

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

THE EFFECTS OF DEFOLIATION AND ROOTPRUNING  
ON COCKSFOOT AND PERENNIAL RYEGRASS;

AND

THE INFLUENCE OF SOIL MOISTURE  
ON ROOT INITIATION

✠      ✠      ✠

Thesis submitted for the Degree of M.Agr.Sc.  
in Field Husbandry, University of New Zealand,  
by D.B. Edmond.

-----

LIST OF CONTENTS.

I.	Introduction	1.
II.	Review of Literature	3.
III.	The Experiment, Layout and General Method	10.
	(a) The Experiment	10.
	(b) Layout	12.
	(c) General Method.	13.
IV.	Materials and Method.	15.
	(a) Grass	15.
	(b) Plaster knobs	16.
	(c) The Plot	18.
	(d) Planting out	19.
	(e) Pretreatment	19.
	(f) Equipment	20.
	(g) Top treatment	22.
	(h) Root Treatment	23.
	(i) Drying and weighing the clippings	24.
	(j) Soil moistures	25.
	(k) Weight sheets and data sheets	26.
	(l) Compilation of results	27.
V.	Results	31.
	A. Top treatments	32.
	(a) - (e) Various differences	36.- 44.
	(f) Components of variance	45.
	(g) Interactions	46.
	(h) Initial Stimulus	47.
	(i) General observations on top growth	49.
	B. Root treatments	52.
	(a) - (d) Various differences	54.- 59.
	(e) Interactions	60.
	(f) Components of variance	61.
	(g) General observations on root initiation	62.
	C. Soil moisture	65.
	D. Differential growth	67.
	E. Rust	68.

F. Numbers required	69.
G. Summary of Results	72.
VI. Discussion	77.
Of the experiment in general	77.
Of the results	79.
VII. Conclusion	84.
VIII. Bibliography	85.
IX. Appendices.	

For explanation of the symbols used in the  
Appendices please refer to Appendix XV.

TABLES AND FIGURES.

Table 1.	Mean average yield of dry top growth per clone for the whole experimental period.	33.
Table 2.	Analysis of variance in top growth yields.	35.
Table 3.	Relative percentages of the various sources of variance (tops).	45.
Table 4.	Mean average number of roots pruned off per clone for the whole experimental period.	53.
Table 5.	Analysis of variance in root numbers.	54.
Table 6.	Percentage contribution of the various sources to total variance.	61.
Figure 1.	Clay mould and Plaster Knobs	17.
Figure 2.	Chainomatic Balance	21.
"	3. Pans and shears	22.
"	4. Reconstruction of operation in progress	24.
"	5. Photograph of Plot area (Feb.9th.1948)	32.
"	6. Histogram of Mean total yields	34.
"	7. Graphs of yield of Cocksfoot clones	37.
"	8. " " " " Cert. Perenn. rye clones	38.
"	9. " " " " Uncert. " " "	39.
"	10. Initial stimulus (graphically)	48.
"	11. Histogram of mean total numbers (roots)	52.
"	12. Graphs of root initiation for Cocksfoot clones.	55.
"	13. Graphs of root initiation for Cert. Perenn. rye clones	56.
"	14. Graphs of root initiation for Uncert. Perenn. rye clones	57.
"	15. Soil sampling area	65.
"	16. Graph of Soil moisture	65.
"	17. Graph of Differential Growth	67.
"	18. Graphs for numbers required	71.

I.

INTRODUCTION.

The world is short of food (1). The population of the world is unequally distributed in relation to the productive ability of the land. Countries, where an extension of the farmed area is possible, are handicapped by a lack of available labour. In general these are the countries where production has not, as yet, reached a maximum level. As labour hinders extension an endeavour must be made to utilise present farm areas in the most efficient manner possible. In this way surpluses of food may be accumulated in these countries, e.g. New Zealand, for despatch to needy areas where the consumption of food is at a low level.

New Zealand produces animal products in quantity. To increase this quantity better use must be made of our chief stock food - grass. By more efficient use of our grasslands the production of our existing herds and flocks will be increased while an increase in our animal population will be inevitable.

For efficient use of our grasslands we must "know" our grasses. It would appear that a grass has an optimum length of leaf, beyond or within which the yield of nutrients decreases. By grazing down to this length the maximum uptake of nutrients should be possible. In nature we cannot consider grass on its own. In farming systems, as we understand them today, there must be a tolerance between plant and animal. If optimum leaf length is maintained then the grazing animal will suffer a lack of food, at some period of the year. Or, if an animal is to be permitted full expression of its potentialities for production, the plant, at some period, will have to be grazed to less than this optimum length. The maltreatment accorded by one to the other may be such as to prevent subsequent normal growth and production. Consequently a suitable middle course must be taken.

Yet, for the evaluation of our different grasses, both species and strains, we must know their optimum leaf lengths - or more loosely, height of grazing - and their reactions to different degrees of leaf removal.

Our knowledge of root growth and development is pitifully inadequate. We must discover the nature of the interrelation of tops and roots. Top growth is seasonal. Evidence points to the likelihood of root growth being seasonal. For a clear appreciation of grass growth a study of the seasonal root behaviour of grasses is essential.

Soil moisture influences our grasses, possibly their roots in particular. Irrigation of our dry land and drainage of our wet, may not be attended by all possible success without this knowledge.

In this experiment an endeavour was made to discover the reactions of different species and strains of grass, to different severities of leaf removal. An attempt was made to follow the seasonal growth of their root systems by observing the initiation of new roots at the base of the plant. The effect of soil moisture on root initiation in grasses was also investigated.

The experiment was laid down on an area at Massey College in March 1948.

## II.

REVIEW OF LITERATURE.

Blackman 1905 (2) stated "the way of those who set out to evaluate exactly the effects of changes in a single factor upon a multi-conditioned metabolic process is hard." He points out that "the analytical treatment of metabolic phenomena is not made any less certain in its procedure, though it is made more complex by the interaction of those metabolic effects which have been described by their investigators as stimulatory." The growth of grass is just such a multi-conditioned metabolic process. Thus it appears odious to consider different phases of growth without regard for the other phases. Nevertheless for convenience and clarity this review is grouped under various arbitrary headings.

SEASONAL GROWTH OF GRASSES.

Grass grows in a seasonal manner. Conclusive evidence for this has been published by Stapledon and Williams 1922(3) in Britain, and Hudson, Doak and McPherson 1934(4) in New Zealand. This seasonal growth of herbage can be modified by cutting or grazing treatments. Many workers have contributed to our knowledge of this aspect of grass management. Frequency and severity of defoliation have been the factors considered most often.

EFFECTS ON HERBAGE OF DIFFERENT FREQUENCIES AND SEVERITIES OF CUTTING.

Lindhard 1913(5), Stapledon and Beddows 1926(6), Stapledon and Milton 1930(7), Graber 1931(8), Robertson 1933(9), Roberts and Hunt 1936(10), Nedrow 1937(11), Harrison and Hodgson 1939(12) and Schofield 1944(13 and 14) all subscribe to the view that frequent cutting, severe cutting or a combination of both, will lead to decreased yields, whereas light cuttings carried out at long intervals of time will have little effect on yields of herbage. Stapledon and Milton state that continued plucking of inflorescences as they appear favoured root and top development.

Ellett and Carrier 1915(15) support the above group of writers and, further, claim that the decrease in herbage yield due to harsh cutting treatments may be more than compensated for by the increased protein percentage of the herbage actually produced. Aldous 1930(16) disagreed claiming that the higher protein percentage did not compensate for the loss in total yield caused by cutting. Lander 1942 (17) found for both arguments. The 1939-40 cycle of seasons was a dry one in India, and under the conditions ruling his results agreed with Ellett and Carriers' findings. The following year 1940-41, was wetter and his results confirmed Aldous' argument. Apparently local conditions determine the soundness of either contention. It seems that Aldous' argument would carry more weight in New Zealand.

In Hawaii Wilsie, Akamine and Takahashi 1940 (18) found that Napier Grass responded conventionally to cutting treatments. They found an 8 weekly cutting to 3 inch height above ground level gave greatest yield of palatable herbage. They claimed that this degree of defoliation was just sufficient to maintain food reserves and to permit good top growth of high palatability. More lenient or less lenient treatment yielded less total palatable fodder. Kennedy and Russell 1948(19) with a Kentucky blue grass-white clover pasture found clipping to  $\frac{1}{8}$ " above ground level each 8 weeks gave, under their conditions, greatest yield of dry matter. As with the Hawaiian workers more lenient or less lenient cutting treatments yielded less. In view of these findings it would seem likely that a particular severity of cutting will give maximum yield of palatable herbage and another particular severity of cutting may give maximum yield of dry matter. Possibly in practice the optimum treatment for grass would be somewhere between the two.

#### EFFECT OF STAGE OF GROWTH ON NUTRIENTS.

Nutrient content varies with stage of growth. Lander

(17) in accord with other workers found that percentage protein was highest at periods of least growth. This seems to be the general case. Bukey and Weaver 1939(20) noted a marked decrease in carbohydrate content under severe cutting conditions. Sturkie 1930(21) claimed that cutting of tops reduced rootstocks of Johnson grass. Plants entering the growing season with well developed rootstocks yielded at least 50% more dry top weight than those which lacked this initial advantage. McCarty and Price 1942(22) find that the storage of carbohydrate reserves by grasses, is cyclic in nature. Minimum storage coincides with maximum top growth, maximum storage occurring in autumn at the completion of secondary herbage growth. They state that early spring growth is dependent on the presence of adequate reserves of carbohydrate, 75% of these reserves producing only 10% of the herbage actually grown. Subsequent growth is dependent on currently assimilated foods. The amount of foliage present during the normal storage period determines the amount of carbohydrate reserve accumulated in roots and stem bases. Severity of cutting treatment is said to be the major influence on quantity of carbohydrate reserves. Graber 1931(8) claimed that the depletion of food reserves consequent on cutting, implied limited root growth and so lowered capacity to resist adverse conditions.

#### STIMULATORY EFFECT TO TOP GROWTH OF CUTTING TREATMENTS.

Immediately following initial cuttings or well spaced cuttings a rapid regeneration of top growth may be recognised. Support to this statement is given by Parker and Sampson 1931 (23), Martin G. Jones 1933(24), Hodgson 1942(25), Sullivan and Sprague 1944(26) and Jacques 1948(27). With cocksfoot Jones ascribed the phenomenon to the use of stored food reserves in the white leaf base. Hodgson, with cocksfoot, found this rapid regeneration decreased following subsequent cuttings. Lenient cuttings did not give this regeneration to any marked extent. Sullivan and Sprague claim that the

vigour of this regeneration can be correlated with reserve food stores, particularly carbohydrates stored in the roots and remaining tops. With ryegrass they indicate that reserves in the leaf base are used first. Thus, dependent on the presence of reserve food material, an initial burst of top growth closely follows a cutting, the more severe the cutting the greater the burst. This initial rapid regeneration declines in strength following repeated cuttings and soon disappears.

#### EFFECT OF DEFOLIATION ON ROOT GROWTH.

Weinmann 1948(28) under the title of "Underground development and reserves of grasses" has reviewed most of the literature pertinent to his subject. Nedrow (11) claimed that little had been done on directly restricting root extent or production. Weinmann confirms this statement, claiming as the object of his review, the stimulation of further research into root-top relationships. That there is such a relationship, and a close one, is made clear by Parker and Sampson 1930(29), Jones (24), Sprague 1933(30), Robertson (9), Roberts and Hunt (10), Jacques 1937(31), Nedrow (11), Whyte 1944 (32), Schofield (13) and Nelson 1945(33) in their various works. They agree, and others concur, that frequent clipping of top growth results in poor root growth. Parker and Sampson and Nelson found that severe defoliation caused reductions in root diameters, root ducts and root length. Jones emphasises that restriction of root growth gives an effect lasting through beyond the present season. Jacques emphasises the inhibiting effect on root development of defoliation of very young plants, preventing the establishment of adequate root systems. He shows that as numbers of "crown roots" increases so total root weight increases. Roberts and Hunt claimed checks, to root growth following cutting of tops, were due to removal of stored reserves from root to tops especially at flowering time. They mention that perennial ryegrass

has its main storage of reserves in the root system, offering a possible explanation for the generally accepted fact that ryegrass stands severe defoliation better than do cocksfoot or timothy. Whyte sums up simply - "it is probably correct to say that grazing and mowing practices have the greatest effect upon the root systems of herbage species. Evidence is great that lenient cutting treatments are best for roots."

#### SEASONAL GROWTH OF ROOTS.

It is fairly definite that root growth is seasonal. Weinmann (28) summarises confirmatory material. At Rhode Island, Stuckey 1941 (34) found root growth was at a minimum in late summer - autumn, with a maximum in early spring falling away again through the summer. She classified plants into annual and perennial groupings according to rooting ability. Perennial ryegrass is classified as "annual" and cocksfoot as "perennial". Yen 1947 (35) found that root growth was seasonal but tended to disagree with Stuckey's classification of perennial ryegrass. He believes that the root system of perennial ryegrass persists for longer than a year. Martin 1934 (36) found roots had special growth periods and that removal of tops during these periods inhibited subsequent growth. Removal at other periods had little detrimental effect. This special growth period is said to vary locally.

#### EFFECT OF INHIBITION OF ROOTS ON TOP GROWTH.

As the preceding material indicates, any pruning or direct inhibition of root growth will be reflected almost immediately in top growth. Robertson (9) tells of a decrease in tiller numbers and tiller size concurrent with restriction of root growth. Jacques (31) found similar indications.

Gericke 1923 (37) found that root pruning

of wheat decreased tiller numbers in proportion to the severity of the pruning. Nedrow with root pruning of grasses to 5 inch depth found decreases in top yields up to 50%. Spencer 1941(38) with maize found the same result. Rogers 1939(39) with apple trees claimed that root growth preceded top growth and continued after top growth ceased. He found that constant exposure of roots to light hastened suberisation. Jacques 1944(40) says that from the point of view of increased herbage yields "no advantage is to be looked for as a result of root pruning."

#### DIFFERENCES BETWEEN SPECIES.

Species react differently to different intensities of defoliation. Stapledon and Beddows (6), Parker and Sampson (23), Robertson (9), Harrison and Hodgson (12), and Lander (17) produce evidence in support of this view. Stapledon and Beddows found strain differences in cocksfoot. Similar differences due to root inhibition seem probable. Weinmann's review seems to imply this.

#### INFLUENCE OF SOIL MOISTURE ON ROOT GROWTH.

Various factors have an influence on root growth. Soil moisture is one of the more important ones. While soil moisture affects plants so too can plants affect soil moisture content. Veihmeyer and Conrad 1929(41), Hendrickson and Veihmeyer 1931(42) and Bosman 1936(43) stress the fact that actively growing plants cause moisture gradients in the soil, making it impossible to obtain an even soil moisture content. The first named workers emphasise the necessity for taking many samples in an endeavour to obtain a reliable result. Hendrickson and Veihmeyer found that roots would not penetrate a soil of 11% moisture content. Bosman quotes Veihmeyer as saying that the optimum conditions for root growth cover the range from soil field capacity to soil wilting point. Bosman, however, found definite variation of growth within this range. Nedrow (11) suggests a figure of 34% moisture content as being about the optimum.

The Wheat Research Institute in New Zealand (44) suggest 20% as being optimum for wheat, with the field capacity of the soil concerned being 27%. Thus an optimum soil moisture content for each individual soil seems likely. Webb 1936(45) also with wheat found differences between species in their ability to produce roots under the same dry conditions. Probably grass responds in this way.

#### CONCLUSIONS.

From the literature we see that grass growth, both of tops and of roots, is seasonal in nature. Cutting of tops produces inhibitions in root growth while pruning of roots restricts top growth - the degree of restriction depending on the severity or leniency of the treatment. Top yields fall as cutting treatments become less lenient and rise as they become more lenient. An initial stimulus of growth results from severe cutting treatments, this stimulus increasing in strength with increasing severity of treatment and decreasing in strength with repetition of the treatment. Root growth proceeds in moist soils. For each soil an optimum soil moisture content may exist, at which root growth is greatest.

## III.

THE EXPERIMENT, LAYOUT AND GENERAL METHOD.(a) THE EXPERIMENT.

The experiment consisted of various top cutting treatments and root pruning treatments. Four grasses were used - a good certified perennial ryegrass, a poor certified perennial ryegrass, a certified italian ryegrass and a good cocksfoot.

The object was - the investigation of the effects of different cutting treatments on top yield as measured by dry weight and on root growth, as measured by the number of new roots produced at the base of the plant ("crown roots"). Also root pruning effects on top growth were to be investigated. It was hoped to show by periodic soil moisture determinations that initiation of new roots and soil moisture content are correlated.

Dry weight was used as a measure of top growth because of its accuracy. Standard methods for drying green material were available and the equipment for their implementation could be found. Greenhill 1936(46) indicates the fallacy of using green weight as a measure of top growth. Dry weight possesses the great advantage that one week's weights are comparable with any other week's weights, a situation required in this experiment.

Variation in the number of new roots initiated at the base of the plant, was to be taken as indicating the response of the plant to stimuli roused in and transmitted by the "feeding" roots to the seat of root initiation. Changes in the various soil factors, including soil moisture, were expected to give the stimulation. Thus when soil moisture conditions were suitable for root growth a vigorous initiation of new roots was expected, with the contrary case when soil moisture conditions were adverse. Seasonal capacity for root initiation was to be traced by the regular initiation of new roots. The effect of

cutting tops on numbers of roots initiated was to be found by variation between plants subjected to different top treatments. It was felt that possibly root initiation might be a measure of the activity throughout the root system at the time. Jacques (31) found root weight increased as numbers of "crown roots" increased - through the addition of newly initiated roots.

Three workable heights of cutting were used. They were in line with cutting treatments carried out at this College previously and possessed the advantage that their effects could be likened to overgrazing, a common condition on some New Zealand farms. Overgrazing gives rise to limiting factors as propounded by Blackman (2). The photosynthetic area of grass is so restricted by overgrazing that the photosynthesis of plant nutrient is slowed down appreciably. Blackman's axiom then applies - "When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the "slowest" factor." This applies equally well to root pruning.

Accordingly plants were cut to within  $\frac{1}{2}$ " of soil surface, to within 1" of soil surface and to within 2" of the soil surface. These treatments were to be repeated for two frequencies of cutting - weekly and fortnightly. This meant a  $\frac{1}{2}$ " cut weekly, a 1" cut weekly and a 2" cut weekly as well as a  $\frac{1}{2}$ " cut fortnightly, a 1" cut fortnightly and a 2" cut fortnightly, i.e. six top treatments.

Root treatments consisted of the presence and absence of a weekly pruning off of new roots, at the base of the plant. Each root treatment was applied to a set of top treatments. In effect this gave 12 treatments all told. Thus six plants were receiving different top treatments while another six were receiving the same six different top treatments as well as a weekly pruning off of new roots. There were four grasses to be investigated, each with the

12 treatments giving 48 treatments in all. Each treatment was applied to a single plant.

(b) LAYOUT.

For any experiment each treatment must be replicated a sufficient number of times to permit a satisfactory statistical analysis of results. If each treatment had been replicated say three times then there would have been great likelihood that the results obtained were due to random variation. Had 100 replications been used an extremely accurate result would have been forthcoming, but at the expense of discarding some planned treatments and thus limiting the information likely to be gained. For plant material was limited, as was the worker's capacity. Somewhere between these two numbers there was a practicable figure. This figure was such that any decrease in number of replications would result in too great a loss of information and any increase in number would result in too little extra information being made available, for the work entailed. Rae 1947(47) when progeny testing rams found that the optimum number of progeny for each ram was 15. This number was adequate for a satisfactory analysis of variance. As no indication could be gained from the literature as to the optimum number of replications needed with plants, Rae suggested using his figure of 15.

The experiment thus consisted of 48 treatments, each treatment being replicated 15 times.

In practice 15 blocks were used, each block containing every treatment once. For convenience each block consisted of two rows of plants, 24 treatments in each row (plants were 1'3" apart and rows were 1'3" apart). The blocks were lettered A to P (O was omitted to avoid confusion with figures) and separated from each other by 2'6". They were arranged as in Appendix I. i.e. two adjoining tiers of seven with Block B split between the two. (See Appendix I.) It was split to permit the planting of two young fruit trees

in the spring of 1948. By using Blocks of treatments in this way, an even cover of the area was achieved. Within each block the 48 treatments were arranged by randomisation. Thus within each block chance alone dictated the position of each treatment. As each treatment occurred only once and at random within each block, variation due to soil heterogeneity, soil fertility gradient, soil moisture gradient etc. would be minimised.

Samples of soil for moisture determinations were taken from the small area bounded by blocks A, B and C.

In an attempt to prevent border effect a strip 2'6" wide was kept clear around the plot area.

(c) GENERAL METHOD.

Top growth was clipped. Clipping presented little difficulty. To ensure, that as nearly as practicable, cutting was equal for all leaves, care was taken to gather all herbage in the hand while clipping it off. In this way all leaves were brought into an upright position permitting an even cutting.

Regular root pruning presented difficulties. Attempts to apply objective methods of measurement to root pruning treatments have resulted, almost without exception, in destruction of the plant material. In this experiment the number of new roots produced each week was to be tallied while the roots themselves were to be pruned off. Consequently the base of the plant had to be exposed. A way of keeping the plant in a position where its base could be exposed regularly, without causing the plant's death and without creating unduly artificial conditions had to be found. It was suggested that an object which would at the one time support the plant in space and deflect inaccessible down growing roots to the accessible sides, would solve the problem. Accordingly plaster of paris knobs, of a shape conducive to comparatively normal downward root growth, were used. A steep dome shape with a flattened

tip was the shape favoured. Each knob was placed in a hole in the ground and pushed in until it was just below ground level. A plant was then set on each knob with its roots draped down the sides of the knob. The earth was filled in around the plant. After a period of establishment the soil was excavated from around the base of the plant until plant base, roots and half the depth of the knob were exposed. From all the roots so exposed 6 of the firmest roots were selected and left. The remainder were pruned off hard up against the plant base with a small pair of scissors. To facilitate subsequent regular prunings the excavation was packed with easily removable sphagnum moss. In an endeavour to maintain the moss in a moist condition, to stay the plants against wind and to keep birds out, opposed 3" x 4" covers of  $\frac{1}{4}$ " pine wood were placed on the moss, and around the plant. Without exception new roots were of a whitish translucent colour. As a result they were easily distinguishable from the six "feeding" roots which lost their translucency rapidly and became brown as suberisation progressed.

## IV.

MATERIALS AND METHOD.(a) GRASS.

The grass plants used in the experiment were provided by courtesy of the Grasslands Division of the D.S. & I.R. Contrasting grasses in general use were needed. The most common pasture grass on ploughable land in New Zealand is perennial ryegrass. Consequently a superior perennial ryegrass plant and an inferior perennial ryegrass plant were obtained. The superior plant was a representative of the improved strains entering the Department of Agriculture's certification scheme in 1948. It is called certified Perennial ryegrass in the text. The inferior plant was representative of a type which has been out of certification for some years. For the purposes of the text it is called Uncertified Perennial ryegrass. The Italian ryegrass plant was an improved type, being above average. The cocksfoot plant was another contrasting grass type in general use in New Zealand. It was a bushy, vigorous, narrowish-leaved plant growing well under dry soil conditions. It was a superior individual.

For clear differentiation of results, variation due to other than experimental factors had to be minimised. By block and randomised treatment layout soil influences were minimised. The variation of the plant material could be controlled to a certain extent. It was thought that clonal material would be less variable than plants grown from "pure line" seed. Within each species all plants would have the same genetic constitution thus eliminating variation due to genetic differences. "Pure line" seed has much greater genetic variability than clonal material and as such was discarded. In actual fact seed would have failed to produce plants large enough and hardy enough to withstand planting out that same autumn. As a result each of the grass plants as provided by Grasslands Division (4 in all) was used as

a source of clonal material. The plants were about one foot in diameter and when broken down to their ultimate tillers yielded 200 - 400 tillers per plant. After elimination of undesirably large or small individuals, the tillers were pricked out (18th Feb. 1948) into propagating boxes containing a free draining horticultural soil (7 of soil : 3 of humus : 2 of sand). Judicious watering and shading in a glasshouse aided early establishment, permitting hardening off from the 2nd of March onward. By planting date sufficient plants of each type were available to enable planting to proceed according to plan. For each grass 180 plants were required, representing 15 replications of 12 treatments. Except with Italian ryegrass, numbers permitted a further elimination of the larger or smaller than average tillers. At planting all tillers were nipped to roughly the same length of leaf and length of root.

(b) PLASTER KNOBS

As explained in section III (General Method) plaster of paris knobs were used. Plaster of paris was chosen as being the most suitable material for the manufacture of the knobs. Durrant (48) explains the setting of plaster of paris. The process is fairly rapid, the end product being gypsum. Gypsum occurs naturally in some soils apparently without any particular effect on root initiation. Consequently it was deemed permissible to use plaster of paris as the parent material for the knobs. The resulting knobs, in reality lumps of gypsum, had the added advantage that they would respond in their own moisture content to variations in soil moisture content; a desirable state of affairs where root growth was concerned.



Figure 1.    A mould and Plaster Knobs.

A sharp dome shape with a flattened tip was aimed at, the dome being  $1\frac{1}{2}$ " deep and  $1\frac{1}{2}$ " diameter by cross section at its base. A wooden mould was turned out on a lathe and a few prototype knobs produced in it. Setting was slow and the knobs could not be extracted from the mould until setting was near completion. 720 knobs were needed. To expedite manufacture modelling clay was used. An impression of a prototype knob was made in a portion of clay. The mould so formed was cut into four segments, by two crosswise downward cuts with a fine wire. The four segments could be gently pressed together to form the mould, and just as easily separated to extract a knob before setting was completed. This speeded manufacture greatly. A fairly stiff mix of plaster, of paris and water was poured into the mould. As the mix set a 4"

length of 8 gauge wire was pushed into the flat base. It became imbedded as setting proceeded. In setting out the knobs this wire was thrust into the soil and served to hold the knob in position during the experiment.

A practical advantage of the white knobs was that they provided a good background on which to view the roots.

(c) THE PLOT.

