A STUDY OF THE EFFECT OF PERIODIC IRREGULARITIES OF FERTILIZER DISTRIBUTION ALONG THE ROW ON THE ESTABLISHMENT, GROWTH DEVELOPMENT AND YIELD OF BARLEY

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by

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CHAPTER I

INTRODUCTION

A considerable volume of evidence derived from field trials throughout New Zealand points to the application of artificial fertilizers (especially superphosphate) to pastures and crops as a primary factor in increased yields: The efficiency of the fertilizer is dependant on the care taken to ensure maximum recovery of the applied nutrient by the crop. This means a consideratic of factors such as, time of application, quantity applied, form of fertilizer and also correct placement and efficient distribution.

Precision is one of the aims of the agronomist in attempting to step up production by the use of fertilizers. How efficient the developments to obtain these objectives have been is clearly illustrated by the increases in production obtained experimentally. The National Joint Committee of Fertilizer Application (1948) and Cooke of Rothamstead (1954) have graphically summarised the results on, time of application in relation to season, the quantity and form of fertilizer applied, and the positioning of the fertilizer in relation to the seed or plant so as to obtain maximum nutrient recovery, while avoiding any deleterious effects such as germination injury. As a result of these experiments machines have been developed to enable the recommended practices to be implemented. With higher concentrations of nutrients in the modern fertilizers lower quantities had to be applied at an accurate rate, and much work has been done in increasing the precision with which fertilizer is positioned in relation to the seed. Attention has been paid to the transverse distribution of fertilizer drills, broadcast distributors, and spinner broadcast machines and an improvement has been made by standardising all distributing units using a metered feed, viz the star wheel. Longitudinal, or "along the row distribution", on the other hand, has received little consideration. Mehring and Cummings (1930) have been the only workers to investigate the effect of variability in along the row distribution on a crop (cotton). Penman (1933) and Cook (1951) have studied the distributing patterns of the drills

commonly used. It has been accepted since Cashmore's (1939) conclusions from a single trial, that the non-uniform pattern distribution of fertilizer exhibited by conventional drills was of little importance.

With greater use of more concentrated fertilizer on improved crop varieties non-uniform distribution may have several effects. There will be areas of high rates of application interspersed with areas of low, or very low rates. High salt concentration in the high rate areas may cause germination injury if fertilizer is in contact with, or close to the seed, even though the average rate of application is below the critical injury level. This may result in a patchiness in the establishment of the crop, and rate of growth, flowering, and onset of maturity may also be affected. Even sowing, uniform growth of the crop and an even onset of maturity are essential prerequisites to the high degree of mechanisation currently employed in agriculture.

The experiment which is the subject of this thesis was designed to investigate the effect of periodic irregularities of fertilizer distribution along the row on barley. A preliminary study of fertilizer distributing mechanisms was carried out to ascertain the pattern which would most satisfactorily simulate the irregular distribution of the star wheel distributing mechanisms employed on current seed and fertilizer drills. The work was carried out on the Field Husbandry Demonstration plots Massey College during the period 26.11.60 - 17.3.61 to ascertain the significance of irregularity in distribution of serpentine superphosphate on such measurable characters as rate of establishment, number of leaves, tillering, height, heading, grain yield, and straw yield.

Linseed was also included in the trial area, but results for this experiment are not reported in this thesis.

CHAPTER II

REVIEW OF LITERATURE

This review will be presented under the following sections:

I Distribution Patterns of Star Wheel Fertilizer Distributors

II The Effect of Non-uniform Fertilizer Distribution on The Crops

III The Response of Barley to Applications of Phosphatic Fertilizers.

IV Horizontal Diffusion of Applied Phosphate in the Soil.

I DISTRIBUTION PATTERNS OF STAR WHEEL FERTILIZER

DISTRIBUTORS

The mechanical imperfection of a fertilizer distributor, such as the star feed of the metered gravity type, has been shown by several workers to result in a consistently recurring heavy and light application pattern of distribution. The design of the hopper and of the distributing mechanism, the physical properties of the fertilizer, the prevailing atmospheric conditions and the precision of manufacture of the machine all contribute toward the resultant inefficiency of distribution.

