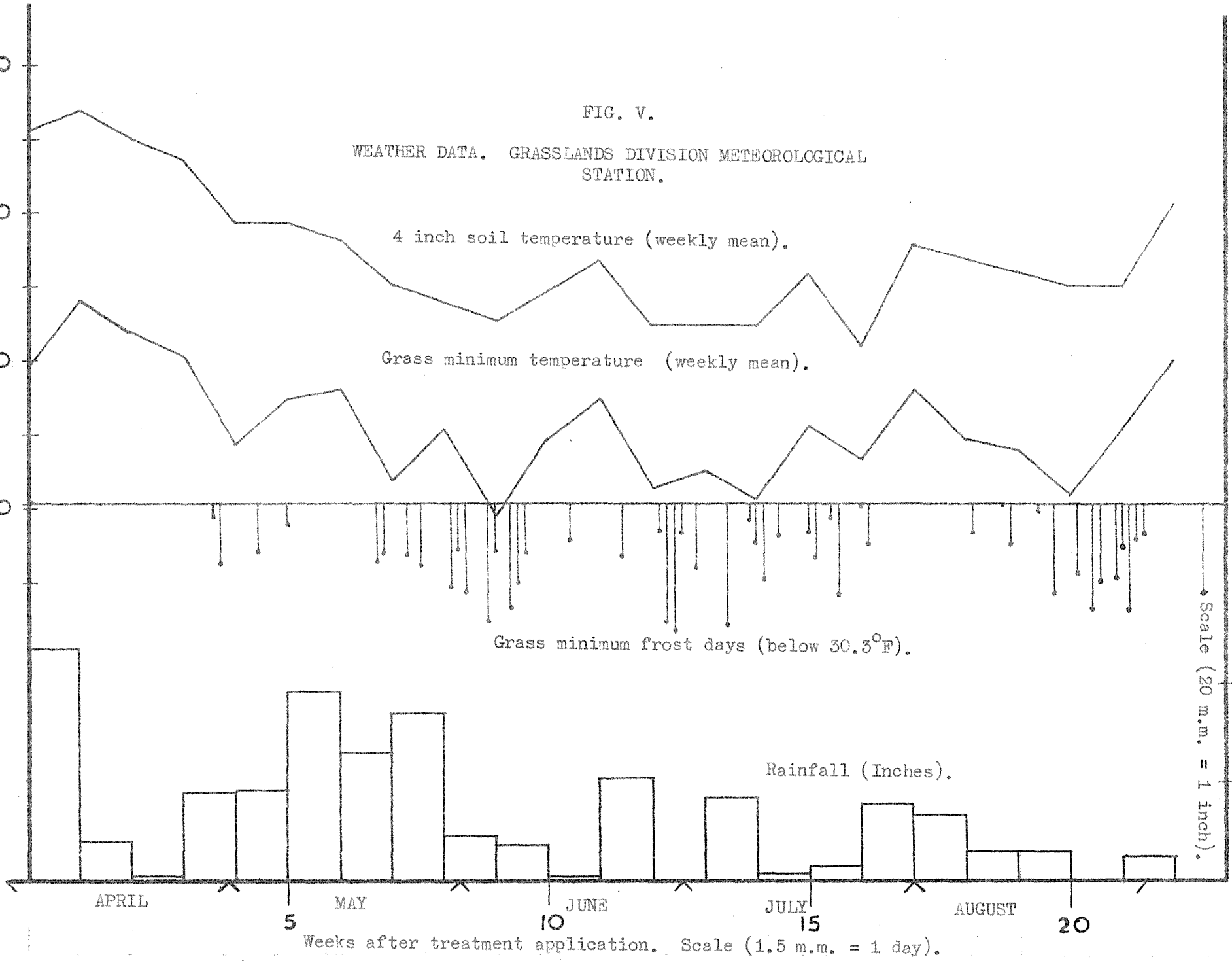
Grass minimum temperature (weekly mean).

Grass minimum frost days (below 30.3°F).

Rainfall (Inches).

Scale (20 m.m. = 1 inch).

Weeks after treatment application. Scale (1.5 m.m. = 1 day).



C. Perennial ryegrass experiment.

(i) First experimental period.

(a) Preliminary observations.

A small amount of leaf distortion was noted on dalapon-treated plots within a few days of treatment. After the first week the two higher rates of treatment could be distinguished from the two lower rates by a progressive yellowing of foliage. Control plots appeared to be growing more rapidly than treated plots. By the first sampling date these effects were quite marked.

(b) First cut (29th April - 25 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix IIIa. The general mean value was 98.4 per cent and the lowest recorded value was 95.6 per cent, indicating that the sward was virtually weed-free.

Individual plot data for dry matter yield of the sown species and details of statistical analysis of these data are shown in Appendix IIIb. The analysis of variance indicates that differences between treatments were significant ( $p = 0.001$ ). Subdivision of the treatments sums of squares indicates that treatment with dalapon caused a significant ( $p = 0.001$ ) check to growth at this stage.

Treatment means together with the standard error and the detectable differences required for significance at three levels are presented in Table IV.

Table IV. Comparison of treatment means for first cut.

Perennial ryegrass. (Dry matter yield.)

Treatment	Means	General Mean	S.E. <sub><math>\bar{x}</math></sub>	<sup>d</sup> 0.05	<sup>d</sup> 0.01	<sup>d</sup> 0.001
0	98.3	70.0	± 4.5	13.3	18.1	24.5
2	74.3					
4	67.3					
6	61.9					
8	48.4					

Fig. VIII and Table IV illustrate that at this stage in the experiment the check to growth caused by dalapon increased with increasing rates of application.

(ii) Second experimental period.

a) Intermediate observations.

The first frosts of the year occurred between the first and second cuts (see Fig. V). The tips of leaves of many plants were frosted. The death of leaves and plants as a result of treatment with dalapon progressed more rapidly on treatments 6 and 8 plots than on treatment 4 plots. Control plots continued to grow vigorously, as did treatment 2 plots, which appeared to have recovered from the effects of dalapon. At sampling time these two treatments could not be distinguished visually. Fig. VI illustrates the condition of the herbage on each treatment immediately after the second cut had been taken.

b) Second cut (17th May - 43 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix IVa. The general mean value was 97.6 per cent and the lowest recorded value was 92.3 per cent indicating that the sward was still virtually weed-free.

Individual plot data for dry matter yield of the sown species and details of statistical analysis of these data are shown in Appendix IVb. The analysis of variance indicates that differences between treatments were significant ( $p = 0.001$ ).

Treatment means, together with the standard error and the detectable differences required for significance at three levels are presented in Table V.

Fig. VI.

Perennial ryegrass.

The condition of the plots at the second sampling date -  
43 days after treatment.

Treatment rate  
lb. per acre

8

0

2

4

6



Table V. Comparisons of treatment means for second cut.  
Perennial ryegrass. (Dry matter yield).

Treatment	Means	General Mean	S.E. $\bar{x}$	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	93.0	65.3	+ 3.6	10.6	14.5	19.6
2	84.8					
4	61.2					
6	47.5					
8	39.9					

Fig. VIII and Table V illustrate that the increased check to growth as rates of applications of dalapon increased had become more marked at this cut. The observational report that treatment 2 plots had apparently recovered from the effect of treatment is confirmed. The difference between yields from control and treatment 2 plots was less at this cut than at the previous one. The severity of the effect of dalapon on treatments 4, 6 and 8 plots is masked by the contribution to dry matter yield of dead and dying herbage, very little of which had decomposed by this sampling date.

(iii) Third experimental period.

a) Intermediate observations.

A series of sharp frosts (see Fig. V) occurred between the second and third sampling dates. The tips of leaves on control plots were frosted. The first of these frosts, on the 21st May caused a visible check to growth on treatment 2 plots. There was a considerable increase in the amount of dead and dying tissue on treatments 4, 6 and 8 plots over a period of two or three days. Heavy rain during the latter half of May led to considerable decomposition of dead material, especially on treatments 6 and 8 plots. At the time of sampling, all treatments, except 6 and 8 could be visually distinguished from one another.

b) Third cut (9th June - 66 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix Va. The general mean value was 98.7 per cent and the lowest recorded value was 92.1 per cent, indicating that the sward was still virtually weed-free.

Individual plot data for dry matter yield of the sown species and details of statistical analysis of these data are shown in Appendix Vb. The analysis of variance indicates that treatment differences were significant. ( $p = 0.001$ ).

Treatment means, together with the standard error and the detectable differences required for significance at three levels are presented in Table VI.

Table VI. Comparison of treatment means for third cut.

Perennial ryegrass. (Dry matter yield.)

Treatment	Means	General Mean	S.E. $\bar{x}$	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	108.1	64.7	± 9.4	27.9	38.0	51.5
2	80.1					
4	54.9					
6	49.0					
8	31.5					

Fig. VIII and Table VI illustrate that the trend of lower yield with increasing rates of dalapon continued. The gap between yields from control and treatment 2 plots was greater at this cut than at the previous one. The full severity of the effect of dalapon was masked at this cut also by the contribution to dry matter yield of dead and dying herbage.

(iv) Fourth experimental period.

a) Intermediate observations.

Little change was observed on dalapon-treated plots between

the third and fourth cuts, apart from the gradual decrease in the amount of dead herbage. Considerable variation in the rate of decomposition of dead herbage within treatments was noticed, especially at the two higher rates of treatment. Growth continued on control plots but there was a tendency for the taller foliage to flag over by the time of the fourth cut, and some of the older leaves began to turn yellow. The three sharp frosts on 29th and 30th June and 7th July did not appear to have any further effect on treated plots.

b) Fourth cut (7th July - 94 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix VIa. The general mean value was 96.3 per cent and the lowest recorded value was 88.8 per cent. At this stage there was little weed, despite the low yield of ryegrass from higher treatments.

It was possible at this sampling date to separate live and dead tissue of the sown species in the laboratory. Data were then calculated and analysed for the dry matter yield of the sown species (Live Herbage) and the dry matter yield of the sown species (Total). Individual plot data and details of statistical analysis for both these measurements appear in Appendices VIb and VIc respectively. The analyses of variance both indicate that treatment differences were significant ( $p = 0.001$ ).

Treatment means, together with standard errors and the detectable differences required for significance at three levels are presented in Table VII.

Table VII. Comparisons of treatment means for fourth cut.

Perennial ryegrass. (Dry matter yield).

Treatment	Measurement	Means	General Mean	S.E. <sub><math>\bar{x}</math></sub>	<sup>d</sup> 0.05	<sup>d</sup> 0.01	<sup>d</sup> 0.001
0	Live herbage	106.0	47.3	+7.8	22.9	31.3	42.3
	Total	132.9	69.5	+10.9	32.1	43.8	59.3
2	Live herbage	61.1					
	Total	92.3					
4	Live herbage	34.4					
	Total	56.0					
6	Live herbage	17.4					
	Total	33.0					
8	Live herbage	17.7					
	Total	33.4					

Separation of live from total herbage allowed a more accurate estimation of the effect of dalapon on plot yield. Fig. VIII and Table VII give an indication of the relative amounts of dead herbage in each treatment. The dead herbage in control plots is due to the death of old leaves, possibly accelerated by frost damage. These may have contributed in some measure to the amount of dead herbage on treatments 2 and 4 plots also. The relative differences between treatments remain the same whether total yield or live herbage yield are considered. The trend of decreased yield with increased rate of dalapon is still evident, although the two higher rates have become indistinguishable. Total yield figures suggest a continued growth increase on control plots and perhaps on treatment 2 plots. The gap between these two treatments and the remainder is greater than at the previous cut. Treatment 4 both in terms of total herbage and live herbage yield was intermediate between treatment 2 and treatments 6 and 8.

(v) Fifth experimental period.

a) Intermediate observations.

Fourth cut until the end of July.

There were very few signs of active growth on any of the treated plots for about three weeks after the fourth cut. Plot inspection revealed a progressive increase in the mortality of old leaves on control plots and, to a lesser extent on treatment 2 plots. This coincided with a period of dry weather and frosts (see Fig.V). Most of the dead herbage on treated plots had decomposed and there was no evidence of any further deterioration of treated plots due to the effect of dalapon. A series of photographs was taken to illustrate the stage of growth and condition of the ryegrass plants under the various treatments at this time. They also provide an indication of ground cover and the ingress of weeds which had commenced after the fourth cut. In particular they show the patchy nature of ryegrass plant survival under treatments 6 and 8. (see Fig. VII). The photographs were taken on the 28th July, 115 days after treatment.

End of July until the fifth cut.

During the last week in July there was evidence of the slow commencement of growth of the surviving plants on all plots. The death of old herbage continued on control and treatment 2 plots, apparently accelerated by the succession of sharp frosts which occurred during the last fortnight before the final cut. At the same time fresh shoots were appearing through the mat of older herbage which by this time had settled down considerably. Growth on treatments 4, 6 and 8 plots was due to the production of new shoots by surviving plants. There was no indication of the germination of seedling ryegrass plants, nor of frost damage to new growth on any treatment. Weeds rapidly colonised the bare ground between surviving plants and it was considered that, although the

Fig. VII.

- 60a -

Perennial ryegrass plots. 28th July, 1959.

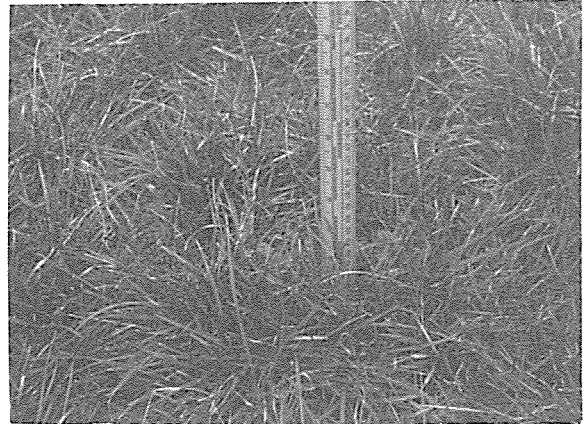
Control



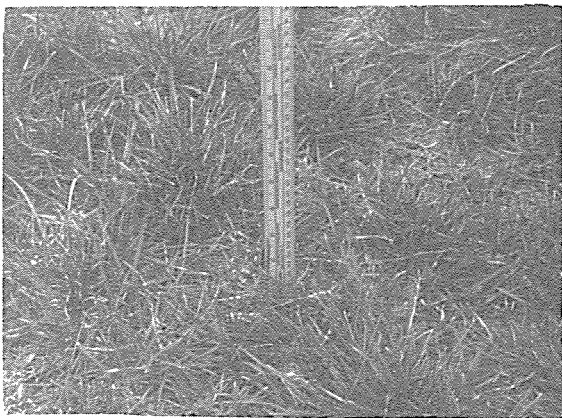
2 lb. per acre



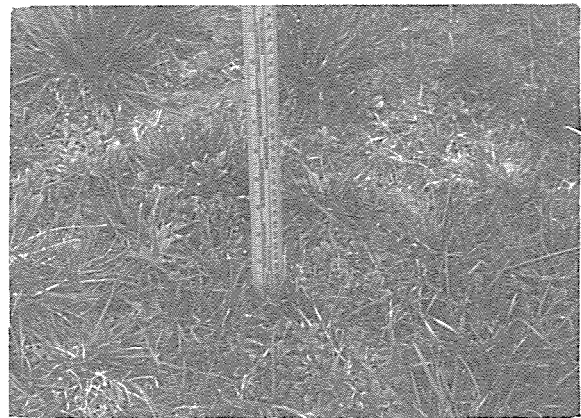
4 lb. per acre



6 lb. per acre



8 lb. per acre



surviving ryegrass plants showed no signs of being suppressed by the weeds, there was no possibility of the sown species regaining control of the sward on treatments 6 and 8 plots. There were, however, sufficient surviving plants close enough together on treatment 4 plots to give the sward a reasonable chance of recovering to complete ryegrass dominance with suitable management.

It was noted that the young growth of ryegrass on treated plots was much darker green and appeared much healthier than that produced by control plots. Accordingly, a bulked sample of fresh young growth from each treatment was analysed for crude protein content. (See Table VIII)

Table VIII. Comparison of treatments for crude protein content of fresh young growth. Perennial ryegrass.

Treatment	0	2	4	6	8
Percentage Crude Protein	11.2	12.6	13.4	13.3	13.2

Each figure is the average of two readings for each bulked treatment sample. It is not possible to calculate a standard error for these values, but the correlation between crude protein and rate of dalapon ( $r = 0.832$ ,  $p = 0.06$ ) shows that the crude protein content of the fresh herbage increased with rate of dalapon.

b) Fifth cut (7th September - 156 days after treatment).

This last cut was delayed for as long as possible to allow treated plots every opportunity to show whether or not they would recover.

The percentage contribution of the sown species to plot yield is shown in Appendix VIIa. Poa annua was the major weed of control plots, while treatment 2 plots contained few weeds. Treatment 4 plots contained a proportion of dicotyledonous weeds. The weed population on treatments 6 and 8 plots showed considerable variation between plots.

The weed cover was underestimated in these two treatments by laboratory analysis, since many of the weeds were below sampling height. The ryegrass yield from these plots resulted from the sampling of a few isolated plants growing vigorously, but surrounded by a carpet of seedling weeds. Cerastium species and Cotula species were the major weeds.

Dead and live herbage was separated for the calculation of yield data. Individual plot data and details of statistical analysis of dry matter yield of sown species for live herbage and for total herbage appear in Appendices VIIb and VIIc respectively. The analyses of variance in both cases indicate that treatment differences were significant ( $p = 0.001$ ).

Treatment means, together with standard errors and the detectable differences required for significance at three levels are presented in Table IX.

Table IX. Comparison of treatment means for fifth cut.

Perennial ryegrass. (dry matter yield.)

Treatment	Measurement	Means	General Mean	S.E. $\bar{x}$	$d_{0.05}$	$d_{0.01}$	$d_{0.00}$		
0	Live herbage	82.7	51.9 77.9	+8.3 - + 13.9	24.6	33.5	45.4		
	Total	135.0						41.1	56.1
2	Live herbage	74.6							
	Total	115.8							
4	Live herbage	41.8							
	Total	61.3							
6	Live herbage	31.9							
	Total	41.7							
8	Live herbage	28.6							
	Total	35.8							

Fig. VIII and Table IX give an indication of the relative amount of dead herbage in each treatment. The large proportion of dead herbage on control and treatment 2 plots confirms the observation that considerable

death of foliage had occurred. The production of new herbage on treatment 2 plots had apparently kept pace with the death of old herbage, but on control plots, the rate of death of old herbage between cuts was considerably greater than the production of fresh growth to replace it. The yields from treated plots at this cut still reflected a linear trend in regard to increasing rates of application of dalapon, except for treatments 6 and 8 which, as at the previous cut were indistinguishable. In terms of live herbage yield, the difference between control and treatment 2 had become much less at the fifth cut than at the fourth cut. In all treated plots there was evidence of an increase in the production of live herbage between the two cuts. This confirmed the observational report.

(vi) Regrowth.