As has been implied in Section III (Layout) the experimental area had to be of even fertility, level surface and easy access. It had to be 1 chain long by  $\frac{1}{2}$  chain wide ( $\frac{1}{20}$ th of an acre in area) while the soil had to be reasonably free draining to permit regular working in wet weather. A suitable area was located in an unplanted portion of the Massey College orchard area. It was reasonably level and was known to be of even fertility. It was accessible being within half a mile of the drying ovens and weighing room. Its soil was known to be sufficiently free draining to permit regular work throughout the year.

The plot was part of a larger area which had been evenly manured and cropped with onions in the previous season. In the last week of February 1948 a Bolens garden tractor, fitted with cultivator tines, was used to work up the ground. Four lengthwise and four crosswise strokes with the tines followed by a discing gave a suitable tilth to 4 inches depth. As it was essential that all plants survive the planting out the area was watered with a sprinkler in the following week. Onions are an exhaustive crop. As a safeguard against possible impoverishment of the soil, as an aid to successful establishment, and to replace in part the lost benefit of growing clover in association with the grass plants, an even broadcast dressing of 25 lbs. Blood and Bone, 8 lbs.  $(\text{NH}_4)_2\text{SO}_4$  and 11 lbs. Superphosphate (equivalent to  $4\frac{1}{2}$  cwt. B. and B. per acre,  $1\frac{1}{2}$  cwt.  $(\text{NH}_4)_2\text{SO}_4$  and 2 cwt. Superphosphate per acre) was

applied. The application was hoed in on the same day (23rd March 1948). Planting began the following day.

(d) PLANTING OUT.

Pegs marking the ends of the rows of plants were set up along the short ends of the plot. A line knotted at the correct intervals (1'3" between plants, 2'6" between blocks and between pegs and blocks) for planting was then strung between each pair of pegs i.e. from one end to the other. At each knot a shallow hole was dug with a trowel. A knob was pushed, anchor wire first, into the soil at the bottom of the hole, until the top of the knob was about  $\frac{1}{2}$ " below ground level. The knobs were previously soaked in water to ensure a moist environment for the roots of the young plants. A little water was added to each hole and the plant set on top of the knob with its roots draped down about the knob. The excavated soil was back filled and after a further light watering the plant was left to establish. The first row planted was that beginning with plant A.1. and ending with plant I.24, while the last row was the one having H.25 and P.48. as its extremes. For each row, one species was planted before the next one was commenced with. A guide plan ensured correct planting. As mentioned previously all plants were trimmed, to roughly the same length of leaf and length of root, prior to planting. They were planted in the order that they came from the propagating box. No intentional selection was practised other than the discarding of the undesirably large or small plants. The 720 plants were planted out in 4 days.

(e) PRE-TREATMENT.

A plant left to establish undisturbed, quickly grows its root system. A drastic defoliation, repeated often, applied to such plants may possibly cause death. Accordingly, as a check to root growth, all plants were given a preliminary cut to about 1 $\frac{1}{2}$ " above ground level on the 6th April. At this time it was found that a number

of Italian ryegrass plants had failed to establish. As a result all Italian ryegrass plants were removed and the trial carried on as originally planned. It was believed that, as all treatments had been located in the blocks by randomisation the abandoning of the Italian plants would not affect the soundness of the experimental layout. A further cut was carried out on the 7th May, on which date all plants were cut back to their experimental heights i.e.  $\frac{1}{2}$ ", 1" or 2" from ground level. Initially all plants had to be given the same root treatment. By doing this the difference between plants subjected to the experimental regular root pruning and those not subjected to it, would be due to treatment only. If the plants not subjected to root treatment had been left without the initial treatment then a true comparison could not have been made with root pruned plants. Commencing on the 29th April the soil was excavated from the base of all the plants in order, and all roots pruned off save six of the strongest and firmest which were left. (See section III General Method.) The soil was replaced with sphagnum moss, moistened to approximate soil moisture conditions. The wooden covers were put on and the experiment was ready to commence on the 7th of May, 8 days later.

Half of the total number of plants in the trial were to be root pruned (6 top treatments carried out on 3 grasses, each replicated 15 times = 270). New roots were pruned off each week. For the continued life of the plants some roots had to be allowed to grow undisturbed. These roots absorbed the nutrients which kept the plant alive and also probably were the seat of stimulation for the root initiation which was measured. Roots to be left for this purpose had to be firm, uninjured and well anchored in the soil. Six was taken as being a suitable number.

(f) EQUIPMENT.

For the pruning off of roots a small pair of curved scissors was used. They were safe and completely satis-

factory. Clipping of tops was done using sheep shears as adapted by Marryatt and Simpson (49). Clipped herbage was placed in small patty pans which were numbered and of known weight. The pans had been punched out of their trays, the trays being used as carriers for the pans. Each tray held 12 pans. Drying of clippings was done in a large electrically heated forced draught oven (at Grasslands Division) and finally in a 15" x 22" capacity unventilated Hearson electric oven with automatic temperature control fitted. Dried samples were stored in a 12" diameter desiccator and two 8" diameter desiccators. Weighing was done on a Christian Becker Chainomatic damped balance, which was fast and accurate. Soil moisture samples were taken with a 1" bore cork borer, the samples being carried and weighed in patty pans. Notebooks, weight sheets and data sheets were used. A calculating machine was made use of, from time to time.

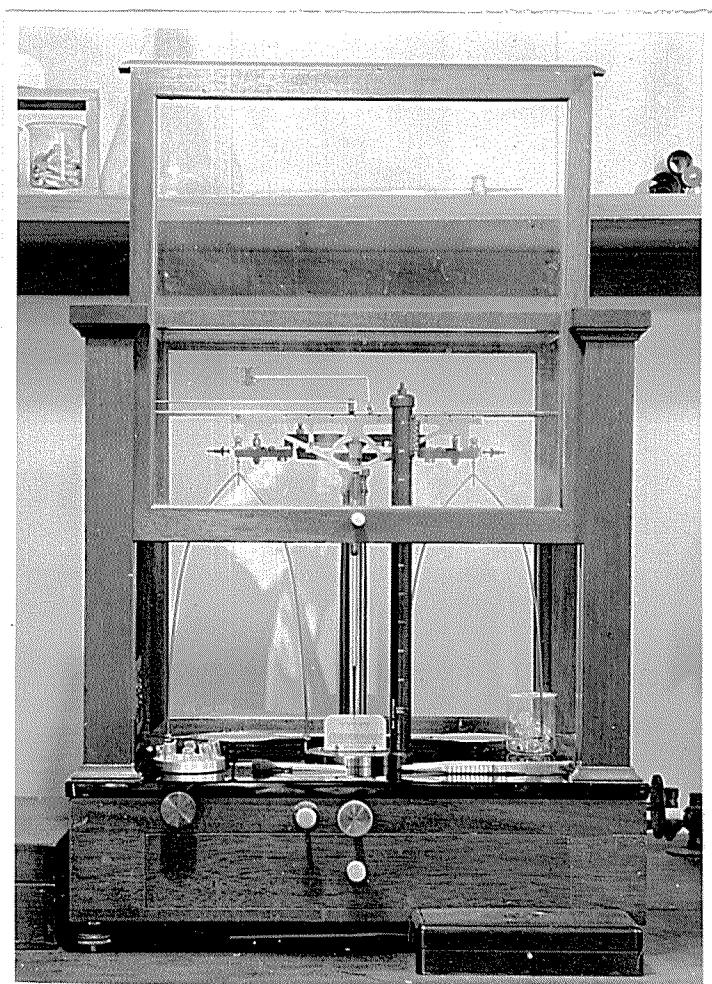


Figure 2. Chainomatic Balance.

factory. Clipping of tops was done using sheep shears as adapted by Marryatt and Simpson (49). Clipped herbage was placed in small patty pans which were numbered and of known weight. The pans had been punched out of their trays, the trays being used as carriers for the pans. Each tray held 12 pans. Drying of clippings was done in a large electrically heated forced draught oven (at Grasslands Division) and finally in a 15" x 22" capacity unventilated Hearson electric oven with automatic temperature control fitted. Dried samples were stored in a 12" diameter desiccator and two 8" diameter desiccators. Weighing was done on a Christian Becker Chainomatic damped balance, which was fast and accurate. Soil moisture samples were taken with a 1" bore cork borer, the samples being carried and weighed in patty pans. Notebooks, weight sheets and data sheets were used. A calculating machine was made use of, from time to time.

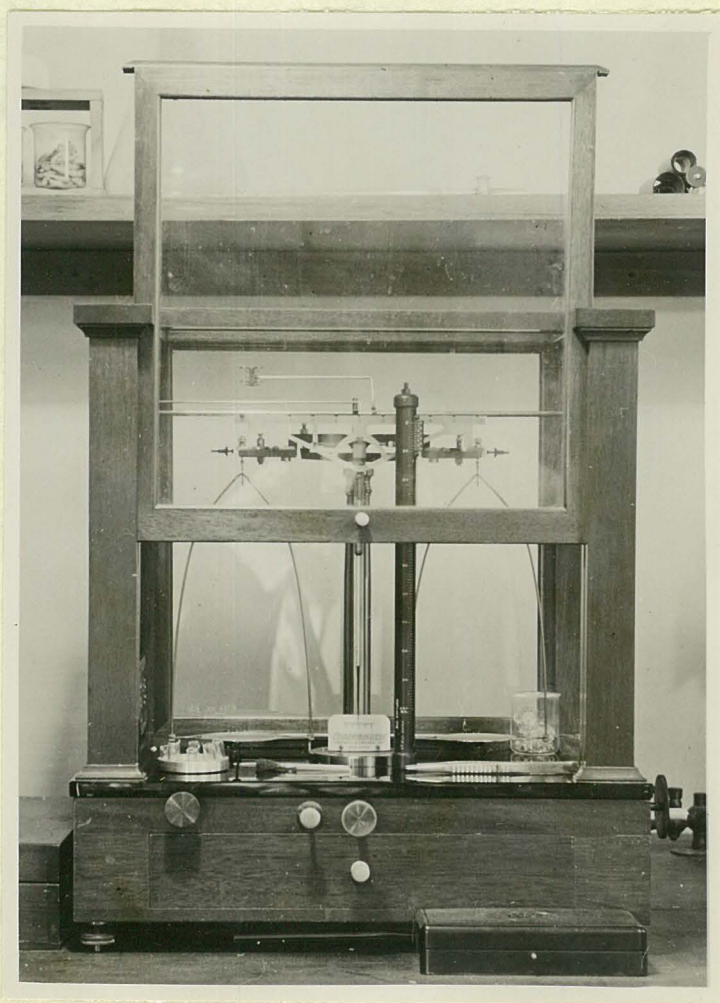


Figure 2. Chainomatic Balance.

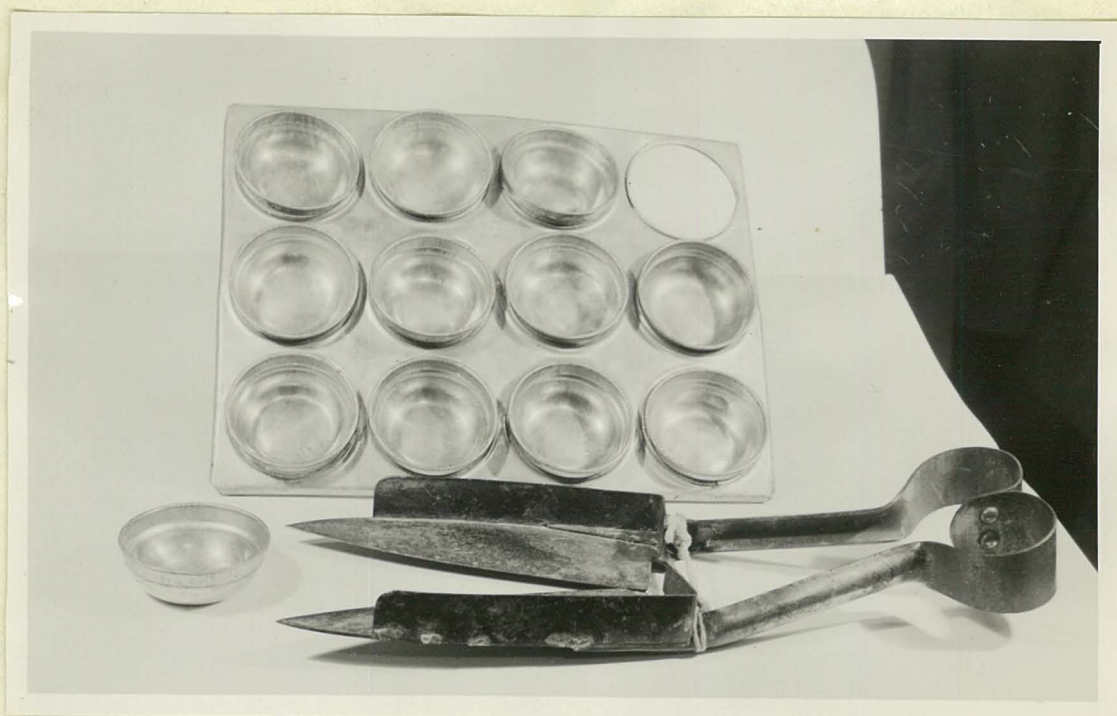


Figure 3. Equipment as described.

(g) TOP TREATMENT.

Before cutting commenced a recording notebook was prepared, for each week. Recorded by blocks were plant numbers and the treatments to be carried out on each plant. Cutting was carried out by blocks in alphabetical order from A to P. As stated (Section III General Method) care was taken to clip all leaves to the same level. The height of cutting was taken from the level of the wooden covers. The plants were planted shallow at planting out so no serious error was incurred. The wooden covers were a very definite level to work from whereas ground level would have been rather hard to estimate.

The forced draught oven was available over the week ends. Because of this cutting was carried out every Friday, the first cut being carried out on the 14th May 1948. A ruler was used to check cutting heights, its

use being more infrequent as experience increased. Clippings were placed in patty pans, the number of each patty pan being entered in the recording book alongside the number of the plant which had been clipped. When full the trays of pans were taken to the forced draught oven for pre-drying.

(h) ROOT TREATMENT.

The first root pruning was carried out on the 17th-18th of May 1948. Subsequent pruning was done each Monday. It was thought that by staggering root and top treatments the severe stress under which some of the plants lived, might have been prevented from becoming lethal. The root treatment involved handling the herbage which became soiled as a result. The period from Monday to Friday gave time for the dirt to be washed or blown off. As with the top treatments a recording notebook was used, the number of roots pruned off each plant being entered alongside that plant's number. The pruning was done by rows, starting at A.1. going to I.24, from I.48 to A.25, B.1. to B. 24 and so on (see Appendix I). The operation involved removing the wooden covers, extracting the sphagnum moss, pruning off all new roots close to the base of the plant, tallying them as they were pruned off, recording the tally in the recording notebook, replacing the moss and finally, replacing the wooden covers. This was carried out weekly. For details of the root pruning operation and of the experimental arrangement see Figure 4.



Figure 4. The operation of root pruning.

(1) DRYING AND WEIGHING THE CLIPPINGS.

The Hearson oven used for drying purposes was of limited capacity. Hence transpiration loss could occur before all clippings could be dried. To prevent this a pre-drying for 4 hours in an electrically heated forced draught oven at about 70°C. was employed. The dry samples were then placed pan by pan in the Hearson oven about 250 at a time. As there were 540 plants in the experiment two fillings of the oven dealt with the bulk of the samples. The standards prescribed by Melville and others (50) for the drying of green material in an unventilated oven, were conformed with. The samples were dried at 100 - 105°C. for 12 - 15 hours. They were then quickly transferred from oven to desiccator. The 12" diameter desiccator with fresh concentrated  $H_2SO_4$  as drying agent was used as the chief storage vessel for

the dry samples. Dried grass may be more hygroscopic than anhydrous  $\text{CaCl}_2$ , but in general, fresh concentrated  $\text{H}_2\text{SO}_4$  is more hygroscopic than dried grass. Smaller desiccators with anhydrous  $\text{CaCl}_2$  as drying agent could be shifted from place to place with ease. They were used as holders from which pans were taken in threes and fours and weighed. They were small enough to be emptied quickly, minimising the likelihood of wetting of the samples from stale anhydrous  $\text{CaCl}_2$ . They also provided a means of minimising the number of times the large desiccator had to be opened to obtain fresh supplies of samples for weighing. Thus exposure to air moisture was minimised.

Weighings were made to three places of decimals (i.e. to the milligramme level) as earlier workers (10 and 23) had apparently found this advisable. Accurate differences rather than precise absolute values were required for analysis purposes. Small weights were anticipated. For differences to be apparent when weights were small, weights had to be accurate.

#### (j) SOIL MOISTURES.

Veihmeyer and Conrad (41) stress the necessity for taking a large number of soil samples from all parts of the experimental area in order to get a representative soil moisture percentage. As a large proportion of the plot was to be trampled in the course of the routine treatments, random sampling of the experimental area was expected to give unreliable and unrepresentative results. No way could be conceived of getting a representative set of samples of soil from the plot area which would give a fair indication of the soil moisture conditions as they were likely to effect the plants. At the outset it was realised that any soil moisture percentages obtained would be able to be correlated with root initiation, in a loose manner only. In an effort to get a clearer picture of changes in soil moisture a sampling area bounded by Blocks A, B and C was

set aside (Fig. 15). Trampling of the area was avoided. Samples were taken with the 1" bore cork borer to a depth of approximately 2". Ten samples were taken at each sampling from all parts of the area. The average moisture content of the ten samples was taken as representing the soil moisture percentage for the area, at the average depth of 1". By sampling to 2 inches a range of depth from 0 - 2" is covered giving an average depth of 1". It was thought that sampling would prove of limited use until the soil moisture dropped below field capacity. Sampling commenced on the 1st Sept. 1948 when the soil began to dry out appreciably and continued at convenient intervals until the close of the experiment on the 16th February.

Soil samples were placed in known weight pans and dried in the Hearson oven for 8 - 12 hours at 100 - 105°C. In this way both wet weights and dry weights were obtained. Soil moisture was expressed as a percentage of oven dry soil. Dry samples were returned to the sampling area and gently tamped into the holes left by their withdrawal. Care was taken during the next two or three samplings to avoid the replaced samples, thus permitting them to regain water and become akin to the rest of the area in their water relationships.

(k) WEIGHT SHEETS AND DATA SHEETS.

Weight sheets were prepared. Printed on them were the number of each pan in order from 1 to 540, together with the known weight of each pan. When each pan of clippings was weighed the weight was entered alongside the appropriate pan number. All pans were numbered. Thus by subtraction the dry weight of the contents of each pan could be calculated. By referring to the record notebook for that week and the weight sheet, the dry weight of tops for each plant could be traced and entered on the data sheets.

Root numbers could be entered on the data sheets directly from the record notebooks.

(1) COMPILATION OF RESULTS.

It is easy to make errors on a calculating machine. Consequently all mathematical operations were carried out twice as a check. The totals for the experiment, for each plant, were checked especially carefully. The accuracy of the analysis of variance was dependent on the accuracy of those totals.

In the course of the experiment some samples were inadvertently spilt. In this way 55 samples, of a total of 16,200 samples, were lost. An adaptation of Yates' "missing yield formula" (51) was supplied by the Biometrics section, D.S. & I.R.

$$x = \frac{bB + sS + wW - 2T}{(b - 1)(s - 1)(w - 1)}$$

x = missing yield

B = total for the block containing the missing yield.

S = " " " species " " " "

W = " " all treatments for the week containing the missing yield.

b = number of blocks

s = number of the particular species on the particular treatment.

w = number of weeks used in the calculation.

T = grand total dry weight for the weeks used in the calculation.

It was thought advisable to take the preceding treatment, the succeeding treatment and the treatment concerned into account when using the formula i.e. three weeks. Consequently separate calculations had to be made for weekly and fortnightly treatments. A treatment period on either side of any particular treatment in the fortnightly series would cover five treatment periods in the weekly series. Three adjoining treatment periods in the weekly series would cover only one fortnightly treatment period at best (i.e. two sets of results). For these reasons "s" was modified from 36 to 18 and "T" from being the grand total

for the three sets of results for the whole experiment to being the grand total for the three sets of weekly results or fortnightly results.

The modified formula used was:-

$$x = \frac{15B + 18S + 3W - 2T}{14 \times 17 \times 2}$$

It took into account the trend of the experiment over three weeks, the particular effect of the species and the effect of the particular week in which the sample was spilt. A complication arose that some samples were spilt in the first fortnightly set of results. Obviously the preceding and succeeding treatment period could not be obtained. As a compromise the week concerned and the two succeeding treatment period results were used. By the use of the formula statistically expected values were obtained and entered on the data sheets. As 55 samples in 16,200 represented only 0.34% of all samples, it was considered to be justifiable to neglect altering the number of degrees of freedom in the final analysis. Therefore summations proceeded in a normal way.

At various stages during the experiment six plants died. Any results attributed to them were deleted from the data sheets, and consequently from consideration when averages were being calculated for each treatment period. Yates' missing yield formula was applied and the needed statistically expected values calculated. These figures appeared in the plant totals (of dry weight) for the whole experiment period. Six degrees of freedom were deducted from the total number possible because as they were calculated values they were considered to be fixed values. They could not have occurred as the result of natural phenomena and consequently possessed no "freedom".

The analysis of variance was done according to the method prescribed by Snedecor 1948(52).

The mean square figures so obtained were used to elucidate the components of variance again by a method

prescribed by Snedecor (pp. 305-309). The formulae used in this elucidation were:-

As on the following pages-

(a) for the top treatments.

Species (mean sum of squares)	=	$s^2 + 30s_{S.C.P.}^2 + 45s_{S.F.P.}^2 + 30s_{S.F.C.}^2 + 90s_{S.P.}^2 + 60s_{S.C.}^2 + 90s_{S.F.}^2 + 180s_S^2$
Frequencies ( " )	=	$s^2 + 45s_{F.C.P.}^2 + 45s_{S.F.P.}^2 + 30s_{S.F.C.}^2 + 135s_{F.P.}^2 + 90s_{F.C.}^2 + 90s_{F.S.}^2 + 270s_F^2$
Cuttings ( " )	=	$s^2 + 45s_{F.C.P.}^2 + 30s_{S.C.P.}^2 + 30s_{S.F.C.}^2 + 90s_{C.P.}^2 + 90s_{F.C.}^2 + 60s_{S.C.}^2 + 180s_C^2$
Prunings ( " )	=	$s^2 + 45s_{F.C.P.}^2 + 30s_{S.C.P.}^2 + 45s_{S.F.P.}^2 + 90s_{C.P.}^2 + 135s_{F.P.}^2 + 90s_{S.P.}^2 + 270s_P^2$
SxF ( " )	=	$s^2 + 45s_{S.F.P.}^2 + 30s_{S.F.C.}^2 + 90s_{S.F.}^2$
SxC ( " )	=	$s^2 + 30s_{S.C.P.}^2 + 30s_{S.F.C.}^2 + 60s_{S.C.}^2$
SxP ( " )	=	$s^2 + 30s_{S.C.P.}^2 + 45s_{S.F.P.}^2 + 90s_{S.P.}^2$
FxC ( " )	=	$s^2 + 45s_{F.C.P.}^2 + 30s_{S.F.C.}^2 + 90s_{F.C.}^2$
FxP ( " )	=	$s^2 + 45s_{F.C.P.}^2 + 45s_{S.F.P.}^2 + 135s_{F.P.}^2$
GxP ( " )	=	$s^2 + 45s_{F.C.P.}^2 + 30s_{S.C.P.}^2 + 90s_{C.P.}^2$
SxFxC ( " )	=	$s^2 + 30s_{S.F.C.}^2$
SxFxP ( " )	=	$s^2 + 45s_{S.F.P.}^2$
SxCxP ( " )	=	$s^2 + 30s_{S.C.P.}^2$
FxCxP ( " )	=	$s^2 + 45s_{F.C.P.}^2$
SxFxCxP ( " )	=	$s^2$

(b) for the root treatments.

Species (mean sum of squares)	=	$s^2 + 30s_{S.C.}^2 + 45s_{S.F.}^2 + 90s_S^2$
Frequencies ( " )	=	$s^2 + 45s_{F.C.}^2 + 45s_{S.F.}^2 + 135s_F^2$
Cuttings ( " )	=	$s^2 + 45s_{F.C.}^2 + 30s_{S.C.}^2 + 90s_C^2$
SxF ( " )	=	$s^2 + 45s_{S.F.}^2$
SxC ( " )	=	$s^2 + 30s_{S.C.}^2$
FxC ( " )	=	$s^2 + 45s_{F.C.}^2$
SxFxC ( " )	=	$s^2$

$s^2$  = variation occurring naturally within the population sample taken i.e. within the experimental plants.

$45s_{F.C.}^2$  in the root treatment series is an example of all the other factors. It represents all the variation due to the interaction of cuttings and frequencies.

Graphs were prepared using averages obtained by dividing the total for a treatment at any particular treatment period by the number of plants, whose combined yields went to make up that total.

The histograms were prepared in the same way save that the totals for the whole experimental period were used.

V.

RESULTS.

POINTS TO BE NOTED.

(a) Just as the different heights and frequencies of cutting influenced yield of dry top growth, so their effect was reflected in the number of roots pruned off at the base of the plants. Similarly, the effect of pruning off the roots each week was reflected in the dry weight of top growth removed. For these reasons, in the results, presence and absence of regular root pruning are included as top treatments while the varying heights and frequencies of cutting tops are included as root treatments.

(b) Whenever the word "species" appears in the statistical section the reference is to the three grasses used in the experiment.

(c) Richens 1945(53) gives a definition of the term clone - "A group of individuals derived from a common parent by asexual reproduction." Thus in theory the experiment was carried out with three clones (cocksfoot, certified Perennial ryegrass, Uncertified Perennial Ryegrass). In emphasis of the fact that within each species all individuals carried the same hereditary mechanism the term clone was applied to each individual rather than to each group of individuals. Consequently wherever the word clone appears it should be understood that an individual, within a species group, is implied and not the whole species group.

(d) Wherever the word "average" appears in the results it implies that, unless otherwise stated, "average per individual clone" is intended.

(e) These results apply under the particular conditions prevailing during the experiment and to the particular grasses used.