The observations by Fincher and Mertens that German distributors did not give uniform distribution because of the condition of the fertilizer and lack of accuracy of the machines were followed up by detailed investigations into the efficiency and reasons for the inaccuracies of several types of distributors by Mehring and Cummings (1930). They found that the flow characteristics of the fertilizer, termed drillability, as well as the imperfections in the design or construction of the machine could affect the pattern of distribution. However, with fertilizers of good drillability (an index of 75 or above) only mechanical imperfections caused significant variations in delivery. The uniformity of distribution was studied at one foot intervals along the row, and the star wheel mechanism demonstrated a periodic impulse of heavy and light applications. When related to the movement of the mechanism the heavy applications corresponded to the exposure of the first half of the delivery port by a star tooth, thus allowing the bulk of the following charge to be dropped. The light applications corresponded to the closure of the same portion of the delivery port by a star tooth. Most machines showed greatest uniformity at a drillability of 85. Fertilizer with indexes lower than this tend to bridge or cake, while the freer flowing ones dropped through the port too quickly or flowed freely from the hopper through the discharge port. In both cases vibration increased the deviation. One star feed machine

demonstrated an average deviation of 38.38% when using fertiliser with a drillability of 95 (maximum delivery per foot 9.45 grams. Minimum 1.57 grams). The use of an improved design incorporating elliptical discharge ports, scrapers and knockers did not improve the pattern of distribution.

Keeble (1930) tested twelve broadcast distributors for accuracy in rate of delivery and uniformity of distribution along and across the track. For "along the track" distribution (measured at 10 yard intervals) the coefficient of variation ranged between 12% - 52% about the mean.

Penman (1933) found that when applying superphosphate with a star wheel type of distributor at a sowing rate of 92.5 lbs per acre the highest and lowest rates per 2" section of the row were 322 and 17 lbs per acre respectively with an average deviation of 57% and an 18% - 348% variation of the mean rate. The fluctuations were periodic in nature, definite impulses in distribution being associated with the position of the points of the star. The amplitude of the cycle of these impulses was 10 feet which corresponds to the distance travelled during the movement of one star tooth to the position occupied by the one before it. He also verifies Mehring and Cummings reason for the periodic impulses and also found the modifications of the discharge port shape and the use of a knocker to counteract irregular delivery inefficient. He suggests the phasing of stars to obviate adjacent rows receiving peak applications at the same time in order to reduce the effect on the crop.

Cooke (1951) tested a top delivery cylinder, a plate and scraper, a star wheel, and a vertical wheel fertiliser distributing mechanism for variations in delivery rates. He found that the delivery rate of bottom delivery types decreased with a head of less than 2" of fertiliser in the hopper. Delivery was proportional to the speed of the rotating part up to a critical level, above which the rate decreased due to slippage between the moving component and the fertiliser. Granular fertiliser maintained better condition and varied in rate with various gate openings less than did powdered fertiliser for different

atmospheric moisture conditions. Variations in delivery per foot of row travelled by the drill were greatest for the star wheel and vertical wheel mechanisms, the output for the star type ranging from 40% - 160% of the mean rate. The plate and scraper mechanism on the other hand demonstrated a fairly uniform distribution pattern. Cooke also verifies Mehring and Cumings findings as to the cause of periodic impulses in delivery. He emphasised the need for a distributing mechanism capable of positively removing a definite quantity of fertilizer from the hopper per unit distance travelled by the drill. In later work (Cooke (1953)) he describes the various types of distributing mechanisms available, classifying them into

Type I Gravity feeds.

Type II Assisted gravity feeds.

Type III Metered gravity feeds.

Type IV Top delivery mechanisms.

He summarises the characteristics affecting delivery rates and distribution as presented in the table on page 7.

Cuming et al (1950) developed an endless belt feed dispenser for experimental work so as to obtain accurate metering and uniformity of distribution not available in conventional machines.

Weston (1959) tested several machines for evenness of delivery rates but only produced photographic records to illustrate uniformity of spread.

Transverse distribution of a plate and flicker, a belt and brush, and spinner broadcast distributors was examined by Hepherd and Pascal (1958). The first two machines gave reasonably even patterns of transverse distribution but the spinners produced a pattern requiring overlapping to obtain an even spread of fertilizer. Longitudinal (along the row) distribution was observed to be inferior for the plate and flicker and belt and brush mechanisms.

As a result of irregular growth of oats N.I.A.E. investigations (1960) revealed the cause to be a wide variation in longitudinal distribution in a recurring pattern with a maximum every 5 - 6 feet of forward travel (the distance travelled during the movement of one star tooth over the discharge port).

Assessment of the Effects of Various Factors on Delivery of Fertilizer by Different Dispensing Mechanisms