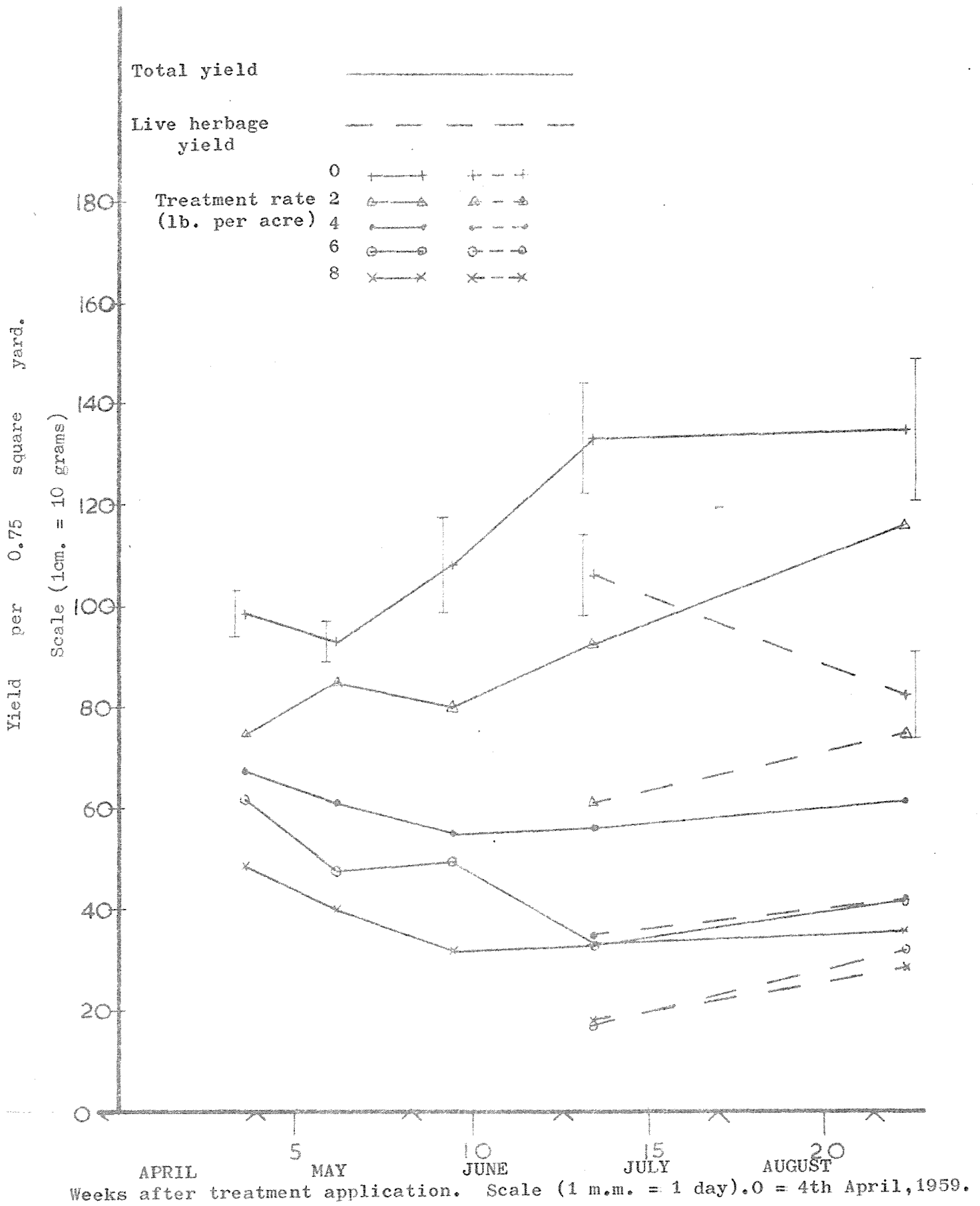
Observations were made on the regrowth of herbage on the previous cut areas of each plot. Regrowth was rapid from the first cut of control and treatment 2 plots, and could be distinguished from that of subsequent cuts until after the fourth sampling date. By the fifth sampling date, the regrowth from the various cuts could not be distinguished. Very little regrowth from any previous cut occurred with the other treatments until the end of July. From then onwards it was not possible to distinguish between areas which had or had not been previously cut on treatments 6 and 8 plots. Uncut areas could, however, be distinguished on treatment 4 plots.

At the fifth sampling date the herbage on previously cut areas on treatment 2 plots appeared more vigorous and was a darker colour than that on control plots, which showed symptoms of a lack of nitrogen. The herbage on treatment 4 plots was similar to that on treatment 2 plots, but the sward was less dense and contained more weeds. The herbage and the amount of weeds on previously cut areas of treatments 6 and 8 plots were similar to that on the uncut area which has been described above.

Fig. VIII.

- 63a -

Perennial ryegrass. Dry matter yield of sown species. Treatment means.



D. Cocksfoot experiment.

(i) First experimental period.

a) Preliminary observations.

Leaf distortion was very noticeable on treated plots within a few days of the application of dalapon. By the end of the first fortnight leaf discoloration became visible on all treated plots, until by the first sampling date treatments 6 and 8 could be distinguished from treatments 2 and 4 by the degree of discoloration. Further growth on treated plots had apparently ceased as a result of treatment, whereas untreated plots had continued to grow vigorously and could be distinguished from treated plots by the greater volume of herbage present, as well as by foliage colour.

b) First cut (27th April - 23 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix VIIIa. The general mean value was 98.5 per cent and the lowest recorded value was 94.4 per cent, indicating that the sward was virtually weed-free.

Individual plot data for dry matter yield of the sown species and details of statistical analysis of these data are shown in Appendix VIIIb. The analysis of variance indicates that treatment differences were significant ( $p = 0.001$ ). Subdivision of the treatments sums of squares indicates that treatment with dalapon caused a significant ( $p = 0.001$ ) check to growth at this stage.

Treatment means, together with the standard error and the detectable differences required for significance at three levels are presented in Table X.

Table X. Comparison of treatment means for first cut.

Cocksfoot. (Dry Matter yield.)

Treatment	Mean	General mean	S.E. $\frac{s}{x}$	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	123.6	92.3	+ 5.9	17.5	23.8	32.2
2	90.8					
4	84.5					
6	79.0					
8	83.6					

Fig. XII and Table X illustrate that the main difference at this stage of the experiment occurred between control and treated plots. No trend within treated plots as a result of increasing rates of application of dalapon could be detected. The effect of dalapon appeared to consist mainly of a check to further growth.

(ii) Second experimental period.

a) Intermediate observations.

The first four frosts of the year occurred between the first and second cuts. Little damage resulted from the first one (see Fig. V), but the second frost on the 29th April caused considerable death of foliage and a severe check to growth on all treated plots, including treatment 2 which up until this time had shown signs of having recovered from treatment with dalapon. The change in the appearance of treated plots overnight was remarkable. The third frost on the 4th May caused more death of foliage on treatment 2 plots. Virtually all the herbage on treatments 6 and 8 plots turned brown overnight and inspection revealed that although the plants themselves were still alive, all the top growth had been killed. The effect of these frosts on control plots was limited to the death of the tips of the leaves of some of the more mature foliage.

At the time of sampling, little decomposition of dead and dying herbage had occurred. However, 0.58 inches of rain on the day after sampling accelerated the knockdown and decomposition of dead material. Fig. IX illustrates the condition of the herbage just prior to sampling.

b) Second cut (14th May - 40 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix IXa. The general mean value was 97.9 per cent and the lowest recorded value was 90.1 per cent, indicating that few weeds were present.

Individual plot data for dry matter yield of the sown species and details of statistical analysis of these data are shown in Appendix IXb. The analysis of variance indicates that treatment differences were significant ( $p = 0.001$ ).

Treatment means, together with the standard error and the detectable differences required for significance at three levels are presented in Table XI.

Table XI. Comparison of treatment means for second cut.

Cocksfoot. (Dry Matter yield.)

Treatment	Mean	General Mean	S.E. $\bar{x}$	<sup>d</sup> 0.05	<sup>d</sup> 0.01	<sup>d</sup> 0.001
0	121.4	78.9	+ 5.8	17.2	23.5	31.8
2	89.5					
4	71.0					
6	57.2					
8	55.3					

Fig. XII and Table XI illustrate that at this cut yield declined as rates of dalapon increased, although treatments 6 and 8 were indistinguishable. The relative position of control plots in relation to treated plots was similar to that at the first cut. Differences

Fig. IX.

Cocksfoot.

The condition of the herbage at the second sampling date -  
40 days after treatment.

Treatment  
rate -  
lb. per  
acre. 2

6

8

0

4



between yields of treated plots were, however, more marked, since the yields from treatments 4, 6 and 8 had declined. The amount of dead and dying herbage on these treatments masked the full effect of the chemical at this stage since relatively little decomposition had occurred. This herbage contributed to dry matter yield. For all practical purposes there was no live herbage in the samples taken from treatments 6 and 8 plots

(iii) Third experimental period.

a) Intermediate observations.

Heavy rain during the latter half of May accelerated the knockdown and decomposition of dead herbage. A series of sharp frosts (see Fig. V) prior to the third cut caused further death of herbage on treatments 2 and 4 plots. Frost damage also caused the death of the top two or three inches of mature foliage on control plots. This contrasted with the effect on treated plots, where the whole leaf turned brown, rather than the tip.

By the third sampling date, control plots were still producing fresh shoots, as were treatment 2 plots, although much of the original foliage on the latter had died. Virtually all the top foliage on treatment 4 plots was dead, but plants were still putting out new shoots, although these grew very slowly. There was no indication of recovery growth from treatments 6 and 8, but close investigation revealed that many plants were still alive.

b) Third cut (5th June - 62 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix Xa. The general mean value was 96.6 per cent and the lowest recorded value was 85.0 per cent, which was due to a clump of perennial ryegrass in the sampled section of the plot. Apart from this, there were few weeds. There was virtually no live herbage from treatments 6 and 8, and the majority of the live herbage from treatments 2 and 4 was

new growth. Control plots contained mostly live original herbage with dead leaf tips and a proportion of undamaged new growth.

Individual plot data for dry matter yield of the sown species and details of statistical analysis of these data are shown in Appendix Xb. The analysis of variance indicates that treatment differences were significant ( $p = 0.001$ ).

Treatment means, together with the standard error and the detectable differences required for significance at three levels are presented in Table XII.

Table XII. Comparison of treatment means for third cut.

Cocksfoot. (Dry matter yield).

Treatment	Mean	General Mean	S.E. <sub><math>\bar{x}</math></sub>	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	117.3	63.4	+7.1	20.8	28.4	38.5
2	73.8					
4	47.2					
6	39.2					
8	39.8					

Fig. XII and Table XII illustrate the increasing gap between control and treated plots. A decline in the yield of all treated plots occurred between the second and third cuts. There was little change in the dry matter yield of control plots, suggesting that the production of fresh growth balanced the decay of dead herbage. Observational notes indicate that the decline in yield of treated plots was mainly due to the decomposition of dead herbage.

(iv) Fourth experimental period.

a) Intermediate observations.

During this period, increasing death of mature foliage on control

plots was observed and much of the foliage was beginning to flag over. These processes appeared to be accelerated by frost and rain. The death of the original herbage on treatment 2 plots continued, but both these treatments were producing fresh growth. New shoots from treatment 4 plots continued to grow slowly. There was no visual evidence of distortion of new leaves produced by surviving plants on treatments 2 and 4 plots. In contrast, there was no fresh growth from plants on treatments 6 and 8 plots and close inspection showed that only a few plants were still alive. The bare ground resulting from the complete kill and rapid decomposition of herbage on treatments 6 and 8 plots encouraged the germination of weed seeds. Fig. X illustrates the condition of the herbage on treatments 0, 4 and 8 plots at the time of sampling.

b) Fourth cut (2nd July - 89 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix XIa. There were few weeds on control plots and varying amounts of dicotyledonous weeds, mainly chickweed (Cerastium species) in treated plots. Occasional clumps of weed had a considerable influence on the composition of samples because of the small contribution of sown species to yield on treated plots. Samples from treatments 6 and 8 had only an occasional live leaf of cocksfoot. At this sampling date it was possible to separate live and dead tissue of sown species in the laboratory. Data were then calculated for the dry matter yield of the sown species (Live Herbage) and of sown species (Total).

Because of the clear differences between the control data and those for the dalapon treatments, both in mean levels and variability, it was necessary to exclude control plots from the analysis of variance to allow a valid standard error to be calculated for comparison between the remaining treatments.

Individual plot data and details of statistical analysis for dry matter yield of sown species (Live Herbage) and dry matter yield of

Fig. X.

- 69a -

Cocksfoot plots. 4th sampling date.

Control



4 lb. per acre



8 lb. per acre



sown species (Total) are shown in Appendices Xib and Xic respectively. The analysis of variance indicates that treatment differences were significant ( $p = 0.01$ ).

Treatment means, together with standard errors and the detectable differences required for significance at three levels are presented in Table XIII.

Table XIII. Comparison of treatment means for fourth cut.

Cocksfoot. (Dry matter yield.)

Treat- ment	Measure- ment	Mean	General Mean	S.E. $\bar{x}$	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	Live herbage Total	72.9 131.3		+10.2 ± 14.2			
2	Live herbage Total	14.0 61.8	6.6 42.9	+2.3 +5.4	7.0 16.2	9.6 22.3	13.3 30.9
4	Live Herbage Total	10.2 44.5					
6	Live herbage Total	1.1 36.3					
8	Live herbage Total	1.1 28.8					

Separation of live from total herbage allowed the full effect of dalapon at this stage to be assessed. Fig. XII and Table XIII give an indication of the relative amounts of dead herbage in each treatment. Control and treatment 2 plots contained a large amount of undecomposed dead herbage. The total yield figures for treatments 6 and 8 disguise the fact that there was virtually no live herbage on these plots. The live herbage figures for treatments 2 and 4 are derived mainly from new growth since treatment. The low dry matter percentage of this material relative to that obtained for live herbage from control plots causes dry matter yield

to show a greater difference between control and these treatments than fresh weight figures suggested. There was little difference in live herbage yield between treatments 2 and 4. Considerable variability between plots within each treatment in terms of live herbage yield existed.

(v) Fifth experimental period.

a) Intermediate observations.

Fourth cut until the end of July.

There were few signs of active growth on any plots for two or three weeks after the fourth cut. Continuing frosts caused more death of old leaves in control plots. Live herbage on control or on treatments 2 4 plots was unaffected. The majority of the old herbage on treated plots had decomposed, with the exception of treatment 2 plots where many of the dead leaves were still attached to the plant. Inspection revealed that only an occasional cocksfoot plant remained alive on treatments 6 and 8 plots, and there was no evidence of the production of new shoots. Weeds and rushes were rapidly colonising all the bare patches on these and on treatment 4 plots. A series of photographs was taken on the 28th July, 115 days after treatment, to illustrate the condition of the plots at this time. (See Fig. XI).

End of July until fifth cut.

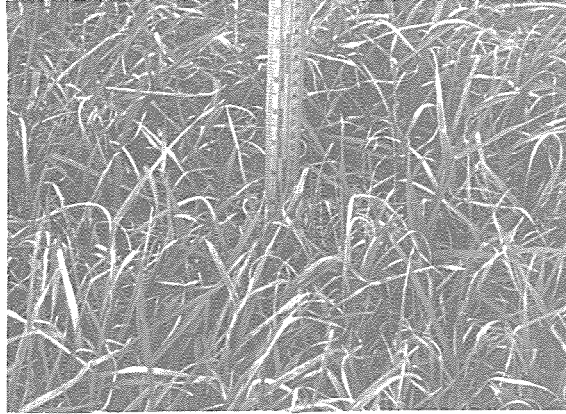
During the last week in July there was evidence of the slow commencement of growth of the surviving plants on all plots. Deterioration of the old herbage on control plots continued, the canopy began to settle down and new shoots appeared through it. Little by way of weeds was present in control plots, due to the dense canopy. Fresh growth and dead tissue on treatment 2 plots also gave a good canopy and although weeds occupied some areas of the plots, there was a fairly even distribution of live cocksfoot plants over the plots. By the fifth sampling date, it

Fig. XI.

- 71a -

Cocksfoot plots. 28th July, 1959.

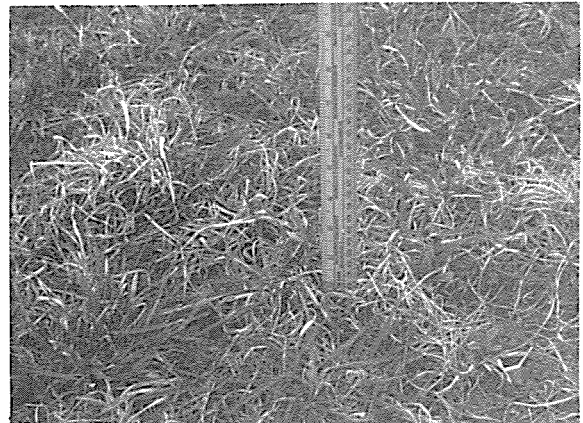
Control



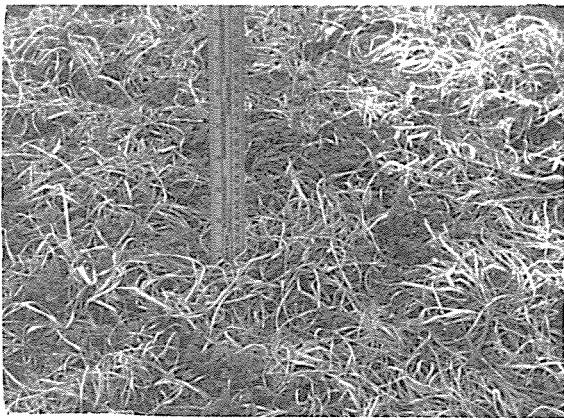
2 lb. per acre



4 lb. per acre



6 lb. per acre



8 lb. per acre



became apparent that recovery would be sufficiently vigorous to smother most of the weeds in a relatively short time. The sward was much thinner on treatment 4 plots and although surviving plants were showing vigorous growth of new shoots, weeds had taken control of large areas of the plots. It was considered that the surviving plants were too far apart and that the weeds had gained too great a foothold for cocksfoot to take control of the sward again. A very occasional plant had survived on treatments 6 and 8 plots, and had produced a few small leaves. These plants were not expected to survive competition from the dense carpet of weeds which was rapidly covering the plots. There was no indication of seedling plants of cocksfoot on any plot.

b) Fifth cut (6th September - 155 days after treatment.)

This last cut was delayed as long as possible to allow treated plots every opportunity to show whether or not they would recover.

The contribution of the sown species to plot yield is shown in Appendix XIIa. Control plots were still virtually weed-free except for an occasional clump of perennial ryegrass. This was also the major grass weed in other treatments, especially treatment 2. Botanical dissection data considerably underestimated the weed cover for higher treatments since much of the weed population was below sampling height. The main dicotyledonous weeds were Cerastium species and Cotula species. Live and dead tissue of the sown species was separated.

It was necessary to exclude control plots from the analysis of variance at this cut also. Individual plot data and details of statistical analysis for dry matter yield of the sown species (Live Herbage) and of sown species (Total) are shown in Appendices XIIb and XIIc respectively. The analysis of variance indicates that there were significant differences between treatments for both live herbage yield ( $p = 0.01$ ) and total yield ( $p = 0.001$ ).

Treatment means together with standard errors and the detectable differences required for significance at three levels are presented in Table XIV.

Table XIV. Comparison of treatment means for fifth cut.

Cocksfoot. (Dry matter yield).

Treat- ment	Measure- ment	Mean	General Mean	S.E. <sub><math>\bar{x}</math></sub>	<sup>d</sup> 0.05	<sup>d</sup> 0.01	<sup>d</sup> 0.001
0	Live herbage Total	83.7 171.9		+6.2 -12.8 +			
2	Live herbage Total	32.6 73.7	16.9 34.8	±4.0 ±8.0	12.2 24.2	16.9 33.4	23.3 46.2
4	Live herbage Total	14.2 27.4					
6	Live herbage Total	14.1 23.2					
8	Live herbage Total	6.8 15.0					

Fig. XII and Table XIV give an indication of the relative amounts of dead herbage remaining in each treatment. The gap between total herbage and live herbage in control plots had increased between cuts, indicating that the rate of production of new herbage was not sufficient to replace the deterioration in old herbage. Treatment 2 plots also contained a large amount of undecomposed dead herbage. The increase in live weight yield of this treatment confirms observational reports on recovery. Comparisons of live yield figures for treatments 4, 6 and 8 are inconclusive. This is due to the variability of plant distribution on treatment 4 plots and to the encroachment of cocksfoot from discard areas on treatments 6 and 8 plots

(vi) Regrowth.