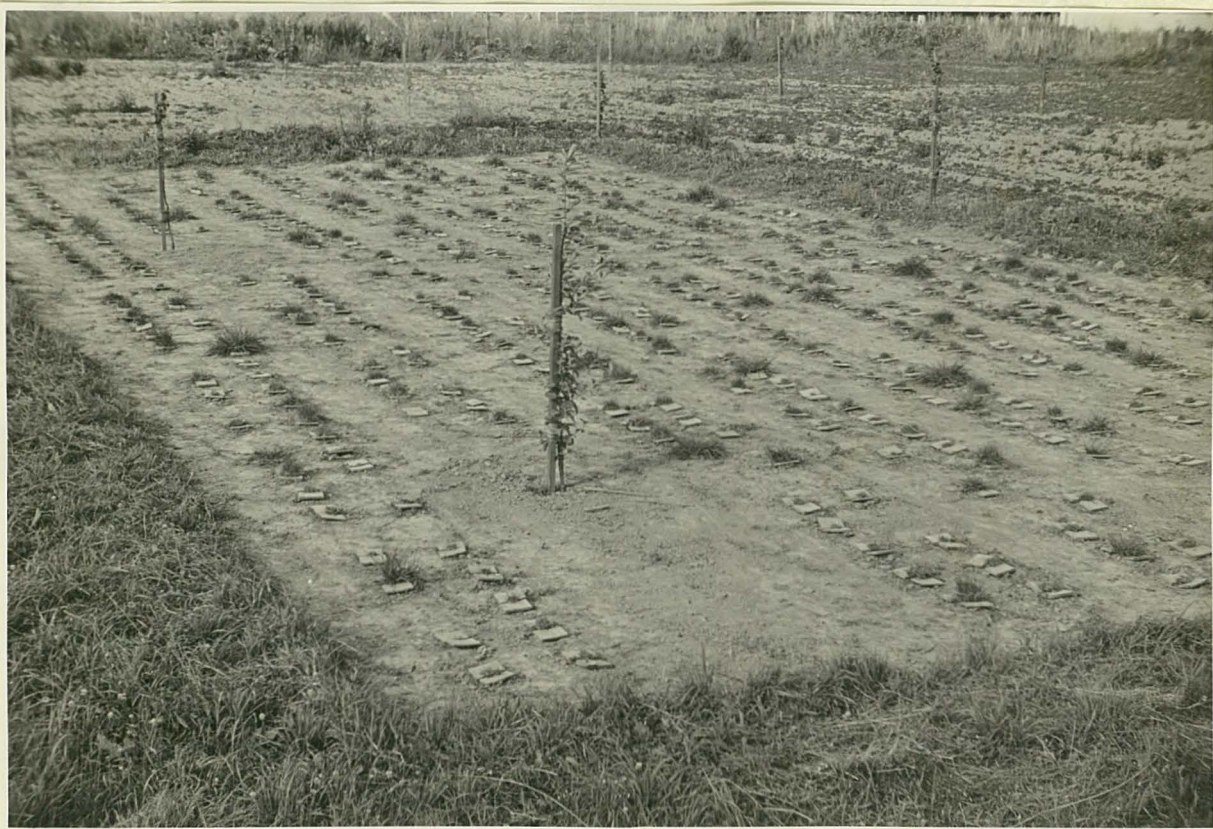
A. TOP TREATMENTS

Figure 5. View of plot looking from A.1. to P.48

There were 540 clones used in the experiment. They were split up into groups, in various ways, between which legitimate comparisons could be made.

Table 1 is a table of the mean average yield of dry top growth per clone for the whole experimental period, recorded in various groupings. (weights in grammes).

Table 1.

Grouping criteria	Groups	
By Blocks	A. 9.965 F.13.378 K.13.690 B.11.713 G.13.632 L.14.032 C.12.617 H.13.128 M.12.584 D.11.430 I.13.997 N.12.093 E.12.569 J.13.758 P.12.066	
By species	Cocksfoot clones = 16.674 Cert. Perenn. Rye clones = 13.000 Uncert. Perenn. Rye clones = 8.456	General mean = 12.710
By Frequency of cutting.	Weekly cuttings = 9.244 Fortnightly cuttings = 16.176	
By different cutting treatments.	$\frac{1}{2}$ " cut = 7.234 1" cut = 11.039 2" cut = 19.856	
By pruning or non-pruning of roots.	Root pruned clones (Pruned) = 7.641 Clones not root pruned (Normal) = 17.779	

There are obvious differences between groups in all cases. It had to be determined whether or not these differences were statistically significant. An analysis of variance was carried out and the following table prepared.

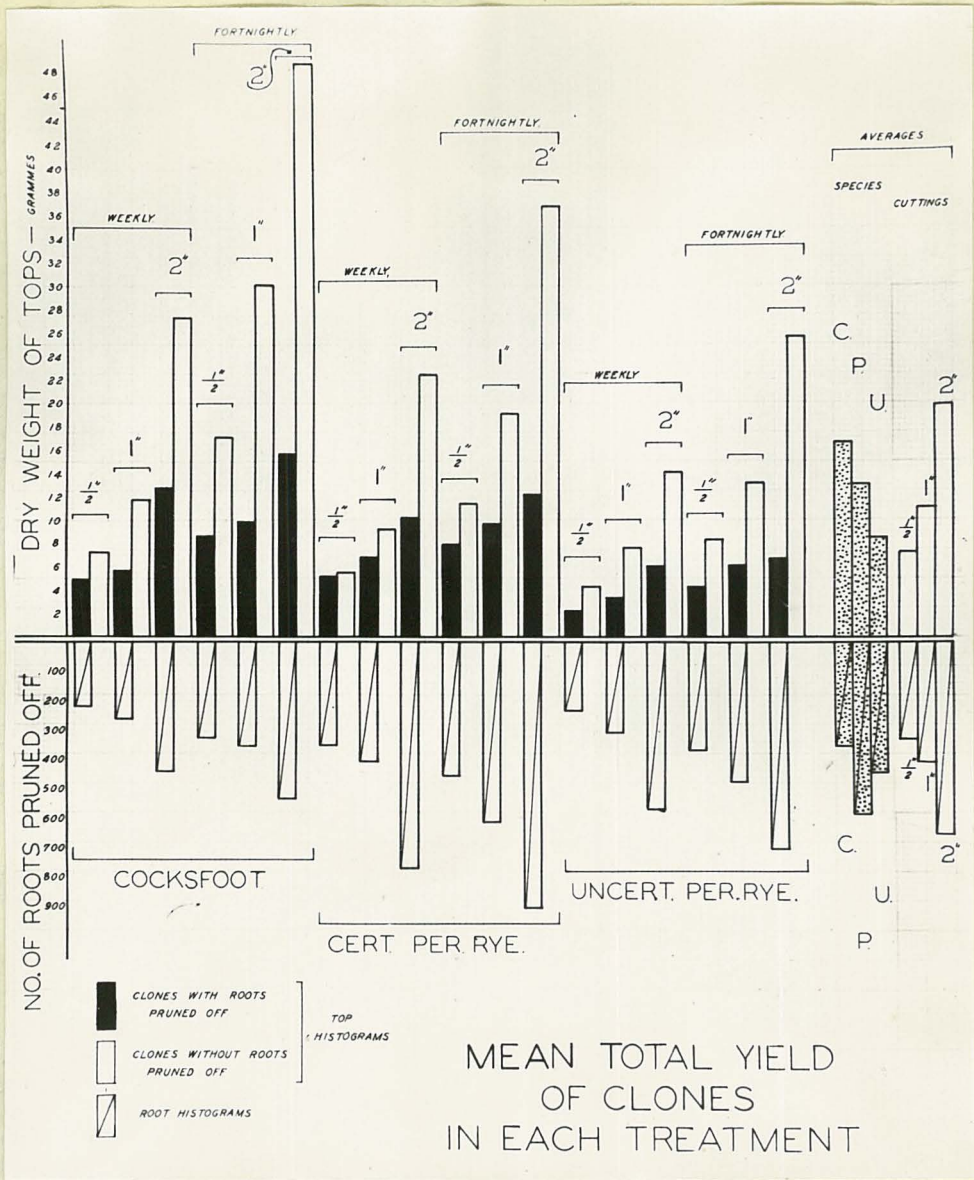


Figure 6. Histogram of Mean Total Yields.

Table 2. Analysis of variance in top growth yields.

Source of variance	Degrees of freedom.	Sums of squares	Mean Square	F. Variance Ratio	Re-quired Ratio	Signif-icance
Total	533	66,148.5632	124.11			
Between blocks	14	645.7121	46.12	1.99	2.12	S
Between Species	2	6,101.7107	3,050.86	131.73	4.66	SS
" Frequencies	1	6,485.5239	6,485.52	280.03	6.70	SS
" Cuttings	2	15,093.0521	7,546.58	325.85	4.66	SS
" Prunings	1	13,876.9756	13,876.98	599.18	6.70	SS
S x F interaction	2	743.9607	371.98	16.06	4.66	SS
S x C "	4	1,133.0984	283.28	12.23	3.36	SS
S x P "	2	1,150.7765	575.39	24.84	4.66	SS
F x C "	2	399.2702	199.64	8.62	4.66	SS
F x P "	1	2,484.6307	2,484.63	107.28	6.70	SS
C x P "	2	5,397.1681	2,698.58	116.52	4.66	SS
S x F x C "	4	51.1109	12.78	0.55	3.36	-
S x F x P "	2	368.7540	184.38	7.96	4.66	SS
S x C x P "	4	312.8531	78.21	3.38	3.36	SS
F x C x P "	2	600.3613	300.18	12.96	4.66	SS
S x F x C x P	4)488	54.2783	13.57	23.16 = s <sup>2</sup>		
Error	484)	11,249.3266	23.24			

S = significant at the 5% level of probability.

SS = " " " 1% " " "

Standard deviation = s = 4.81

∴ Coefficient of variation  $\frac{s}{\bar{x}}$  = 37.8%  $\bar{x}$  = General mean.

Variation due to the third order interaction failed to approach significance when compared with random variation (Error).

As such it was presumed that there was no third order interaction and it was bulked in with the error variance, the resulting figure being taken as error for all the calculations.

(a) DIFFERENCES BETWEEN BLOCKS.

As can be seen from Table 1 there were differences between blocks. Variation was remarkably small, save when considering Block A. Small as it was the variation was statistically significant. The value given as being its significance is not extraordinarily high, proving that the area was reasonably even in fertility and in other features affecting plant top growth. As this variation between blocks was proportionately small, variation due to the treatments could be satisfactorily evaluated. Within the blocks the species contributed in regular manner to yield i.e. for any block cocksfoot yielded most and uncertified perennial ryegrass least, the differences between cocksfoot and certified perennial ryegrass, and between certified perennial ryegrass and uncertified perennial ryegrass being of much the same order in all blocks.



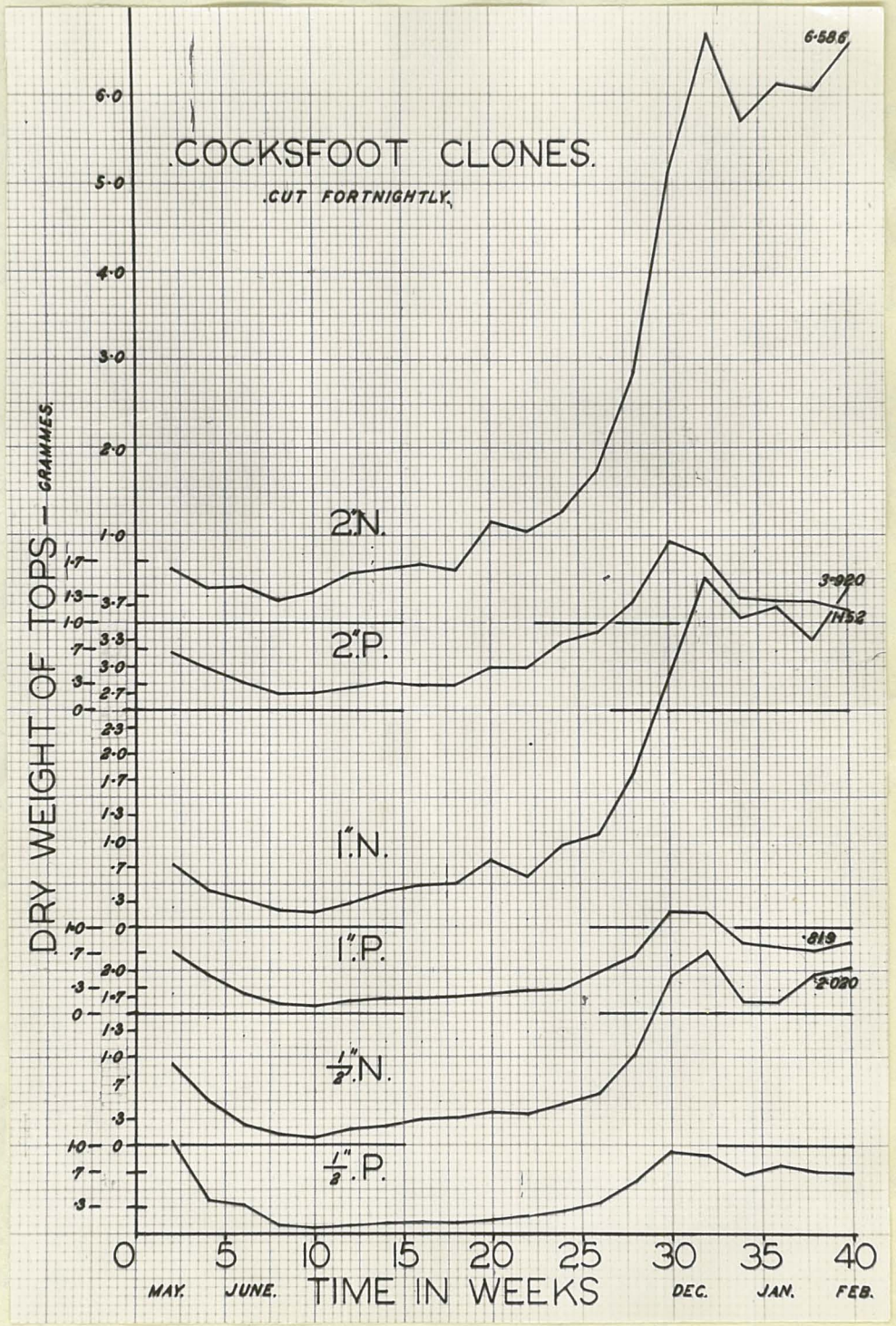
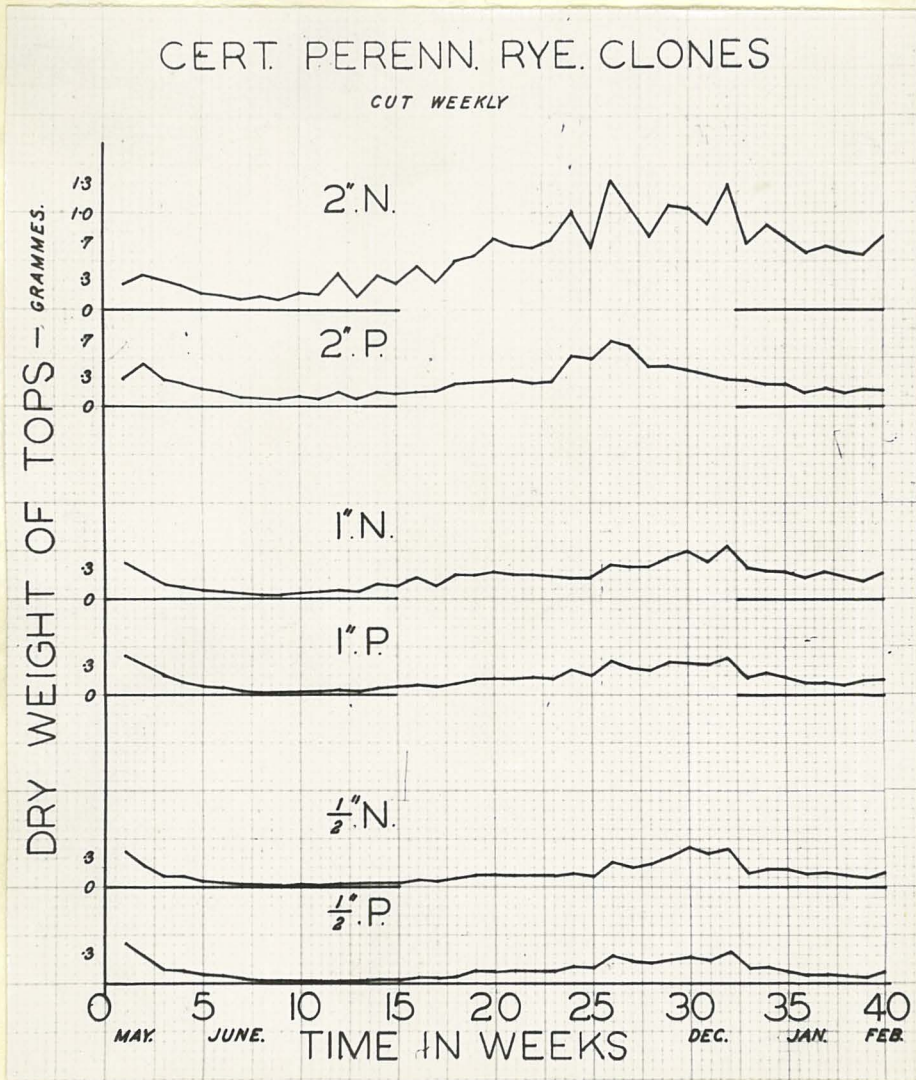


Figure 7. Graphs of the yield of Cocksfoot Clones under the different treatments.



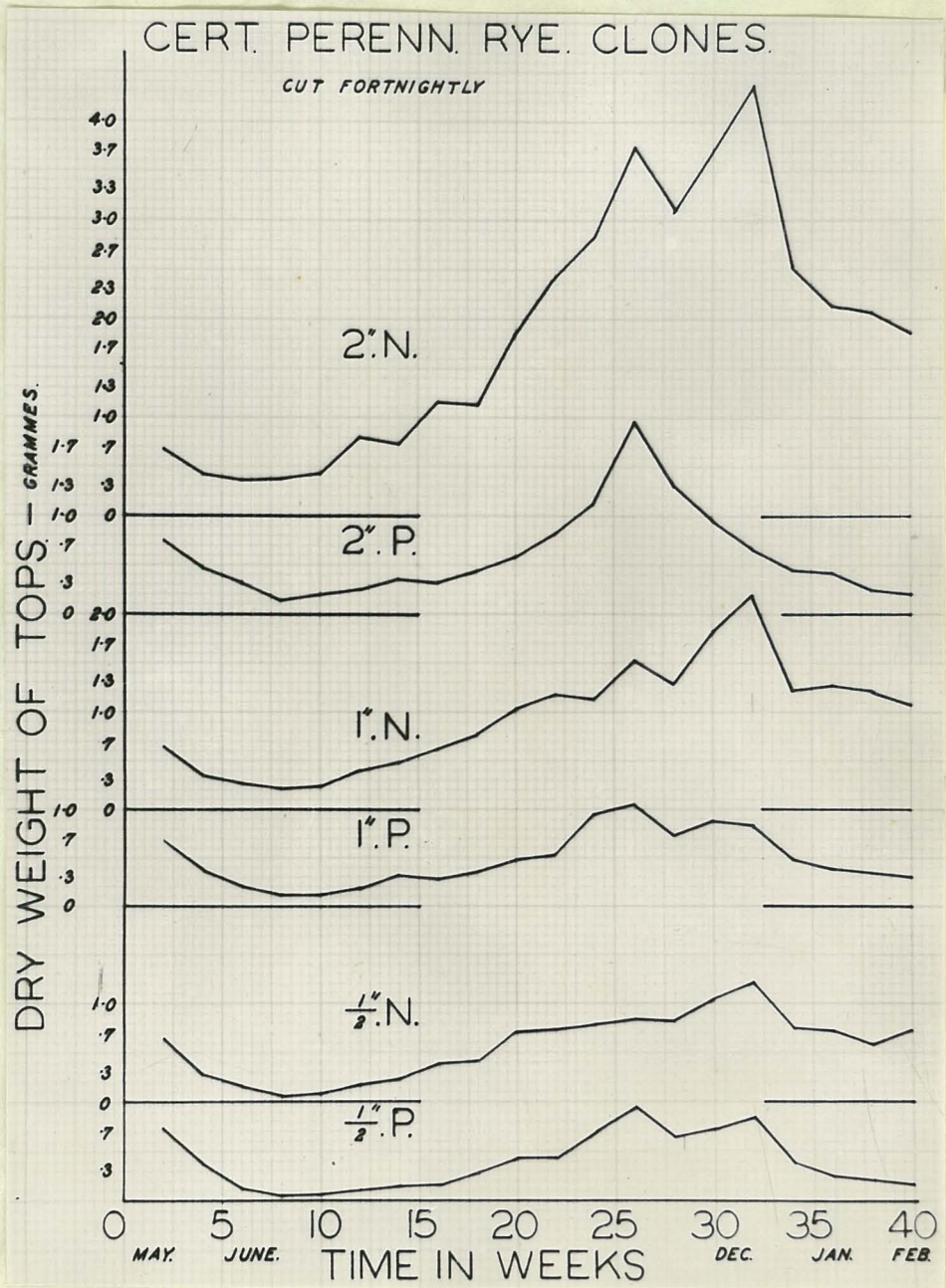


Figure 8. Graphs of the yield of Certified Perennial Rye-grass clones under the different treatments.

# UNCERT. PERENN. RYE. CLONES

GUT WEEKLY

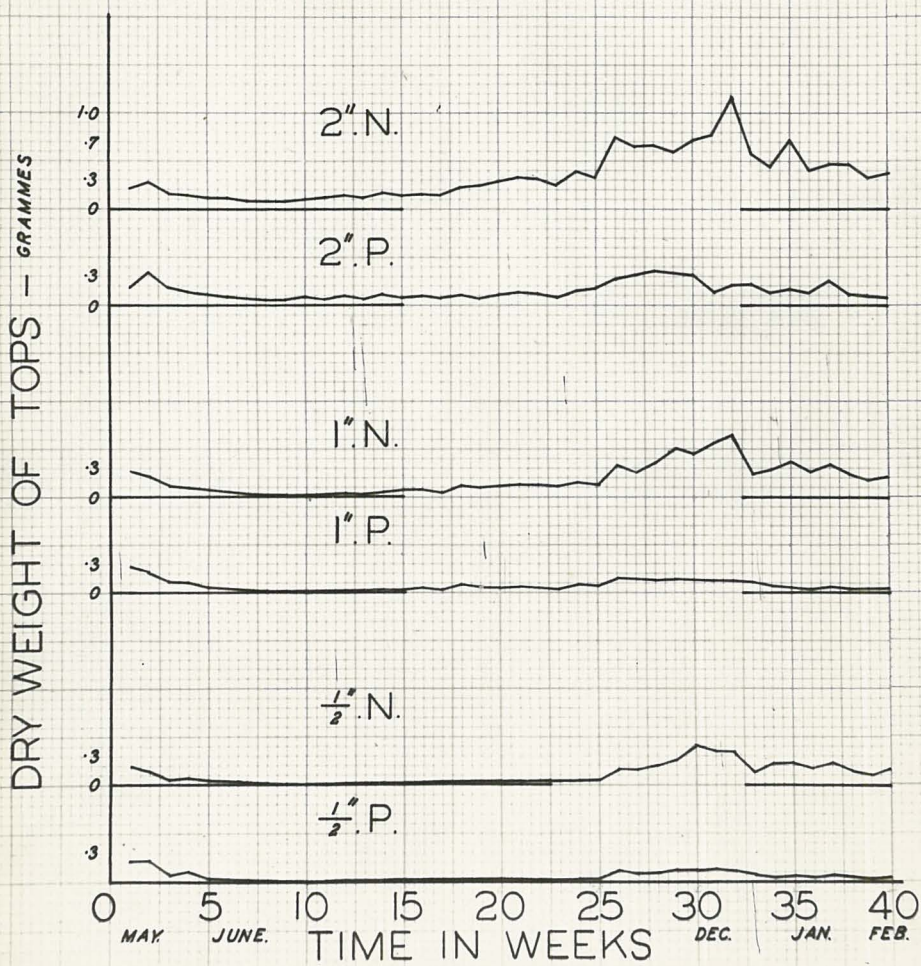


Figure 8. Growth of the yield of certified Perennial Rye- grass clones under the different treatments.

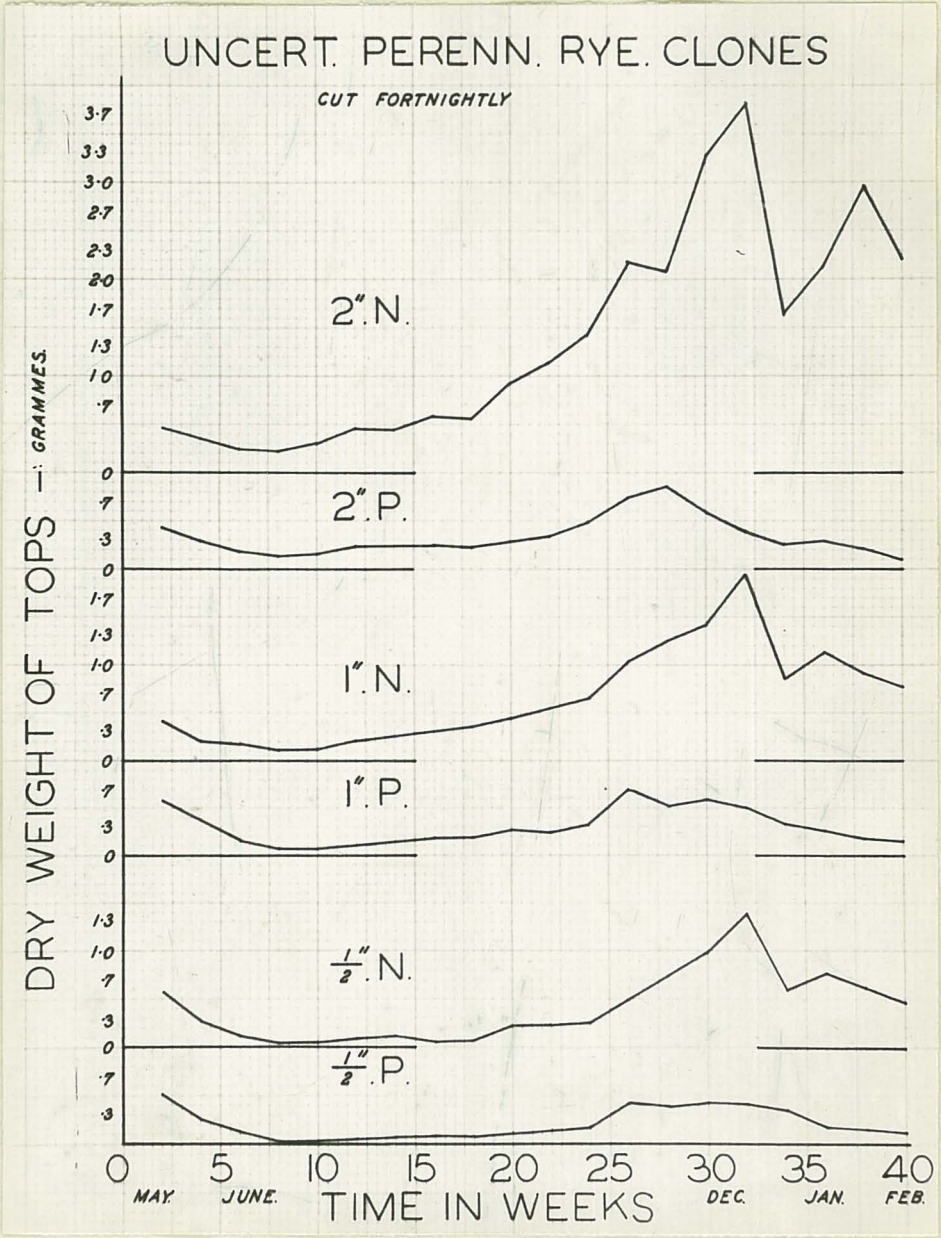


Figure 9.