Key + serious effect

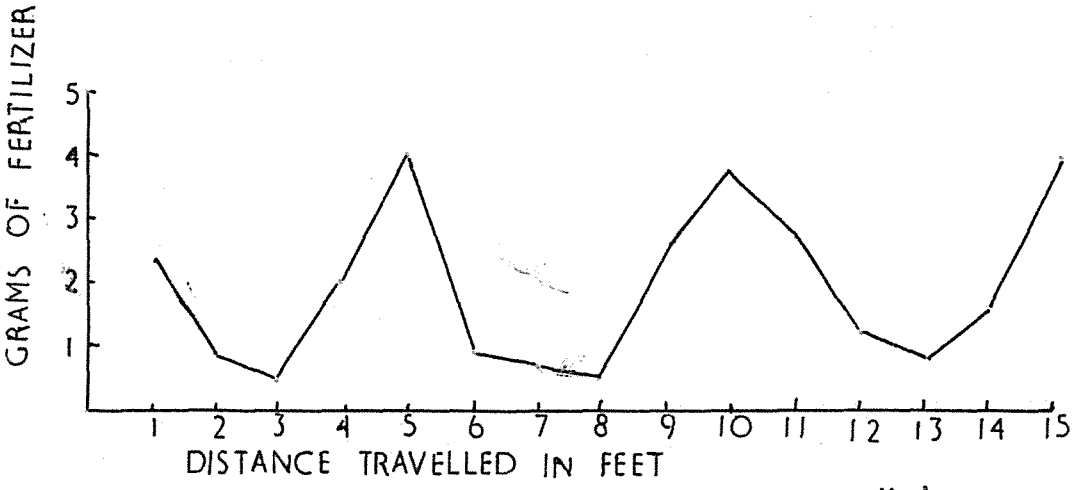
\- slight effect

0 no practical importance

Factor	Type I	Type II (Worm feed)	Type III					Type IV (Top	Typ Deliv
			Plate	Star Wheel	Endless Belt	Reciprocating Plate	Roller		
Head of fertilizer	+	-	-	-	-	-	-	0	0
Inclination of Machine	+	-	+	+	+	-	-	0	0
Incorrect speed (of dispersing component)		+	-	+	-	+	-	0	0
Inherent Periodicity		+	0	+	0	+	0	0	0
Compaction of fertilizer (upward pressure)	0	0	0	0	0	0	0	+	0
Poorly conditional fertilizer	+	+	-	+	-	+	+	0	0
Liability to excess gravily flow using free running fertilisers	+	+	0	0	0	0	+	0	0
Need for Agitator	Yes	No	No	No	No	Yes	Yes	No	N

John Deere's Development Department (1960) using Mehring and Cumings procedure obtained similar results with a star wheel mechanism. At an average rate of 2.19 grams per foot of row there was a variation of 36% - 240% about the mean with a cycle amplitude of 5 feet in one case reported.

A graph illustrating the distribution pattern of this drill is shown below.



Hutchinson's investigations (1961) revealed that the ~~cause of the~~ mosaic pattern in colour, and poor growth resulted as the effect of recurring cyclic undulations (43" - 83" amplitude) in the distribution of fertilizer which corresponded to the movement of adjacent teeth of the star wheel over the hopper orifice. He found that all machines, irrespective of modifications, showed a wide variation in delivery rate over short distances the best having a range of 67% - 146% of the mean (granular fertilizer was used). His measurements were made at 3 inch intervals using specially designed "V" trays.

All workers are in agreement as to the cause of the irregular patterns reported.

II THE EFFECT OF NON-UNIFORM FERTILIZER

DISTRIBUTION ON THE CROPS

Workers in the field of fertilizer application have reported observations of irregular responses supposedly attributable to the nature of the fertilizer distribution pattern. Mehring and Cuming (1930) refer to McGinnis 1876 who emphasised the need for thorough dissemination of manure for the best results. Haskel (1923) and Collings (1954) both report the occurrence of mosaic colour patterns and uneven growth in cereal crops resulting from uneven distribution which also interferred with orderly maturing of the crop. Mehring and Cumings (1932) investigated the efficiency of fertilizer distributors with respect to the effect of variability in distribution on the germination, earliness of blooming, rate of growth and yield of cotton. There was a definite tendency for a greater number of seeds to germinate promptly when the compound fertiliser was applied irregularly along the row. Conversely the spacing was proportionaly more regular with the uniform applications, the plants being bunched at the low points of delivery for the irregular distributions. Uniform applications prompted more rapid and even growth. When the coefficient of variability of fertilizer distribution V was 0 there was far earlier flowering than at V 8, 9, 10 or 56. The yield was increased by 47% above the average for the irregular machines when the concentrated 12:24:12 compound fertilizer was applied uniformly, and it was reduced as the V increased. Uniformly applied fertilizer in nearly every instance hastened maturity to a greater extent than the same amount applied irregularly.

Cashmore et al (1939) applied concentrated nitrogenous fertilizers in the spring to autumn sown wheat at 3 cwt per acre in varying patterns of uniformity. The treatments comprised broadcast, 7" 14" and 28" bands of fertilizer spaced 7" 14" and 28" apart respectively, and an unmanured control. These gave colour differences due to banding of the fertilizer which persisted until harvest. The yield response was a highly significant increase

for broadcasting over control, and the 7" band treatment was also significantly superior to the evenly manured treatment. The 14 and 28" band treatments produced no significant differences. Cashmore said that further work was required due to the influence of the dry season which probably reduced the availability of water necessary to effect an efficient nitrogen response.