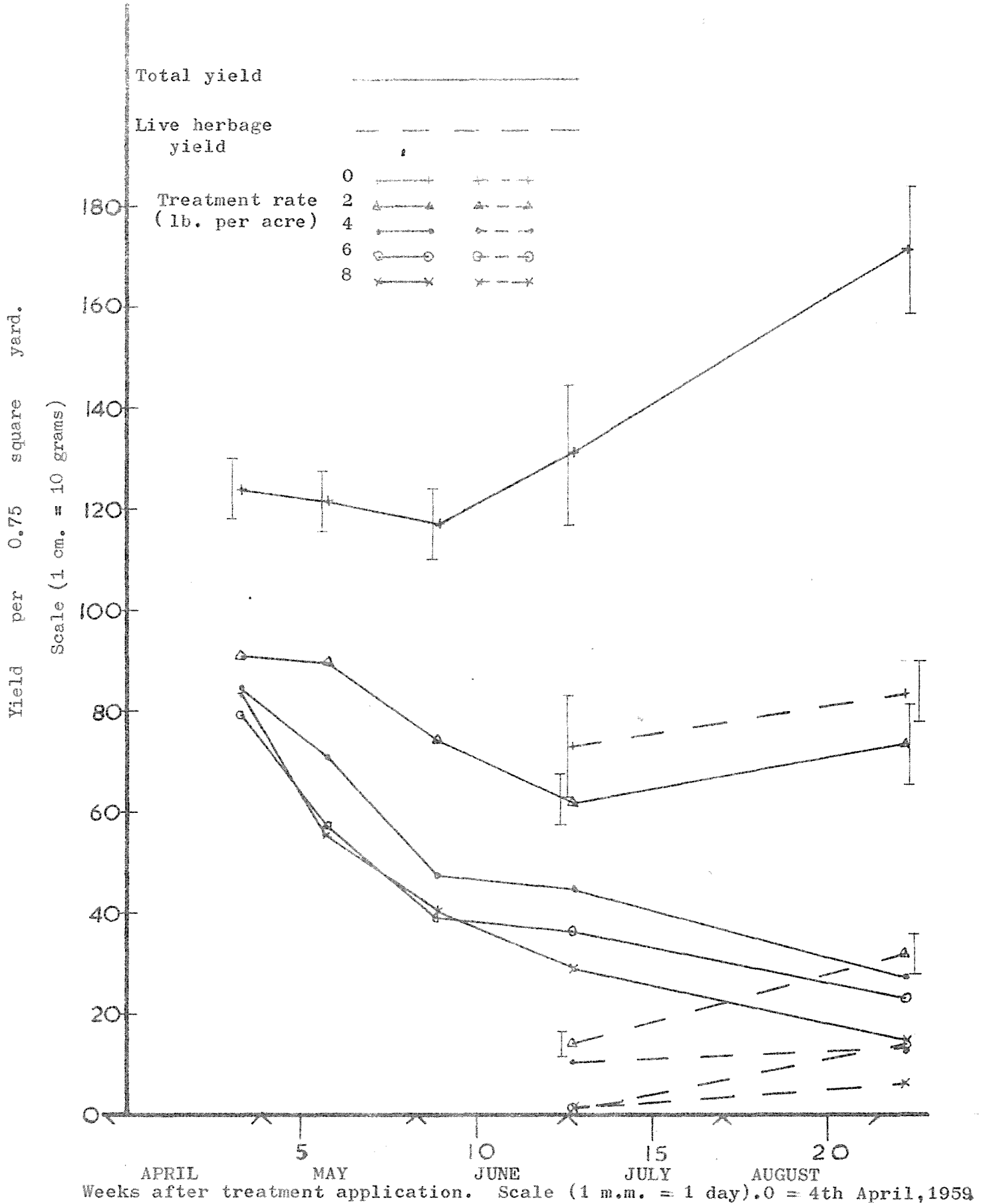
Observations were made on the regrowth of herbage on the previously cut areas of each plot. Recovery from the first cut was rapid on control and treatment 2 plots, but very slow on the rest. By the fourth cut, regrowth on treatments 6 and 8 had died and cut areas were indistinguishable from uncut areas except for the larger proportion of undecomposed dead material on uncut areas. Regrowth on treatments 2 and 4

plots was similar to that on uncut areas. At the time of the fifth cut, regrowth areas on control plots were indistinguishable and formed a dense sward with few weeds. Cut areas on treated plots could not be distinguished except for the amount of dead herbage, from uncut areas.

Fig. XII.

- 74a -

Cocksfoot. Dry matter yield of sown species.  
Treatment means.



E. Browntop Experiment.

(i) First experimental period.

a) Preliminary observations.

Some leaf distortion was observed on treated plots within a few days of treatment and by the end of a week the herbage on all treated plots was turning yellow. Growth apparently ceased on these plots, while control plots continued to produce a new foliage. By the first sampling date control plots could be distinguished by their greater amount of herbage and by their colour. No difference between treated plots could be observed.

b) First cut (21st April - 17 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix XIIIa. Considerable variation existed between plots due to the lack of uniformity of the area before treatment. Very few dicotyledonous weeds were present and the main impurities were perennial ryegrass, Poa annua and various rushes and sedges. However, in all but two of the plots browntop was the dominant species.

Individual plot data for dry matter yield of sown species and details of statistical analysis of these data are shown in Appendix XIIIb. The analysis of variance indicates that treatment differences were not significant. Subdivision of the treatment sums of squares, however, indicates that there was a significant difference ( $p = 0.01$ ) between treatment with dalapon and no treatment.

Treatment means, together with the standard error and the detectable differences required for significance at three levels are presented in Table XV.

Table XV. Comparison of treatment means for first cut.  
Browntop. (Dry matter yield).

Treatment	Mean	General Mean	S.E. $\bar{x}$	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	63.8	47.6	+ 6.0 - 6.0	17.9	24.4	33.0
2	43.1					
4	45.8					
6	44.9					
8	40.6					

Fig. XV and Table XV illustrate that the main difference at this stage was between control and treated plots. No trend within treated plots as a result of the increasing rates of dalapon could be detected.

(ii) Second experimental period.

a) Intermediate observations.

The first frosts of the year (See Fig. V) occurred between the first and second cuts, but no effect on browntop plants, treated or untreated, was observed. Progressive yellowing of treated herbage was noted and by the second sampling date it was possible to distinguish the two higher rates of application of dalapon from the two lower rates by the degree of discoloration of the herbage. Control plots continued to grow. Fig. XIII illustrates the condition of the herbage on the day of the second cut.

b) Second cut (8th May - 34 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix XIVA. The variability was less at this cut, due to a marked decrease in the amount of grass weed seedlings and rush seedlings on treated plots which had apparently been killed by dalapon.

In order to assess more accurately the effects of different

Browntop.

The condition of the plots at the second sampling date -  
34 days after treatment.

Treatment rate  
lb. per acre

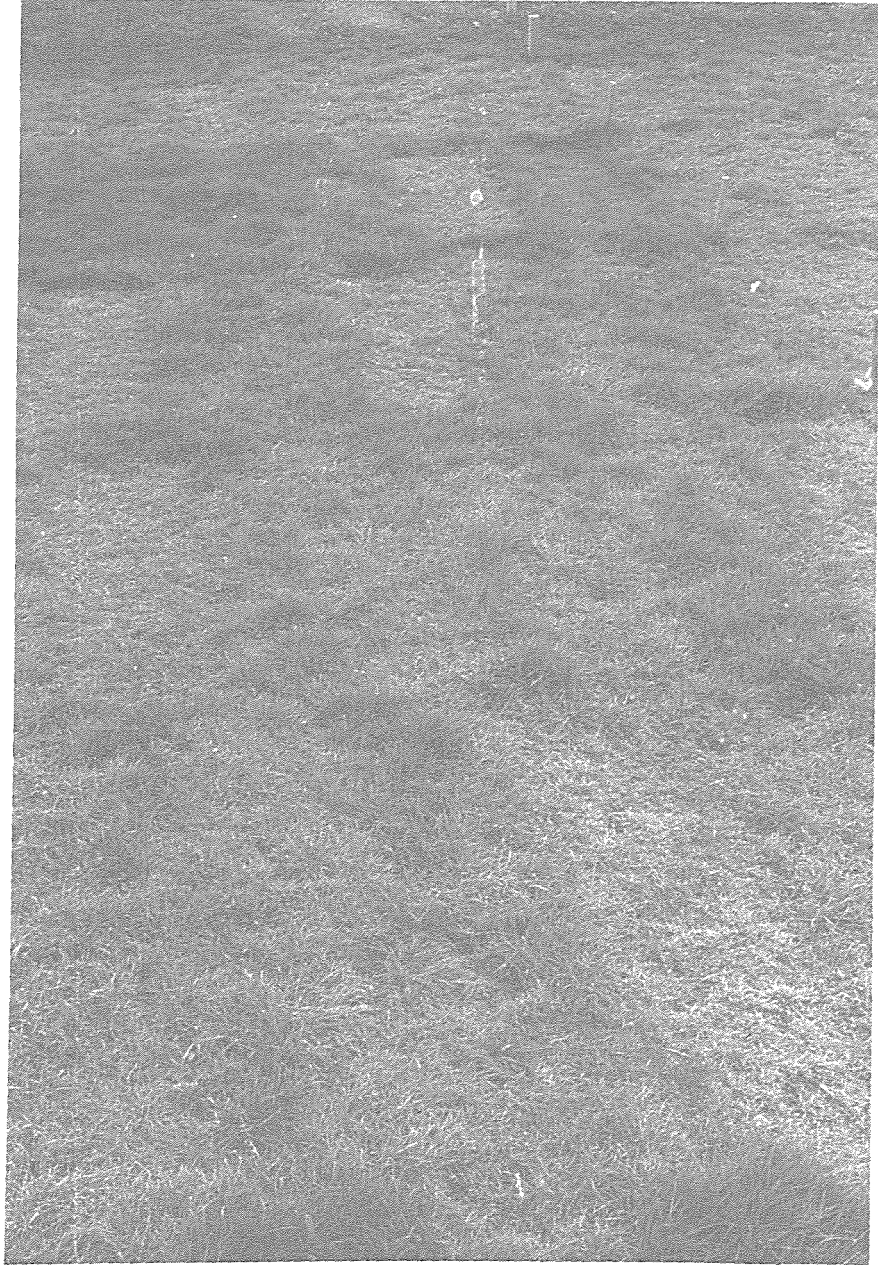
6

0

2

4

8



rates of treatment with dalapon, control plots were excluded from the analysis of variance. Individual plot data and details of statistical analysis for dry matter yield of sown species are shown in Appendix XIVb. The analysis of variance indicated that differences between treatments were not significant. No significant difference could be detected between the lower (2 and 4) and higher (6 and 8) rates of treatment, although yield data suggested that treatments might be grouped together in such a way.

Treatment means, together with standard errors and the detectable differences required for significance at three levels are presented in Table XVI.

Table XVI. Comparison of treatment means for second cut.

Browntop. (Dry matter yield).

Treatment	Mean	General Mean	S.E. $\bar{X}$	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	67.5		$\pm 13.1$			
2	39.4	36.4	$\pm 6.2$	18.7	25.9	35.8
4	41.4					
6	31.0					
8	34.0					

Fig. XV and Table XVI illustrate that the main difference at this stage was still between treated and untreated plots. No trend corresponding with increasing rates of application of dalapon was apparent. Yields from treated plots tended to be less than at the previous cut.

(iii) Third experimental period.

a) Intermediate observations.

Frosts over this period (see Fig. V) killed the tips of a few leaves on control plots, but no sharp effect on treated plots was observed. Treated herbage slowly and progressively turned brown and died on treatments 6 and 8 plots. Some clumps of more mature herbage on treatments

2 and 4 plots were apparently unaffected at this stage. By the third sampling date, considerable death of foliage on treated plots had occurred. There was no indication of the production of new shoots on any but control plots. Heavy rain during the latter part of May assisted the knockdown and decomposition of dead herbage.

b) Third cut (3rd June - 60 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix XVa. Very few grass or rush weeds were present in treated plots and the impurities consisted mainly of Cerastium species and Cotula species which were colonising some of the bare patches in the sward resulting from pre-treatment weeding. Monocotyledonous weeds were the main impurities in control plots.

Control plots were excluded from the analysis of variance. Individual plot data for dry matter yield of sown species and details of statistical analysis of these data are shown in Appendix XVb. The analysis of variance indicates that treatment differences were not significant. However, subdivision of the treatments sums of squares indicates that a significant difference could be detected between low and high rates of dalapon.

Treatment means, together with the standard errors and the detectable differences required for significance at three levels are presented in Table XVII.

Table XVII. Comparison of treatment means for third cut.

Browntop. (Dry matter yield).

Treatment	Mean	General Mean	S.E. <sub><math>\bar{X}</math></sub>	<sup>d</sup> <sub>0.05</sub>	<sup>d</sup> <sub>0.01</sub>	<sup>d</sup> <sub>0.001</sub>
0	73.5		± 11.1			
2	30.2	22.3	± 4.7	14.1	19.5	27.0
4	27.0					
6	18.5					
8	13.4					

Fig. XV and Table XVII illustrate that the gap between control and treated plots was much greater than at previous cuts. Yields from treated plots had declined considerably since the previous sampling date, and treatments appeared for the first time in descending order of yield with increasing rates of application of dalapen.

(ig) Fourth experimental period.

a) Intermediate observations.

During this period grass weeds such as perennial ryegrass and Poa annua continued to colonise less dense areas of control plots, increasing the variability of the distribution of species within these plots. Growth of browntop on control plots appeared to have slowed down considerably. On examination, all plants on treatments 6 and 8 plots were found to be dead. The vast majority of plants on treatment 4 plots were also dead, but an occasional clump of more mature herbage also survived on treatment 2 plots. Leaves of plants on both these treatments were, however, dying back from the tips. Most of the dead herbage on treated plots had decomposed by the fourth sampling date. There was no evidence of the production of fresh growth on any of the treated plots and the weed population of these plots, especially treatment 6 and 8, was considerable.

b) Fourth cut (29th June - 86 days after treatment.)

The percentage contribution of the sown species to plot yield is shown in Appendix XVIa. The presence of a much higher weed population than at previous cuts is confirmed. The main weeds of control plots were grasses, as indicated above, while the weeds in treated plots were almost exclusively at this stage of Cerastium species and Cotula species. The presence of isolated clumps of live herbage from treated plants was present in samples from treatments 6 and 8 plots. The spread of browntop from discard areas on to unoccupied areas of treated plots however,

caused a small amount of live herbage to be recorded in these plots and raised the yield of the other treated plots slightly.

At this cut, live and dead herbage of sown species <sup>were</sup> separated in the laboratory. Data were then calculated for the dry matter yield of sown species (Live Herbage) and of sown species (Total). Individual plot data for both these measurements and details of statistical analyses are shown in Appendices XVib and XVic respectively. Control plots were excluded from the analysis of variance. In the case of sown species (Live Herbage) the analysis of variance indicates that treatment differences were significant ( $p = 0.05$ ). Subdivision of the treatments sums of squares indicates that low (2 and 4) and high (6 and 8) rates of dalapon were significantly different ( $p = 0.01$ ). The analysis of variance for sown species (Total), on the other hand indicates that treatment differences were not significant.

Treatment means, together with standard errors and the detectable differences required for significance at three levels are presented in Table XVIII.

Table XVIII Comparison of treatment means for fourth cut.  
Browntop. (Dry matter yield).

Treat- ment	Measure- ment	Mean	General Mean	S.E. $\bar{x}$	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	Live herbage Total	44.7 59.4		+16.5 +19.8			
2	Live herbage Total	4.2 18.7	2.6 14.1	+0.9 +3.3	2.7 10.0	3.7 13.9	5.1 19.2
4	Live herbage Total	3.8 16.5					
6	Live herbage Total	2.1 12.1					
8	Live herbage Total	0.4 8.9					

Separation of live from total herbage allowed the full effect of dalapon at this stage to be assessed. Fig. XV and Table XVIII illustrate the relative amounts of dead herbage remaining in each treatment. Live herbage data for treatments 6 and 8 are not included in the graph. The considerable variability within control plots is indicated. Live herbage data for treatments 2 and 4 show that relatively little live herbage remained on these plots. Estimation of survival in terms of yield must, however, take into account the relatively small size and weight of individual leaves of this species compared with those of the species in the previous experiments. Total herbage yields were lower at this cut on treated plots, indicating that the decomposition of dead tissue continued.

(v) Fifth experimental period.

a) Intermediate observations.

Fourth cut until the end of July.

There were few signs of active growth of the sown species in any treatment for several weeks after the fourth cut. A series of sharp frosts (see Fig. V) caused considerable damage to mature herbage on control plots, but had no visible effect on the remaining herbage on treatments 2 and 4 plots. Some of surviving clumps on treatment 2 plots were still dying off slowly, while in others, the deterioration appeared to have halted and a few fresh leaves were produced. These did not show any distortion or malformation due to dalapon. Nearly all the plants on treatment 4 plots were dead or dying, including the isolated clumps noted at the previous cut. Fig. XIV. illustrates the condition of the plots on the 28th July, 115 days after treatment and indicates the extent of weed invasion on treated plots.

End of July until fifth cut.

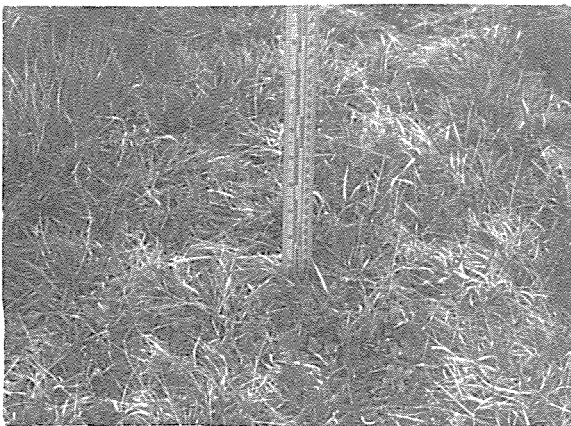
During the last week of July, there was evidence of the slow commencement of growth on control and treatment 2 plots but not on the remainder. Deterioration of the mature herbage on control plots

Browntop plots. 28th July, 1959.

Control



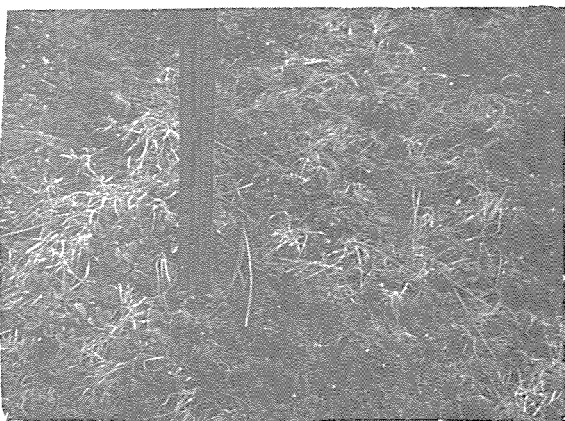
2 lb. per acre



4 lb. per acre



6 lb. per acre



8 lb. per acre



continued, but fresh shoots appeared through the canopy of older herbage. Weed grasses, especially perennial ryegrass were plentiful. On treatment 2 plots, old herbage continued to die off, but fresh shoots appeared and grew rapidly from the crowns of the surviving plants. The vigour of these shoots and the number of surviving plants on these plots suggested that despite the high weed population, browntop would survive and spread to take control of the plots. Virtually all plants on treatment 4 plots were dead and there was no evidence of recovery except for a very few rather sickly shoots. It was considered that this treatment had to all intents and purposes completely killed browntop. There were no live treated plants on treatments 6 and 8. No seedling browntop plants were observed on any of the treated plots.

b) Fifth cut (4th September - 153 days after treatment).