Graphs of the yield of Uncertified Perennial Ryegrass clones under the different treatments.

(b) DIFFERENCES BETWEEN SPECIES.

The "average cocksfoot clone" yielded 16.674 grammes of dry topweight for the whole experimental period irrespective of the various treatments.

For the same period, and in the same way, the "average certified perennial ryegrass clone" yielded 13.000 grammes of dry topweight, while the "average uncertified perennial ryegrass clone" yielded 8.456 grammes of dry topweight. The differences, which are apparent, were highly significant (see Table 2.)

Thus for the whole period cocksfoot yielded significantly more dry topweight than did certified perennial ryegrass, which in its turn was significantly superior to uncertified perennial ryegrass.

The differences between the species were consistent irrespective of whether clones were cut weekly or fortnightly (Fig. 6.)

C.foot weekly = 11.639 gms. Cert. P. weekly = 9.852

Uncert. P. weekly = 6.242

C.foot fort.ly. = 21.710 gms. Cert.P. fort.ly = 16.148

Uncert. P. fort.ly. = 10.669

They were not significant ( $\frac{S}{S \times F}$  = not significant - see Appendix (X) ) as there was a highly significant species and frequency interaction. As the number of degrees of freedom for both numerator and denominator is small this result cannot be accepted as conclusive. The experiment was designed to test the major factors, viz. species, cutting at different heights, cutting at different frequencies and pruning off of newly initiated roots. Consequently secondary effects cannot be accurately tested. Further experimentation to elucidate this point in particular would be needed.

The differences between species were significant irrespective of whether the clones were cut to the  $\frac{1}{2}$ " level, the 1" level or the 2" level ( $\frac{S}{S \times C}$  = SS highly significant.)

This is consistent with the expected result as recorded here and in Appendix III.

C.foot.	$\frac{1}{2}$ "	= 9.473gms.	Cert.P.rye	$\frac{1}{2}$ "	= 7.464	Uncert.P.rye	$\frac{1}{2}$ "	= 4.765
"	1"	= 14.421	"	"	"	1"	= 11.164	"
"	2"	= 26.129	"	"	"	2"	= 20.371	"
"			"	"	"	1"	= 7.532	"
"			"	"	"	2"	= 13.070	"

The differences between species were consistent irrespective of whether clones were subjected to root pruning or not.

(Appendix III).

C.foot Pruned	= 9.580gms.	Cert.P.rye P.	= 8.597	Uncert.P.rye P.	= 4.746
" "Normal"	= 23.769	" " " N.	= 17.403	" " " N.	= 12.166

These differences were not statistically significant due to the presence of a significant species and pruning interaction ( $\frac{S}{S \times P}$  = not S.) Thus again a definite conclusion cannot be formulated.

We see that total yield of dry top growth was significantly different for the three species when all treatment considerations were ignored. The species reacted in a significantly different way to the variations of cutting treatment (i.e.  $\frac{1}{2}$ ", 1" or 2"). For instance clones cut to 1" yielded differently from clones cut to 2" in a significantly varied way for the diverse species. Although not proved statistically, it seems to be certain that the three species reacted in significantly different ways to the two contrasted frequencies of cutting and to the pruning off of new roots, i.e. in production of dry top growth.

(c) DIFFERENCES BETWEEN FREQUENCIES.

From the total yield of all clones cut each week during the experiment the average yield per clone, irrespective of species or other treatment consideration, was 9.244 gms. and for clones cut each fortnight was 16.176 gms. The difference between these two was highly significant. Thus fortnightly cutting of the grasses permitted significantly higher production than did weekly cutting.

The difference between frequencies was consistent for all three species. When tested statistically it just failed to achieve significance ( $\frac{F}{S \times F}$  = nearly significant). The interaction was of large value and degrees of freedom few in number. Consequently it was thought justifiable to say that a significant difference between weekly and fortnightly cuttings held for the three species.

C.foot Weekly = 11.639 gms. Cert.P.rye W. = 9.852 Uncert.P.rye W = 6.242  
 " Fort.ly. = 21.710 " " " F. = 16.148 " " " F = 10.669

The difference between frequencies was significant irrespective of whether the clones were cut to  $\frac{1}{2}$ " level, 1" level or 2" level.

(Appendix III and Fig. 6 ) ( $\frac{F}{F \times C} = S$ ).

$\frac{1}{2}$ " Weekly = 4.896 gms. 1" W. = 7.405 2" W. = 15.432  
 $\frac{1}{2}$ " Fortnightly = 9.573 1" F. = 14.673 2" F. = 24.281

The difference between frequencies was consistent irrespective of whether the clones had been subject to pruning off of roots or not (Fig. 6 ).

Weekly cut, root Pruned = 6.320 gms. W., "Normal" = 12.169  
 Fortnightly cut " " = 8.961 F., " = 23.390

Due to the large frequencies and prunings interaction the difference was not statistically significant under these conditions. Although evidence points to actual significance, a conclusive statement cannot be made.

In summary, clones cut weekly, when averaged, produced significantly less dry top weight than clones cut fortnightly. The difference between these two groups was significant irrespective of species or cutting considerations. In all probability root pruned clones and "Normal" clones exhibited a significant difference when grouped into weekly and fortnightly cutting groups.

(d) DIFFERENCES BETWEEN CUTTINGS.

Irrespective of species or other treatment considerations,

the average total yield per clone cut to within  $\frac{1}{8}$ " of ground level was 7.234 grammes, to within 1" of ground level was 11.039 grammes and to within 2" of ground level was 19.856 grammes. The differences apparent between these different treatments were found to be highly significant.

The differences between the cutting treatments were highly significant for each species in turn, disregarding other considerations. ( $\frac{C}{SXC} = SS$ ). Appendix III and Fig. 6 bear this out.

C. $\frac{1}{8}$ " = 9.473 grms.	P. $\frac{1}{8}$ " = 7.464	U. $\frac{1}{8}$ " = 4.765
C. 1" = 14.421	P. 1" = 11.164	U. 1" = 7.532
C. 2" = 26.129	P. 2" = 20.371	U. 2" = 13.070

The differences between the cutting treatments were significant for clones cut weekly or for clones cut fortnightly ( $\frac{C}{FXC} = S$ ) See Appendix IV and Fig. 6 .

$\frac{1}{8}$ " Weekly = 4.896 gms.	$\frac{1}{8}$ " Fortnightly = 9.573
1" " = 7.405	1" " = 14.673
2" " = 15.432	2" " = 24.281

The differences between the cutting treatments were consistent for all clones grouped either as root pruned or as "normal".

$\frac{1}{8}$ " pruned = 5.481	$\frac{1}{8}$ " "Normal" = 8.988
1" " = 6.909	1" " = 15.169
2" " = 10.532	2" " = 29.181

They were not statistically significant ( $\frac{C}{CXP} = \text{not } S$ ), due to the large interaction cuttings and prunings. Accordingly despite the indications in favour of significance a conclusive finding cannot be presented.

Thus, the various cutting treatments permitted significantly different yields, irrespective of species and of the frequency of cutting. The indications are that the cutting treatments did produce significantly different yields in both root pruned clones and "normal" clones, yet it is not proven so.

(e) DIFFERENCES BETWEEN PRUNINGS.

By grouping all clones into a root pruned group and a "normal" group an average total yield of dry top weight was obtained for root pruned clones 7.641 grammes and for "normal" clones 17.779 grammes. The difference was highly significant.

The difference in yield between clones subject to the pruning off of new roots, and clones not subjected to this treatment was significant irrespective of species ( $\frac{P}{SXP} = S$ ). In another way the obvious drop in production caused by root pruning is significant in all three species.

(Appendix III and Fig. 6 ).

C.foot Pruned = 9.580 gms. Cert.P.rye P. = 8.597 Urbert.P.rye P.=4.746  
 " "Normal" =23.769 " " " N. =17.403 " " " N.=12.166

The difference in yield produced by the pruning off of new roots was consistent for both frequencies of cutting.

(Appendix IV and Fig. 6 ).

Weekly Pruned = 6.320 gms. Fortnightly Pruned = 8.961  
 " "Normal" = 12.169 " "Normal" =23.390

Yet it also, failed to achieve significance, again due to a large interaction between frequency and prunings ( $\frac{P}{FXP} = \text{not } S$ ). The differences appear to warrant significance but it cannot be assumed that significance would be inevitable under any conditions.

The differences in yield produced by the pruning off of new roots was consistent for all the cutting treatments

(Appendix IV and Fig. 6 )

$\frac{1}{2}$ " Pruned = 5.481 gms. 1" P. = 6.909 2" P. =10.532  
 $\frac{1}{2}$ " "Normal" = 8.988 1" N. =15.169 2" N. =29.181

These differences were not significant also, ( $\frac{P}{UXP} = \text{not } S$ ) again due to a large interaction, cuttings and prunings. Probably had a more sensitive test been applied, then significance may have followed.

Clones differ significantly in yield when subjected to the pruning off of new roots and when left without this

treatment. Cocksfoot, certified perennial ryegrass and uncertified perennial ryegrass each show this in a significant manner. The assumptions that the differences in yield resulting from root pruning hold significance, if clones are grouped either by frequency of cutting or by different cutting treatments, are open to conjecture.

(f) COMPONENTS OF VARIANCE.

Using the method prescribed by Snedecor (p.307) and the formulae as in Section IV (compilation of Results) the components of variance were calculated.

TABLE 3. Relative percentages of the various sources of variance.

Source of variance	Percentage contribution to total variance
Between Prunings	19
CxP interaction	15
Between Cuttings	15
Error variance	13.5
FxP interaction	9
Between Frequencies	9
"    Species	7
FxCxP interaction	3.5
SxP    "	2
SxC    "	2
SxFxP  "	2
SxF    "	1
SxCxP  "	1
FxC    "	1
SxFxC  "	0
	<u>100.0%</u>

The more important contributors to total variance may be seen. It can be seen that the major factors (species, frequency of cutting, height of cutting and pruning of roots) contribute 50% of all variance leaving 50% of variance due to error and the 10 interactions. Of this 50% error

contributes 13.5% leaving 36.5% of which two interactions (CxP and FxP) contribute 24%.

Thus it is obviously necessary to attempt an interpretation of the interactions.

(g) INTERACTIONS.

i. Between cuttings and prunings. It was highly significant. This implies that the pruning off of new roots produced different effects in different cutting treatments. As may be seen in Fig. 6 cocksfoot clones cut to  $\frac{1}{2}$ " level weekly when root pruned yielded about  $\frac{2}{3}$  the production of the "normal" plants. But cocksfoot clones cut to 2" fortnightly when root pruned yielded less than half of the production of the "normal" plants.

ii. Between frequencies and prunings. It was highly significant. This implies that the pruning off of new roots produces different responses in clones cut each week and in clones cut fortnightly.

Weekly Pruned = 6.320 gms. Fortnightly Pruned = 8.961  
 " "Normal" = 12.169 " "Normal" = 23.390

The differences can be observed to be different, in accord with the result of the analysis.

iii. Between species and prunings. It was a highly significant interaction. The implication is that each species reacts differently to the same change in root pruning treatment i.e. presence or absence of root pruning.

C.foot Pruned = 9.580 gms. Cert.P.rye P. = 8.597 Uncert.P.rye P. = 4.746  
 " "Normal" = 23.769 " " " N. = 17.403 " " " N. = 12.166

The differences apparent between pruned and "Normal" clones thus are significantly different from one another.

iv. Between species and cuttings. A highly significant interaction. This infers that the different species react differently to the different cutting treatments.

C.foot differences. Cert.P.rye Uncert.P.rye  
 Between  $\frac{1}{2}$ " & 1" = 5.0 gms.  $\frac{1}{2}$ " & 1" = 9.8  $\frac{1}{2}$ " & 1" = 2.8  
 1" & 2" = 13.7 1" & 2" = 16.1 1" & 2" = 3.5

These differences thus vary significantly from species to species.

v. Between species and frequency. This interaction was highly significant. According to it the various species react significantly differently to the change in frequency of top cutting.

C.foot differences between weekly and fortnightly = 10.071 gms.

Cert.P.rye " " " " " = 6.296

Uncert.P.rye " " " " " = 4.427

The analysis thus affirms a highly probable assumption that these differences do vary significantly.

vi. Between frequency and cuttings. Also a highly significant interaction. This means that the various cutting treatments yield in a significantly different way when the frequency of cutting is altered.

Differences between weekly and fortnightly cuts

for  $\frac{1}{2}$ " = 4.677 gms. 1" = 7.268 2" = 8.849

(see Appendix IV). These figures indicate the truth of the analysis finding.

vii. Third order interactions. These were considered to be too complex to warrant an attempt at interpretation. Any interpretation made would be one possibility out of several, all of which may apply equally well. As a result they were ignored.

In passing it may be noted that the cuttings x prunings interaction was highly significant, undeniably so, for all species. ( $\frac{C \times P}{S \times C \times P} = SS$ ).

(h) INITIAL STIMULUS.

In the first weeks of this experiment a stimulus, apart from naturally occurring seasonal growth, appeared to be exerted resulting in peculiar yields from clones under different treatments. For convenience this stimulus is called "initial stimulus", since it has not been observed later in the experiment. Its presence is mentioned in Section II. As it was purely coincidental an analysis of

variance of those first few weeks was not attempted. Also the second weekly top treatment was inadvertently delayed by some two days.

Figure 10.

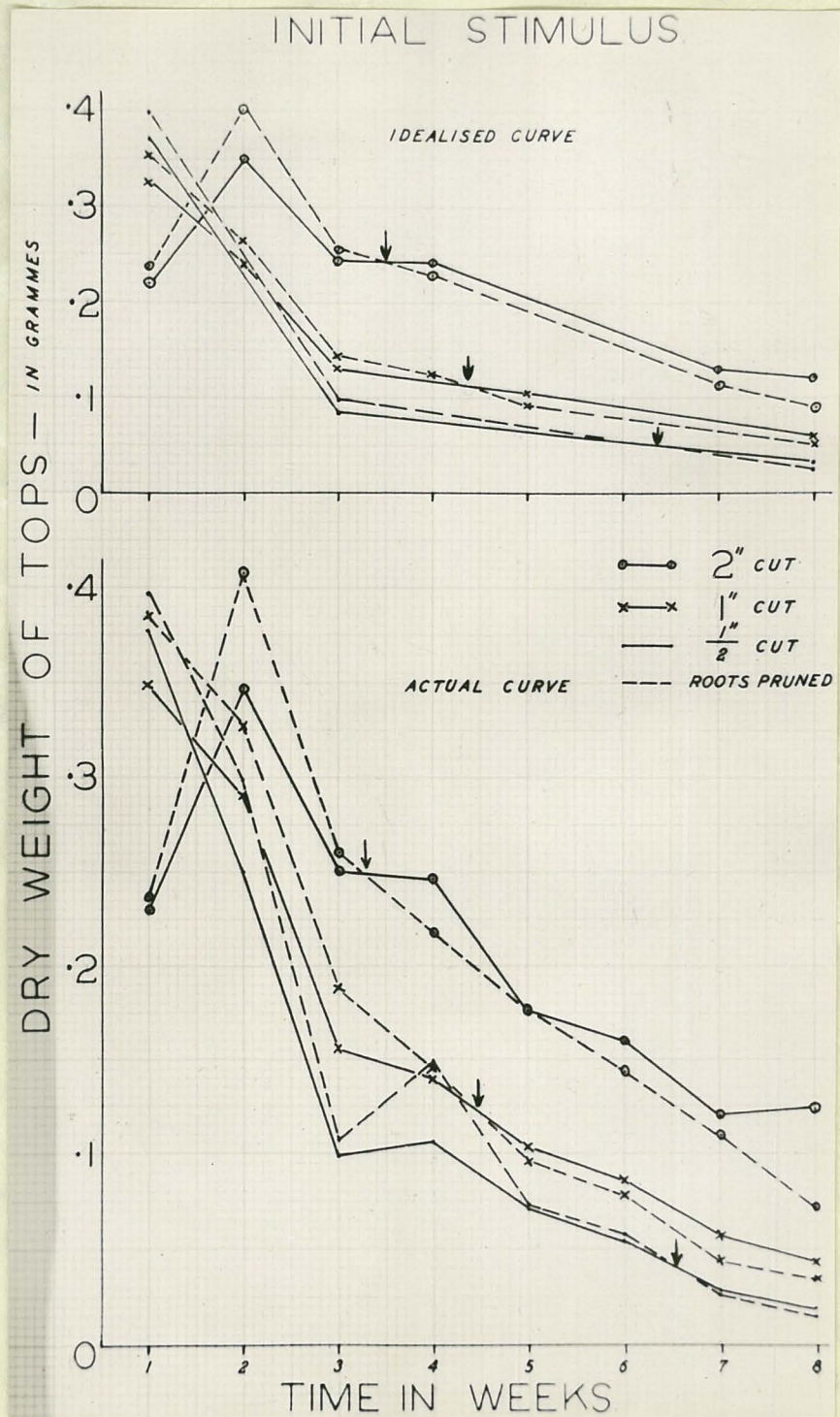


Figure 10 illustrates the actual results obtained and an idealised version of the same. The figure was produced by averaging the values obtained for the three species. Each species reacted in a similar way. By averaging the three

it was hoped to get a smoother representative curve.

The following points seem to be of probable significance.

i. At the commencement of the trial all clones were cut to their correct heights. The first week's weighings showed that those clones cut to the  $\frac{1}{8}$ " level outyielded those cut to the 1" level, these latter in turn outyielded those cut to the 2" level.

ii. It was observed that clones which had been subjected to root pruning outyielded those which had not, for the first few weeks at least.

iii. After the first week, at the second cutting date, the 2" plants were outyielding the 1" clones, which in their turn were outyielding the  $\frac{1}{8}$ " clones. This state of affairs held good for the rest of the experimental period.

iv. Root pruned clones which were expected to yield less than those not under root pruning, eventually did yield less. They changed from superior yield to inferior yield at times differing for the three levels of cutting. After  $4\frac{1}{2}$  weeks, from the pretreatment cut, the 2" root pruned clones subsided beneath their 2" "Normal" colleagues. This point was reached in  $5\frac{1}{2}$  weeks for the 1" clones and in  $7\frac{1}{2}$  weeks for  $\frac{1}{8}$ " clones. Thereafter the root pruned clones were inferior yielders of dry top growth.

(1) GENERAL OBSERVATIONS ON TOP GROWTH.

Growth was seasonal for all three species and for all 36 treatments. In the initial stages of the experiment a marked decline in productivity was common. This may have been due to waning of the rapid growth of establishment or of the "initial stimulus" effect, but it seems very probable that a natural decline in production occurred due to the onset of winter.

Without exception late June - early July was the period of least growth. Production was virtually halted save in the cases of the most leniently treated clones. Even so production was low. From mid July to late August growth

increased gradually. September appeared to be the start of rapid growth. Cocksfoot clones showed this rapid increase for a brief period and then resumed a slower rate of increase, until November when they too proceeded with a very rapid increase in growth. Peak production was reached at different times for different species.

From early November to late December certified perennial ryegrass produced at a very high level with peak production occurring within that period. Uncertified perennial ryegrass produced at a high level, though lower than certified, for the same period of time as certified but with peak production occurring within the period but later than for certified perennial ryegrass. The cocksfoot produced well from late November until the end of the trial there being indications of a slight decline in production only.

In each case it was notable that the clones which had been subjected to root pruning reached their peak production at least a fortnight or three weeks earlier than did the non root pruned ("Normal") clones e.g. root pruned certified perennial ryegrass clones reach their peak about the first week in November whereas "Normal" clones reached their peak about mid December.

Throughout the experiment differences between treatments were obvious, just as were the differences between species. Except for a period in August and September cocksfoot out-yielded certified and uncertified perennial ryegrasses consistently. Cocksfoot appeared to respond to the spring in a laggardly manner. Apart from a brief increase in production in September there was no sizable response to improving growth conditions until about the second week in November. This appeared to hold for all treatments.

Ryegrass responses were more gradual. Although growth did not reach as high a peak as that of cocksfoot yet following the June - July period it proceeded at a gradually increasing rate. Thus whereas November was reached before

cocksfoot responded in sizeable measure the ryegrasses, certified in particular, by that time had increased their rate of production by an appreciable amount. The ability of the certified perennial ryegrass to produce in the transition period, winter - spring, was most marked. Following peak production a decline set in Cocksfoot showed little of it, even in the root pruned treatments. Certified and uncertified perennial ryegrass showed it to a marked degree, the root pruned treatments in particular. The most leniently treated uncertified perennial ryegrass clones ( $\frac{1}{2}$ ", 1" and 2" "Normal" clones cut fortnightly) showed a brief increase in production during January.

The treatments differed one with another. In general root pruned clones reached peak production before the "Normal" clones under the same top treatment. However in the harshest treatments (tops cut to  $\frac{1}{2}$ " or 1" weekly) there did not appear to be such a difference. Under these treatments both root pruned and "Normal" clones seemed to follow a very similar curve with a scarcely discernible peak in December.

The least lenient treatments were backward in responding to the spring. In general the most lenient treatments responded earliest and most rapidly to the spring. It appears that fortnightly cuttings and the lightest top cuttings favour growth, in that response to changed environmental conditions is not greatly hindered.

As can be seen the pruning off of new roots has a drastic effect on the production of dry top growth. Yields were decreased and growth response to spring delayed. Root pruning, in general, effected an advance in time of peak production. There were species differences with respect to time of peak production.

The time of production of flower stalks is of interest here. The first flower stalks appeared on ryegrass plants

by the 29th of October. By the 5th of November many ryegrass clones were producing them. Between the 12th and the 19th of November cocksfoot flower stalks appeared. Stapledon and Milton (7) record that continued plucking of inflorescences in cocksfoot stimulated top growth. Thus the peak growth may have been extended by the frequent removal of inflorescences. As no distinction between seedstalks and leaves was made, the recorded weighings consist of dry leaf and dry flower stalk. Flower stalks were few or almost absent from clones cut to  $\frac{1}{2}$ " and 1" weekly. Consequently yields ascribed to them contained but few variations due to flower stalks. By the middle of January flower stalk formation was almost completed.

**B. ROOT TREATMENTS**

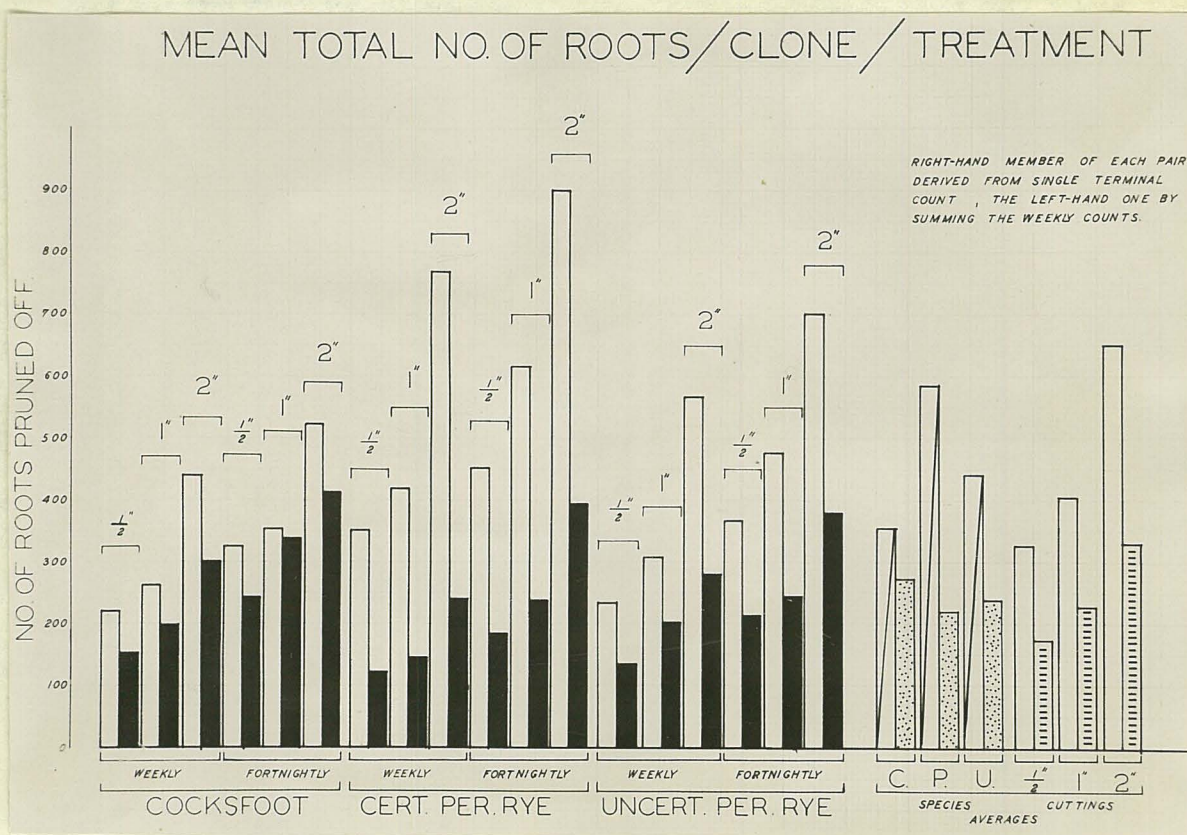


Figure 11. Histogram of mean total numbers

Of the 540 clones under top treatment, 270 were simultaneously under root treatment i.e. the pruning off of roots initiated each week. As all clones had been randomised when planning the experiment it was possible to regard the 270 clones under root treatment as constituting a separate experiment. This separate experiment consisted of testing the effects of various cutting treatments on numbers of roots initiated each week. The 270 clones were randomised 18 per block throughout the 15 blocks. Thus they could be split up into comparable groups, by top treatment, between which legitimate comparisons could be made.