Cross (1959) observed periodic irregularities in the growth response of linseed to applied superphosphate, the effect being attributed to the delivery pattern of the fertilizer distributor on the drill.

Cooke (1960) has found that irregular growth and damage to the germination of cereals corresponds to the variation in delivery from a star wheel distributor when applying the concentrated compound fertilizers containing nitrates or urea.

At Massey College the frequent irregularity of response of the drilled crops, such as linseed, lupins, chou moellier, rape, mustard, and barley, to serpentine superphosphate corresponded to the irregularity in the distribution pattern observed for the setting of the drill used. When drought conditions prevailed at sowing the typical fertilizer response pattern was most marked and in many cases persisted till maturity.

III THE RESPONSE OF BARLEY TO APPLICATIONS OF PHOSPHATE FERTILIZERS

Barley yield responses to phosphate vary according to the prevailing soil and environmental conditions. The increases are especially marked in phosphate deficient soils under drought conditions according to Domanski (1958) working on Dutch soils. Loizides (1958) found inconsistent responses due to a residual build up of phosphate from previous applications. The New Zealand Department of Agriculture (1957 - 1960) reports results of manured trials which indicate that the greatest number of significant responses occur at an application rate of 2 cwt. per acre. The increase in yield in these cases varies from 5 - 16 bushels per acre. Soils high in phosphate due to a build up by previous applications or a naturally high phosphate status did not generally demonstrate significant responses.

Rothamstead Experimental Station (1954), Cook (1954), The National Joint Committee of Fertilizer Application (1948) and Reith (1952) all concluded that 1 cwt per acre of phosphatic fertilizer placed in close proximity to the seed produced yields equivalent to those obtained from 2 cwt per acre broadcast. Placement allowed a quicker uptake during early growth and the barley plants were more drought resistant due to better development of the rooting system.

McLeod (1960) applied 1 cwt of superphosphate to a spring cereal and obtained a significant increase of 10 bushels per acre, a greater number of heads per 10 feet of row and a greater number of tillers per plant, but no improvement in germination.

IV HORIZONTAL DIFFUSION OF APPLIED PHOSPHATES IN THE SOIL

The horizontal movement of phosphate through the soil has generally been found to be negligible, the root systems of plants having to be extended to the zone of application before any benefit is derived.

Olsen et al (1950) found a maximum vertical movement of 3" - 4" with no appreciable horizontal diffusion. Lawton (1954) using radioactive phosphate, P 32, detected a maximum horizontal movement of 1" with moisture at field capacity. Also using P 32 Heslep and Black (1954) detected a maximum diffusion of 3 - 4 cms after 4 weeks.

Wit (1953) suggests that the distance of placement from the crop row affects only early growth and not the final yield. Tesar et al (1954) used radioactive phosphate on alfalfa seedlings and found that plants placed 0", 1", 2", 3", and 4" to the side of a fertilizer band 1½" deep, obtained 98%, 66%, 15%, 3% and 0%, respectively, of their phosphate from the applied fertilizer after one month. Two months after seeding the plants had obtained 77%, 62%, 50%, 24% and 7%, respectively, of their phosphate intake from the band application. Seedlings therefore have to be directly over the fertilizer band or within 1" to one side to obtain more than 60% of their phosphate from the applied fertilizer in the first 2 months. Chamenchenko (1956) found phosphate uptake slower at 2 - 5 cm from the seed row compared with contact placement and at 8 - 10 cm a further delay in uptake occurred.

CHAPTER III

MATERIALS AND METHODS

This chapter is presented in five parts as follows:-

I The Experiment

II Layout of the Experiment

III The Experimental Area

IV Establishment and Maintenance of the Trial

V Sampling Methods and Experimental Technique.

I THE EXPERIMENT

In this experiment the aim has been to determine the effect of seven fertilizer treatments on the establishment, rate of growth, tillering, heading and yield of barley using serpentine superphosphate as the fertilizer. Linseed was also used in an associated trial not reported in this thesis.

The use of barley and linseed was decided upon as a result of their response to non-uniform applications in a pilot trial carried out at Massey College in the early spring of 1960, plus the observed responses on previous occasions on the same area.

Serpentine superphosphate was used as it causes no germination injury when sown in contact with the seed as was done in this trial. The variety of barley used was Proctor, a malting barley of English origin which has been found to be noticeably susceptible to phosphate deficiencies by the New Zealand Department of Agriculture (1957 - 1960).