This last cut was delayed for as long as possible to allow treated plants every opportunity to show whether or not they would recover.

The contribution of the sown species to plot yield is shown in Appendix XVIIa. The figures indicate the extent to which weed invasion had occurred by the fifth sampling date. Considerable variations in the weed content of individual plots existed. The ingress of browntop from surrounding areas caused a small amount of live herbage to be recorded in treatments 6 and 8, and increased slightly the amounts recorded in treatments 2 and 4.

Dead and live tissue of the sown species were separated and data calculated for the dry matter yield of sown species (Live Herbage) and of sown species (Total). Individual plot data and details of statistical analyses are shown in Appendices XVIIb and XVIIc respectively. Control plots were excluded from the analysis of variance. In both cases the analysis of variance indicates that treatment differences were significant ( $p = 0.01$ ).

Treatment means, together with standard errors and the

detectable differences required for significance at three levels are presented in Table XIX.

Table XIX. Comparison of treatment means for fifth cut.

Browntop. (Dry matter yield).

Treatment	Measurement	Mean	General Mean	S.E. x	d <sub>0.05</sub>	d <sub>0.01</sub>	d <sub>0.001</sub>
0	Live herbage	52.3		+12.9			
	Total	96.5		± 28.8			
2	Live herbage	13.8	5.0	+2.3	7.0	9.7	13.4
	Total	21.2	7.7	± 3.7	11.1	15.4	21.3
4	Live herbage	4.3					
	Total	6.6					
6	Live herbage	0.6					
	Total	0.8					
8	Live herbage	1.4					
	Total	2.3					

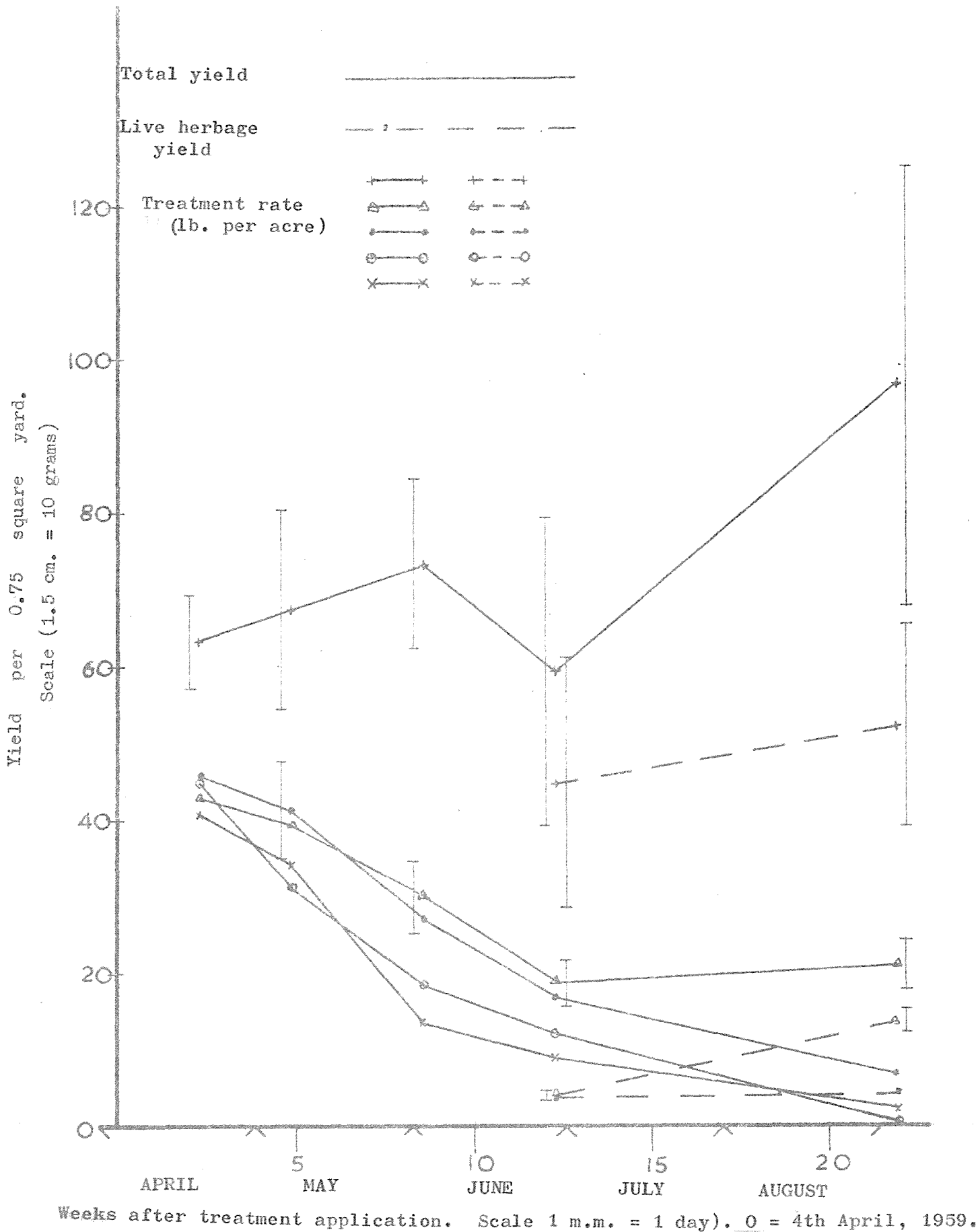
Fig. XV and Table XIX illustrate the considerable variability between control plots which existed at this sampling date. Total herbage figures for treatments 4, 6 and 8 indicate that decomposition of the dead herbage was virtually complete. Live herbage data for treatments 6 and 8 are not included in the graph. A marked increase in the yield of live herbage from treatment 2 plots since the previous cut confirmed observations of recovery. Little if any change in the amount of live herbage recorded on treatment 4 plots is indicated.

(vi) Regrowth.

Regrowth from cut areas on control plot continued steadily throughout the experiment. While regrowth from the different cutting dates could be distinguished at the fourth sampling date, there was no visible difference at the fifth sampling date. Some regrowth from the two earliest cuts was present on treatments 2 and 4 plots at the time of the fifth cut. This growth was very patchy, but showed signs of spreading on treatment

2 plots. The number of plants involved was much less on treatment 4 plots. Regrowth from later cuts was much poorer. On treatments 6 and 8 plots, some of the plants cut at the first sampling date produced fresh leaves, but these died later and by the fifth sampling date no browntop plants were alive on previously cut areas.

Browntop. Dry matter yield of sown species.  
Treatment means.



F. White Clover experiment.

(i) First experimental period.

a) Preliminary observations.

Observations of the area on the day following spraying showed that the leaves of red clover plants, which formed a small percentage of the sward on most plots at the time of treatment, had all turned black and shrivelled up on treated plots. This point was especially noticeable because no such effect was visible with white clover plants. The treated red clover plants apparently died very quickly since none were found in botanical dissection ten days later at the first cut. Three days after treatment leaf scorching became visible on treatments 4, 6 and 8 plots. All treated plots had apparently received a check to growth, since control plots became distinguishable within a few days because of the rapidly increasing volume of herbage. At the first sampling date treatments 2 and 4 could be distinguished from treatments 6 and 8 by the degree of leaf scorching present.

b) First cut (14th April - 10 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix XVIIIa. In all cases, white clover was the dominant species in the sward. The main impurities were browntop and sheep's sorrel. Considerable variation in the weed content of plots existed.

Individual plot data for dry matter yield of sown species and details of statistical analysis of these data are shown in Appendix XVIIIb. The analysis of variance indicates that treatment differences were significant ( $p = 0.01$ ). Subdivision of the treatments sums of squares indicates that there was a significant difference ( $p = 0.001$ ) between control and treated plots.

Treatment means together with the standard error and the detectable differences required for significance at three levels are presented in Table XX.

Table XX. Comparison of treatment means for first cut.

White clover. (Dry matter yield).

Treatment	Mean	General Mean	S.E. <sub><math>\bar{x}</math></sub>	<sup>d</sup> 0.05	<sup>d</sup> 0.01	<sup>d</sup> 0.001
0	76.4	63.2	+ 3.4	10.2	13.9	18.7
2	63.3					
4	57.1					
6	59.1					
8	60.1					

Fig. XXI and Table XX illustrate that the main difference at this stage was between control plots and those treated with dalapon. No trend within treated plots as a result of increasing rates of dalapon could be detected. The effect of the chemical appeared as a check to further growth.

(ii) Second experimental period.

a) Intermediate observations.

Leaf scorching became more apparent on all treated plots as time progressed. The leaves were not usually killed since only part of the leaf might be affected. This part turned brown and died, but the rest of the leaf remained healthy and showed no signs of treatment effects. All treated plots, with the exception of treatment 8 plots appeared to recover from the check to growth and produced new herbage rapidly. No further growth was visible on treatment 8 plots. Growth on treatment 2 plots was so vigorous that at one stage it became difficult to distinguish control from treatment 2 plots. Frost on the 30th April (See Fig. V) checked growth on treated plots overnight. Control plots were unaffected. Another frost on the 4th May caused considerable damage and death of foliage on all treated plots, the severity of which increased with higher rates of application of dalapon. Treatment 2 plots showed considerable death of both scorched and unscorched leaves. Damaged foliage turned black and shrivelled up. The degree of damage on treatment 8 plots was

such that all foliage turned black and appeared to have been killed. Treatments 4 and 6 showed intermediate effects. Control plots were unaffected. Fig. XVI illustrates the condition of the herbage on the day of sampling.

b) Second cut (5th May - 31 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix XIXa. The general mean value was 80.6 per cent and the lowest value recorded was 69.1 per cent. A general increase in the purity of treated plot samples was noted, mainly due to a decrease in grass weeds which had presumably been killed by dalapon. Large quantities of dead clover were present in treated plot samples.

Individual plot data for dry matter yield of sown species and details of statistical analysis of these data are shown in Appendix XIXb. The analysis of variance indicates that treatment differences were significant ( $p = 0.01$ ).

Treatment means, together with the standard error and the detectable differences required for significance at three levels are presented in Table XXI.

Table XXI. Comparison of treatment means for second cut.

White clover. (Dry matter yield).

Treatment	Mean	General Mean	S.E. <sub><math>\bar{x}</math></sub>	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	104.1	76.2	+ 10.2	30.2	41.2	55.8
2	97.9					
4	69.4					
6	65.9					
8	43.9					

Although much of the herbage on treated plots was dead or dying, it had not had time to decompose and therefore contributed to dry matter yield,

Fig.XVI.

White Clover.

The condition of the plots at the second sampling date -  
31 days after treatment.

Treatment rate  
lb. per acre

6

4

8

2

0



so that Fig. XXI and Table XXI illustrate the degree of recovery which had taken place on treated plots since the previous cut. Yield on treatment 8 plots had declined, but other treatments, notably treatment 2 had increased in yield between cuts. At this cut yield from treated plots decreased with increased rates of application of dalapon.

(iii) Third experimental period.

a) Intermediate observations.

Heavy rain during May (see Fig. V) aided the knockdown and decomposition of dead herbage on treated plots. The deterioration of foliage on treatments 4, 6 and 8 plots continued and by the third sampling date there was very little live or dead herbage available to cut. Inspection showed, however, that the clover runners were still alive. Growth on control plots had apparently slowed down. Treatment 2 plots showed signs of recovering and produced some new leaves, but a series of frosts prior to cutting caused very considerable death of older foliage within two or three days. Most of the grassweeds in treated plots had disappeared by the third sampling date. It is of interest to note that sheep's sorrel reacted to dalapon and frost in the same way as clover. No sheep's sorrel foliage remained alive on treatments 4, 6 and 8 plots. Clover in control plots had to compete with this weed and also various grass weeds. Flatweeds, which had been kept in check by the clover canopy on treated plots, were now able to spread over the treated plots and some very large plants resulted. These weeds had presumably been protected from the spray by the clover and sorrel canopy at the time of treatment, since they showed no signs of the effect of the herbicide.

b) Third cut (2nd June - 59 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix XXa. In comparing treatments, it is necessary to take into account the actual yield of clover obtained from each plot. The presence of occasional large plants of weeds such as dandelion and thistle

contributed to plot variation.

Because of the clear differences between the control data and those for the dalapon treatments, both in mean levels and variability, it was necessary to exclude control plots from the analysis of variance to allow a valid standard error to be calculated for comparison between the remaining treatments.

Individual plot data and details of statistical analysis for dry matter yield of sown species are shown in Appendix XXb. The analysis of variance indicates that treatment differences were significant ( $p = 0.05$ ).

Treatment means together with the standard errors and the detectable differences required for significance at three levels are presented in Table XXII.

Table XXII. Comparison of treatment means for second cut.

White clover. (Dry matter yield).

Treatment	Mean	General Mean	S.E. $\bar{x}$	<sup>d</sup> 0.05	<sup>d</sup> 0.01	<sup>d</sup> 0.001
0	87.3		± 12.5			
2	32.0	16.1	+ 5.2	15.6	21.6	29.8
4	18.1					
6	7.0					
8	7.2					

Fig. XXI and Table XXII illustrate that a considerable decline in yield had taken place since the previous cut. Little dead herbage, except on treatment 2 plots was present to mask the effect of dalapon. Treatment yields appear in descending order with increasing rates of dalapon except for treatments 6 and 8 which are indistinguishable.

(iv) Fourth experimental period.

a) Intermediate observations.

The canopy of mature clover leaves on control plots settled down as older leaves died. The growth rate had become much slower and new leaves were smaller. This caused a marked decline in the volume of

herbage on control plots over the fourth period. Virtually all the original herbage had died on treatment 2 plots and although new growth from the clover runners was plentiful, the leaves were much smaller than those produced by control plots. Treatment 4 plots showed very rapid production of new leaves but these, although they opened, were unable to grow and remained static for several weeks. A high mortality rate of clover runners was noted on treatments 6 and 8 plots. A few new leaves were produced but did not grow. Weed seed germination was very rapid on these plots and they soon became infested with rushes and various flatweeds. Fig. XVII illustrates the condition of treatments 0, 4 and 8 plots at the time of sampling.

b) Fourth cut (26th June - 83 days after sampling).

The percentage contribution of the sown species to plot yield is shown in Appendix XXIIa. The invasion of treated plots by weeds is confirmed.

Control plots were excluded from the analysis of variance. Individual plot data for dry matter yield of the sown species and details of statistical analysis of these data are shown in Appendix XXIIb. The analysis of variance indicates that treatment differences were significant ( $p = 0.01$ ).

Treatment means together with standard errors and the detectable differences required for significance at three levels are presented in Table XXIII.

Treatment	Mean	General Mean	S.E. $\bar{X}$	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	50.7		$\pm 5.7$			
2	12.1	5.8	$\pm 1.7$	5.1	7.0	9.7
4	7.3					
6	2.1					
8	1.8					

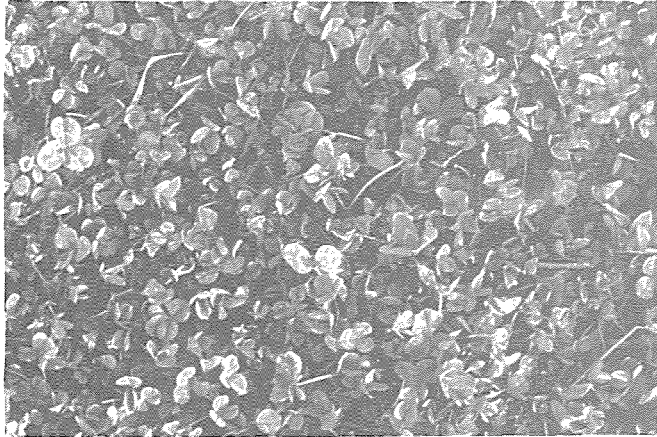
Fig. XXI and Table XXIII illustrate that yield from control plots was

Fig. XVII.

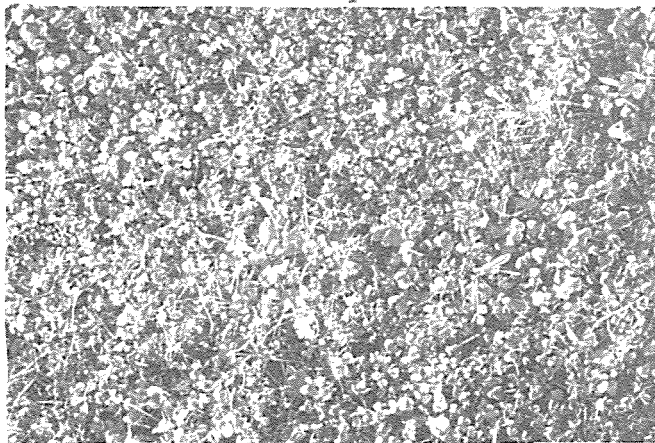
- 90a -

White clover plots. 4th sampling date.

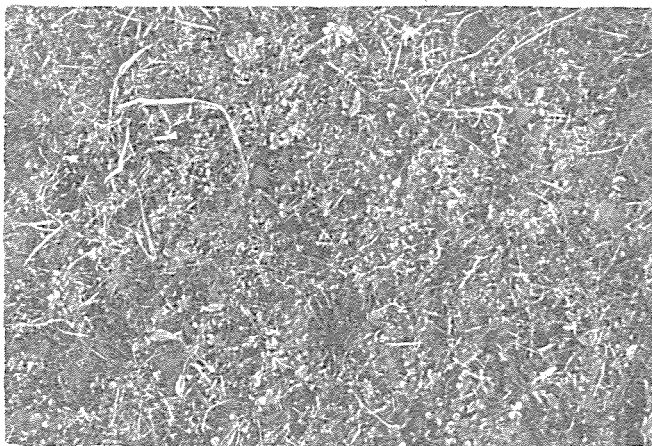
Control



4 lb. per acre



8 lb. per acre



considerably lower at this cut than at the previous one. The reasons for this have been reported above. The decline in yield of treated plots between cuts was due to the decomposition of the remaining sprayed herbage and the yield data were due almost entirely to fresh growth. The effect of dalapon was, however, still evident in terms of decreased yield with increased rates of application.

(v) Fifth experimental period.

a) Intermediate observations.

Fourth cut until the end of July.

Little active leaf expansion took place on treatments 4, 6 and 8 plots for almost a month after the fourth cut. What did happen was that surviving runners produced numerous distorted new leaves which opened and then died off after a few days without expanding any farther. New leaves appeared in profusion at all live nodes and at the growing point of affected runners. The major difference between treatments at this stage was in the number of surviving runners. A high mortality rate of new leaves was observed on treatments 6 and 8 plots, while that on treatment 4 plots was less and the leaves produced were able to expand a little more. Treatment 2 plots were not nearly so severely affected and although abnormal ~~tissue~~ proliferation and leaf distortion was evident, many of the new leaves produced appeared to grow and expand normally.

Samples of clover runners and malformed leaves were sent to Plant Diseases Division, Auckland, who confirmed that malformation was not due to a virus disease. This substantiated a test made in the greenhouse, where malformed clover leaves were macerated and the extract applied to the leaves of young pea plants. No symptoms of distortion or disease during subsequent growth were noted. It was concluded that the inhibition of growth and distortion of leaf tissue was due solely to the effect of treatment. Personal observations made on white clover plants on another experimental area, some 20 miles away, in which dalapon had

been used to kill a hill sward, confirmed the conclusion that dalapon was the causative factor.