Table 4 is a table of the mean average number of roots pruned off per clone for the whole experimental period, recorded in various groupings (Expressed in numbers).

Table 4.

Method of Grouping	Groups	
By blocks	A.471.8 F.397.3 K.517.4	General mean = 461.4
	B.515.3 G.359.9 L.539.1	
	C.494.0 H.350.4 M.448.4	
	D.401.6 I.528.8 N.518.0	
	E.369.4 J.514.1 P.494.8	
By species	Cocksfoot clones =355.4	
	Cert.Perenn.rye clones =585.7	
	Uncert.Perenn.rye clones =442.9	
By frequency of top cutting	Weekly top cutting =397.7	
	Fortnightly top cutting =525.0	
By different top cutting	$\frac{1}{2}$ " top treatment =326.5	
	1" " " =406.6	
	2" " " =651.0	

An analysis of variance was carried out to test the significance of the differences as apparent above.

Table 5. ANALYSIS OF VARIANCE IN ROOT NUMBERS.

Source of Variance	df	Sums of squares	Mean Square	F	Ratio req'd.	
Total	265	13,214,792.2	49,867.1			
Between Blocks	14	1,149,374.5	82,098.2	6.06	2.17	SS
" Species	2	2,432,548.5	1,216,274.3	98.45	4.71	SS
" Frequencies	1	1,095,066.8	1,095,066.8	88.64	6.76	SS
" Cuttings	2	5,143,968.1	2,571,984.1	209.19	4.71	SS
SxF interaction	2	40,411.0	20,205.5	1.64	4.71	-
SxC "	4	391,192.1	97,798.0	7.92	3.41	SS
FxC "	2	22,028.2	11,014.1	0.89	4.71	-
SxFxC "	4)	24,414.96	6,103.7)	12353.8)	2	
Error variance	234)	2,915,788.04	12,460.6)			

SS = significant at the 1% level of probability.

Standard Deviation =  $s = 111.15$

∴ Coefficient of variation =  $\frac{s}{\bar{x}} = 24.09\%$   $\bar{x}$  = General mean.

The sources which failed to reach significance at the 1% level also failed to reach it at the 5% level.

The second order interaction failed to achieve significance and was accordingly bulked in with error variance, the new error term so derived being used for all calculations.

(a) BLOCK DIFFERENCES

The differences between blocks are more pronounced with root numbers than with dry top weight. They are highly significant statistically. Yet this variation between blocks does not appear to be exceptionally large, pointing again to the relative evenness of the area in respects pertaining to plant growth. It is understandable that roots should vary more, due to soil variations, than tops. Any effect due to soil variation must pass through the plant to reach the leaves. Food reserves may be mobilised thus buffering these soil effects. Possibly a small variation in top growth may indicate a larger variation in root initiation and in root growth as a whole.

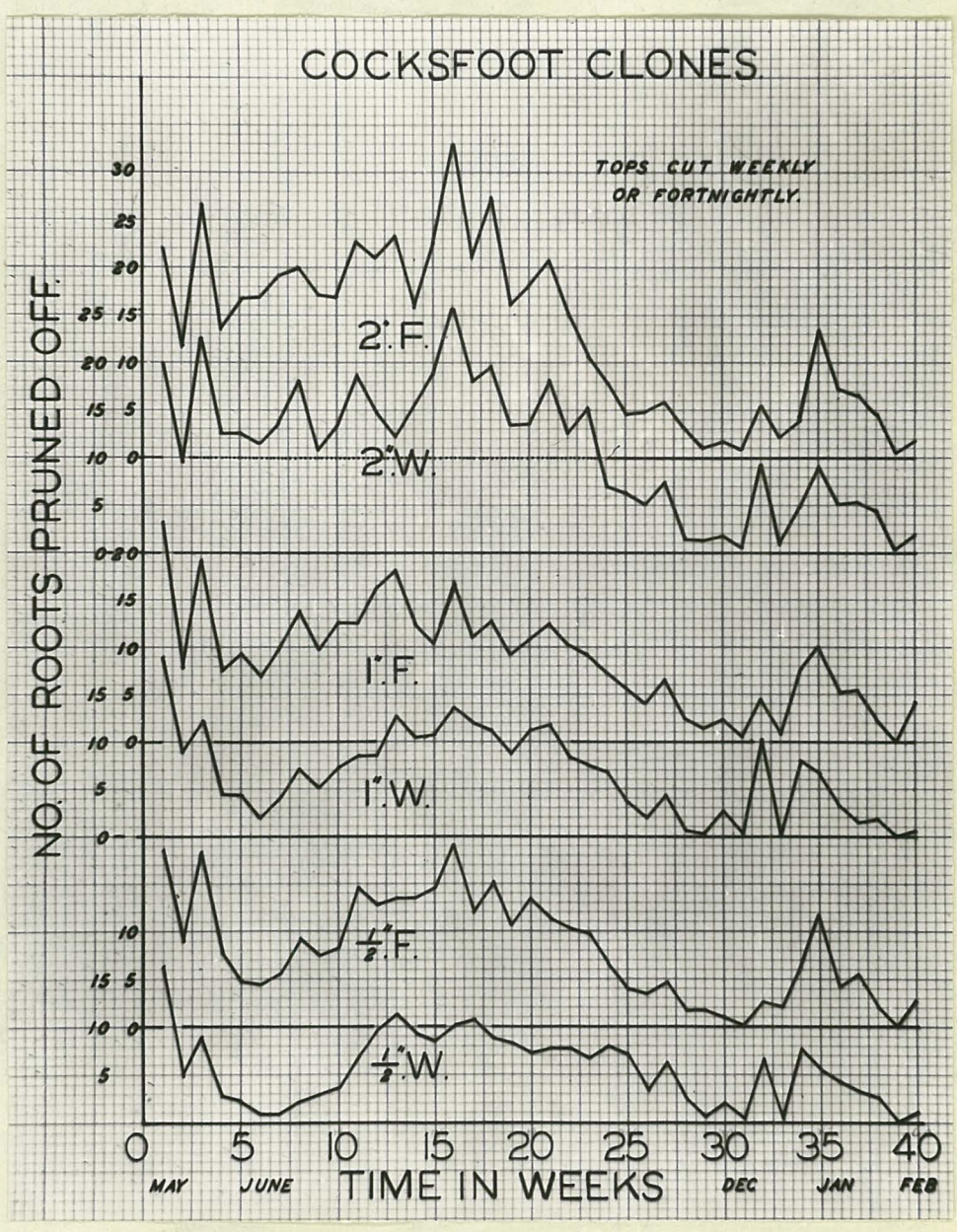


Figure 12. Graphs of root initiation for Cocksfoot clones.

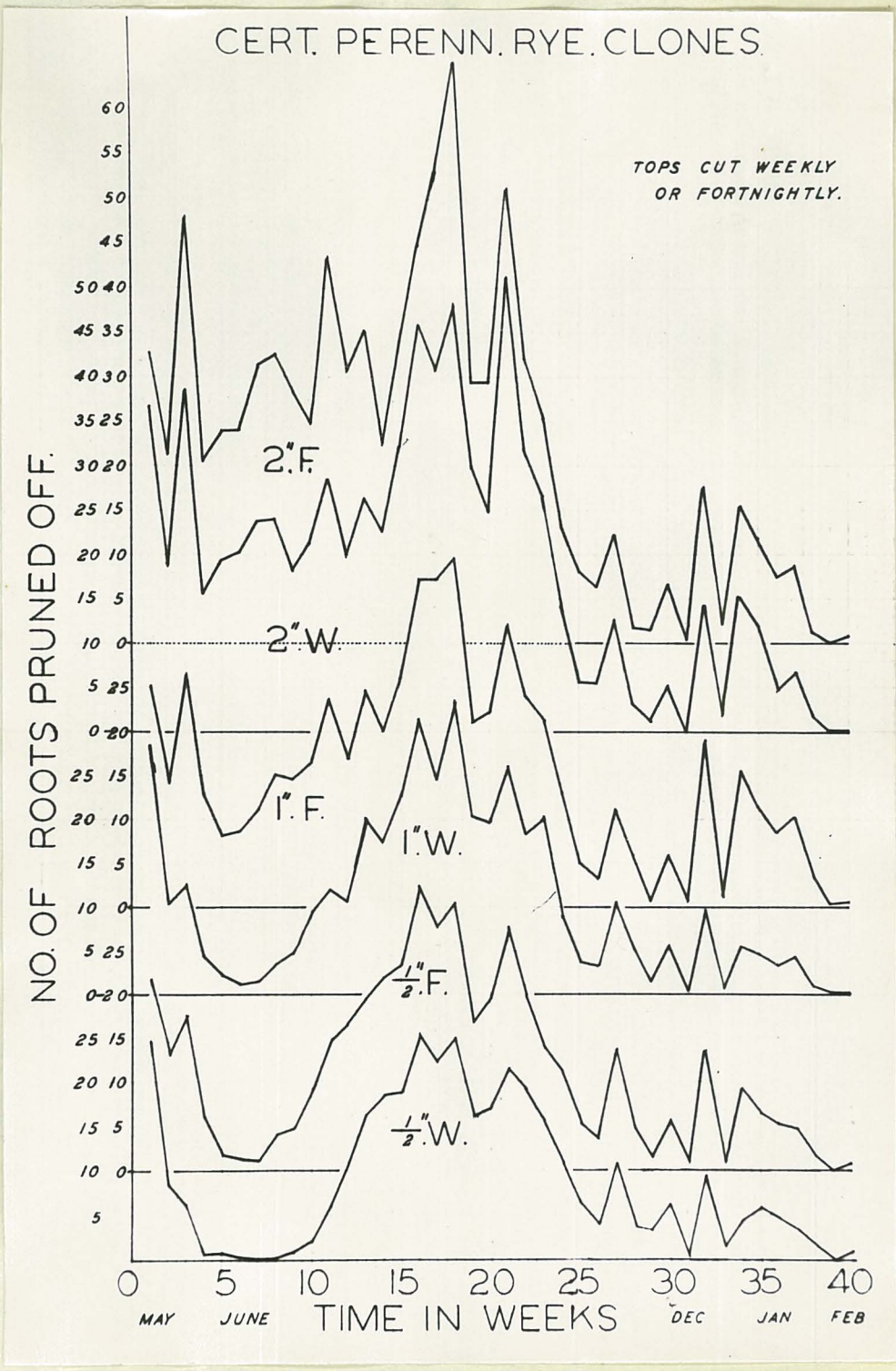


Figure 13. Graphs of root initiation for Certified Perennial ryegrass clones.

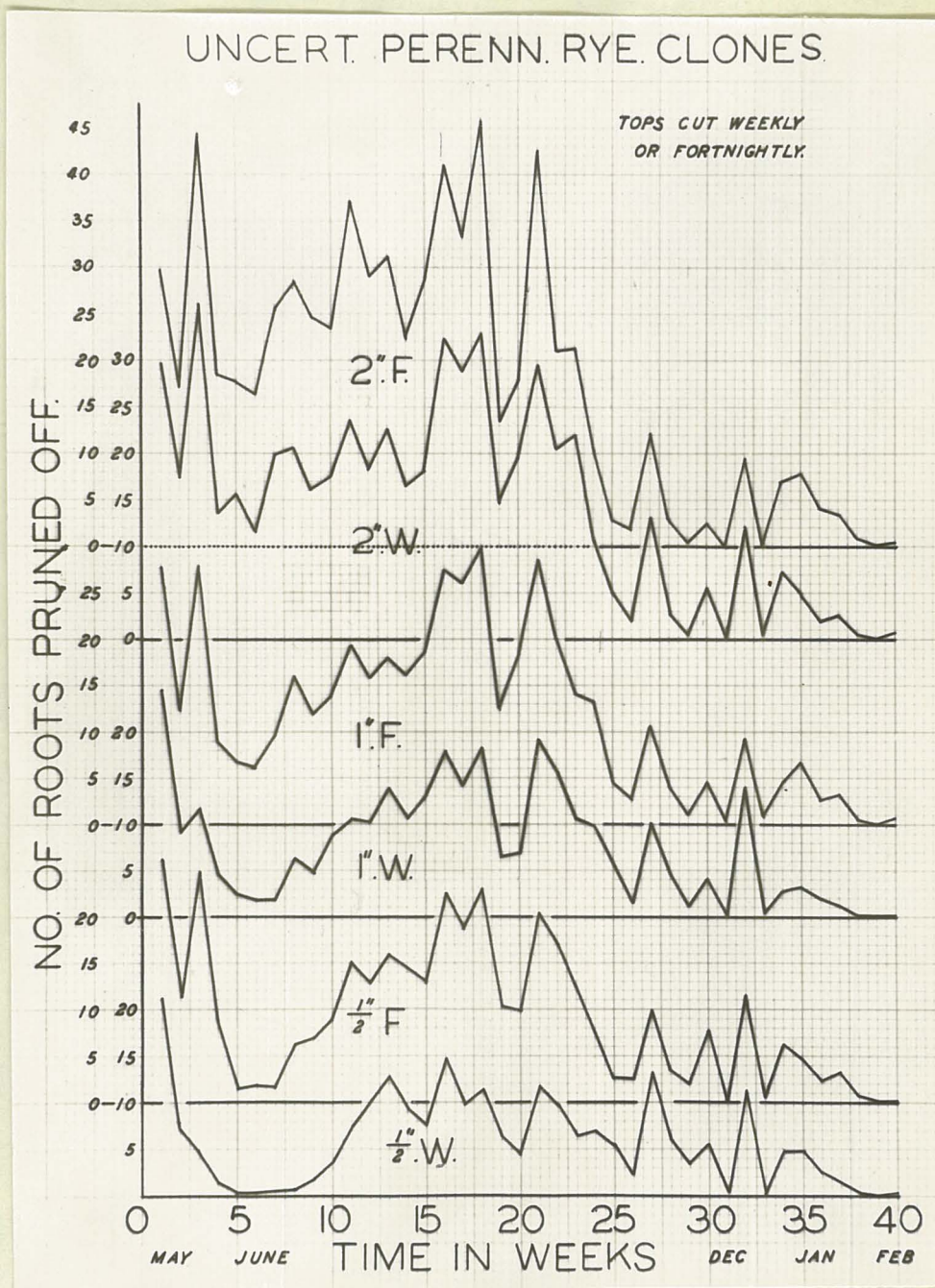


Figure 14. Graphs of root initiation for Uncertified Perennial ryegrass clones.

(b) DIFFERENCES BETWEEN SPECIES.

The average number of roots per clone for the whole experimental period, irrespective of cutting treatment, was for cocksfoot 355.4, for certified perennial ryegrass 585.7 and for uncertified perennial ryegrass 442.9 (Appendix III). The differences between the species were highly significant statistically. Thus from point of view of numbers of roots initiated certified perennial rye initiated most, then uncertified perennial ryegrass and finally with the lower number, cocksfoot.

The differences between species, in numbers of roots initiated, was significant irrespective of whether tops were cut weekly or fortnightly ( $\frac{S}{SxF} = S$ ) see Appendix VI. Thus within the weekly treatment group significant differences occurred and also within the fortnightly treatment group. From Appendix VI we get -

C.foot weekly	= 309.0	C.foot fortnightly	=401.8
Cert. P. rye weekly	= 514.0	Cert.P. rye fortnightly	=657.4
Uncert.P.rye "	= 370.0	Uncert.P.rye "	=515.9

The differences between species were significant, irrespective of the height of cutting of tops ( $\frac{S}{SxG} = S$ ). Thus within the ranks of all clones cut to say 1" height, there were significant species differences. Naturally this applies to the  $\frac{1}{2}$ " and 2" heights equally well. Again from Appendix VI we get -

C.foot	$\frac{1}{2}$ " =274.3	C.foot	1"=309.8	C.foot	2"=482.2
Cert.P.rye	$\frac{1}{2}$ " =404.1	Cert.P.rye	1"=517.1	Cert.P.rye	2"=835.9
Uncert.P.rye	$\frac{1}{2}$ " =301.0	Uncert.P.rye	1"=392.9	Uncert.P.rye	2"=634.9

In summary, root numbers as measured in this experiment were effected substantially by variations in top treatment. There were significant differences, in number of new roots initiated, between species for the experiment as a whole, for the two frequencies of cutting the tops and for the three different heights of cutting the tops.

(c) DIFFERENCES BETWEEN FREQUENCIES OF TOP CUTTING.

Over the whole experimental period. the clonal average

number of roots initiated at the base of the plant was 397.7 for clones with top treatments carried out weekly and 525.0 for clones which were top out fortnightly. The difference between the two was highly significant statistically.

The difference between clones with weekly top cuttings and with fortnightly top cuttings was significant irrespective of species. ( $\frac{F}{S \times F} = S$ ).

C.foot weekly =309.0 Cert.P.rye W. =514.0 Uncert.P.rye W=370.0  
 " "Fortnighly =401.8 " " F. =657.4 " " F=515.9

These differences can be observed above. Within each species a significant difference due to different frequencies of top cutting may be found.

This same difference between weekly and fortnightly groups, was found to be significant irrespective of height of top cutting ( $\frac{F}{F \times C} = S$ ). Thus for clones cut to say the 2" level the difference between weekly cutting and fortnightly cutting was significant. Similarly for the other heights of cutting. From Appendix VI we get -

$\frac{1}{2}$ " topcut weekly =270.5 1" W =330.3 2" W = 592.2  
 $\frac{1}{2}$ " " fortnighly =382.4 1" F =483.0 2" F = 709.8

Thus the difference in numbers of roots initiated between clones top cut weekly and those top cut fortnightly was highly significant for the whole experiment and significant within each species as well as within each cutting group.

#### (d) DIFFERENCES BETWEEN THE TOP CUTTINGS

Over the experimental period the average number of roots initiated per clone, per top cutting height, irrespective of other considerations was for the  $\frac{1}{2}$ " height 326.5, for the 1" height 406.6 and for the 2" height 651.0. The differences between these groups were statistically significant.

These differences were significant for all three species

( $\frac{C}{S \times C} = S$ ).

C.foot	$\frac{1}{2}$ "	topcut	=274.3	Cert.P.rye	$\frac{1}{2}$ "	=404.1	Uncert.R.rye	$\frac{1}{2}$ "	=301.0
"	1"	"	=309.8	"	1"	=517.1	"	1"	=392.9
"	2"	"	=482.2	"	2"	=835.9	"	2"	=634.9

Again the data proves the validity of the statistical argument.

These differences were also significant for the two frequencies of top cutting ( $\frac{G}{F \times G} = S$ ). From Appendix VI -

$\frac{1}{2}$ "	top cut	weekly	= 270.5	$\frac{1}{2}$ "	top cut	fortnightly	= 382.4
1"	"	"	= 330.3	1"	"	"	= 483.0
2"	"	"	= 592.2	2"	"	"	= 709.8

As can be seen, within the weekly cutting group the clones under different cutting treatments yielded differently.

Similarly for the fortnightly cutting group.

Root numbers varied significantly in response to different heights of top cutting. These differences were significant for the whole experimental population, for the three species and for the clones under each frequency of top cutting.

(e) INTERACTIONS.

1. Between species and frequency of top cut.

The species and frequency interaction was not significant statistically. From fig. 11 and Appendix VI it would appear that the three species do react differently to variations in frequency of cutting their tops (in root numbers).

C.foot	weekly	=309.0	Cert.P.rye	W.	=514.0	Uncert.P.rye	W.	=370.0
"	Fortnightly	=401.8	"	"	F.	=657.4	"	"
							"	"
							F.	=515.8

However as the point is not statistically proved a sound conclusion cannot be made.

ii. Between species and different top cuttings.

It was highly significant. Thus one is safe in concluding that the three species varied significantly in their response to the various top cutting treatments. Fig. and Appendix VI lend support to the conclusion.

C.foot	$\frac{1}{2}$ "	topcut	=274.3	Gert.P.rye	$\frac{1}{2}$ "	=404.1	Uncert.P.rye	$\frac{1}{2}$ "	=301.0	
"	1"	"	=309.8	"	"	1"	=517.1	"	1"	=392.9
"	2"	"	=482.2	"	"	2"	=835.9	"	2"	=634.9

111. Between frequency of topcut and different top cuts.

It was not statistically significant. Fig. 11 and Appendix VI give indications that possibly an experiment designed to test this interaction might give a significant result.

$\frac{1}{2}$ "	top cut	weekly	=270.5	$\frac{1}{2}$ "	topcut	fortnightly	=382.4
1"	"	"	=330.3	1"	"	"	=483.0
2"	"	"	=592.2	2"	"	"	=709.8

(f) COMPONENTS OF VARIANCE.

Using the formulae recorded in Section IV "Compilation of Results" the components of variance were calculated.

Table 6. Percentage contribution of the various sources to total variance.

Source of variance	Percentage contribution to total variance.
Between top cutting groups	40
Error variance	27
Between species	18
Between frequencies of top cutting	11
Due to SxC interaction	4
" " SxF "	0
" " FxC "	0

100.0%

It can be seen that the main effects, notably the variation of top cutting, contributed 69% of total variance, while the interactions contributed only 4%. This would suggest that possibly the interactions which failed to achieve significance in this experiment actually might fail to achieve significance in an experiment designed to test them.

(g) GENERAL OBSERVATIONS ON ROOT INITIATION.

At the commencement of the trial all plants were pruned back to six roots. A count taken at the conclusion of the trial showed an average of seven roots for each clone which had been subjected to weekly root pruning throughout the trial. In two cases where the plaster knob had been placed unreasonably deep over 100 roots were found for each clone. By averaging out any error resulting from these two indiscretions was minimised.

All plants not subjected to regular root pruning were lifted at the conclusion of the trial and a count made of the roots growing from the base of each plant. Many of these roots were fine and difficult to distinguish. As a result the count made was not an accurate one, insufficiently accurate to warrant analysing the results statistically. Appendix VII or VIII give the appropriate figures for the repeated weekly and for the one final count of root numbers. Figures 12, 13 and 14 record the periodical changes in numbers of roots initiated by the clones under the various treatments.

Provided conditions were suitable growth seemed to be seasonal. In all cases root initiation started off at a high level possibly due to an "initial stimulus", such as appeared to influence top production. It was felt that in all probability root initiation had been at a high level during the establishment period. The onset of the cold wet conditions in June caused a diminution in root initiation, thus contributing to this decline in root initiation. All treatments showed a low level of initiation during June, the ryegrasses more so than the cocksfoot. In July root initiation increased to a high level which was maintained until mid October. Without exception peak level of initiation was reached within a week of the 6th September 1948 (17th week of trial). From mid October a marked decrease in initiation was noted until in mid December root

initiation virtually ceased. Immediately following this there appeared to be a response to stimuli in that, from about the 3rd week in December to the end of January, a small increase and decline in initiation occurred.

There were species differences in behaviour throughout the trial. For the greater part of the trial uncertified perennial ryegrass initiated fewer roots than certified perennial ryegrass. It responded to changing conditions in an almost exactly similar way to certified perennial ryegrass, but to a lesser extent. Variations were large in both the ryegrasses and smaller in the cocksfoot. At about the 32nd week a sharp peak of initiation occurred. A peculiarity may be seen, in that cocksfoot clones top cut fortnightly did not respond to any large extent at this time. Cocksfoot appeared to be able to stand closer cutting than the ryegrasses without serious prejudice to root initiation. Only the harshest top cutting treatment showed a serious halting of initiation in cocksfoot. At the same time, in June, the three harshest top treatments for the ryegrasses showed halting of initiation to a comparable degree.

There were differences in the groups under different top cutting treatments. The more lenient top cutting treatments, in all cases, permitted a consistently higher level of root initiation. Under those treatments winter slumping was less marked than under the least lenient treatments. The least lenient treatments showed a more definite peak of initiation in late winter and showed smaller responses to variations in conditions than did the more lenient treatments. At about the 20th week (20 -27th Sept. 1948) a pronounced slump in initiation occurred. This coincided with a drop in soil moisture.

As stated, those clones which had been left undisturbed for the duration of the trial were lifted and a tally made of the roots growing off the base of the clones. These figures are collated in Appendix VIII and abstracted for comparison purposes in Appendix III under the heading

"Normal". The various heights and frequencies of cutting tops showed their effect in changes in root initiation just as they did for the clones whose new roots were tallied and pruned off each week. The effects were very similar. A notable fact was, that in only one case did the numbers of roots, as found at the single terminal count, approach closely to the numbers of roots got by weekly tally of the strictly comparable group i.e. comparing  $\frac{1}{2}$ " weekly cocksfoot without root pruning and  $\frac{1}{2}$ " weekly cocksfoot with root pruning. (Figure 11). By summing the weekly counts it was found that cocksfoot had produced the fewest roots per clone and certified perennial the most, but here it was found that cocksfoot had the most and certified perennial the least. In both cases uncertified perennial ryegrass filled a median position.

It appears to be possible to postulate a ratio which could be used to predict naturally occurring initiation using as a base the numbers of roots initiated under the experimental pruning off system. For the cocksfoot clone used, the ratio giving the approximate number appears to be about 1 : 0.77 (1 root under experimental weekly prunings = 0.77 roots under natural undisturbed initiation) for the certified perennial ryegrass plant used 1 : 0.38 and for the uncertified perennial ryegrass plant used 1 : 0.54. This ratio varied within each species in the different treatments. Cocksfoot had a range of 1 : 0.72 - 0.86, certified perennial ryegrass had a range of 1 : 0.37 - 0.38 and uncertified perennial ryegrass a range of 1 : 0.50 - 0.57.