The treatments applied were based on knowledge obtained about the distribution patterns of current star wheel fertilizer distributors. At an average of 2 cwt. per acre light rate sections of the row had an application rate of less than $\frac{1}{3}$ of cwt per acre extending between 12" and 60" while the heavy rate sections received nearly $\frac{2}{3}$ cwt per acre extending between 15" and 30" in length. For the trial two distances were used for the heavy rates - 6" and 18", and the light rate sections were made the same, but received no fertilizer at all.

The treatments were as follows:-

1.	Control Co	Control - received no fertilizer but the seed was sown as per every other treatment.
2.	Uniform at 3 cwt U3	A uniform distribution of fertilizer at 3 cwt per acre sown at an even rate along the entire length of the row.

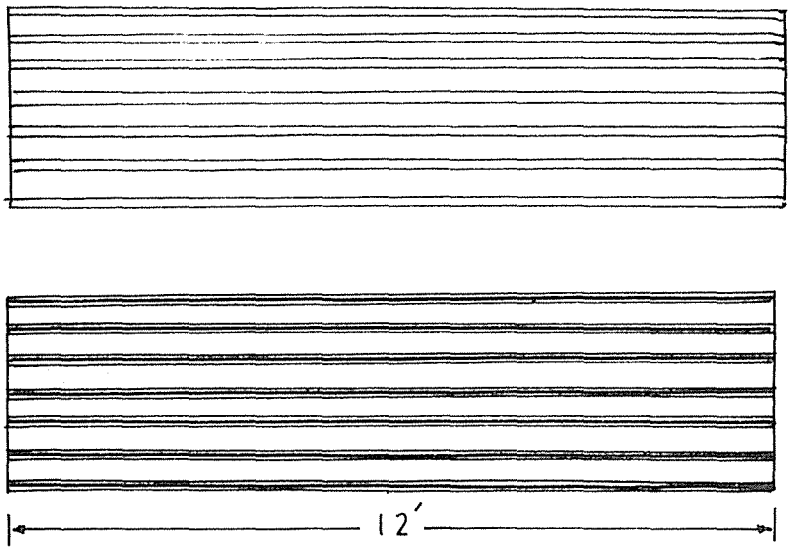


FIGURE .1.

TREATMENT PATTERNS and PLOT PLAN

3.	Uniform at 6 Cwt U6	A uniform distribution of fertilizer at 6 cwt of fertilizer per acre sown as per 2.
4.	Simultaneous 6" Gaps S6	A non-uniform distribution which consisted of periodic impulses with an amplitude of 12", a 6" length of row receiving fertilizer at a rate of 6 cwt per acre followed by a 6" gap with no fertilizer (an average rate of 3 cwt of fertilizer per acre). The gaps occurred simultaneously across the plot.
5.	Alternate 6" Gaps A6	Non-uniform distribution with a 12" cycle as per 4 where the 6" gaps alternated with fertilized 6" sections in adjacent rows across the plot. (an average rate of application of 3 cwt of fertilizer per acre.)
6.	Simultaneous 18" Gaps S18	Non-uniform distribution which consisted of periodic impulses with an amplitude of 36", an 18" length of row receiving 6 cwt of fertilizer per acre followed by an unfertilized 18" gap. The gaps occurred simultaneously across the plot. (an average rate of application of 3 cwt of fertilizer per acre.)
7.	Alternate 18" Gaps A18	Non-uniform distribution with a 36" cycle as per 6. where the 18" gaps alternated with fertilized 18" sections in adjacent rows across the plot. (an average rate of application of 3 cwt of fertilizer per acre.)

The above treatments' distribution patterns are illustrated in figure 1. They approximate a comparison between a star wheel at a slow speed (a 36" cycle), a star at high speed (a 12" cycle) of impulses and a perfectly uniform