Fig. XVIII shows a clover runner from a treatment 4 plot exhibiting typical symptoms, as described above, of dalapon inhibition. To illustrate the comparative effects of the different treatment rates, typical runners were taken from the areas cut at the fourth sampling date (26th June) one fortnight later. This ensured that only fresh growth would be present on all runners, including those from treatments 0 and 2. Since no original herbage was present, dalapon symptoms in the leaves must have been due to the presence of the chemical in the runners. The photographs in Fig. XIX were taken on the 10th July 97 days after treatment. Much of the foliage depicted had been produced during the previous fortnight since any which had attained even half-an-inch in height would have been removed at the fourth sampling date and the life-span of the more seriously distorted leaves was only a few days.

No effect of frost was noted on the fresh growth of treated or control plots. Weeds continued to colonise treatments 4, 6 and 8 plots. Grass weeds, especially ryegrass and browntop became more evident in control and treatment 2 plots.

End of July until fifth cut.

During the last week in July and the first week in August, there were indications that clover leaves on treated plots were able to outgrow the symptoms of dalapon inhibition and expand normally. There appeared to be no order or sequence about the production of undamaged leaves. One leaf might be produced and grow normally in the midst of distorted small leaves produced before and after it from the same node. The lower the treatment rate the more normal were the leaves produced. The close network of surviving runners on treatment 2 plots soon produced

Fig. XVIII.

White clover plant exhibiting symptoms of inhibition by dalapon.



Fig. XIX.

White clover runners exhibiting the effect of various rates of dalapon - 97 days after treatment.

Treatment rate  
lb. per acre

8 (4)



6 (2)

4

2

0



sufficient normal foliage to form a canopy which hid the presence of distorted leaves near the ground and discourages the growth of weed seedlings. Recovery on treatment 4 plots was patchy due to the uneven distribution and smaller numbers of surviving runners over the plot area. Relatively few normal clover leaves were present on treatment 6 and 8 plots. The survival of clover runners on these plots was in any case poor. Fig. XX illustrates the condition of the clover plants on treated plots on the 6th August, 124 days after treatment.

The last sampling date was delayed for as long as possible to allow treated plants every opportunity to show whether or not they would recover.

By the fifth sampling date, rapid recovery had taken place on treatment 2 plots. A proportion of ryegrass and flatweeds was present, but observations suggested that within a few weeks the clover would take complete control of the sward. In contrast, control plots showed a considerable increase in the grass weed content. Recovery was still patchy on treatment 4 plots. Some areas grew as rapidly as those in treatment 2, while on others growth was virtually at a standstill. The weed population, mainly rushes and flatweeds, was higher than in treatment 2, but observation suggested that the clover would eventually recover completely and smother competition. A very high weed population was present on treatments 6 and 8 plots. The production of distorted small leaves from the scattered surviving runners still greatly outnumbered that of normal leaves. Observations suggested that clover could not provide much competition for weeds and that the dense carpet of weeds present was rapidly forming a canopy which would smother the small leaves of the surviving clover plants. Most of the clover leaves on treatments 4, 6 and 8 plots were still below sampling height when the last cut was taken. Considerable leaf distortion was still visible at ground level on all treated plots.

Fig. XX.

- 93a -  
White clover plots. 6th August, 1959.

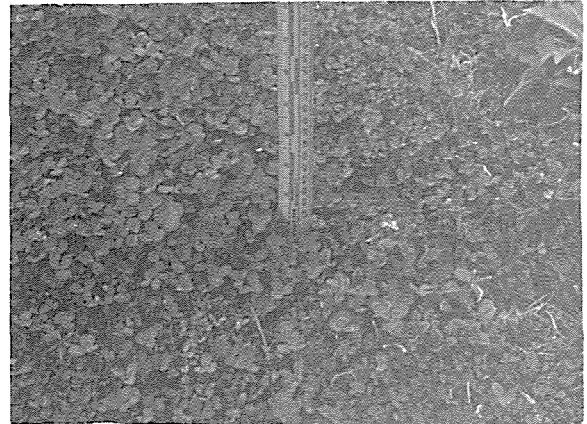
Control



2 lb. per acre



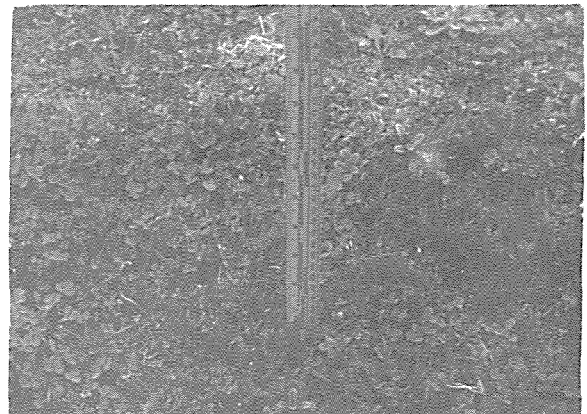
4 lb. per acre



6 lb. per acre



8 lb. per acre



b) Fifth cut (1st September - 150 days after treatment).

The percentage contribution of the sown species to plot yield is shown in Appendix XXIIa. The impurities in control and treatment 2 plots were mainly grass weeds. The considerable variability of samples from higher treatment plots indicates the patchy distribution and recovery of clover plants.

Control plots were excluded from the analysis of variance. Individual plot data for dry matter yield of sown species and details of statistical analysis of these data are shown in Appendix XXIIb. The analysis of variance indicates that treatment differences were significant ( $p = 0.001$ ).

Treatment means, together with standard errors and the detectable differences required for significance at three levels are presented in Table XXIV.

Table XXIV. Comparison of treatment means for fifth cut.

White clover. (Dry matter yield).

Treatment	Mean	General Mean	S.E. $\bar{x}$	$d_{0.05}$	$d_{0.01}$	$d_{0.001}$
0	62.5		$\pm 8.9$			
2	37.9	17.8	$\pm 4.2$	12.7	17.6	24.3
4	19.1					
6	8.5					
8	5.9					

Fig. XXI and Table XXIV illustrate that yield from treated plots was higher at this cut than at the previous one. Yield had increased most rapidly on treatment 2 plots. The trend of decreasing yield with increasing rate of dalapon was still visible at this stage.

(vi) Regrowth.

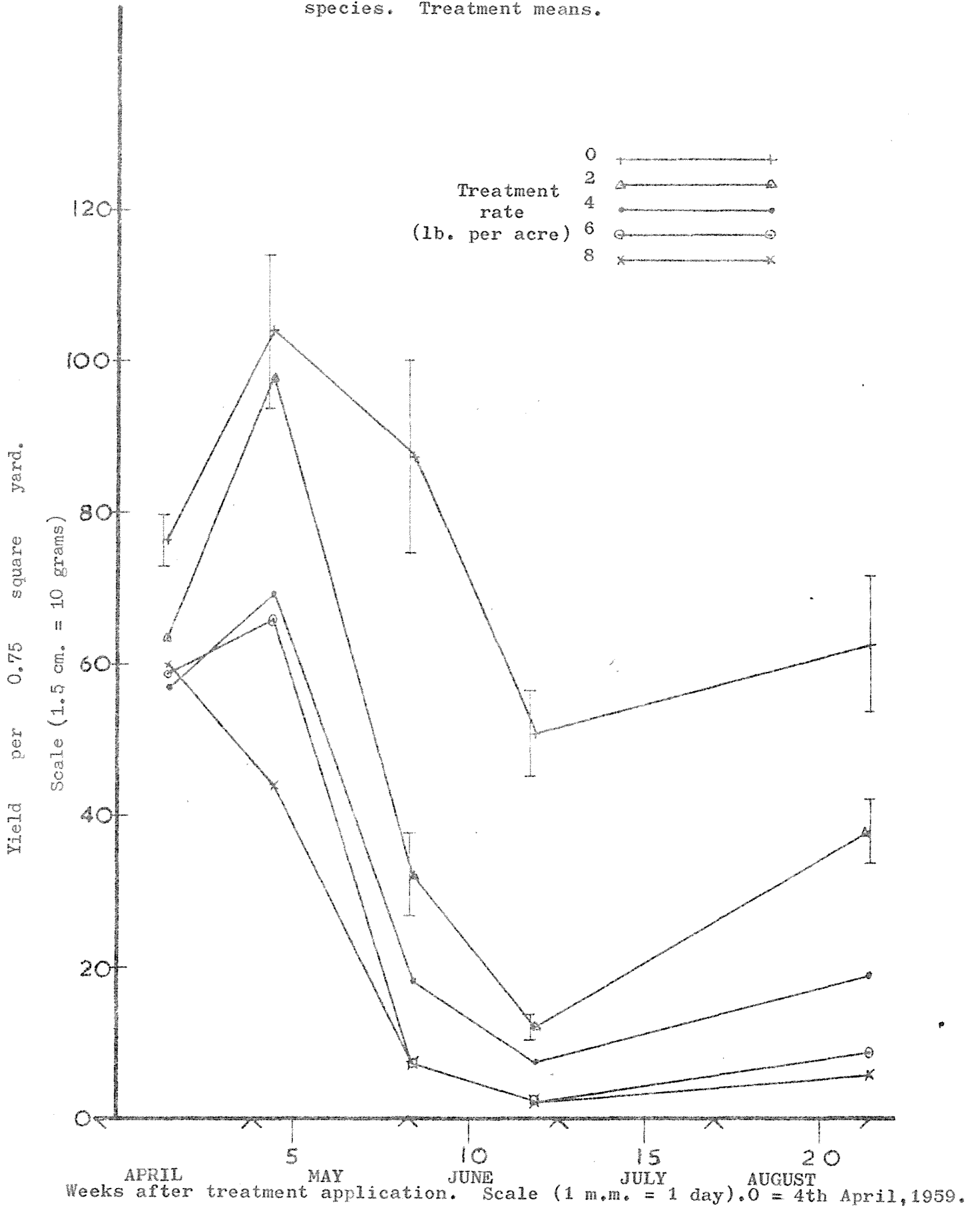
Observations were made on theregrowth from previously cut

areas of each plot. Regrowth after the first cut was rapid on control plots but new leaves produced by plants on treated plots exhibited the lack of leaf expansion reported above for uncut areas after the original foliage had been killed. Plants remained in this condition until the commencement of growth at the end of July. At the fourth sampling date it was not possible to distinguish between areas which had or had not been cut previously on treated plots, since the original foliage had decomposed. The behaviour of regrowth from sampled areas was identical to that reported above for uncut areas. Control plots became so variable by the fifth cut that it was not possible to distinguish between previously cut areas.

Fig. XXI.

- 95a -

White clover. Dry matter yield of sown species. Treatment means.



## CHAPTER V

### DISCUSSION

Thompson (1959) ascribed the considerable variations in effect which had been reported from applications of a given quantity of dalapon to a sward to two main factors:-

Seasonal changes in specific tolerance and,  
The height and maturity of the treated growth.

Comparison of present results with those of other workers is made difficult by the lack of information in many reports, on the season and stage of growth at which treatment was applied. In addition, only a very few experiments have been conducted on pure species swards.

#### A. The experiments.

The experiments were planned in such a way that one facet of the practical utilization of dalapon - namely specific tolerance - might be studied separately, free from the many variable factors which are present in the normal mixed sward. In addition, the conflicting influences of mixed herbicides, oversowing, fertilizer application and grazing which lead to confusion in many of the field trials with this chemical were avoided. The use of pure swards is warranted in view of the possible interaction of competition in a mixed sward where varying degrees of damage are sustained by different species.

Treatment was applied in mid-autumn and the plots were mown previously to produce fresh young herbage and the conditions advocated by Blackmore (1957) for seed germination and seedling protection where oversowing follows treatment. In addition, an effort was made to maintain low fertility conditions similar to those which might be found in the type of pasture upon which dalapon would be used in farm practice. This last aim was perhaps carried too far and was no doubt responsible for some, but by no means all of the weed problem

encountered during pre-treatment management. Higher seeding rates of the species sown would probably have been advantageous in promoting better initial establishment.

The production of pure swards was successfully accomplished with perennial ryegrass and cocksfoot. The majority of the weeds remaining in both clover and browntop plants was killed by treatment with dalapon and did not affect the recovery of the sown species. The original weed population in these two trials was, however, responsible for considerable lack of uniformity in control plots which increased as the experiments progressed. Exclusion of control plots from statistical analyses, by removing this complicating factor, allowed a more accurate assessment of the differences between rates of application of dalapon to be made.

The ingress of weed seedlings towards the end of the experimental period could not be avoided and did not influence the recovery of the sown species to any great extent.

It is considered that the application of 24 - D in December to control sheep's sorrel had no effect on the results obtained from the subsequent application of dalapon.

The design and layout of the experiments proved to be satisfactory with regard to ease of handling the material and the examination of results. The number of replications was sufficient to allow major treatment differences to be established as statistically significant, despite the increase in the variability of the trial areas over the experimental period.

Mitchell and Coles (1955) pointed out that certain experimental treatments, especially unfavourable ones, may increase plant variability and that this may increase or decrease as the experiment progresses, depending on the type of treatment. Variability in plots treated with the two lower rates of dalapon increased due to

the uneven distribution of surviving plants. At the two higher rates, weed ingress was a contributing factor, while on all plots, uneven decomposition of dead herbage considerably increased the variation between and within plots. An increase in sample size or in the number of replications to allow for this increased variability would have been impracticable and would not have been justified by the results obtained.

Competition from weeds on browntop and white clover control plots and winterburn of rank herbage in all species control plots tended to reduce the usefulness of control as a standard by which to assess the effects of the various levels of treatment with dalapon. Explanation of the reasons for the sampling procedure followed in these experiments has been given previously. The alternative would have been to mow the whole plot and then mow the regrowth, if any, at intervals. Thompson (1959) used this technique, and thereby removed excessive growth from control plots. However, if such a procedure had been adopted in the experiments under discussion, a great deal of useful information particularly in relation to the recovery of treated herbage and the effect of frost would have been lost.

Observations suggested that there was no interaction between dalapon and cutting, except that plants from which the treated foliage had been removed endeavoured to produce new foliage, while those on uncut areas tended to produce relatively little new foliage until a considerable proportion of the treated herbage had died and decomposed. This did not apply to the 2 lb. and 4 lb. per acre treatments or perennial ryegrass and cocksfoot, where treated plants continued to produce new foliage throughout the experimental period.

Measurement of the effect of dalapon in terms of yield was the most satisfactory method of assessing the check to further growth which occurred soon after treatment and of the degree of recovery of treated plots later in the experiments. An estimation of the number

of plants surviving per unit area of treated plots would, however, have contributed to the assessment of the potential recovery of the sward. Separation of live and dead herbage at every sampling date would have allowed a more accurate estimation of the severity of treatment with dalapon at these cuts. This was not possible, however until the fourth cut..

B. The overall effect of dalapon on the species studied.

(i) Perennial ryegrass.

All rates of application caused an initial check to the further growth of treated foliage. This check was short-lived on plots treated with 2 lb. per acre and six weeks after spraying this treatment had apparently fully recovered and plot yield was not significantly different from that of control. Frost damage during the second half of May resulted in the death of much of the treated foliage. Little further growth occurred until the end of July, from which time recovery was rapid. Few plants had been killed and by the first week in September yield from this treatment was again approaching that of control.

Plots subjected to treatment with higher rates of dalapon did not recover in autumn from the initial growth check. The death of treated foliage and of plants during the winter resulted in an extremely patchy sward which rapidly became colonised with flatweeds. Little active growth of the sown species occurred until early spring when the surviving plants produced new shoots and began to grow vigorously. Sufficient survivors remained on the 4 lb. per acre treatment to enable ryegrass to maintain control of the sward and it was considered that this treatment despite the severe check caused by the application of dalapon would eventually recover to full production and a relatively pure sward. Only a few isolated plants survived the winter on plots treated with 6 and 8 lb. per acre and although these plants recovered rapidly in spring and showed no signs of being suppressed by the dense carpet of weeds, they were too few in number to influence the future composition of the sward.

These results are in general agreement with reports by Thompson (1959) who applied  $1\frac{1}{2}$ ,  $2\frac{1}{2}$  and 5 lb. per acre at the same time of year to a ryegrass-white clover pasture.

6 lb. and 8 lb. per acre gave equally good results, but neither completely killed all plants. Thompson found that 10 lb. per acre gave a complete kill and it is considered that this rate would have been sufficient to ensure the same result in the experiment under discussion.

(ii) Cocksfoot.

All rates of application caused a check to further growth of treated foliage within a few days of treatment. As in the ryegrass experiment, the check was short-lived on plots treated with 2 lb. per acre and plants were exhibiting signs of recovery when the first frosts of the year caused considerable death of treated foliage. A progressive decline in yield from these plots was obtained during the winter period and all the original foliage was killed, but vigorous regrowth in early spring showed that few plants had died and the sward showed signs of complete recovery.

Higher rates of dalapon, aided by frost caused the death of all the treated foliage during autumn. Very few plants survived the winter on plots treated with 4 lb. per acre, but the survivors proceeded to grow very rapidly in spring. Weeds had colonised the bare patches between surviving plants however, and the cocksfoot plants were too isolated to maintain control of the sward. 6 and 8 lb. of dalapon gave a complete kill of cocksfoot plants on all plots during winter.

No reports have been published concerning autumn application of dalapon to cocksfoot. These results, however help to confirm the statements by Thompson (1958, 1959) that the resistance of cocksfoot to dalapon may vary considerably and that at certain seasons the species is much more susceptible than at others. The results from April application were more severe than those reported by him from September and November applications.

(iii) Browntop.

All rates of application above 2 lb. per acre gave a complete kill of all plants of this species. 6 and 8 lb. per acre gave a more rapid kill than 4 lb. per acre, however. Considerable mortality of plants occurred on plots treated with 2 lb. per acre, but surviving plants commenced to grow vigorously and spread over the plot area in spring. The distribution of surviving plants and their rapid spread suggested that the species would maintain control of the sward, despite weed invasion.

No detailed investigations regarding the seasonal tolerance of browntop have been reported. General recommendations for control of this species range from  $2\frac{1}{2}$  to 5 lb. per acre (Blackmore, 1958). Present results would suggest that in April the tolerance limit lies between 2 lb. and 4 lb. per acre. Accurate assessment of this limit at various seasons would require a much smaller interval between treatment rates than may be practicable under field trial conditions. Such an assessment would, however, be of great value where selective removal of this species from a mixed sward is contemplated.

(iv) White clover.

All plots received a check to growth from application with dalapon. Recovery was rapid from all except the 8 lb. per acre treatment and it appeared that dalapon had had only a slight effect at 2 lb. per acre and a moderate effect at 4 and 6 lb. per acre. The checks to plants in the 2 lb. per acre treatment, was shortlived and subsequent to treatment they appeared to grow more rapidly than control plots and by the second sampling date, one month after treatment, yield from these two treatments was not significantly different. The first frosts of the year, however, caused severe damage to all treated plots. All the original foliage on plots treated with 6 and 8 lb. per acre was

killed within a few days, while that on plots treated with 2 and 4 lb. per acre died off gradually over a period of several weeks. Recovery growth was poor on all plots during winter and many clover runners died, especially at the higher treatments. In early spring, recovery of all the surviving runners commenced. Vigorous growth from the 2 lb. per acre treatment ensured the complete recovery of the sward and in early September yield was fast approaching that of control plots. Recovery from the 4 lb. per acre treatment was less rapid, due to the continuing action of dalapon and the death of many runners during winter made the sward patchy. However, growth was sufficiently vigorous to ensure that clover would maintain control of the sward despite a high weed population. Relatively few runners survived the winter after treatment with 6 and 8 lb. per acre. The effects of dalapon were still much in evidence and the continued inhibition of leaf growth made these runners unable to compete with the dense carpet of weeds which colonised the plots. It is probably that clover plants that survived the winter on these plots would eventually have recovered from the inhibitive effect of the chemical if the plots had been kept free from weeds in spring.