C. SOIL MOISTURE.



Figure 15. Soil sampling area.

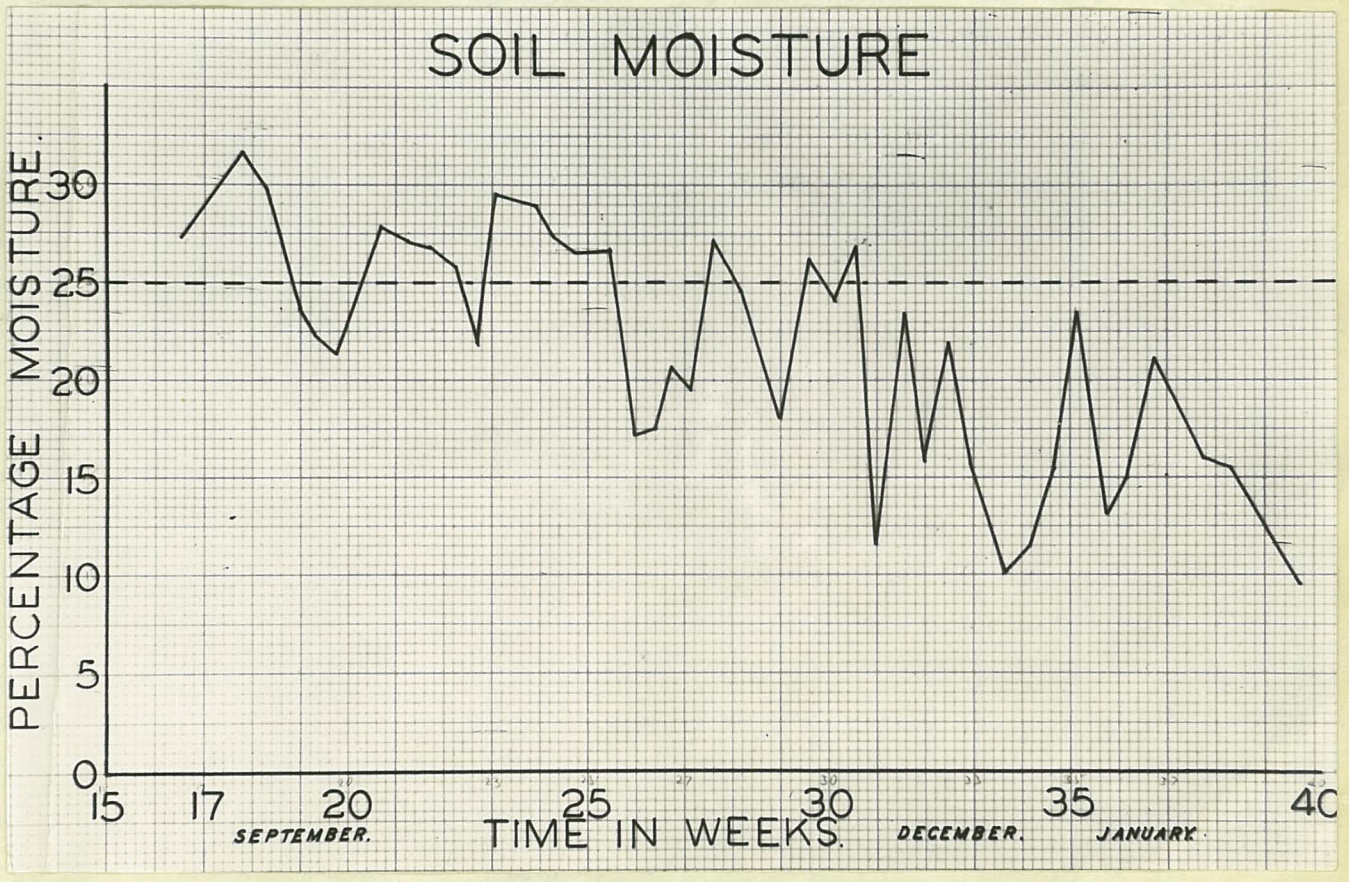


Figure 16. Graph of soil moisture.

Sampling commenced on the 1st September 1948 and continued at three day intervals (approx.) until the end of the trial. There were depressions in the soil moisture curve on the 19th week, 22nd week (minor only) 26 - 27th week, 29th week, 31st week, 33 - 34th week, 36th week and a final fall in the last two weeks. The effect of all of these drops in soil moisture may be observed in most of the root initiation graphs, particularly in those representing the most lenient treatments. It would seem that soil moisture was the main determinant of root initiation for the greater part of the trial. Soil temperature (from Grasslands Division records) was relatively constant between 10 and 15°C. until mid December. A peculiar peak of initiation occurred at that time when a soil moisture of about 20% was associated with a soil temperature of about 22°C. A pronounced slump in root initiation occurred in the 19th week of the experiment (20 -27th September 1948) Soil moisture fell at that time from 32% to 22%.

Root initiation appeared to fall altogether at a soil moisture of about 10 - 12%. (Appendix X and Figs. 16, 12, 13 and 14)

D. DIFFERENTIAL GROWTH.

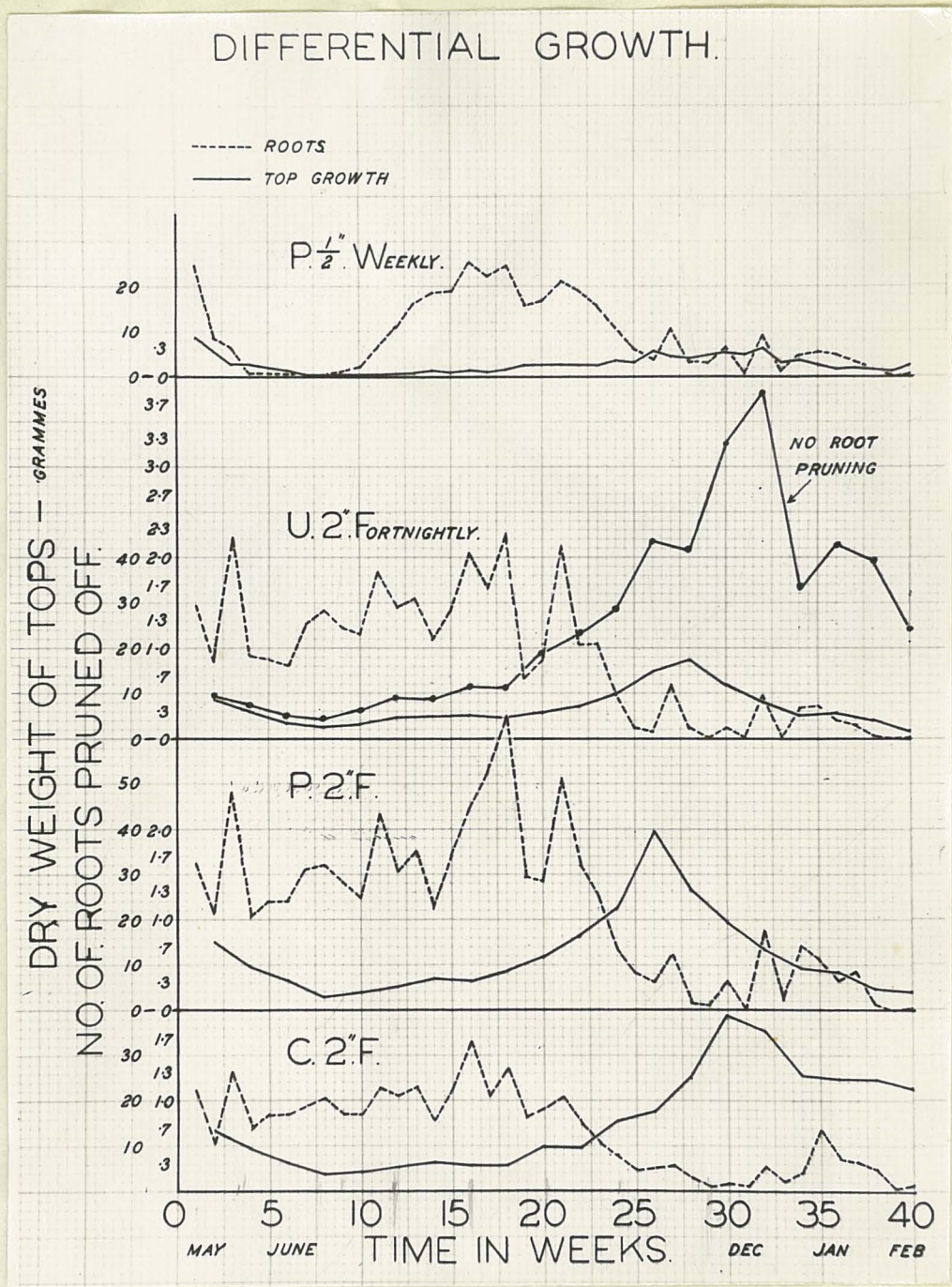


Figure 17. Graph of differential growth.

From the review of literature one knew that in all probability root growth i.e. initiation, and herbage growth did not coincide. Figure 17 illustrates that such was the case in this experiment. Root initiation was at a low ebb in June, as was top growth. However, root initiation began to increase in rate earlier than did top growth. When top growth began to increase at a rapid rate root initiation began to decrease at a rapid rate. Thus in October the emphasis of growth changed from root initiation to top growth. Then in January as top production declined a minor peak of

root initiation was observed. In Figure 17 the graph for the uncertified perennial ryegrass clones cut to 2" fortnightly and root pruned is supplemented by the graph for uncertified perennial ryegrass clones cut to 2" fortnightly and not regularly pruned. This further emphasises the differential growth of roots and herbage. This phenomenon applied to all three species and to all treatments. The graph for certified perennial ryegrass cut to  $\frac{1}{2}$ " weekly is that at the top of the figure and was taken as illustrating the fact that all treatments responded similarly.

#### E. RUST.

It has been the common belief that more mature plants i.e. those with more leaf, are more susceptible to rust. It has been suggested that a possible method of minimising rust would be the close grazing of susceptible areas during the spore forming period (December - January). In this experiment rust was found in early January. In the second week in January all plants in the trial were checked for evidence of rust and classified arbitrarily, as in Appendix X/, into four groups of differing degrees of rusting - rust found after investigation, rust clearly discernible, rust extensive and rust very severe.

There were species and strain differences. Only one plant was found rusted in the cocksfoot series and it was rusted only slightly. The certified perennial ryegrass showed less evidence of rusting (25 clones) than did the uncertified perennial ryegrass (44 clones).

There were treatment differences. The treatments were arranged in order of production i.e. from most lenient to least lenient. It was found that the most lenient treatments had the greatest number of clones rusted. Furthermore the more lenient the treatment the more severely were the clones rusted. The most lenient treatment of certified perennial ryegrass showed less rust and less severe rusting than did the most lenient treatment of uncertified perennial

ryegrass. In general the certified perennial ryegrass treatments which showed rust were on a higher production level than those of uncertified perennial ryegrass. This indicates that the newer perennial ryegrasses, which have been selected for rust resistance, actually are more resistant than older types.

*Puccinia coronata* was the rust encountered.

F. NUMBERS REQUIRED.

No matter how well planned an experiment may be, or how many replications there are of each treatment there will always be the likelihood that the results obtained may be due to fortuitous variation. Obviously the greater the number of replications the less chance there is of chance variation being responsible for the result obtained. However, in an experiment too many replications may lead to a prohibitive volume of routine operations. By taking too few replications the chance that the results are due to fortuitous variation is great. Somewhere between these extremes is a number of replications where the gain in accuracy occasioned by taking an extra replication is small and where the numbers are such as to be workable under experimental conditions. Such a number of replications gives results with an adequate degree of accuracy and ensures that work can proceed at a decent pace. By taking more replications pace is slowed down by over accuracy, and by taking less replications pace is slowed down by inaccuracy.

Hetzer and Brier 1939 (54) quote a formula for "t".

$$t = \frac{d}{s \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where t = "Student's" t for n-1 degrees of freedom  
d = difference between the means of the two groups  
s = standard deviation  
n<sub>1</sub> = number of individuals in one group  
n<sub>2</sub> = number of individuals in other group

Here comparable groups were of equal numbers i.e. n<sub>1</sub> = n<sub>2</sub>

Thus the formula as amended was

$$n = \frac{2t^2 s^2}{d^2}$$

Thus by substituting different values for "d" the following curves were drawn.

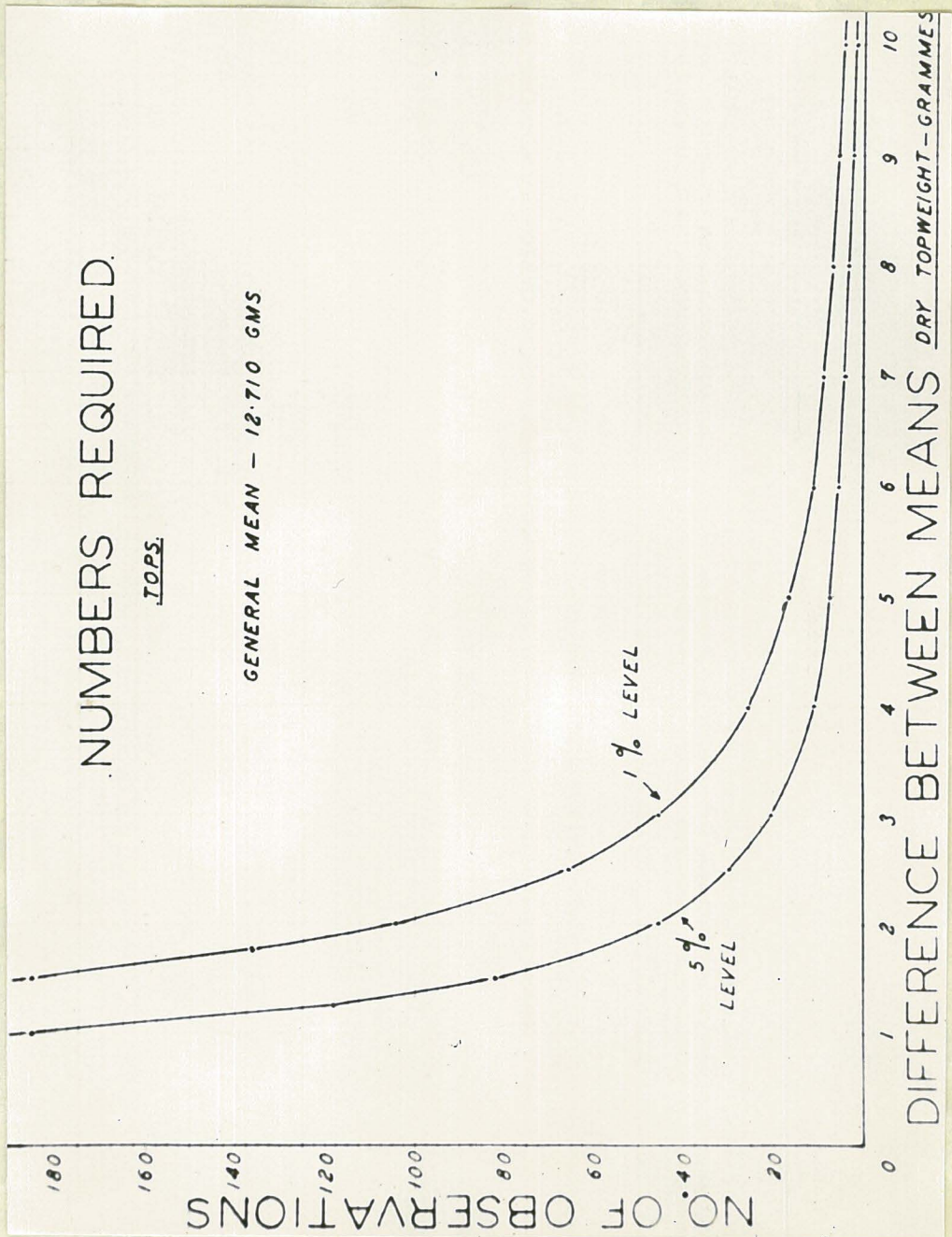
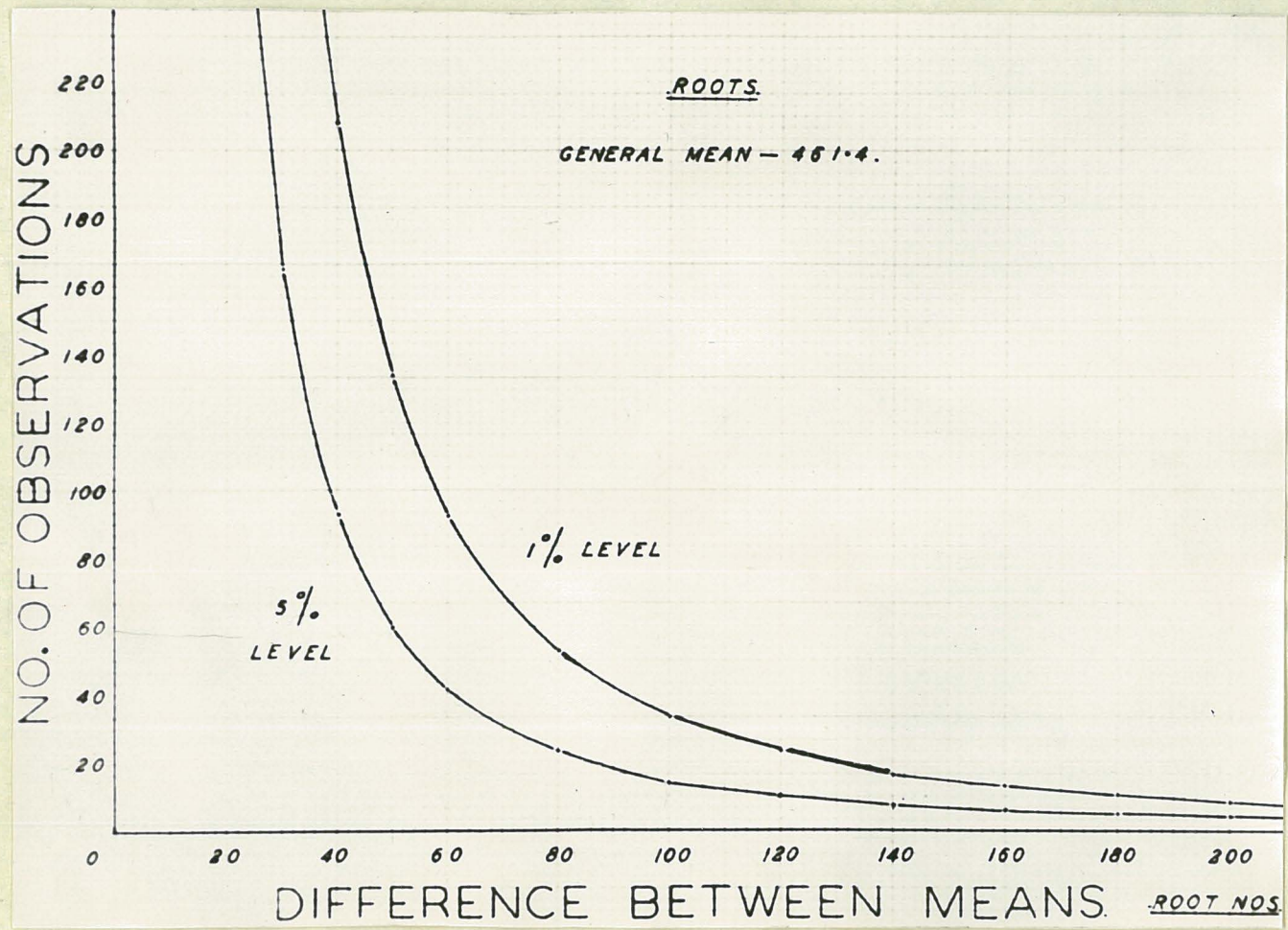


Figure 18.a. Graphs for numbers required.

Figure 18. Graphs for numbers required.



Correction. Figures for "Difference Between Means" should be multiplied by 0.6655 .

From these it would appear that when cutting tops of grass clones under conditions akin to those ruling during this experiment, and for a similar period of time, a number of 15 - 18 replications would prove adequate where the differences under investigation are not too fine. For root pruning, as carried out here, possibly 20 - 23 replications would prove adequate. However as most experiments are multifactorial 15 replications of each plant treatment may give in effect, as in this experiment, 180 replications of  $\frac{1}{2}$ " top cutting, 90 replications of  $\frac{1}{4}$ " top cutting carried out weekly and so on. If a single factor experiment was planned with clones, then greater numbers would be practicable and so the problem would be resolved on its own.

#### G. SUMMARY OF RESULTS.

##### (a) Tops.

1. There was significant variation between blocks (as measured by dry weight of tops).

2. There were significant differences between cocksfoot certified perennial ryegrass and uncertified perennial ryegrass.

These differences were significant irrespective of whether the clones were cut to the  $\frac{1}{2}$ ", 1" or 2" level.

The differences were consistent, though not significant for clones cut weekly and for clones cut fortnightly, as well as for clones which had been root pruned and those which had not.

3. There was a significant difference between weekly cut clones and fortnightly cut clones.

This difference was significant irrespective of whether the clones were cut to the  $\frac{1}{2}$ ", 1" or 2" level.

It was consistent, though not significant, for all three grasses and irrespective of whether or not clones had been root pruned.

4. There were significant differences between the levels of cutting ( $\frac{1}{2}$ ", 1" and 2").

These differences were significant for all three grasses and for all clones under weekly cutting and those under fortnightly cutting.

The differences were consistent though not significant for all clones subjected to root pruning and for all clones not subjected to it.

5. There was a significant difference between clones subjected to root pruning and clones not subjected to root pruning.

This difference was significant for cocksfoot, certified perennial ryegrass and uncertified perennial ryegrass.

It was consistent though not significant for weekly and fortnightly cuttings as well as for each of the levels of cutting ( $\frac{1}{2}$ " , 1" and 2").

6. The pruning off of new roots produced significantly different effects in the three cutting treatments ( $\frac{1}{2}$ " , 1" and 2"), in clones cut weekly and in clones cut fortnightly, as well as in each of the three grasses.

Each of the three grasses reacted in a significantly different way to different levels of cutting ( $\frac{1}{2}$ " , 1" and 2") and to a change in frequency of cutting (weekly - fortnightly)

The three levels of cutting produced yields which varied significantly when carried out each week and each fortnight i.e. the difference between  $\frac{1}{2}$ " cut weekly and  $\frac{1}{2}$ " cut fortnightly was significant as was the same difference for the 1" and 2" levels of cutting.

7. The main factors (species, frequency of cutting, level of cutting and pruning of roots) contributed 50% of all variance with error variance 13.5%. Of the 50%, 19% was due to root pruning and 15% to cutting differences.

8. In the early stages of the experiment an "initial stimulus" could be observed, in the weekly cuts. Initially  $\frac{1}{2}$ " cut clones yielded better than did 1" cut clones which in turn yielded better than 2" cut clones. This stimulus lapsed within two weeks of the preliminary cut. Root

pruned clones initially yielded more than clones not root pruned. This effect lasted four and a half weeks for 2" cut clones, five and a half weeks for the 1" cut clones and seven and a half weeks for the  $\frac{1}{2}$ " cut clones.

9. Top growth was seasonal. Winter production was low, late spring was high and late summer moderately low.

10. There were obvious species differences throughout the trial.

11. The more lenient treatments yielded most while the less lenient treatments yielded least.

12. The more lenient treatments responded to the onset of spring earlier than did the less lenient.

13. The more lenient treatments reached peak production at a later date than did the less lenient treatments.

(b) Roots.

1. There was significant variation between blocks as measured by numbers of roots newly initiated and pruned off.

2. There were significant differences between the three grasses in their ability to initiate new roots.

These differences were significant irrespective of whether the top treatments had been carried out weekly or fortnightly and of whether the level of cutting was the  $\frac{1}{2}$ " the 1" or the 2".

3. There was a significant difference, in numbers of roots initiated, between clones under weekly top cutting and those under fortnightly top cutting.

This difference was significant irrespective of whether cocksfoot, certified perennial ryegrass or uncertified perennial ryegrass was concerned, and of whether the tops had been cut to  $\frac{1}{2}$ ", 1" or 2" level.

4. There were significant differences between clones top cut to the  $\frac{1}{2}$ " level, those top cut to the 1" level and those top cut to the 2" level.

These differences were significant for all three grasses as well as for clones under either weekly top cutting or

fortnightly top cutting.

5. The change in top treatment caused by weekly and fortnightly cuttings produced different, though not statistically so, responses in root initiation of the three grasses.

The three levels of top cutting ( $\frac{1}{2}$ ", 1" and 2") produced significantly different responses in the three contrasted grasses.

6. The main factors (level of top cutting, species and frequency of top cutting) contributed 69% more or less, of total variance. Level of top cutting caused 40% and species 18% of the 69%.

7. Root initiation appeared to be seasonal. Low rate of initiation held until mid winter followed by great activity until late spring followed by a slump in the summer.

8. Species differences were obvious throughout the trial. Cocksfoot varied least, certified perennial ryegrass most and uncertified perennial ryegrass almost as much as the certified ryegrass.

9. The more lenient top treatments permitted greatest initiation while the less lenient top treatments permitted least initiation.

10. A terminal count of "crown roots" of clones not regularly root pruned gave similar differences to those ruling in each species under regular pruning.

11. Whereas under regular pruning certified perennial ryegrass produced greater numbers of roots than did either uncertified perennial ryegrass or cocksfoot, under this terminal count the order was reversed. Cocksfoot had most, uncertified perennial ryegrass fewer and certified perennial ryegrass least roots.

12. It seems possible to postulate a ratio between root numbers as got by weekly prunings and root numbers as got by one terminal count, for any particular grass.

(c) Soil moisture.

1. During the period of sampling moisture ranged

from 32% to 9.5% a general decline in percentage being obvious throughout.

2. When soil moisture was greater than 25% initiation proceeded at a rapid rate.

3. Root initiation appeared to fail at 10 - 12% moisture level.

4. For every drop in soil moisture there was a drop in root initiation.

(d) Differential growth.