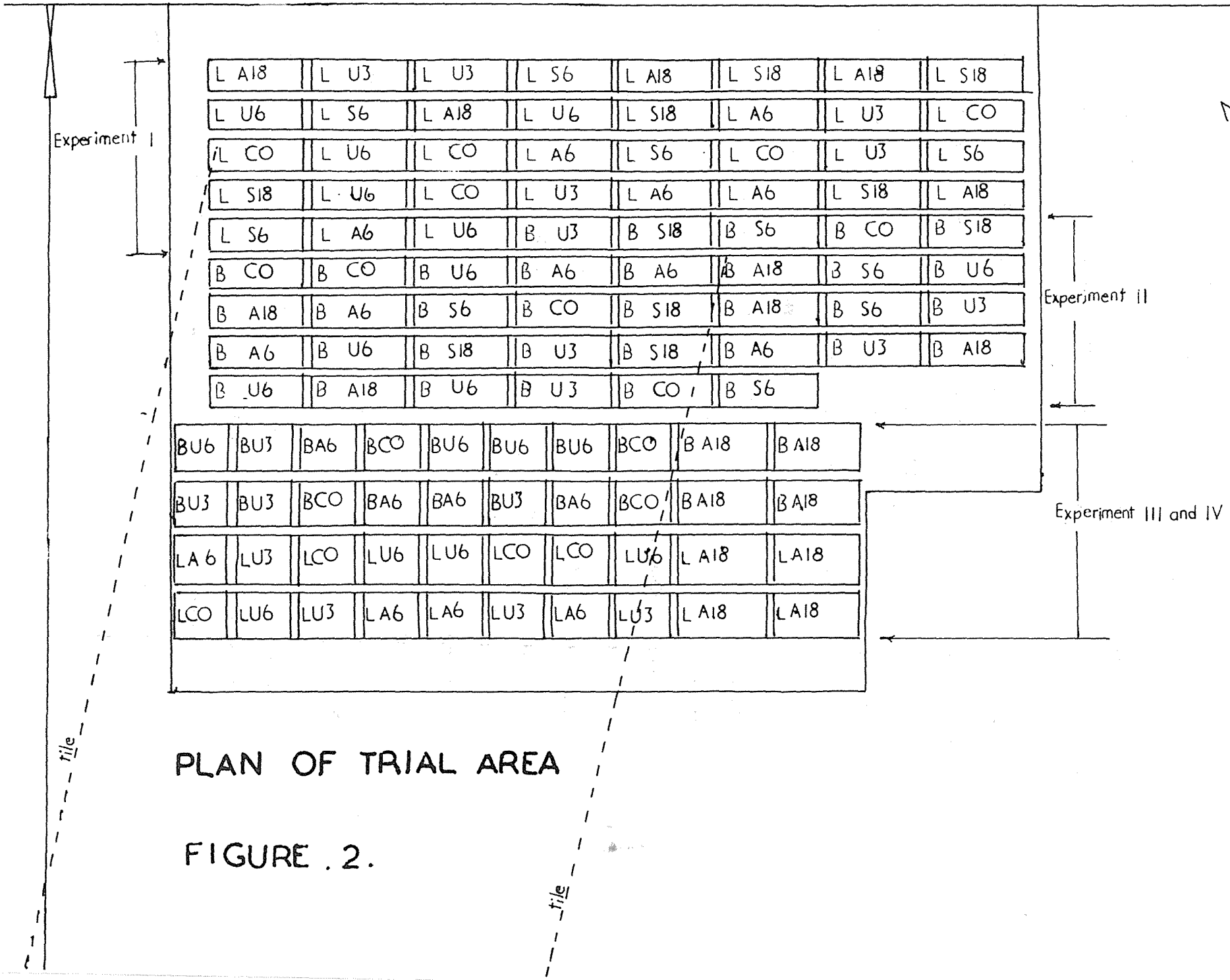
application. The two different patterns applied to both the 12" and 36" cycle treatments is aimed at simulating extremes in phasing of the stars of a fertilizer distributor so as to determine whether there is any beneficial effect in the recommended practice of preventing the peaks in delivery from occurring side by side in adjacent rows.

As well as the main experiments which were designed to investigate the overall effect of the above treatments, two subsidiary experiments were planned to examine sections of the treatment rows to determine the reasons for any variations. The marginal effect of the fertilized sections of the row on the unfertilized sections was also to be studied. However, owing to lack of precision in the sampling technique and difficulty in maintaining the samples in situ as removed from the plots, these subsidiary experiments were abandoned in favour of future work using radio active tracers under controlled conditions. (these subsidiary experiments are represented by Experiment III and IV in figure 2.)

Key to Treatment Notations in Figure 2

Experiment I Linseed (Not in Trial)		Experiment II Barley
L Co	Control	B Co
L U3	Uniform at 3 cwt/acre	B U3
L U6	Uniform at 6 cwt/acre	B U6
L S6	Non-uniform - Simultaneous 6" gaps	B S6
L A6	Non-uniform - Alternate 6" gaps	BA6
L S18	Non-uniform - Simultaneous 18" gaps	B S18
L A18	Non-uniform - Alternate 18" gaps	B A18

The abbreviations denoting the various treatments on pages 14 and 15 in this section will be used throughout the remainder of this thesis in the text, tables and figures.



PLAN OF TRIAL AREA

FIGURE . 2.

II LAYOUT OF THE EXPERIMENT

The experiment was completely randomised in layout as the soil analysis (table 1 page 19) showed a reasonably uniform pattern which obviated the need of blocking to overcome any fertility gradient. At the time of laying down the trial moisture conditions were neglected as a factor capable of affecting the results. The effect of resultant soil moisture variations will be discussed in Chapter V.