These results are in complete disagreement with those of Maclean (1955) who reported that rates of up to 10 lb. per acre of dalapon caused no suppression of mature white clover plants. This worker conducted trials on clover at various stages of maturity and gave the opinion that "clover sown in pure stands is usually more tolerant and recovers more rapidly than when it is competing with grasses in a pasture." It is not evident from the text at what season these trials were conducted, but a possible explanation of the disparity in the results obtained in the present experiment and those reported by Maclean may lie in seasonal tolerance variations. Thompson (1958) found that clover in

a mixed sward was severely reduced by applications of  $2\frac{1}{2}$  and 5 lb. per acre of dalapon in September, but recovered more quickly from a November application. These results, however, reflect the factor of interspecific competition as well as the effect of dalapon. The effect of April applications of dalapon in the experiment under discussion was more severe than that reported by Thompson in his September and November trials. This suggests that clover shows the same trend of seasonal tolerance as has already been reported for grass species. It could be that a plant that is entering its period of maximum growth is less susceptible than one that is entering a low production period even apart from the effects of frost.

(v) Comparison of the four species.

a) 2 lb. per acre.

This rate of application was sufficient to check growth of all the species. Only on the browntop trial, however, did it result in the death of a substantial number of plants in the sward. Perennial ryegrass was the least affected and continued to produce new foliage throughout the winter. White clover and cocksfoot were more severely damaged and lost most of their original foliage during the late autumn. Production during winter was very low, but recovery in spring was rapid and complete. White clover recovery was somewhat better than that of cocksfoot. All the original herbage died off slowly during winter on browntop plots. In early spring, however, surviving plants produced vigorous new shoots and spread rapidly.

b) 4 lb. per acre.

All species received an initial check to growth from which browntop failed to recover. Considerable mortality among ryegrass, clover and cocksfoot plants during winter resulted in patchy rather open swards. The surviving ryegrass plants were sufficiently numerous and vigorous in early spring to maintain control of the sward. White clover

recovery was slower but the network of surviving runners gave a better distribution of tillers over the plot area. The few surviving cocksfoot plants were too isolated to retain control of the sward.

c) 6 lb. per acre.

This rate killed all plants on browntop and cocksfoot plots and left only a few survivors on perennial ryegrass plots. The majority of clover runners were killed and the continuing inhibitive effect of dalapon prevented normal recovery in spring of the survivors.

d) 8 lb. per acre.

No distinction between 6 lb. and 8 lb. per acre, except possibly in speed of kill, could be made on any species trial.

e) General.

Perennial ryegrass was the most resistant species at all rates of application, with white clover next, followed by cocksfoot and then browntop. The relative tolerances of the three grass species are in agreement with the report of Thompson (1958) on trials at other seasons of the year. The overall range of tolerance of the four species in the present experiments was comparatively small. 2 lb. per acre was not sufficient to completely kill any species, but 6 lb. per acre killed all browntop and cocksfoot plants and left few survivors on white clover and ryegrass plots. These results suggest that mid-autumn might be a suitable time of year to obtain an economical general kill of pasture species, but would not be satisfactory for the selective utilization of dalapon. This suggestion is in line with observations by Merry (1959).

The classification of white clover as being more susceptible to dalapon than perennial ryegrass in these experiments demonstrates that the reported selectivity of the chemical against monocotyledonous plants is purely relative and may not necessarily apply at all times of the year.

Considerable variation in the tolerance to dalapon within a species was noted. Many ryegrass plants were killed at 4lb. per acre, but a few survived 8 lb. per acre. The range for cocksfoot plants was less - few, if any plants were killed at 2 lb. per acre but all at 6 lb. per acre. White clover plants died on 4 lb. per acre plots and some survived at 8 lb. per acre although still suffering from dalapon inhibition. The range for browntop could not be determined since many plants died at the lowest rate applied. The upper limit was however 4 lb. per acre.

C. Factors affecting the efficiency and mode of action  
of dalapon.

The review of literature has illustrated the importance of environmental and other factors in deciding the efficiency of utilization of dalapon. Any discussion of the effect of the chemical on the species studied would therefore be of limited value without an assessment of the manner in which the experimental conditions influenced the results.

(i) Environmental factors.

Environmental conditions during treatment and for 48 hours after, were conducive to the rapid absorption and translocation of the chemical (see Woodford et al., 1958). Two factors which had a major effect on the subsequent reactions of plants to treatment were rain and frost.

General growing conditions during the winter would not favour the rapid recovery of affected plants.

a) Rain.

1.38 inches of rain was recorded at Grassland Division Meteorological Station on the second day after treatment (see Table III). This was followed by 0.92 inches over the next three days. Reports by Holstun and Loomis (1956) would suggest that this amount of rain and a short period was more than sufficient to wash any unabsorbed dalapon off the leaves of treated plants and to completely leach it from the surface layers of the soil. It is therefore considered probable that rain precluded further foliar absorption some 48 hours after treatment and leached any remaining dalapon below the root zones of treated plants within 4-5 days after application.

Soil conditions were not optimum for the activity of the bacteria concerned in the decomposition of dalapon in the soil (see Holstun and Loomis, 1956). In view of this and because of the rapidity

of leaching as a result of heavy rain, bacterial inactivation of dalapon in the soil is not considered to have been of more than minor importance in these experiments.

b) Frost.

The burning of mature herbage during the winter months is a common phenomenon. It appears initially in the death of leaf tips in the longer leaves of grasses and the damage increases in proportion as the foliage becomes more mature and the winter progresses. (Stapledon, 1926; Davies and Fagan, 1938; Gardner and Hunt, 1955). Rain, wind and frost are the factors responsible. Ryegrass and cocksfoot are known to be susceptible to winterburn, while severe frost may kill the top growth of clover completely. Little damage is suffered by young short growth. (Woodman, 1934).

Symptoms of winterburn became evident on all control plots towards the end of the experimental period. This was emphasised by the maturity of the herbage. The earlier frosts which caused such considerable damage to herbage on treated plots had little or no effect on control plots.

There is no report in any of the available literature of frost interaction with dalapon resulting in an enhanced kill of plants. The only evidence relating to frost deals with the effect of sub-lethal rates of dalapon in increasing frost resistance in seedlings (Miller and Corns, 1957). Although no study of the action of frost was planned during these trials, the experimental design allowed such a study to be made. No temperature readings were taken on the plots, and although the records of Grasslands Division Meteorological Station may be used to indicate accurately the frequency of frost, intensity of frosts on the experimental area can only be gauged approximately.

Frosts in April and May severely damaged treated herbage

on the perennial ryegrass, cocksfoot and white clover swards. The degree of tissue destruction increased with higher rates of application of dalapon. This indicated a relationship between treatment with dalapon and the susceptibility of plant foliage to frost damage. At the two lower rates of application, leaves produced after treatment were undamaged while leaves on the same plant which had received the spray solution, and could be distinguished by the consequent discoloration, were severely damaged. Little new foliage was produced after treatment at the higher rates. Since presumably dalapon was present in these new leaves also, because of its reported rapid circulation throughout the plant and translocation to regions of active growth (Crafts and Foy, 1959), the major difference between treated and subsequently produced foliage was that dalapon had been absorbed by the former as a result of foliar application. This suggests that there was no effect <sup>of</sup> translocated dalapon on susceptibility to frost. It is possible that dalapon in the process of penetration and absorption into the leaf may have brought about chemical changes in the structure of the cuticle which rendered it more susceptible to frost damage. This appears to be a feasible explanation. The greater severity of damage to the leaf in higher treatments suggests that the effect of dalapon upon the cuticle increased with higher concentrations of the chemical. Discussion of the possible chemical processes involved is beyond the scope of this thesis.

The severity of frost damage to treated herbage was different with each species. It appeared to be related more to their normal resistance to frost damage than to their susceptibility to dalapon. Maturity should not have been responsible since the treated herbage was much less mature than that on control plots which were unaffected.

It is not possible to estimate the severity of the effect of dalapon had there been no frost, or whether frost enhanced the

efficiency of dalapon. Many of the plots gave the appearance of having recovered from the initial growth check caused by dalapon before frost damage occurred. This was especially the case with 2 lb. per acre treatments. Regrowth from areas sampled before frost damage was somewhat better than that produced by areas sampled later. This may, however, have been due to more favourable growing conditions in the early stages of the experiment.

(ii) Sward factors.

Pre-treatment mowing had been directed towards producing a dense canopy of young vigorous foliage. This was accomplished satisfactorily with all but the browntop trial, where the foliage cover was thin and the sward patchy. Most of the spray should have been retained by the foliage on the perennial ryegrass, cocksfoot and white clover trials. In the case of browntop, however, much of the spray solution reached the soil surface.

The active growth on all plots should have ensured rapid translocation, whether from foliar or root absorption, to all parts of the plant.

The more vigorous and darker green foliage produced by treated plots relative to control plots of perennial ryegrass in spring was associated with an increased crude protein content. This was attributed to the readily available source of nitrogen in the form of decomposed herbage present on treated plots. This indirect effect of dalapon may possibly detract from the direct inhibitive effect of the chemical on plant recovery in spring.

D. The action of dalapon on the plant.

The first noticeable effect was the distortion of a number of leaves on the grass species trials, followed by a progressive yellowing of foliage. Observations, corroborated by yield data at the first sampling dates reported a check to the further growth of herbage on treated plots of all species. Treated herbage, after an initial apparent recovery in some cases, eventually died off, the process being accelerated on all but the browntop sward by the action of frost. The possible effect of dalapon on the susceptibility to frost of the treated herbage has been discussed above.

The subsequent ability of the plant to produce new leaves to replace those killed was related to the rate of application of dalapon. In the grass species trials, little if any new foliage was produced on treatments above 2 lb. per acre during the winter and many plants died. The mortality rate increased with higher rates of treatment. No evidence of distortion was found on new leaves produced by treated plants at any stage. In early spring surviving plants began to recover, produce new leaves and grow vigorously.

The above symptoms and reactions of plants to dalapon corresponds to those cited in the literature (Dow Chemical Company, 1953; Woodford et al. 1958) for monocotyledonous plants. Unfavourable environmental conditions and the natural tendency for less active growth during winter would possibly enhance the effect of the chemical on treated plants. This may, in part, be responsible for the more efficient kill of pasture species reported by Thompson (1959) from autumn and early winter applications.

The effect on clover recovery was somewhat different. There was little indication of the production of new leaves on treated plots until the original foliage died down and the new leaves when

produced were unable to expand and grow. The effect was most severe at high rates of application. Similar effects were noted on the regrowth from previously sampled areas. This inhibition to leaf expansion persisted throughout the winter and many clover runners died. Recovery of the surviving plants commenced at the end of July and from this time onwards considerable distortion and death of rapidly produced new leaves was noted. Plants treated with 2 lb. per acre of dalapon overcame this effect fairly quickly, while those treated with 4 lb. per acre took somewhat longer to recover. At higher rates of dalapon plants were still producing distorted foliage by the end of the experiment and there was no evidence of the effect of dalapon being overcome.

These results suggest that dalapon was stored in the clover runners over the winter period until growth commenced and was then transported to sites of meristematic activity. Similar results with cotten plants have been reported by Crafts and Foy(1959). No other worker has so far reported the effect of dalapon on white clover plants obtained in this experiment.

C H A P T E R VI.

General Conclusions.

The review of literature has shown :-

- 1) The wide range of field conditions under which dalapon may be used and the occasional need to sacrifice the optimum conditions for dalapon utilization because of the requirements of subsequent pasture management.
- 2) The multiplicity of factors which influence the ultimate effect of the chemical on the plant and the species.
- 3) The present paucity of information about the tolerance levels of the different New Zealand pasture species and the effect of seasonal and other factors on these tolerance levels.

The general conclusion which emerges from a study of the literature is the great need for basic research in New Zealand on the properties of dalapon and the factors affecting its efficiency under the field conditions pertinent to its use in this country. Much general information has been garnered from numerous field trials throughout the country, but this requires to be supplemented by many more detailed investigations into separate aspects of the utilization of the chemical.

The susceptibility of the species in the pastures to be treated at different times of the year and under various environmental and sward conditions is one of the most important of these aspects. Without a thorough knowledge of the factors involved, the amount of chemical required to give the desired results on a sward cannot be accurately assessed. This may account to a large extent for the considerable variability in the results from field trials with dalapon.

The present experiments have given an indication of the tolerance of four pasture species to dalapon application in mid-autumn. The following is a brief summary of the conclusions:-

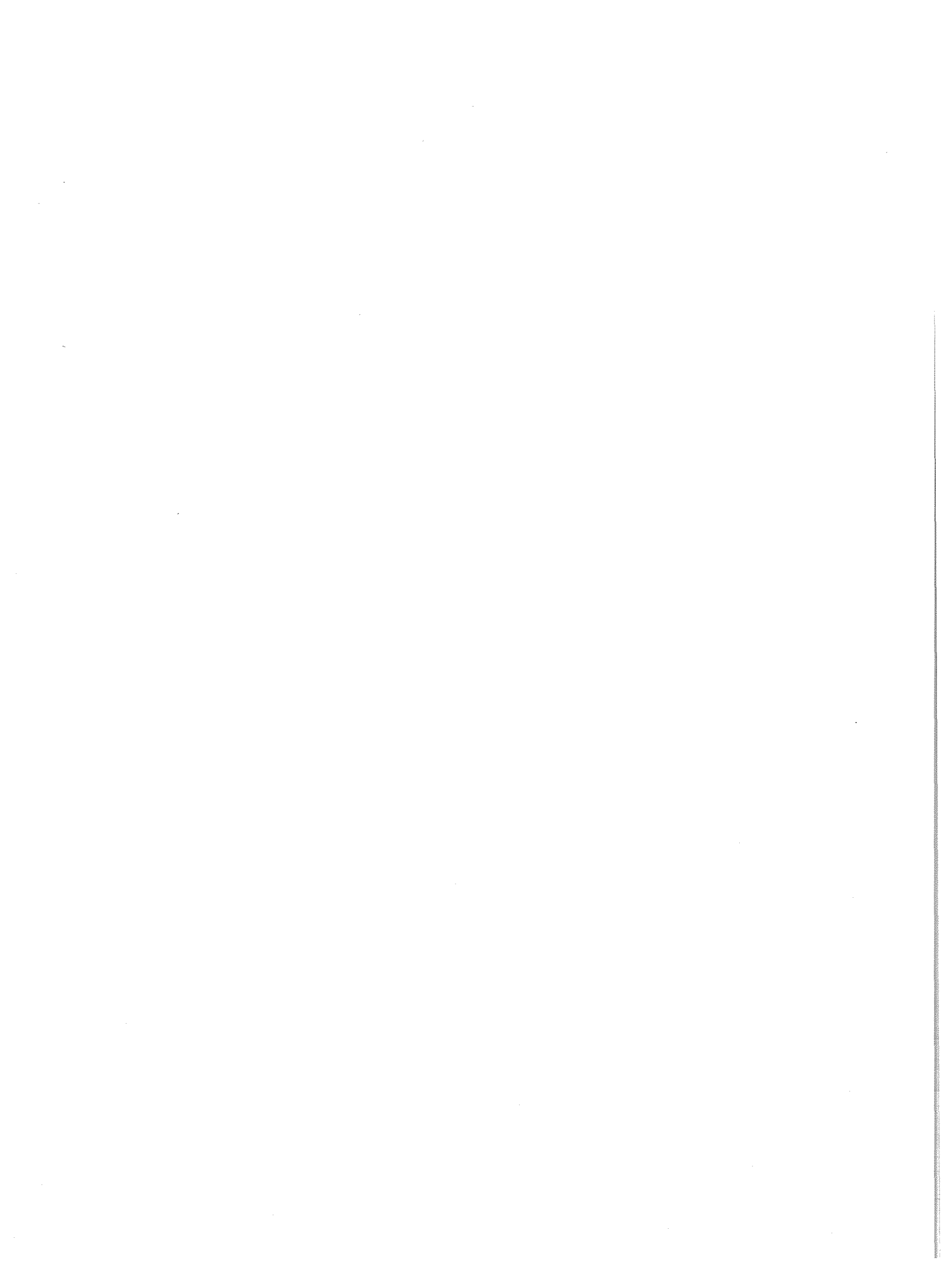
- 1) The pasture species studied were extremely sensitive to the

application of dalapon in mid-autumn.

2) White clover was less tolerant than perennial ryegrass at this time of year. Browntop and cocksfoot were the most susceptible species. The relative tolerances were maintained at each treatment rate.

3) The range of tolerance between species was small.

4) Dalapon affected the resistance of sprayed herbage to frost. This factor may possibly be partly responsible for the enhanced kill of pasture species obtained during autumn and winter.



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Appendix I

List of common names and chemical abbreviations of weedkillers mentioned in the text.

The following list, based on that adopted by the Weed Society of America has been approved by the British Weed Control Council.

dalapon.....2,2, dichloropropionic acid.  
amitrol.....3-amino-1,2,4-triazole.  
T.C.A.....trichloroacetic acid.  
2,4-D.....2,4-dichlorophenoxyacetic acid.  
dinoseb.....4,6-dinitro-o-sec-butylphenol.  
P.C.P.....pentachlorophenol.

Appendix II

Table indicating random allocation of  
plot sample sections.

Perennial Ryegrass Experiment.

T  
R  
E  
A  
T  
M  
E  
N  
T  
S

1 345162	6 534126	11 463521	16 236415	21 352146	26 312564
2 531462	7 614523	12 435612	17 564231	22 124563	27 462513
3 621354	8 624351	13 315264	18 615243	23 653214	28 514263
4 213645	9 352641	14 426315	19 513624	24 543261	29 236145
5 216453	10 412356	15 431625	20 432615	25 163243	30 345216

BLOCKS

Appendix IIIa

Perennial Ryegrass,

First Cut.

Percentage Contribution of Sown Species  
to Plot Yield.

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	98.2	98.5	99.0	98.3	99.3	99.9	98.9
	2	96.6	98.6	98.5	95.6	98.3	98.8	97.7
	4	99.1	98.4	97.6	99.8	98.4	98.2	98.6
	6	98.8	98.7	97.5	98.7	97.4	99.5	98.4
	8	97.9	99.5	96.6	98.5	98.8	99.2	98.4
							General Mean:	98.4

Appendix IIIb

Perennial Ryegrass,                      First Cut  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	81.8	101.3	69.0	92.3	112.7	132.6	589.7	98.3
2	68.0	59.4	76.0	62.5	78.6	101.5	446.0	74.3
4	72.9	58.5	51.4	57.7	72.4	91.1	404.0	67.3
6	72.4	53.3	40.2	60.1	52.5	92.6	371.1	61.9
8	35.7	51.4	36.8	54.7	58.8	52.7	290.1	48.4
Block Totals	330.8	323.9	273.4	327.3	375.0	470.5	Grand Total 2,100.9	General Means 70.0

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	4,515.56	903.11	7.49	2.71	4.10	6.46	***
Treatments	4	8,165.86	2,041.47	16.93	2.87	4.43	7.10	***
O V Rest	1	5,986.88	5,986.88	49.64	4.35	8.10	14.82	***
Error	20	2,412.74	120.63					
Total	29	15,094.16						
SE $\bar{Y}$	$\pm 4.5$	8.05	13.3	8.01	18.1	8.001	24.5	

Appendix IVa

**Perennial Ryegrass, Second Cut  
Percentage Contribution of Sown Species  
to Plot Yield**

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	97.6	93.9	94.5	98.0	96.8	99.8	96.8
	2	98.9	97.8	98.2	92.3	97.2	99.4	97.3
	4	99.1	98.8	98.6	98.7	97.2	99.2	98.6
	6	99.6	98.3	99.1	96.9	93.8	98.8	97.8
	8	99.1	99.3	96.5	98.4	97.3	95.2	97.6
							<b>General Means</b>	<b>97.6</b>

Appendix IVb

Perennial Ryegrass, Second Cut.

Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	94.4	86.2	74.7	85.8	83.4	133.6	558.1	93.0
2	84.2	79.1	64.8	95.5	79.8	105.1	508.5	84.8
4	73.3	51.4	33.6	54.0	64.8	89.9	367.0	61.2
6	57.9	39.4	40.0	46.5	32.8	68.6	285.2	47.5
8	31.5	43.3	32.1	31.6	43.7	57.3	239.5	39.9
<b>Block Totals</b>	<b>341.3</b>	<b>299.4</b>	<b>245.2</b>	<b>313.4</b>	<b>304.5</b>	<b>454.5</b>	<b>Grand Total 1958.3</b>	<b>General Means 65.3</b>

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	4,920.53	984.12	12.67	2.71	4.10	6.46	***
Treatments	4	12,741.39	3,185.35	41.01	2.67	4.43	7.10	***
Error	20	1,553.39	77.67					
Total	29	19,215.31						
$SE_{\bar{x}}$	$\pm 3.6$	<sup>d</sup> 0.05	10.6	<sup>d</sup> 0.01	14.5	<sup>d</sup> 0.001		19.6

Appendix Va

Perennial Ryegrass, Third Cut  
 Percentage Contribution of Sown Species  
 to Plot Yield.

		Blocks						Means	
		I	II	III	IV	V	VI		
T r e a t m e n t s	0	99.4	98.2	99.0	98.8	99.6	98.0	98.8	
	2	99.5	98.5	98.7	98.4	99.4	99.8	99.1	
	4	99.3	99.5	99.3	100.0	97.0	99.1	99.0	
	6	97.9	99.2	98.9	98.9	99.2	98.4	98.8	
	8	98.9	92.1	97.1	99.7	98.0	99.8	97.6	
							General Mean	98.7	

Appendix Vb

Perennial Ryegrass, Third Cut  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	189.9	75.3	70.4	95.7	82.4	134.7	648.4	108.1
2	90.8	64.9	47.8	71.6	90.1	115.1	480.3	80.1
4	58.7	37.3	49.8	42.3	29.1	112.0	329.2	54.9
6	39.0	57.4	40.4	49.6	51.4	56.3	294.1	49.0
8	31.2	21.3	18.7	35.3	45.1	37.5	189.1	31.5
Blocks Totals	409.6	256.2	227.1	294.5	298.1	455.6	Grand Total 1941.1	General Means 64.7

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	8,034.41	1,606.88	3.00	2.71	4.10	6.46	*
Treatments	4	21,360.51	5,340.13	9.98	2.87	4.43	7.10	***
Error	20	10,704.13	535.21					
Total	29	40,099.05						
SE <sub>x</sub>	± 9.4	<sup>d</sup> 0.05	27.9	<sup>d</sup> 0.01	38.0	<sup>d</sup> 0.001	51.5	

Appendix    Via

Perennial Ryegrass,      Fourth Cut.

Percentage Contribution of Sown Species to Plot  
Yield.

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	99.1	99.1	96.8	95.8	97.9	98.5	97.9
	2	96.7	93.6	97.9	97.6	97.6	99.6	97.2
	4	98.8	97.1	90.3	97.4	96.3	98.2	96.4
	6	92.1	88.8	96.0	99.6	96.5	99.5	95.4
	8	89.3	96.5	90.1	97.0	95.7	99.7	94.7
							General Mean	96.3

Appendix VIb

Perennial Ryegrass, Fourth Cut.  
 Dry Matter Yield of Sown Species  
 (Live Herbage).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	159.9	108.1	70.0	76.9	77.3	143.8	636.0	106.0
2	62.2	36.7	43.2	57.9	64.5	102.0	366.5	61.1
4	60.1	25.0	14.9	27.5	37.0	42.0	206.5	34.4
6	11.8	10.8	29.0	12.4	13.0	27.3	104.3	17.4
8	7.7	13.8	12.3	30.0	16.7	25.4	105.9	17.7
Block Totals	301.7	194.4	169.4	204.7	208.5	340.5	Grand Total 1419.2	General Means 47.3

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	4,627.42	925.48	2.56	2.71	4.10	6.46	N.S.
Treatments	4	33,454.68	8,363.67	23.11	2.87	4.43	7.10	***
Error	20	7,238.14	361.91					
Total	29	45,320.24						
SE $\bar{x}$		±7.8	<sup>d</sup> 0.05	22.9	<sup>d</sup> 0.01	31.3	<sup>d</sup> 0.001	42.3

Appendix VIc

Perennial Ryegrass, Fourth Cut.  
Dry Matter Yield of Sown Species  
(Total).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	214.2	129.8	83.7	96.7	94.3	178.6	797.3	132.9
2	96.5	56.4	64.3	92.5	101.4	142.7	553.8	92.3
4	89.3	44.5	26.8	47.2	64.0	63.9	335.7	56.0
6	27.2	23.3	49.1	31.0	25.6	42.0	198.2	33.0
8	20.0	30.6	23.9	53.5	30.6	41.7	200.3	33.4
Block Totals	447.2	284.6	247.8	320.9	315.9	468.9	Grand Total 2085.3	General Mean 69.5

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	8,056.13	1,611.23	2.27	2.71	4.10	6.46	N.S.
Treatments	4	44,130.73	11,032.68	15.57	2.87	4.43	7.10	***
Error	20	14,168.85	708.44					
Total	29	66,355.71						
$SE_{\bar{x}}$	$\pm 10.9$	$^d 0.05$	32.1	$^d 0.01$	—43.8	$^d 0.001$		59.3

Appendix VIIa

Perennial Ryegrass, Fifth Cut.

Percentage Contribution of Sown Species to  
Plot Yield.

		Blocks							
		I	II	III	IV	V	VI	Means	
Treatments	0	85.5	84.0	89.0	85.5	92.9	98.4	89.2	
	2	99.5	90.3	88.4	95.4	98.5	89.1	93.5	
	4	72.4	92.9	89.6	90.2	92.8	95.2	88.9	
	6	66.3	88.3	58.3	56.1	88.0	80.7	73.0	
	8	81.2	72.4	38.7	52.2	94.3	39.5	63.1	
								General Mean:	81.5

Appendix VIIb

Perennial Ryegrass, Fifth Cut.

Dry Matter Yield of Sown Species  
(Live Herbage).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	110.8	67.8	32.5	52.6	92.9	139.4	496.0	82.7
2	135.5	48.4	33.2	61.5	73.5	95.4	447.5	74.6
4	24.8	34.4	25.9	40.5	40.6	84.6	250.8	41.8
6	25.6	37.3	17.4	16.6	56.7	37.8	191.4	31.9
8	31.5	28.6	6.1	11.9	49.8	43.5	171.4	28.6
Block Totals	328.2	216.5	115.1	183.1	313.5	400.7	Grand Total 1557.1	General Means 51.9

Analysis of Variance

Variations due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	11,222.09	2,244.22	5.40	2.71	4.10	6.46	**
Treatments	4	15,045.45	3,761.36	9.05	2.87	4.43	7.10	***
Error	20	8,308.75	415.44					
Total	29	34,576.29						
SE <sub>y</sub>	+8.3	<sup>d</sup> 0.05	24.6	<sup>d</sup> 0.01	33.5	<sup>d</sup> 0.01	45.4	

Appendix VIIc

Perennial Ryegrass, Fifth Cut.

Dry Matter Yield of Sown Species  
(Total).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	175.1	102.4	48.5	91.5	153.7	238.6	809.8	135.0
2	211.7	73.9	50.2	88.3	118.6	152.2	694.9	115.8
4	38.8	51.8	34.0	66.9	60.8	115.5	367.8	61.3
6	31.7	47.3	22.3	23.2	81.9	43.6	250.0	41.7
8	37.6	36.4	6.5	13.8	70.7	49.9	214.9	35.8
Block Totals	494.9	311.8	161.5	283.7	485.7	599.8	Grand Total 2337.4	General Mean 77.9

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	26,760.88	5,352.18	4.60	2.71	4.10	6.46	**
Treatments	4	48,322.18	12,080.55	10.39	2.87	4.43	7.10	***
Error	20	23,255.44	1,162.77					
Total	29	98,338.50						
$SE_{\bar{x}}$	$\pm 13.9$	$d_{0.05}$	41.1	$d_{0.01}$	56.1	$d_{0.001}$	75.9	

Appendix VIIIa

Cocksfoot,                      First Cut.

Percentage Contribution of Sown Species to Plot  
Yield.

Blocks								
	I	II	III	IV	V	VI	Means	
T r e a t m e n t s	0	99.8	98.4	96.3	95.0	99.1	99.3	98.0
	2	98.6	99.7	96.8	99.0	99.3	99.7	98.9
	4	99.3	99.2	94.4	98.3	98.6	99.8	98.3
	6	99.9	98.3	97.7	95.8	99.2	99.7	98.4
	8	98.4	99.5	97.4	99.6	98.3	100.0	98.9
							General Mean	98.5

Appendix VIIIb

Cocksfoot, First Cut.  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	174.3	97.6	111.3	93.1	118.6	146.7	741.6	123.6
2	92.6	74.5	75.3	83.2	94.4	124.5	544.5	90.8
4	113.8	74.5	70.4	83.3	70.0	94.9	506.9	84.5
6	70.7	63.2	81.8	72.0	82.0	104.2	473.9	79.0
8	85.5	65.6	68.9	93.8	88.0	99.9	501.7	83.6
<b>Block Totals</b>	<b>536.9</b>	<b>375.4</b>	<b>407.7</b>	<b>425.4</b>	<b>453.0</b>	<b>570.2</b>	<b>Grand Total 2768.6</b>	<b>General Mean 92.3</b>

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	5,836.78	1,167.36	5.57	2.71	4.10	6.46	**
Treatments	4	7,775.55	1,943.89	9.27	2.87	4.43	7.10	***
O V Rest	1	7,353.94	7,353.94	35.06	4.35	8.10	14.82	***
Error	20	4,194.78	209.74					
Total	29	17,807.11						
SE $\frac{y}{\sqrt{v}}$	$\pm$ 5.9	$^d$ 0.05	17.5	$^d$ 0.01	23.8	$^d$ 0.001	32.2	

Appendix IXa

Cocksfoot,                      Second Cut.

Percentage Contribution of Sown Species to  
Plot Yield.

		Blocks							
		I	II	III	IV	V	VI	Means	
Treatments	0	99.7	98.0	95.2	94.3	100.0	100.0	97.9	
	2	98.7	99.1	95.2	98.8	99.5	100.0	98.6	
	4	99.9	97.8	91.5	99.6	96.6	99.9	97.6	
	6	99.6	94.7	96.2	90.1	99.6	99.2	96.6	
	8	99.6	96.9	95.6	100.0	100.0	100.0	98.7	
							General Mean	97.9	

Appendix IXb

Cocksfoot, Second Cut.  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	129.9	98.4	118.8	97.7	130.7	153.1	728.6	121.4
2	88.8	83.2	80.4	70.0	89.5	124.8	536.7	89.5
4	90.0	46.5	46.2	78.8	57.7	106.7	425.9	71.0
6	50.5	43.9	44.1	55.4	71.8	77.6	343.3	57.2
8	50.5	38.8	55.9	77.9	56.4	52.0	331.5	55.3
Block Totals	409.7	310.8	345.4	379.8	406.1	514.2	Grand Total 2366.0	General Mean 78.9

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	4,865.22	973.04	4.77	2.71	4.10	6.46	**
Treatments	4	18,075.27	4,518.82	22.16	2.87	4.43	7.10	***
Error	20	4,078.12	203.91					
Total	29	27,018.61						
$SE_{\bar{x}}$	$\pm 5.8$	$d_{0.05}$	17.2	$d_{0.01}$	23.5	$d_{0.001}$	31.8	

Appendix      Xa

Cocksfoot              Third Cut.

Percentage Contribution of Sown Species  
to Plot Yield.

	Blocks							Means
	I	II	III	IV	V	VI		
T r e a t m e n t s	0	95.8	98.5	94.0	93.2	100.0	100.0	96.9
	2	98.6	94.7	98.1	99.2	98.4	99.6	98.1
	4	94.8	98.9	92.3	99.4	99.3	96.9	96.9
	6	98.3	93.6	93.8	85.0	98.9	97.1	94.5
	8	90.0	97.5	97.2	100.0	93.5	100.0	96.4
General Mean								96.6

Appendix Xb

Cocksfoot, Third Cut.  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	159.4	105.6	102.7	85.0	124.0	127.0	703.7	117.3
2	68.7	33.7	81.5	66.8	71.1	121.0	442.8	73.8
4	47.5	62.7	36.3	53.3	38.3	45.0	283.1	47.2
6	40.6	39.9	33.7	32.7	45.9	42.4	235.2	39.2
8	57.9	37.9	30.2	26.7	36.1	49.8	238.6	39.8
Block Totals	374.1	279.8	284.4	264.5	315.4	385.2	Grand Total 1903.4	General Mean 63.4

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	2,623.34	524.67	1.76	2.71	4.10	6.46	N.S.
Treatments	4	26,512.30	6,628.08	22.17	2.87	4.43	7.10	***
Error	20	5,977.99	298.90					
Total	29	35,113.63						
SE $\frac{s}{x}$	$\pm 7.1$	$d_{0.05}$	20.8	$d_{0.01}$	28.4	$d_{0.001}$	38.5	

Appendix                      XIa

Cocksfoot,                      Fourth Cut.

Percentage Contribution of Sown Species to  
Plot Yield.

		Blocks							
		I	II	III	IV	V	VI	Means	
T r e a t m e n t s	0	97.1	97.8	91.9	97.6	99.2	99.3	97.2	
	2	93.5	84.0	83.8	92.5	92.1	92.0	89.7	
	4	98.0	89.3	52.6	88.7	92.7	99.7	86.8	
	6	91.7	97.8	65.2	95.4	99.0	94.9	90.7	
	8	88.6	89.2	89.0	96.8	95.1	91.7	91.7	
							General Mean	91.2	

Appendix      XIb

Cocksfoot,                  Fourth Cut.  
Dry Matter Yield of Sown Species.  
(Live Herbage)

	I	II	III	IV	V	VI	Treatment Totals	Means
0	101.5	44.6	57.4	60.2	67.7	106.0	437.4	72.9
	SE $\frac{\sigma}{\sqrt{x}}$ for 6 figures = $\pm$ 10.2							
2	23.6	17.3	10.7	12.0	6.4	14.2	84.2	14.0
4	29.8	7.4	2.1	4.2	13.7	4.0	61.2	10.2
6	0.4	2.6	0.1	0.3	2.8	0.6	6.8	1.1
8	0.5	0.1	0.3	0.2	0.5	5.0	6.6	1.1
Block Totals	54.3	27.4	13.2	16.7	23.4	23.8	Grand Total 158.8	General Mean 6.6

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	265.87	53.17	1.66	2.90	4.56	7.57	N.S.
Treatments	3	770.08	256.69	8.02	3.29	5.42	9.34	**
Error	15	480.06	32.00					
Total	23	1,516.01						
SE $\frac{\sigma}{\sqrt{x}}$	$\pm$ 2.3	$d_{0.05}$	7.0	$d_{0.01}$	9.6	$d_{0.001}$	13.3	

Cocksfoot,

Fourth Cut.

Dry Matter Yield of Sown Species  
(Total).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	167.5	94.8	105.5	112.1	127.9	179.9	787.7	131.3
							SE $\frac{\sigma}{\sqrt{k}}$ for 6 figures = $\pm 14.2$	
2	58.6	70.9	54.1	50.9	43.6	92.6	370.7	61.8
4	77.0	44.0	20.7	38.0	45.1	42.2	267.0	44.5
6	35.7	46.7	20.5	29.3	49.1	36.3	217.6	36.3
8	29.9	18.2	22.0	29.1	31.2	42.4	172.8	28.8
Block Totals	201.2	179.8	117.3	147.3	169.0	213.5	Grand Total 1028.1	General Mean 42.8

## Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	1,561.09	312.22	1.81	2.90	4.56	7.57	N.S.
Treatments	3	3,611.61	1,203.87	6.99	3.29	5.42	9.34	**
Error	15	2,582.40	172.16					
Total	23	7,755.10						
SE $\frac{\sigma}{\sqrt{k}}$	$\pm 5.4$	$\sigma^2 0.05$	16.2	$\sigma^2 0.01$	22.3	$\sigma^2 0.001$	30.9	

Appendix      XIIa

Cocksfoot,              Fifth Cut.  
 Percentage Contribution of Sown Species to  
 Plot Yield.

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	95.1	95.2	75.9	90.4	97.4	99.0	92.2
	2	77.8	71.9	74.8	84.6	86.3	99.5	82.5
	4	62.6	59.1	23.1	40.8	55.6	63.4	50.8
	6	84.1	47.5	9.4	20.1	54.3	47.2	43.8
	8	63.2	9.6	33.0	10.5	17.5	76.7	35.1
							General Mean	60.9

Appendix XIIb

Cocksfoot, Fifth Cut.

Dry Matter Yield of Sown  
Species (Live Herbage.)

	I	II	III	IV	V	VI	Treatment Totals	Means
0	73.6	97.1	81.8	61.1	85.8	102.6	502.0	83.7
							SE $\frac{\_}{x}$ for 6 figures = $\frac{\_}{+}$ 6.2	
2	24.1	31.0	24.5	31.9	23.7	60.5	195.7	32.6
4	17.2	21.8	8.8	7.3	17.0	13.0	85.1	14.2
6	28.9	23.0	3.3	9.3	15.3	4.9	84.7	14.1
8	5.1	1.3	12.6	-	5.6	16.1	40.7	6.8
Block Totals	75.3	77.1	49.2	48.5	61.6	94.5	Grand Total 406.2	General Mean 16.9

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	403.11	80.62	< 1	2.90	4.56	7.57	N.S.
Treatments	3	2,186.91	728.97	7.42	3.29	5.42	9.34	**
Error	15	1,473.18	98.21					
Total	23	4,063.20						
SE $\frac{\_}{x}$	$\frac{\_}{+}$ 4.0	$\frac{\_}{d}$ 0.05	12.2	$\frac{\_}{d}$ 0.01	16.9	$\frac{\_}{d}$ 0.001		23.3

Appendix XIIc

Cocksfoot, Fifth Cut.  
Dry Matter Yield of Sown Species  
(Total).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	154.8	180.3	145.2	145.3	178.0	227.6	1031.2	171.9
							SE $\frac{\quad}{x}$ for 6 figures = $\pm$ 12.8	
2	58.2	59.7	54.1	69.8	60.5	139.6	441.9	73.7
4	29.6	39.0	13.4	17.4	33.5	31.6	164.5	27.4
6	45.6	37.0	5.8	13.9	29.5	7.4	139.2	23.2
8	29.9	5.5	18.8	2.1	9.3	24.3	89.9	15.0
Block Totals	163.3	141.2	92.1	103.2	132.8	202.9	Grand Total 835.5	General Mean 34.8

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	2,049.46	409.89	1.06	2.90	4.56	7.57	N.S.
Treatments	3	12,546.57	4,182.19	10.86	3.29	5.42	9.34	***
Error	15	5,776.32	385.09					
Total	23	20,372.35						
SE $\frac{\quad}{x}$	$\pm$ 8.0	$d_{0.05}$	24.2	$d_{0.01}$	33.4	$d_{0.001}$	46.2	

Appendix      XIIIa

Browntop,                      First Cut.