1. Maximum root initiation occurred at a time when herbage growth was slow.

2. Maximum herbage growth occurred at a time when root initiation was at a low ebb.

3. Both growth phenomena were at a low ebb in early winter, root initiation was at a high level during late winter and early spring while as it declined herbage production increased in October. In summer herbage production was relatively high while root initiation was low.

(e) Rust

1. Uncertified perennial ryegrass was more susceptible to rust than certified perennial ryegrass. Cocksfoot had one plant only infected.

2. The maturer plants (under the more lenient treatments) suffered the most in both cases. Fortnightly cut plants suffered most.

(f) Numbers required.

1. Sufficient replications were taken for the success of the experiment. Possibly as few as 12 replications may have proved satisfactory.

2. For similar experiments carried out under similar conditions greater numbers may be needed if the experiment is not multifactorial.

VI.DISCUSSION.

This experiment was carried out under conditions which were not natural. They did not approach the conditions obtaining in the average pasture. There was no competition between adjacent plants (or if there was, it must have been small); there was no associated clover (with its coincidental nitrogen fixing bacteria); there was no "spelling period" (as understood in farmers' phraseology); there was no trampling by stock (with consequent damage to plants), and above all there was no return of animal excreta as found on pastures (clipped material was removed entirely).

Nevertheless few experiments can be carried out under natural or near natural pasture conditions. Yet progress has been made at an appreciable rate with experiments conducted under similar conditions to those ruling in this experiment. Consequently it is felt that the three grasses used may respond differently, when under pasture conditions, to treatments akin to those practised here. It is also felt that their responses would be such as to permit findings derived from this experiment to hold good under those natural conditions. The results achieved here should be of some value in the elucidation of pasture problems.

As was expected, and as has been stressed before, top treatments induced responses in root initiation, while the very act of pruning off new roots induced responses in top growth. The intimate relationship between roots and tops was demonstrated - in no uncertain manner.

Of the experiment in general.

Survival of the Italian ryegrass clones would have added further interest to the experiment. However, it was realised at an early stage that 540 plants were going to be sufficient material for one person to handle successfully. The taking of dry weights proved to be a sound precaution. In many cases green weights would have been impossible to

measure, due to rain, dew, frost, etc. Likewise the pre-drying of the clippings was of inestimable value. Excess water was removed quickly and transpiration rapidly terminated. The layout of the experiment proved admirable for working. As it was designed to test the main effects (cutting at various levels, cutting weekly or fortnightly, root pruning, species) it was thought that the lesser effects (e.g. effect of varying the frequency of cutting on each species rather than on the whole experiment "without regard for species") would not be under adequate test. This thought was borne out in practice. Further specific experiments are needed to test these lesser effects. Rae's suggestion of 15 replications for each treatment proved to be a conservative estimate. For testing of the major effects possibly 7 or 8 replications would have proved adequate. Possibly 10 - 12 replications might have given the same information as was gained from the 15.

Clipping involved errors. Measurement of clipping heights was done, of necessity, largely by eye. Particularly in the early stages a ruler was used as a check. It was found that in general the  $\frac{1}{2}$ " cut was slightly less than half an inch, while the 1" and 2" cuts were satisfactory. The plaster knobs proved to be eminently suitable for the job. The choice of six feeding roots appeared to be a happy one. In general, the end of the trial found clones carrying 5 roots or less. As the experiment progressed suberisation of the roots increased and the roots became brittle. It is thought that some of the roots which appeared to be living may actually have been dead, even though anchored in the ground. Of note was one plant which ended the trial with one root. This plant had four tillers deriving support from the one root.

Continued removal and replacement of the sphagnum moss led to its dispersion. (See appendix XIII for a reconstruction photograph of the experimental method). From

mid September little moss was found around the plants. The addition of moist moss was avoided. It was felt that a false level of initiation may have been induced by faulty water relationships in the moss. It is realised now that had moss been kept in a shallow trench in the soil and so been kept at near soil moisture dampness, regular additions to emptying cavities would have had no adverse effect on the results.

Clonal material was used and proved to be suitable. By its use variation due to diverse genetic makeup was avoided. However, the tillers broken out of the parent plants were not even. By trimming top growth and root growth a measure of control was gained. The width of leaf and absorptive capacity of the remaining roots could not be standardised. As a result photosynthetic area and absorptive root area varied giving some tillers an initial advantage. Also some tillers were from the centre of the plant and as such may have been further advanced in their development than the immature outer tillers. A trial along these lines comparing "pure line" seed and clonal material for the first season would be of value.

Drying of the clippings was influenced to small measure by uneven heating on the bottom of the Hearson oven. Some fifteen samples were involved in each filling. Some caramelisation of carbohydrates undoubtedly occurred resulting in losses of dry weight. They were small, and, as chance located the pans in the oven, were ignored.

#### Of the results.

All the results were grouped in various ways and subjected to an analysis of variance. In both analyses (i.e. for tops and for roots) the main effects were, without question, highly significant statistically. Therefore fortuitous significance can be ruled out, and they can be stated to be the cause of the variation, with confidence. As can be seen the main effects caused most of the variation. But even when error variance or variance due to uncontrolled

Conditions is removed a sizable proportion of variance is left, being the variance due to interactions. Most interactions were highly significant in top analysis. Hence one feels safe in assuming that they actually are of great importance. Interactions between different top treatments do not appear to be as important in their effects on root numbers as on top yield. As these interactions are large the supplementary tests of significance of the main effects e.g.  $\frac{S}{S_{XF}}$  \* not S, sometimes failed to show significance when all the indications were that significance was there. Too few degrees of freedom were involved. A properly planned experiment to test these points would no doubt yield significance in most cases. It would seem safe to say that there were species differences which held for all comparisons made. Similarly the difference between weekly and fortnightly top cuttings appear to hold for all valid comparisons. Similarly for the other causes of variation.

The major effect seems to be the pruning off of roots. This has a large effect on the plant. Cutting of top growth seems to be very little less important in its effect on the plant. Species and frequency of top cutting seemed to be of similar importance in affecting top growth but species differences were more obvious in root numbers pruned off. This would seem to conform with accepted ideas - many harrowings or successive wrenchings arrest top growth while the effect of grazing is measured by its closeness rather than by the frequency with which it is carried out.

The differences between species can be seen in the Figures 6, 7, 8 and 9. Yet all share a seasonal growth curve for top production. Every indication points to there being a seasonal initiation of roots. Now Jacques has shown (31) that as "crown root" numbers increased so root weight increases, suggesting that as the "crown roots" increase in number so general root growth increases. As these pruned off newly initiated roots are in reality

"crown roots" it would seem reasonable to conclude that an increase in initiation is one sign of a general increase in root growth. The writer believes this is so, but further experimentation is required to clarify the point.

As expected the three grasses varied slightly in their seasonal top growth. They varied in their ability to withstand close frequent cutting. The poor certified perennial ryegrass was poorest in all respects. The good certified perennial ryegrass was best in ability to withstand the harshest treatments while cocksfoot in 16 top treatments was superior to both ryegrasses. Cocksfoot has been known to lack the power to withstand hard frequent defoliation. This fact is borne out here. But the discrepancy between cocksfoot and the good certified perennial ryegrass in the two harshest treatments is small. This leads one to think that as the new superior cocksfoot strains come into certification, a change of ideas and management will be necessary for their optimum use.

From a terminal count of root numbers in the normally unpruned plants it was found that, on comparison with the comparable cumulative count in the normally pruned plants, cocksfoot showed very little response to root pruning i.e. the cumulative count was little greater than the terminal count. Thus cocksfoot's root system would appear to be relatively unable to adapt itself to adverse conditions. On the other hand good certified perennial ryegrass had a large discrepancy in all treatments, leading one to conclude that the root system of the latest superior perennial ryegrasses must be very adaptable under adverse conditions. The poor certified perennial ryegrass (uncertified) filled a median position. Thus good certified perennial ryegrass may owe much of its hardihood when under stress to its adaptable root system.

The more lenient cutting treatments yielded more herbage while the less lenient cutting treatments yielded less herbage. The former permitted a greater degree of root initiation than did the latter. The former also reached their peak production later than did the latter, pointing to the possibility that the latter were unable to sustain growth until their potential peak was reached.

For each of the three grasses a ratio of terminal count : cumulative count, in root numbers, seems possible. Three distinct ranges were got for the three grasses used here. By the use of these ratios it appears possible to estimate from weekly root pruning, just how many roots the undisturbed plants would be initiating. If this is so then this experiment will have achieved one end.

Soil moisture definitely appears to affect root initiation. The optimum soil moisture for spring temperatures appears to be about 25% but later as the temperature (soil) rises this percentage seems to drop to about 20%. Thus although moisture has the appearance of being the main determinant of root initiation, yet soil temperature cannot be underestimated in importance. Maximum root initiation (with the assumed concurrent general root growth) occurred before maximum herbage growth. It would appear that while herbage growth is low root initiation may proceed while when herbage growth is rapid root initiation is curtailed.

It seems likely that reserve food storage affects this differential growth just as it must affect all other growth phenomena. The slower response to spring of root pruned plants could be ascribed to low food reserves, as could the earlier peak production of root pruned or hard cut plants. In the latter case early depletion of food reserves could give an inability to reach the potential peak production level.

The findings with reference to rust conform with general opinion. The superior ryegrass represents the culmination of a programme of selection for rust resistance. That this selection is in large measure successful is patently obvious.

As far as numbers required are concerned the capacity of the individual worker should not be overestimated. To ensure continued accuracy the number of factors under investigation should be kept at a minimum. In this experiment 12 replications of the various treatments may have proved to be an adequate number.

## VII.

CONCLUSION.

The objects of the experiment were to discover the reactions of different species and strains of grasses to various severities of leaf removal; to attempt to follow seasonal root growth by observing root initiation; and to find the effect, if any, of soil moisture on root initiation. All three were achieved in greater or lesser degree.

It is concluded that the pruning off of roots is the major inhibitor of herbage growth, while the severity of the cutting treatment has a greater effect than the frequency with which it is repeated. Each species differs but to such an extent that until a careful management policy is adduced the same relative production maybe obtained by using any one of the three grasses.

The severity of the cutting treatment is the major determinant of root initiation. Species differ in their capacity for initiation but the severity of defoliation outweighs this consideration. The frequency with which the cuttings are repeated prove important but not outstandingly so, the severity of the cut being more effective as an inhibitor of initiation than the frequency with which it is repeated.

Top growth is definitely seasonal while root growth as measured by root initiation appears to be seasonal.

Soil moisture does play an important part as a determinant of root initiation but is not all inclusive in its action.

Rust attacks the more leniently treated plants and the more susceptible plants.

VIII.BIBLIOGRAPHY.

1. - World Food Appraisal as of April 1949.  
F.A.O. p.46 1949
2. Blackman F.F. Annals of Botany 19p.281-295 1905
3. Stapledon R.G. & Williams R.D.  
Welsh Plant Breeding Station Bulletins -  
Series H.No.1 1922
4. Hudson A.W., Doak B.W. & McPherson G.K.,  
N.Z. D.S.I.R. Bulletin No.31 1934
5. Lindhard E. Experiment Station record  
29p.431 1913
6. Stapledon R.G. & Beddows A.R.  
Welsh Jour.Ag. 2p.103-113 1926
7. Stapledon R.G. & Milton W.E.J.  
Ibid 6p.165-174 1930
8. Graber L.F. Plant Physiology 6 p.43-71 1931
9. Robertson J.H. Ibid 8 p.425-447 1933
10. Roberts R.A. & Hunt I.V.  
Welsh Jour.Ag. 12 p.158-170 1936
11. Nedrow W.W. Ecology 18 p.27-52 1937
12. Harrison C.M. & Hodgson C.W.  
Journal of the American Soc.  
of Agronomy 31 p.418-430 1939
13. Schofield J.L.  
Queensland Jour.Ag.Sci. 1(4)p.1-58 1944
14. Schofield J.L. Ibid 3(1)p.44-80 1946
15. Ellett W.B. & Carrier L.  
Jour. A.S.A. 7 p.85-87 1915
16. Aldous A.E. Ecology 11 p.752-759 1930
17. Lander P.E.  
Indian Jour.Agr.Science 12(3)p.409-423 1942
18. Wilsie G.P., Akamine E.K. & Takahashi M.  
Jour A.S.A. 32(4)p.266-273 1940
19. Kennedy W.K. & Russell M.B.  
Ibid. 40(6)p.535-540 1948
20. Bukey F.S. & Weaver J.E.  
Ecology 20(2)p.246-252 1939
21. Sturkie D.G. Jour. A.S.A. 22 p.82-93 1930
22. McCarty E.C. & Price R.  
U.S. Dept. of Agric. Technical  
Bulletin No. 818 1942
23. Parker K.W. & Sampson A.W.  
Hilgardia 5 p.361-381 1931

24. Jones M.G.  
Empire Journal of Experimental  
Agric. 1p.45-48 1933
25. Hodgson C.W.  
Biological Abstracts 16(2) No.  
17498 1942
26. Sullivan J.F. & Sprague V.G.  
Herbage Abstracts 14 No. 264 1944
27. Jacques W.A.  
Proc. Annual Meeting Sheep  
Farmers Massey College 1948
28. Weinmann H.  
Jour. British Grasslands Soc. 3(2)p.115-  
140 1948
29. Parker K.W. & Sampson A.W.  
Plant Phys. 5p.543-553 1930
30. Sprague H.B. Soil Science 36p.189-209 1933
31. Jacques W.A.  
N.Z. Jour. of Sci. & Tech. 19(7)p.441-  
450 1937
32. Whyte R.O.  
Imp. Ag. Bureau. Joint Public-  
ation No. 6 Chap 3. 1944
33. Nelson M. Biol. Abs. 19(7)No.  
14107 1945
34. Stuckey I.H.  
American Jour. Botany 28p.486-491 1941
35. Yen D.E.  
Thesis for M. Agr. Sci. Massey College 1947
36. Martin J.N. Am. Jour. Botany 21p.140-159 1934
37. Gericke W.F. Botanical Gazette 75p.320-322 1923
38. Spencer J.T. Jour. A.S.A. 33p.481-489 1941
39. Rogers W.S.  
Horticultural Abstracts 9 Nos. 796  
& 797 1939
40. Jacques W.A. N.Z. Jour. of Sci.  
& Tech. 26(1)p.32-41 1944
41. Veihmeyer F.J. & Conrad J.P.  
Hilgardia 4 p.111-134 1929
42. Hendrickson A.H. & Veihmeyer F.J.  
Plant Phys. 6 p.567-576 1931
43. Bosman F.H.  
Farming in South Africa 11 p.233-235 1936
44. -  
Wheat Growing Part V. Leaflet  
from Wheat Research Institute of N.Z. circa. 1932
45. Webb R.B.  
Jour. of Ag. Research 52 p.569-584 1936

46. Greenhill A.W. Ap.145-151  
Emp.Jour.Expt.Agric. & 274-282 1936
47. Rae A.L.  
Thesis for M.Agr.Sci. Massey College 1947
48. Durrant P.J.  
General and Inorganic Chemistry. Longmans  
& Green 1939
49. Marryatt E.R. & Simpson J.E.V.  
N.Z.Jour.of Sci. & Tech. 20A.p.324-325 1938-39
50. Melville J. et al.  
Jour.N.Z.Institute of Chemistry 11(4)p.104 1947
51. Yates F.  
Emp.Jour.Expt.Agric 1 p.129-142 1933
52. Snedecor G.W.  
Statistical Methods. Iowa State College Press 1948
53. Richens R.H.  
Imp.Ag.Bureau.Joint Publication No. 8 1945
54. Hetzer H.O. & Brier G.W.  
Proc.American Soc.Animal Production p.157-161 1938-39

#### ACKNOWLEDGMENTS.

Oven facilities and the grass plants used, were provided by the Grasslands Division of the Dept. Scientific and Industrial Research. Thanks are due to the officers concerned. Thanks are also due to the Horticultural Department of this college for facilities provided.

The writer is indebted to Messrs. A.L. Rae (Massey College) D.S. Flux (D.R.I.) and P. Armstrong (Biometrics Section, D.S.I.R.) for assistance in the statistical section and to Mr. N. Strawbridge for assistance in photographic work.



## PLANT SITES SELECTED AT RANDOM.

Species	Treat- ment.	BLOCKS.															
		A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	P.	
Cocksfoot	1/2" 1.p.	14	33	42	1	13	17	13	41	39	32	9	28	28	7	7	
	1" 1.p.	7	21	41	25	44	32	10	18	36	13	32	2	18	38	41	
	2" 1.p.	23	4	2	18	15	23	28	48	4	26	13	16	21	39	12	
	1/2" 2.p.	34	22	47	10	6	29	3	30	29	31	31	13	45	26	18	
	1" 2.p.	44	10	25	5	45	38	4	37	46	7	30	47	5	43	23	
	2" 2.p.	4	5	31	17	23	14	42	27	26	41	24	12	48	42	8	
	1/2" 1.--	1	17	34	3	33	41	29	40	42	24	48	23	27	21	1	
	1" 1.--	15	15	10	19	47	35	18	33	16	20	41	48	46	45	31	
	2" 1.--	37	23	24	2	9	44	6	12	14	47	1	40	22	16	20	
	1/2" 2.--	46	20	13	41	31	31	15	38	33	5	6	34	43	18	33	
	1" 2.--	10	18	38	45	42	18	11	43	34	12	33	22	6	10	27	
	2" 2.--	41	42	8	37	35	26	44	3	11	6	39	45	24	47	35	
	1/2" 1.p.	33	16	4	48	16	11	5	16	8	34	38	15	25	17	24	
	Cert. Perenn. Ryegrass	1" 1.p.	42	19	29	42	19	36	38	45	25	35	15	5	7	30	45
2" 1.p.		19	27	18	26	36	5	24	14	4	26	3	46	37	37	46	
1/2" 2.p.		5	39	39	22	29	43	16	46	3	15	5	17	30	6	4	
1" 2.p.		12	45	21	36	18	46	31	19	9	39	28	4	15	29	5	
2" 2.p.		21	25	45	34	21	20	23	20	6	16	22	21	33	15	48	
1/2" 1.--		28	2	15	44	1	47	1	35	24	28	16	43	31	46	28	
1" 1.--		31	35	48	28	43	33	40	34	7	37	18	20	8	48	16	
2" 1.--		9	37	19	13	32	16	39	7	1	42	20	25	39	40	2	
1/2" 2.--		27	34	33	23	11	15	25	36	27	23	44	1	20	28	13	
1" 2.--		20	7	40	12	14	25	27	42	18	36	25	33	42	9	22	
2" 2.--		18	29	1	15	25	39	12	44	35	30	37	41	19	4	10	
1/2" 1.p.		39	26	14	7	7	22	46	6	17	33	21	38	34	14	6	
Uncert. Perenn. Ryegrass		1" 1.p.	40	32	17	9	12	37	43	22	40	25	2	31	12	2	38
		2" 1.p.	38	36	5	38	24	40	33	11	43	14	36	26	32	34	9
	1/2" 2.p.	48	24	27	21	10	7	47	5	23	19	17	7	17	32	15	
	1" 2.p.	25	38	3	35	17	21	26	25	31	44	45	9	36	5	34	
	2" 2.p.	22	44	16	11	26	13	30	32	41	40	12	27	23	25	11	
	1/2" 1.--	2	11	20	33	8	24	17	15	45	10	46	6	29	8	40	
	1" 1.--	8	30	26	31	37	8	45	47	38	9	26	32	11	12	17	
	2" 1.--	26	9	9	32	27	3	14	26	2	29	23	14	4	3	30	

continued.

Species	Treat- ment.	BLOCKS.														
		A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	P.
	½#2.-.	29	43	11	46	3	45	21	24	20	2	19	11	47	19	47
	1#2.-.	35	14	35	16	20	19	32	17	5	48	11	10	1	44	3
	2#2.-.	36	3	37	30	34	30	48	39	48	18	40	3	3	36	25

SYNOPSIS OF AVERAGES

Dry weight of tops.

	C.	P.	U.	General Averages
Pruned	9.580	8.597	4.746	7.641
Normal	23.769	17.403	12.166	17.779
½" cut	9.473	7.464	4.765	7.234
1" cut	14.421	11.164	7.532	11.039
2" cut	26.129	20.371	13.070	19.856
Weekly	11.639	9.852	6.242	9.244
Fort-nightly	21.710	16.148	10.669	16.176
General overall averages	16.674	13.000	8.456	12.710

No. of roots pruned off

	Pruned	Normal	General Averages
C.	355.4	274.8	315.1
P.	585.7	220.0	402.9
U.	442.9	238.0	340.5
½" cut	326.5	173.7	250.1
1" cut	406.6	227.7	317.2
2" cut	651.0	331.4	491.2
Weekly cut	397.7	198.1	297.1
Fortnightly cut	525.0	294.1	408.5
General overall averages	461.4	244.3	352.8

ALL CLONES USED IN THE EXPERIMENT.

Dry weight of tops - grand totals.

Treatments	C.	P.	U.	Totals	Treatment Averages	
P.	½."W.	73.814	77.182	32.431	183.427	4.076
	1."W.	85.864	101.495	49.908	237.267	5.273
	2."W.	191.720	150.908	89.891	432.519	9.612
	½."F.	128.801	117.473	63.567	309.841	6.885
	1."F.	148.361	144.759	91.432	384.552	8.546
	2."F.	233.602	181.888	99.877	515.367	11.453
N.	½."W.	110.121	82.038	65.028	257.187	5.715
	1."W.	177.745	137.935	113.532	429.212	9.538
	2."W.	408.234	337.122	211.018	956.374	21.253
	½."F.	255.642	171.175	124.876	551.693	12.260
	1."F.	453.282	285.663	197.074	936.019	20.800
	2."F.	734.177	552.358	383.391	1669.926	37.109
		3001.363	2339.996	1522.025	6863.384	12.710

Averages.

C. = 16.674

P. = 13.000

U. = 8.456

½" = 7.234

1" = 11.039

2" = 19.856

Weekly = 9.244

Fortnightly = 16.176

Pruned = 7.641

Normal = 17.779





UNCERTIFIED PERENNIAL RYEGRASS CLONES.

Dry weight of tops - totals for experiment.

Treat ment	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	P.	Totals	Treatment Average
½" W.	1.772	1.165	2.231	2.321	1.588	2.179	2.048	1.800	3.290	2.801	1.962	1.218	2.732	2.838	2.486	32.431	2.162
1" W.	2.751	4.092	3.493	5.125	2.454	3.349	2.375	4.005	4.521	2.007	4.304	1.967	3.707	2.468	3.290	49.908	3.327
2" W.	7.728	8.489	3.952	5.404	1.807	6.760	2.258	4.504	8.864	5.258	3.404	7.359	5.040	8.166	10.898	89.891	5.993
½" F.	4.631	5.260	4.065	3.164	1.228	4.036	3.840	6.121	3.995	4.735	2.123	4.263	3.338	8.974	3.794	63.567	4.238
1" F.	6.000	6.949	5.428	1.870	7.670	4.577	5.494	4.099	8.794	7.144	10.517	6.338	6.019	6.176	4.347	91.432	6.095
2" F.	8.217	2.603	8.169	5.379	4.203	9.534	5.942	9.270	10.407	3.533	5.462	6.825	8.424	5.087	6.822	99.877	6.658
½" W.	1.062	4.320	4.920	4.230	4.650	5.087	7.247	5.928	1.623	4.403	5.095	3.919	4.333	3.883	4.328	65.028	4.335
1" W.	6.338	7.604	6.561	6.466	7.676	8.653	8.718	6.830	7.403	8.608	6.706	10.016	8.068	6.572	7.313	113.532	7.569
2" W.	8.877	9.635	16.968	10.345	13.236	15.505	13.485	14.919	19.124	17.325	19.073	20.888	10.955	9.887	10.796	211.018	14.068
½" F.	6.485	5.079	13.827	7.875	4.248	8.524	13.989	3.347	6.366	15.232	9.940	8.700	7.342	5.439	8.483	124.876	8.325
1" F.	8.814	10.541	16.504	8.038	18.047	19.505	8.780	17.120	7.155	11.466	13.025	21.362	9.860	15.165	11.692	107.074	13.138
2" F.	19.437	12.863	22.048	41.533	21.915	50.971	22.209	15.516	25.689	26.608	26.758	26.197	15.422	28.240	27.985	383.391	25.559
																1522025	Mean 8.456

Averages:-

Pruned = 4.746  
Normal = 12.166

½" = 4.765  
1" = 7.532  
2" = 13.070

Weekly = 6.242  
Fortnightly = 10.669

ALL CLONES USED IN THE EXPERIMENT.

No. of roots pruned off - grand totals (of cumulative and terminal counts).

Top Treatments	C.	P.	U.	Totals	Treatment Averages	
P.	½".W.	3328	5321	3525	12174	270.5
	1".W.	3971	6272	4618	14861	330.3
	2".W.	6607	11539	8505	26651	592.2
	½".F.	4901	6803	5505	17209	382.4
	1".F.	5322	9242	7169	21733	483.0
	2".F.	7859	13538	10542	31939	709.8
				124,567		
N.	½".W.	2303	1714	1997	6014	133.6
	1".W.	2955	2194	3012	8161	181.4
	2".W.	4542	3621	4206	12369	274.9
	½".F.	3657	2775	3186	9618	213.8
	1".F.	5073	3578	3683	12334	274.1
	2".F.	6204	5916	5340	17460	388.0
				65,956		
				190,523	352.8	

Averages

C. = 355.4  
P. = 585.7  
U. = 442.9

½". = 326.5  
1". = 406.6  
2". = 651.0

Weekly = 397.7  
Fort-  
nightly = 525.0

C. = 274.8  
P. = 220.0  
U. = 238.0

½". = 173.7  
1". = 227.7  
2". = 331.4

Weekly = 196.6  
Fort-  
nightly = 291.9

Pruned (cumulative average) = 461.4  
Normal (terminal average) = 244.3

C. = 315.1

P. = 402.9

U. = 340.5

½". = 250.1

1". = 317.2

2". = 491.2

Weekly = 297.1  
Fortnightly = 408.5

NUMBERS OF ROOTS AT THE BASE OF CLONES.

Clones root pruned throughout experiment.