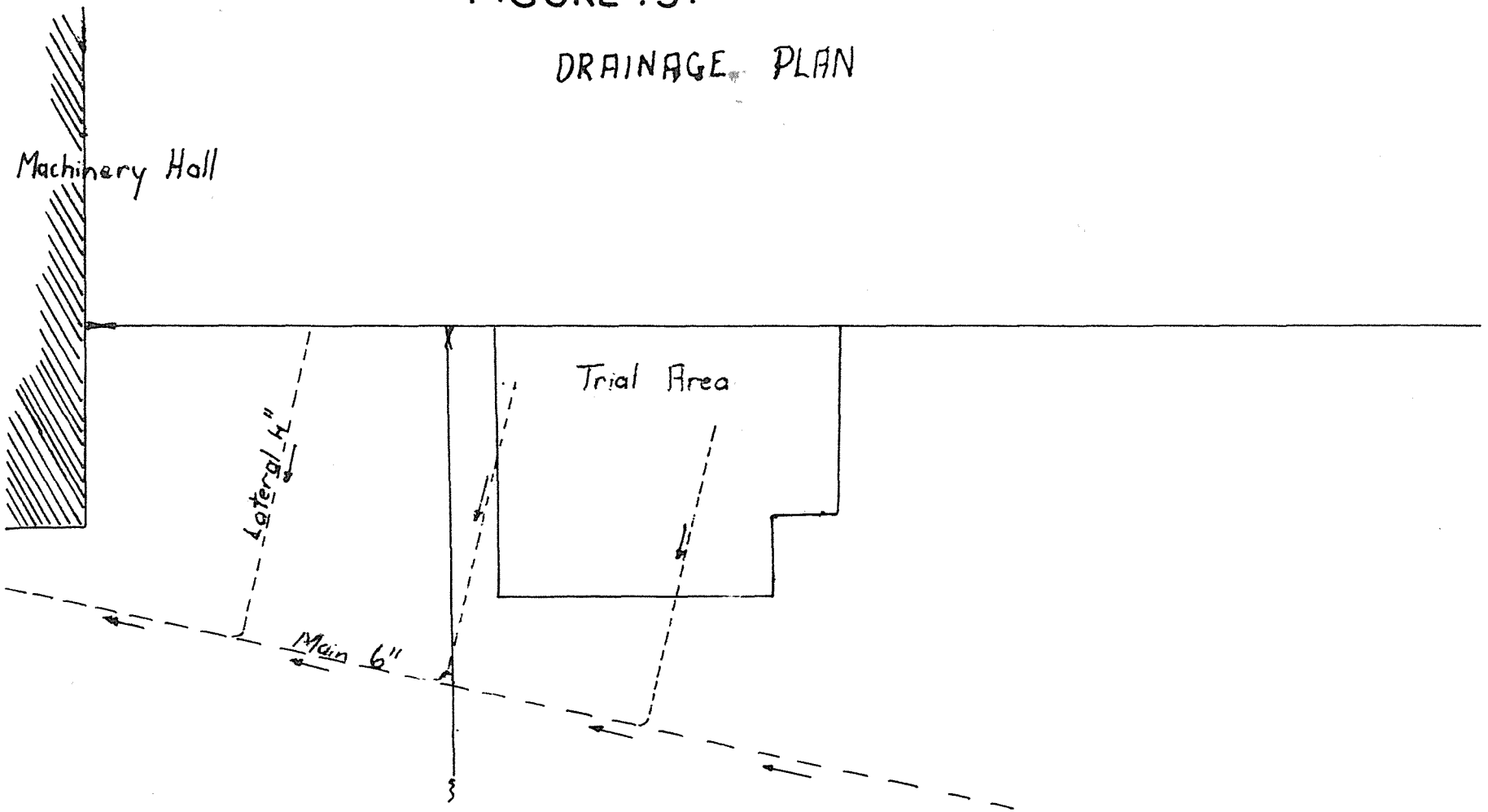
In view of the Dept. Agric. experience with previous fertiliser trials the statistical analysis of results demanded at least 5 replications per treatment to be used. Therefore 35 plots were required for the 7 treatments in the experiment. The experiment using barley reported here is represented in the plan of the trial area in figure 2. as "Experiment II". The randomisation of treatments was done using figures from Goulden (1952).

The area of each plot was kept to a minimum to enable uniformity within the plots to be obtained and also to lay the whole trial down within 24 hours. The size was also limited by the area available, and that able to be protected efficiently from bird damage. The size of each plot was 3 feet 6 inches wide by 12 feet long comprising seven rows 6 inches apart, the three centre ones being sampled from the middle 9 feet section, leaving two guard rows on either side and a 1 foot 6 inches length at either end of the plot to eliminate edge effects.

As can be seen in figure 2. the plots were placed lengthwise along the northern fence line. The seed rows continued the entire length of each block of plots, the gaps between each being sown with seed but not fertiliser. The treatment applied to the guard rows was identical within each plot with that applied to the sample rows.