Percentage Contribution of Sown Species to  
Plot Yield.

		Blocks							
		I	II	III	IV	V	VI	Means	
T r e a t m e n t s	0	62.2	53.1	82.9	50.9	79.2	89.8	69.7	
	2	27.6	81.2	64.7	84.8	78.6	89.5	71.0	
	4	88.9	42.6	57.9	63.2	87.5	94.9	72.5	
	6	77.9	53.6	86.1	83.7	74.2	89.4	77.5	
	8	89.3	84.1	86.2	78.1	85.8	79.4	83.8	
								General Mean	74.9

Appendix XIIIb

Browntop, First Cut.

Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	49.3	27.3	82.7	51.5	76.6	95.3	382.7	63.8
2	15.7	44.1	16.4	45.1	61.6	75.9	258.8	43.1
4	25.4	10.6	15.9	42.2	72.9	107.6	274.6	45.8
6	38.9	30.5	35.3	37.0	49.8	77.9	269.4	44.9
8	33.8	31.4	18.7	38.1	61.7	59.7	243.4	40.6
Block Totals	163.1	143.9	169.0	213.9	322.6	416.4	Grand Total 1428.9	General Mean 47.6

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	11,758.05	2,351.61	10.72	2.71	4.10	6.46	***
Treatments	4	2,051.80	512.95	2.34	2.87	4.43	7.10	N.S.
Control V rest	1	1,956.98	1,956.98	8.92	4.35	8.10	14.82	**
Error	20	4,389.28	219.46					
Total	29	18,199.13						
SE $\frac{s}{x}$	$\pm 6.0$	$d_{0.05}$	17.9	$d_{0.01}$	24.4	$d_{0.001}$		33.0

Browntop,

Second Cut.

Percentage Contribution of Sown Species to  
Plot Yield.

		Blocks							
		I	II	III	IV	V	VI	Means	
T r e a t m e n t s	0	53.2	78.3	71.6	79.1	89.1	91.6	77.2	
	2	81.1	81.4	76.9	86.7	92.4	90.2	84.8	
	4	91.5	73.2	75.4	87.4	83.0	97.7	84.7	
	6	68.1	76.0	77.7	84.7	79.8	96.2	80.4	
	8	92.0	53.0	84.0	80.6	85.5	90.2	80.9	
								General Mean	81.6

Appendix XIVb

Browntop, Second Cut.  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	36.7	30.2	80.9	65.0	74.0	118.1	404.9	67.5
					SE $\frac{s}{x}$ for 6 figures = $\pm$ 13.1			
2	32.4	42.6	15.8	23.9	73.3	48.3	236.3	39.4
4	31.0	20.5	19.0	74.4	42.6	61.1	248.6	41.4
6	8.2	29.5	22.1	25.7	46.2	54.4	186.1	31.0
8	39.2	7.2	24.3	23.8	45.7	63.2	203.4	34.0
Block Totals	110.8	99.8	81.2	147.8	207.8	227.0	Grand Total 874.4	General Mean 36.4

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	4,488.89	897.78	3.89	2.90	4.56	7.57	*
Treatments	3	416.76	138.92	< 1	3.29	5.42	9.34	N.S.
Low V High	1	379.21	379.21	1.64	4.54	8.68	16.58	N.S.
Error	15	3,462.10	230.81					
Total	23	8,367.75						
SE $\frac{s}{x}$	$\pm$ 6.2	$^d$ 0.05	18.7	$^d$ 0.01	25.9	$^d$ 0.001		35.8

Appendix      XVa

Browntop,                      Third Cut.

Percentage Contribution of Sown Species  
to Plot Yield.

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	72.6	75.6	86.1	90.9	90.0	89.7	84.2
	2	81.9	84.9	83.8	83.1	89.4	90.1	85.5
	4	81.7	80.7	81.1	84.5	82.7	88.6	83.2
	6	66.1	82.8	72.3	72.2	55.5	80.2	71.5
	8	81.2	56.4	66.4	64.4	77.5	64.9	68.5
							General Mean	78.6

Appendix      XVb

Browntop,              Third Cut.  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	48.3	33.3	88.3	84.3	81.2	105.4	440.8	73.5
SE $\frac{s}{x}$ for 6 figures = + 11.1								
2	40.2	25.5	8.3	19.5	34.7	52.7	180.9	30.2
4	17.7	6.5	8.5	29.6	47.7	52.0	162.0	27.0
6	4.8	29.9	18.9	7.9	7.5	41.7	110.7	18.5
8	10.7	3.5	9.5	8.6	23.8	24.4	80.5	13.4
Block Totals	73.4	65.4	45.2	65.6	113.7	170.8	Grand Total 534.1	General Mean 22.3

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	2,641.91	528.38	4.02	2.90	4.56	7.57	*
Treatments	3	1,064.64	354.88	2.70	3.29	5.42	9.34	N.S.
Low V High	1	958.87	958.87	7.29	4.54	8.68	16.58	*
Error Total	15	1,972.11	131.47					
Total	23	5,678.66						
SE $\frac{s}{x}$	+ 4.7	<sup>d</sup> 0.05	14.1	<sup>d</sup> 0.01	19.5	<sup>d</sup> 0.001	27.0	

Appendix      XVIa

Browntop,              Fourth Cut.

Percentage Contribution of Sown Species to  
Plot Yield.

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	44.6	37.3	70.0	77.5	83.1	90.0	67.1
	2	36.7	55.4	70.0	63.9	65.4	74.7	61.0
	4	71.9	64.3	58.4	61.6	50.4	68.1	62.5
	6	70.5	34.2	42.2	22.1	34.1	64.0	44.5
	8	31.7	29.1	50.0	18.0	69.5	31.9	38.4
								General Mean 54.7

Appendix                      XVib

Browntop,                      Fourth Cut.  
 Dry Matter Yield of Sown Species  
 (Live Herbage).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	17.5	16.9	50.1	16.5	45.8	121.1	267.9	44.7
SE $\frac{1}{x}$ for 6 figures = $\pm$ 16.5								
2	3.0	2.8	3.9	4.5	3.9	6.8	24.9	4.2
4	0.6	0.1	4.1	5.0	4.4	8.4	22.6	3.8
6	7.0	2.3	0.6	-	0.1	2.3	12.3	2.1
8	0.2	0.2	-	0.1	1.2	0.4	2.1	0.4
Block Totals	10.8	5.4	8.6	9.6	9.6	17.9	Grand Total 61.9	General Mean 2.6

Analysis of Variance

Variation due to	D.F.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	21.47	4.29	< 1	2.90	4.56	7.57	N.S.
Treatments	3	54.76	18.25	3.83	3.29	5.42	9.34	*
Low V High	1	45.65	45.65	9.57	4.54	8.68	16.58	**
Error	15	71.61	4.77					
Total	23	147.84						
SE $\frac{1}{x}$	$\pm$ 0.9	$d_{0.05}$	2.7	$d_{0.01}$	3.7	$d_{0.001}$		5.1

Appendix      XVIc

Browntop,              Fourth Cut.  
 Dry Matter Yield of Sown Species  
 (Total).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	19.8	18.5	72.0	30.8	69.5	145.5	356.1	59.4
SE $\frac{\quad}{x}$ for 6 figures = $\pm$ 19.8								
2	7.7	14.0	17.6	15.0	19.7	38.1	112.1	18.7
4	5.7	1.9	8.9	19.2	17.9	45.5	99.1	16.5
6	25.0	9.7	4.6	5.1	6.8	21.3	72.5	12.1
8	5.4	4.5	2.2	2.0	21.4	17.9	53.4	8.9
Block Totals	43.8	30.1	33.3	41.3	65.8	122.8	Grand Total 337.1	General Mean 14.0

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	1,527.28	305.46	4.59	2.90	4.56	7.57	**
Treatments	3	347.66	115.89	1.74	3.29	5.42	9.34	N.S.
Error	15	977.38	66.49					
Total	23	2,872.32						
SE $\frac{\quad}{x}$	$\pm$ 3.3	<sup>d</sup> 0.05	10.0	<sup>d</sup> 0.01	13.9	<sup>d</sup> 0.001		19.2

Browntop,

Fifth Cut.

Percentage Contribution of Sown Species to  
Plot Yield.

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	57.8	46.1	72.6	62.9	69.2	81.5	65.0
	2	43.1	51.4	24.2	30.7	37.8	64.4	41.9
	4	18.5	15.8	19.4	13.0	9.7	27.4	17.3
	6	2.6	1.1	6.7	2.5	2.5	0.8	2.7
	8	-	9.0	0.7	0.4	14.8	2.0	4.2
								General Mean 26.2

Appendix      XVIIb

Browntop,              Fifth Cut.

Dry Matter Yield of Sown Species  
(Live Herbage).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	23.1	25.4	53.7	56.6	44.9	109.8	313.5	52.3
$SE_{\frac{\bar{x}}{x}}$ for 6 figures = $\pm 12.9$								
2	11.9	13.9	4.0	2.3	16.2	34.2	82.5	13.8
4	2.8	2.2	2.9	7.1	2.5	8.5	26.0	4.3
6	0.1	0.8	1.1	0.1	1.1	0.3	3.5	0.6
8	-	0.9	0.1	0.2	5.3	1.9	8.4	1.4
Block Totals	14.8	17.8	8.1	9.7	25.1	44.9	Grand Total 120.4	General Means 5.0

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	231.39	46.28	1.44	2.90	4.56	7.57	N.S.
Treatments	3	656.83	218.94	6.82	3.29	5.42	9.34	**
Error	15	481.69	32.11					
Total	23	1,369.91						
$SE_{\frac{\bar{x}}{x}}$	$\pm 2.3$	$d_{0.05}$	7.0	$d_{0.01}$	9.7	$d_{0.001}$		13.4

Appendix      XVIIc

Browntop,              Fifth Cut.

Dry Matter Yield of Sown Species  
(Total).

	I	II	III	IV	V	VI	Treatment Totals	Means
0	34.8	33.3	105.7	100.9	79.0	225.4	579.1	96.5
SE $\frac{\_}{x}$ for 6 figures = + 28.8								
2	18.9	21.7	5.3	3.5	23.6	54.0	127.0	21.2
4	4.0	2.5	4.3	11.5	3.9	13.1	39.3	6.6
6	0.1	0.8	1.4	0.2	1.4	0.6	4.5	0.8
8	-	1.0	0.1	0.4	8.9	3.1	13.5	2.3
Block Totals	23.0	26.0	11.1	15.6	37.8	70.8	Grand Total 184.3	General Mean 7.7

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	587.99	117.60	1.44	2.90	4.56	7.57	N.S.
Treatments	3	1,564.06	521.35	6.36	3.29	5.42	9.34	**
Error	15	1,228.85	81.92					
Total	23	3,380.90						
SE $\frac{\_}{x}$	+ 3.7	<sup>d</sup> 0.05	11.1	<sup>d</sup> 0.01	15.4	<sup>d</sup> 0.001	21.3	

Appendix XVIIIa

White Clover, First Cut.

Percentage Contribution of Sown Species to Plot Yield.

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	80.2	78.7	70.8	79.1	84.1	67.4	76.7
	2	72.9	73.5	77.5	71.4	89.4	70.3	75.8
	4	61.8	69.2	45.3	77.0	48.1	64.2	60.9
	6	87.8	87.9	60.8	56.2	52.0	81.1	71.0
	8	74.2	80.5	60.0	65.7	81.7	68.4	71.8
								General Mean 71.2

Appendix XVIIIb

White Clover, First Cut.  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	90.0	78.2	64.6	74.8	79.0	70.6	458.1	76.4
2	51.9	72.8	64.3	62.4	66.2	62.2	379.8	63.3
4	55.4	75.5	51.4	62.3	45.9	52.2	342.7	57.1
6	61.8	74.4	55.8	50.2	50.7	61.6	354.5	59.1
8	42.9	63.6	65.1	67.8	54.6	66.3	360.3	60.1
Block Totals	302.9	364.5	301.2	317.5	296.4	312.9	Grand Total 1895.4	General Mean 63.2

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	627.77	125.55	1.77	2.71	4.10	6.46	N.S.
Treatments	4	1,420.84	355.21	5.01	2.87	4.43	7.10	**
O V Rest	1	1,300.87	1,300.87	18.33	4.35	8.10	14.82	***
Error	20	1,419.32	70.97					
Total	29	3,467.93						
SE $\frac{\sigma}{K}$	+ 3.4	<sup>d</sup> 0.05	10.2	<sup>d</sup> 0.01	13.9	<sup>d</sup> 0.001	18.7	

Appendix                      XIXa

White Clover,                      Second Cut  
 Percentage Contribution of Sown Species  
 to Plot Yield.

		Blocks							
		I	II	III	IV	V	VI	Means	
T r e a t m e n t s	0	70.7	83.3	79.2	75.2	90.7	71.8	78.5	
	2	77.5	85.2	92.1	86.8	70.5	86.0	83.0	
	4	74.2	83.4	70.8	90.1	78.4	83.1	80.0	
	6	73.8	94.4	86.1	83.5	80.0	69.1	81.2	
	8	77.3	75.3	81.7	86.7	80.2	80.5	80.3	
							General Mean	80.6	

Appendix XIXb

White Clover, Second Cut.  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	160.5	94.3	98.0	81.4	90.1	100.1	624.4	104.1
2	95.3	137.5	82.9	77.4	45.0	149.5	587.6	97.9
4	53.6	86.4	57.2	78.9	66.4	73.1	416.1	69.4
6	54.1	118.8	56.2	52.5	71.4	42.3	395.3	65.9
8	49.7	46.5	49.5	31.7	49.3	36.6	263.3	43.9
<b>Block Totals</b>	<b>413.2</b>	<b>483.5</b>	<b>344.3</b>	<b>321.9</b>	<b>322.2</b>	<b>401.6</b>	<b>Grand Total 2286.7</b>	<b>General Mean 76.2</b>

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	4,052.90	810.58	1.29	2.71	4.10	6.46	N.S.
Treatments	4	14,679.65	3,669.91	5.84	2.87	4.43	7.10	**
Error	20	12,559.74	627.99					
Total	29	31,292.29						
$SE_{\bar{x}}$	$\pm 10.2$	$d_{0.05}$	30.2	$d_{0.01}$	41.2	$d_{0.001}$		55.8

**White Clover,                      Third Cut.**  
**Percentage Contribution of Sown Species**  
**to Plot Yield.**

		Blocks							
		I	II	III	IV	V	VI	Means	
T r e a t m e n t s	0	77.9	78.5	75.9	86.7	96.3	79.1	82.4	
	2	90.7	86.9	76.6	57.5	72.4	92.0	79.4	
	4	54.2	81.4	84.7	96.3	47.5	66.1	71.7	
	6	31.2	71.3	62.9	47.3	63.0	75.7	58.6	
	8	19.8	64.3	39.9	52.5	86.5	69.2	55.4	
								General Mean	69.5

Appendix XXb

White Clover, Third Cut.

Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	78.1	63.2	51.3	104.2	136.6	90.1	523.5	87.3
							SE $\frac{s}{x}$ for 6 figures = $\pm$ 12.5	
2	21.1	31.8	30.9	21.5	25.2	61.7	192.2	32.0
4	17.4	9.6	29.8	34.6	6.8	10.2	108.4	18.1
6	1.1	6.1	4.7	7.6	10.0	12.4	41.9	7.0
8	0.5	5.6	2.1	1.2	33.0	0.9	43.4	7.2
Block Totals	40.2	53.1	67.5	64.9	75.0	85.2	Grand Total 385.9	General Mean 16.1

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	317.04	63.41	< 1	2.90	4.56	7.57	N.S. *
Treatments	3	2,516.81	838.94	5.23	3.29	5.42	9.34	
Error	15	2,406.46	160.43					
Total	23	5,240.30						
SE $\frac{s}{x}$	$\pm$ 5.2	$d_{0.05}$	15.6	$d_{0.01}$	21.6	$d_{0.001}$	29.8	

Appendix      XXIa

White Clover,      Fourth Cut.

Percentage Contribution of Sown Species  
to Plot Yield.

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	71.9	87.4	60.7	97.4	95.4	79.7	82.1
	2	40.6	71.0	64.1	67.0	41.3	48.6	55.4
	4	24.3	49.1	64.7	58.8	38.3	49.6	47.5
	6	36.7	7.9	27.2	14.3	2.4	62.2	25.1
	8	16.9	11.4	10.1	76.8	0.9	14.3	21.7
							General Mean	46.4

Appendix XXIb

White Clover, Fourth Cut.  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	37.4	39.6	40.0	70.5	53.7	62.7	303.9	50.7
SE $\frac{s}{\sqrt{n}}$ for 6 figures = $\pm$ 5.7								
2	9.0	12.6	7.1	21.0	10.3	12.8	72.8	12.1
4	1.9	4.4	14.5	2.5	6.0	14.7	44.0	7.3
6	1.5	0.3	1.9	0.3	0.7	8.0	12.7	2.1
8	1.8	0.4	0.5	5.8	0.3	2.0	10.8	1.8
Block Totals	14.2	17.7	24.0	29.6	17.3	37.5	Grand Total 140.3	General Mean 5.8

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	97.99	19.60	1.16	2.90	4.56	7.57	N.S.
Treatments	3	432.13	144.04	8.50	3.29	5.42	9.34	**
Error	15	254.28	16.95					
Total	23	784.40						
SE $\frac{s}{\sqrt{x}}$	$\pm$ 1.7	$\sqrt{0.05}$	5.1	$\sqrt{0.01}$	7.0	$\sqrt{0.001}$		9.7

Appendix      XXIIa

White Clover,              Fifth Cut.

Percentage Contribution of Sown Species  
to Plot Yield.

		Blocks						
		I	II	III	IV	V	VI	Means
T r e a t m e n t s	0	59.8	63.4	61.7	27.7	38.4	50.8	50.3
	2	50.2	86.8	75.0	54.4	81.8	79.4	71.3
	4	20.4	37.5	75.3	63.1	50.3	54.6	50.2
	6	22.4	58.1	17.9	61.1	7.0	45.2	35.3
	8	11.0	21.8	17.9	28.7	10.6	48.8	25.1
							General Mean	46.0

Appendix      XXIIB

White Clover,      Fifth Cut.  
Dry Matter Yield of Sown Species.

	I	II	III	IV	V	VI	Treatment Totals	Means
0	71.7	76.3	76.9	37.2	32.1	80.9	375.1	62.5
					SE $\frac{1}{x}$	for 6 figures = $\pm$ 8.9		
2	26.8	44.9	41.1	28.2	22.4	64.0	227.4	37.9
4	5.3	16.9	30.9	3.8	28.3	29.2	114.4	19.1
6	3.2	9.9	3.5	24.6	2.1	7.6	50.9	8.5
8	2.3	7.7	3.0	10.5	1.2	10.9	35.6	5.9
Block Totals	37.6	79.4	78.5	67.1	54.0	111.7	Grand Total 428.3	General Mean 17.8

Analysis of Variance

Variation due to	d.f.	S.S.	M.S.	F	F required			Result
					5%	1%	0.1%	
Blocks	5	800.55	160.11	1.50	2.90	4.56	7.57	N.S. ***
Treatments	3	3,799.35	1,266.45	11.86	3.29	5.42	9.34	
Error	15	1,601.58	106.77					
Total	23	6,201.48						
SE $\frac{1}{x}$	$\pm$ 4.2	<sup>d</sup> 0.05	12.7	<sup>d</sup> 0.01	17.6	<sup>d</sup> 0.001	24.3	