Treatments	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	P.	Totals	Treatment Averages
$\frac{1}{2}$ W.	188	231	295	165	176	244	234	140	153	338	212	235	211	196	310	3328	222.0
1W.	265	354	272	235	233	149	212	358	291	272	291	404	261	272	102	3971	265.0
2W.	431	443	304	401	354	377	253	329	515	409	713	585	356	463	674	6607	440.5
$\frac{1}{2}$ F.	408	338	297	280	326	281	198	127	327	244	602	555	245	361	312	4901	327.0
1F.	331	527	452	469	257	262	219	299	408	458	296	480	334	301	229	5322	355.0
2F.	503	400	601	477	643	441	533	466	556	705	563	474	457	452	588	7859	524.0
$\frac{1}{2}$ W.	341	609	337	372	374	242	271	316	350	355	401	363	160	401	429	5321	355.0
1W.	444	493	473	353	433	205	393	480	439	515	510	359	391	495	289	6272	418.0
2W.	827	651	891	671	535	691	567	709	951	884	851	774	805	939	793	11539	769.0
$\frac{1}{2}$ F.	412	597	494	377	403	366	385	341	533	472	379	616	565	446	417	6803	453.5
1F.	611	781	569	548	463	594	604	448	623	571	493	727	764	802	644	9242	616.0
2F.	883	824	743	532	919	816	637	567	1085	1159	1130	1315	673	1029	1226	13538	902.5
$\frac{1}{2}$ W.	225	289	286	203	177	242	167	144	298	275	276	113	315	261	254	3525	235.0
1W.	311	328	409	430	227	345	275	186	404	266	364	201	384	152	336	4618	308.0

Averages  
 C=355.4  
 P=585.7  
 U=442.9  
 $\frac{1}{2}$ "=326.5  
 1"=406.6  
 2"=651.0  
 Weekly = 397.7  
 Fort-nightly = 525.0

APPENDIX VII.

Treatments	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	P.	Totals	Treatment Averages
2 $\frac{1}{2}$ W.	680	756	722	475	187	428	281	426	760	587	464	798	349	837	758	8505	567.0
$\frac{1}{2}$ W.	294	582	319	138	206	350	356	270	389	419	340	424	460	624	334	5505	367.0
1 $\frac{1}{2}$ F.	518	514	612	321	248	457	434	277	580	531	539	596	643	634	265	7169	478.0
2 $\frac{1}{2}$ F.	821	559	816	782	488	661	459	424	856	795	893	686	698	658	946	10542	703.0
	8493	9276	8892	7229	6649	7151	6478	6307	9518	9255	9314	9705	8071	9323	8906	124,567	Mean 461.36

NUMBERS OF ROOTS AT THE BASE OF CLONES.

Clones not root pruned during experiment.

Treatments.	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	P.	Totals	Treatment Averages
1/2 W.	177	213	209	217	210	129	62	212	216	105	81	189	100	138	45	2303	153.5
1 W.	213	190	238	192	190	350	123	248	249	175	215	181	132	188	71	2955	197.0
2 W.	227	442	347	261	370	224	349	316	321	284	311	145	286	303	356	4542	303.0
1/2 F.	245	352	170	235	310	147	263	343	198	275	267	278	268	232	74	3657	244.0
1 F.	273	515	301	337	314	380	377	307	340	416	332	307	377	246	251	5073	338.0
2 F.	525	529	497	493	535	209	298	390	330	242	502	369	434	463	388	6204	413.5
1/2 W.	127	-	226	152	98	138	108	140	181	57	72	83	153	137	42	1714	122.5
1 W.	189	246	113	175	145	223	134	215	83	94	132	198	90	100	57	2194	146.0
2 W.	336	326	336	334	255	237	254	224	157	218	202	232	153	132	225	3621	241.5
1/2 F.	160	173	226	281	207	265	142	289	205	167	177	127	162	101	93	2775	185.0
1 F.	220	182	352	304	290	115	202	286	380	250	159	231	235	176	196	3578	238.5
2 F.	575	495	382	497	335	417	415	454	414	259	302	273	234	355	509	5916	394.5
1/2 W.	89	221	182	199	159	108	130	122	71	165	104	98	116	122	111	1997	133.0
1 W.	307	194	190	236	271	278	180	80	233	132	162	233	154	162	200	3012	201.0
2 W.	264	265	407	358	297	288	187	336	206	194	256	411	240	236	261	4206	280.5
1/2 F.	239	155	616	257	138	144	202	96	241	278	237	104	123	177	179	3186	212.5

Averages  
 O=274.8  
 P=220.0  
 U=238.0  
 1/2"=173.7  
 1"=227.7  
 2"=331.1  
 Weekly=  
 198.1  
 Fort-  
 nightly=  
 294.1

APPENDIX VIII.

continued.

Treat-ments.	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	P.	Totals	Treatment Averages
1 <sup>st</sup> F.	256	224	552	216	261	213	216	216	196	196	248	261	191	244	193	3683	245.5
2 <sup>nd</sup> F.	310	456	382	648	473	424	272	294	410	-	335	440	353	257	286	5340	381.5
Totals	4732	5178	5726	5392	4858	4289	3914	4568	4431	3507	4094	4160	3801	3769	3537	65956	Mean 244.3

Significance of Minor Effects.

a. Tops.

$\frac{S}{S \times F}$	=	8.20	NS.	$\frac{F}{S \times F}$	=	17.44	NS.	Nearly significant.
$\frac{S}{S \times C}$	=	10.77	S.	$\frac{F}{F \times C}$	=	32.49	S.	
$\frac{S}{S \times P}$	=	5.30	NS.	$\frac{F}{F \times P}$	=	2.61	NS.	
$\frac{C}{S \times C}$	=	26.64	SS.	$\frac{P}{S \times P}$	=	24.12	S.	
$\frac{C}{F \times C}$	=	37.80	S.	$\frac{P}{F \times P}$	=	5.59	NS.	
$\frac{C}{C \times P}$	=	2.80	NS.	$\frac{P}{C \times P}$	=	5.14	NS.	
$\frac{C \times P}{S \times C \times P}$	=	345.04	SS.					
$\frac{S \times F}{S \times F \times C}$	=	29.11	SS.					} Interpretation not attempted.
$\frac{S \times C}{S \times F \times C}$	=	22.17	SS.					
$\frac{S \times P}{S \times C \times P}$	=	7.36	S.					

All other tests proved to be non-significant.

b. Roots.

$\frac{S}{S \times C}$	=	12.44	S.	$\frac{F}{S \times F}$	=	54.20	S.
$\frac{S}{S \times F}$	=	60.20	S.	$\frac{F}{F \times C}$	=	99.42	SS.
$\frac{C}{S \times C}$	=	26.30	SS.	$\frac{C}{F \times C}$	=	233.52	SS.

APPENDIX X.

Soil Moisture Determinations.

$$\text{Soil Moisture percentage} = \frac{(\text{wet weight of soil} - \text{oven dry})}{\text{oven dry weight of soil}} \times 100$$

<u>Date</u>	<u>Percentage</u>	<u>Date</u>	<u>Percentage</u>
1. 9.48	27.3	16.11.48	27.1
8. 9.48	31.7	20.11.48	24.6
12. 9.48	29.9	26.11.48	18.1
17. 9.48	23.7	30.11.48	26.2
19. 9.48	22.4	4.12.48	24.1
22. 9.48	21.4	7.12.48	26.9
29. 9.48	27.9	10.12.48	11.6
3.10.48	27.2	14.12.48	23.4
6.10.48	26.8	17.12.48	15.7
10.10.48	25.8	20.12.48	22.0
13.10.48	21.7	23.12.48	15.6
16.10.48	29.6	28.12.48	10.0
19.10.48	-	1.1.48 <sup>9</sup>	11.4
21.10.48	29.0	4. 1.48 <sup>46</sup>	15.5
24.10.48	27.4	8. 1.48	23.5
27.10.48	26.7	11. 1.48	13.1
1.11.48	26.7	14. 1.48	15.0
5.11.48	17.2	19. 1.48	21.2
8.11.48	17.5	26. 1.48	16.0
10.11.48	20.6	30. 1.48	15.5
13.11.48	19.5	9. 2.48	9.6

12 samples of the experimental area on 9.2.48 gave a soil moisture percentage 12.4.

RUSTED PLANTS.

70 plants were infected. Average no. rusted per block was  $4\frac{2}{3}$  with a range from 7 to 2, the popular numbers being 4, 5 or 6.

R - = rust found after investigation  
 R - = rust clearly discernible  
 R+ = rust extensive  
 R++ = rust very severe

Weight Range	Treatment	R-	R.	Totals
37gms.	P.2.2.-.	6	4	10
	P.2.1.-.	4	2	6
	P.1.2.-	3		3
	P.2.2.P.	3		3
	P.1.2.-.	2		2
10gms.	P.2.1.P.	1		1
		19	6	25

No P plants were found rusted in the R+ and R++ categories.

Weight Range	Treatment	R-	R	R+	R++	Totals
26 gms	U.2.2.-.	1	1	9	3	14
	U.2.1.-.	5	4	3		12
	U.1.2.-.	6	3	4		13
	U.1.2.-.		2			2
	U.1.1.-.		1			1
	U.2.2.P.	1				1
6 gms.	U.2.1.P.	1				1
		14	11	16	3	44

One cock foot plan was infected  
 C.1.2.p.R.

APPENDIX XII.

Number of observations required to give significance to various differences.

- with reference to clonal material of the same variation and to experiments carried out under very similar conditions.

Differences in grammes	Tops.		Differences in numbers	Roots.	
	No. of observations required			No. of observations required	
	for significance at 1% level t = 3	for significance at 5% level t = 2		for significance at 1% level t = 3	for significance at 5% level t = 2
1.00	416.9	185.3	20	835.4	371.3
1.25	266.8	118.6	30	371.3	165.0
1.50	185.3	82.3	40	208.9	92.8
2.00	104.2	46.3	50	133.7	59.4
2.50	66.7	29.6	60	92.8	41.3
3.00	46.3	20.6	80	52.2	23.2
4.00	26.1	11.6	100	33.4	14.9
5.00	16.7	7.4	120	23.2	10.3
6.00	11.6	5.1	140	17.0	7.6
7.00	8.5	3.8	160	13.0	5.8
8.00	6.5	2.9	180	10.3	4.6
9.00	5.2	2.3	200	8.4	3.7
10.00	4.2	1.9	220	6.9	3.1
12.00	2.9	-	240	5.8	-

$$s^2 = 23.16$$

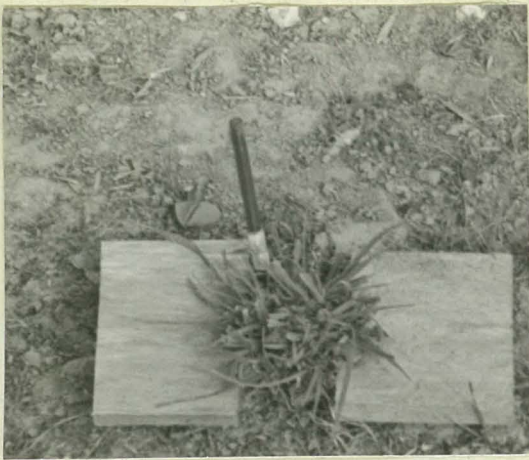
$$s^2 = 18564$$

There were 14 degrees of freedom (15 replications) giving  
 t (at 1% level) = 2.977 and t (at 5% level) = 2.145  
 for convenience t (1%) = 3 t (5%) = 2



Illustration of a reconstruction of the plant in its relationships with experimental material.

Individual clones representative of each treatment.



Cocksfoot clone, cut to  $\frac{1}{2}$ " weekly, not root pruned. C. $\frac{1}{2}$ .1.p.

C. $\frac{1}{2}$ .1.-. Cocksfoot clone, cut to  $\frac{1}{2}$ " weekly, root pruned.



C.1.1.-.

C.1.1.p.



C.2.1.-.

C.2.1.p.



C.1.2.-.



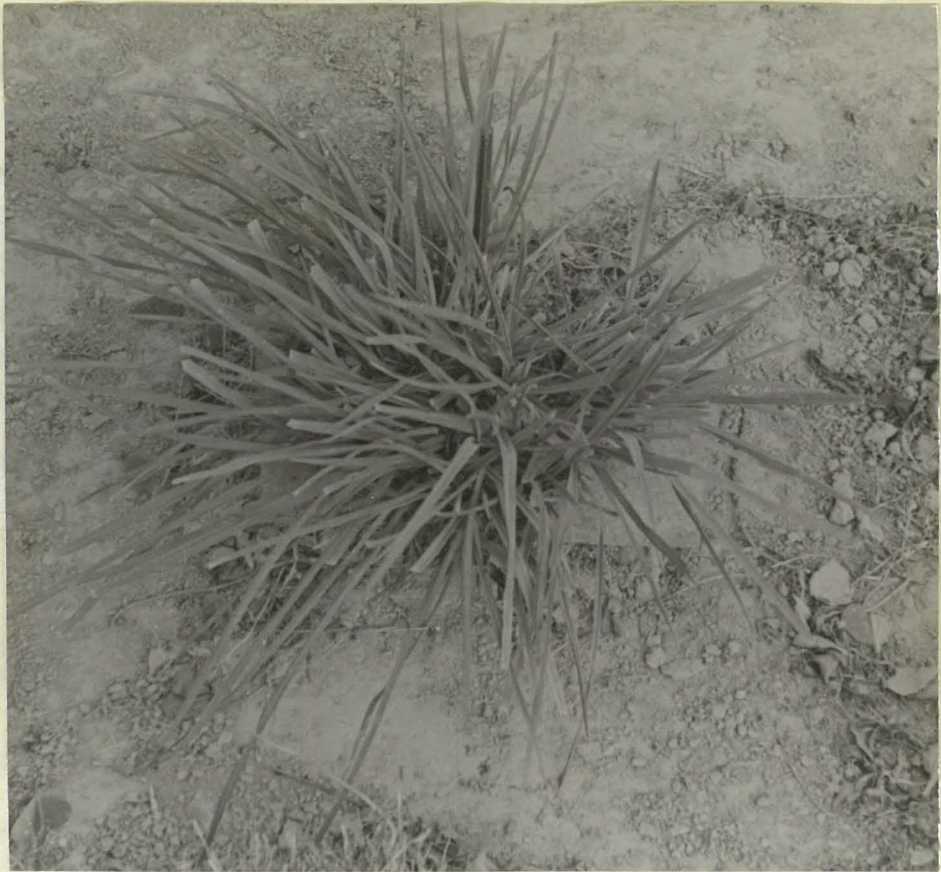
C.1.2.p.



C.1.2.-



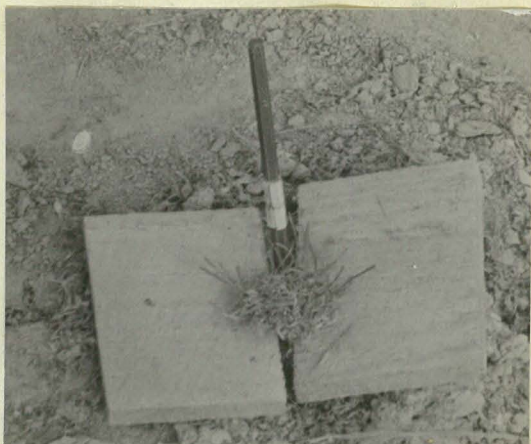
C.1.2.p.



C.2.2.-.



C.2.2.p.



Cert. Perenn.rye clone, cut to  $\frac{1}{8}$ " weekly, not root pruned.

P. $\frac{1}{8}$ .l.p.

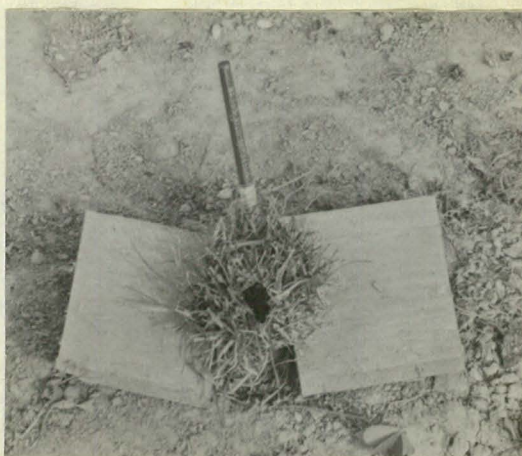
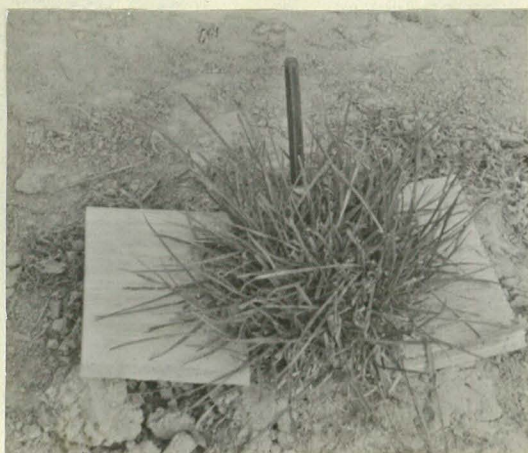
P. $\frac{1}{8}$ .l.-.

Cert. Perenn.rye clone, cut to  $\frac{1}{8}$ " weekly, root pruned.



P.l.l.-.

P.l.l.p.



P.2.l.-.

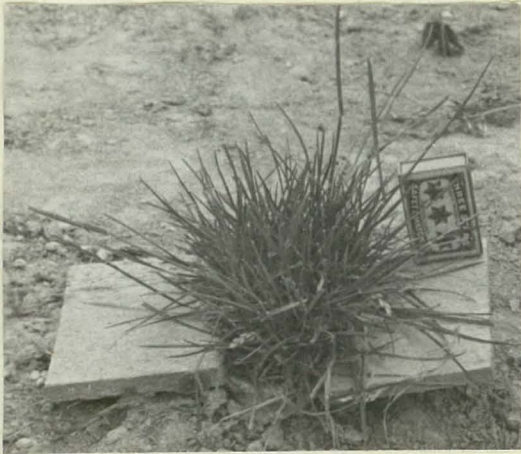
P.2.l.p.



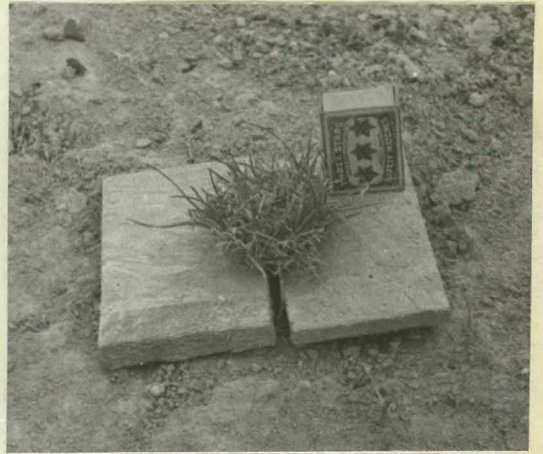
P.1.2.-.



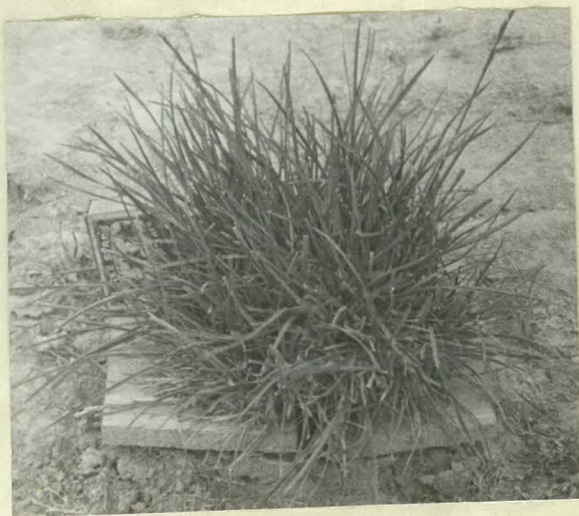
P.1.2.p.



P.1.2.-.



P.1.2.p.



P.2.2.-.



P.2.2.p.



Uncert. Perenn. rye. cut to  $\frac{1}{2}$ " weekly, not root pruned.

U. $\frac{1}{2}$ .1.-.

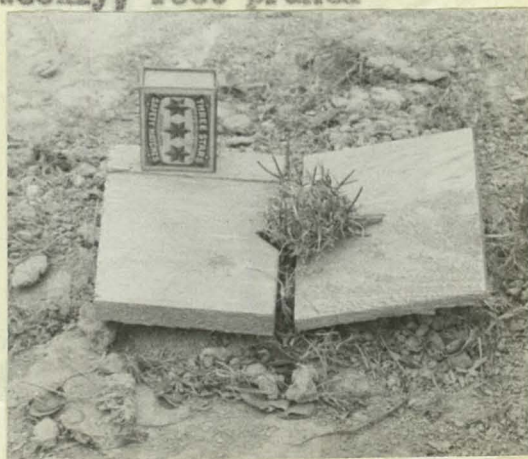


U. $\frac{1}{2}$ .1.p.

Uncert. Perenn. rye, cut to  $\frac{1}{2}$ " weekly, root pruned



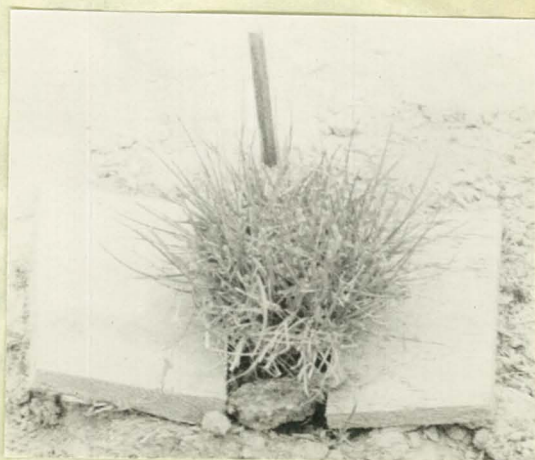
U.1.1.-.



U.1.1.p.



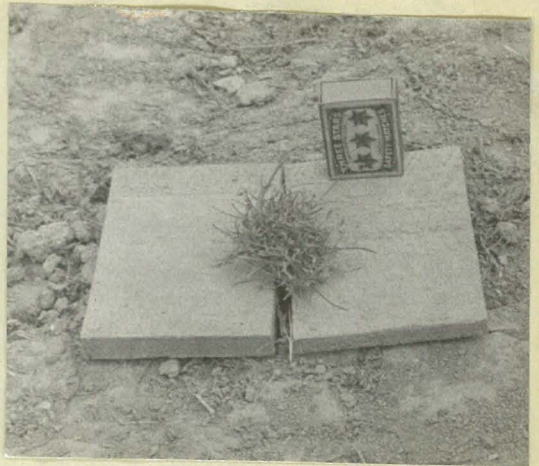
U.2.1.-.



U.2.1.p.



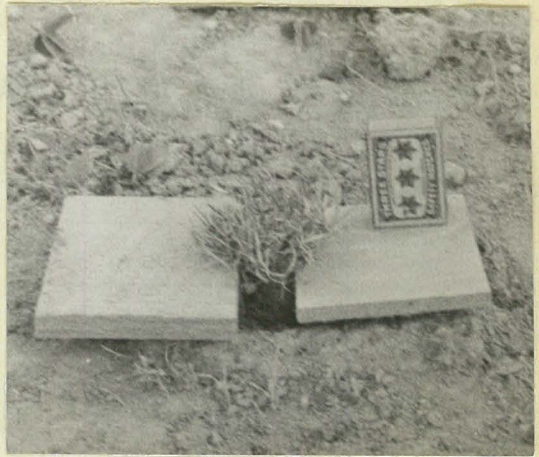
U.1.2.-.



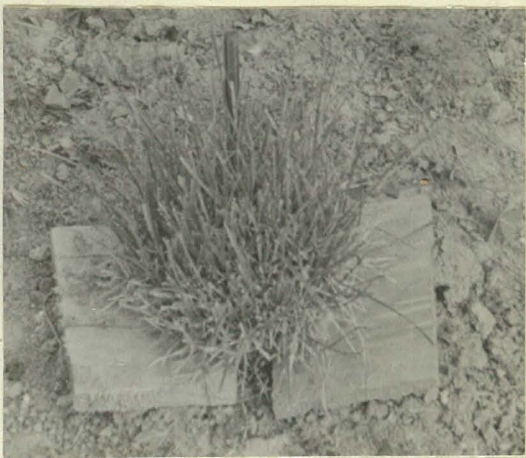
U.1.2.p.



U.2.2.-.



U.2.2.p.



U.3.2.-.



U.3.2.p.

KEY TO SYMBOLS.

As stated in the Result section, top treatments are included as root treatments and root treatments as top treatments.

Whenever the word "average" appears in the appendices "average per individual clone" is implied.

- C = Cocksfoot clones  
 P = Certified Perennial ryegrass clones  
 U = Uncertified Perennial ryegrass clones  
 $\frac{1}{2}$ " = tops were cut to within  $\frac{1}{2}$ " of board level.  
 1" = " " " " " 1" " " "  
 2" = " " " " " 2" " " "  
 W = " " " each week  
 F = " " " " fortnight  
 P = Pruned clones i.e. clones subjected to regular root pruning  
 N = Normal clones i.e. clones not subjected to regular root pruning

Thus in APPENDIX II:

$\frac{1}{2}$ .1.p. denotes a clone cut to  $\frac{1}{2}$ " level, each week, subjected to regular root pruning.

2.2.+ denotes a clone cut to 2" level, each fortnight, not subjected to regular root pruning.

## APPENDIX IV:

$\frac{1}{2}$ ".W. denotes a clone cut to  $\frac{1}{2}$ " level, each week irrespective of other considerations.

1" F. denotes a clone cut to 1" level, each fortnight irrespective of other considerations.

## APPENDIX IX:

In this appendix C = cuttings (i.e.  $\frac{1}{2}$ ", 1" or 2" level)

P = prunings (i.e. presence or absence)

F = frequencies of cutting (i.e. weekly or fortnightly)

S = species (i.e. cocksfoot, cert. perenn. rye and uncert. perenn. rye).

APPENDIX XIV:

These photographs, which are all on the same scale, illustrate the cumulative effect of the different treatments by the end of the experiment. The plants illustrated are all average or near average for their particular treatments.