FIGURE .3.

DRAINAGE PLAN



III THE EXPERIMENTAL AREA

The experiment was laid down on part of the Field Husbandry demonstration area at Massey College. The trial area had previously been ploughed and a crop of kale taken off in 1948 before being sown down with a general pasture mixture. The area has since received no? treatment whatsoever. It is adjacent to a series of long term pasture fertilizer trials which may explain the unusually high P_2O_5 figure in plot 16 of the soil analysis in table 1. (a mistaken or accidental application of phosphate to areas external to the trials).

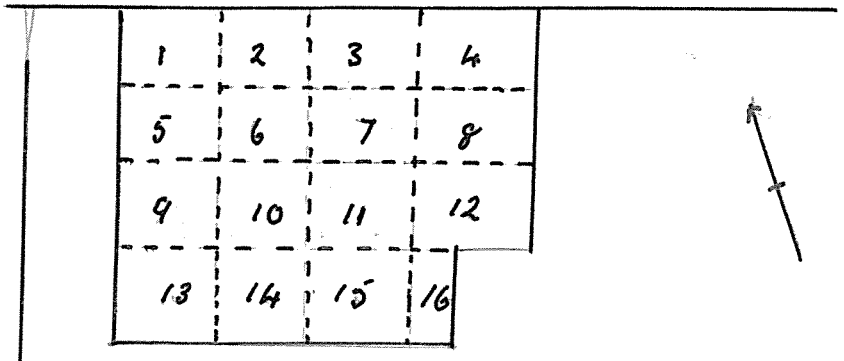
The trial was located in a paddock on an intermediate terrace of the Tiritea stream the soil type being similar to Tokomaru silt loam (Soil Bureau bulletin No. 5 1954). The soil profile in this area may be described as a brown slightly gravelly silt loam 0" - 8", a yellow brown slight to moderately mottled bright rusty brown clay loam with some stones 0" - 24" on gravel - Pollok (1962). A soil analysis presented in table 1. shows that the soil is acid and deficient in phosphate the phosphate status being reasonably uniform over the entire area. The high P_2O_5 plot was not included in the experiment described here.

No buildings open drains or hedges are within 100 feet of the plots. The area was tile drained at the time of ploughing in 1948 at 66 feet intervals, 4" laterals draining in to a 6" main tile. A drainage plan is presented in figure 3. and indicates that two drains traversed the experiment.

TABLE I

SOIL ANALYSIS RESULTS

Plot ?	pH	Ca	K	P_2O_5
1	5.1	6	12	3
2	5.1	5	11	2
3	5.2	6	8	2
4	5.3	6	9	2
5	5.2	6	10	1
6	5.2	6	11	2
7	5.1	6	8	2
8	5.1	6	8	2
9	5.1	6	11	2
10	5.2	6	9	2
11	5.2	6	10	2
12	5.3	6	10	2
13	5.1	7	7	2
14	5.3	6	10	2
15	5.2	6	9	3
16	5.0	6	6	11



Sampling Sites.

IV ESTABLISHMENT AND MAINTENANCE OF THE TRIAL

A. ESTABLISHMENT

After soil sampling the area on the 12.8.60 two cultivations with a rotary hoe on the 22.8.60 and 5.9.60 gave a satisfactory break up of surface vegetation. This ensured rapid decomposition of the plant matter on burial when the area was ploughed.

On the 13.9.60 using a 2 X 12" furrow plough the area was ploughed to a depth of 6" one way so as to eliminate the ridge of a feering or the hollow of a finish. The use of skimmers on the coulters enabled a complete burial of surface vegetation. A week later the area was rolled and lightly disced along the line of the furrow. A double discing to a depth of 5" on the 4.10.60 and a double harrowing on the 25.10.60 improved the tilth and controlled the weeds. After removing the stones brought to the surface in previous cultivating operations a further two harrowings on the 12.11.60 and 22.11.60 were used to reduce the weed population.

On the 23.11.60 the experiment was laid down and a V ringed roller was used with the aid of sighting poles to form the furrows into which the fertilizer and seed would be sown. The V ringed roller provided furrows of uniform depth and a uniform 3" row spacing but only each alternate furrow was utilized giving the required 6" row spacing. An added advantage in using this method of forming the furrows was the production of an adequately compacted seed bed, especially important due to the dry period just prior to sowing. Only the furrows of five rows of plots, comprising one experiment, were rolled at a time so as to prevent the loose earth on the ridges from filling the furrows prior to sowing.

After forming the furrows the area was pegged out marking each corner of the individual plots.

The fertilizer was then applied to the plots in the patterns shown in

FIGURE 4

A General View of the Trial

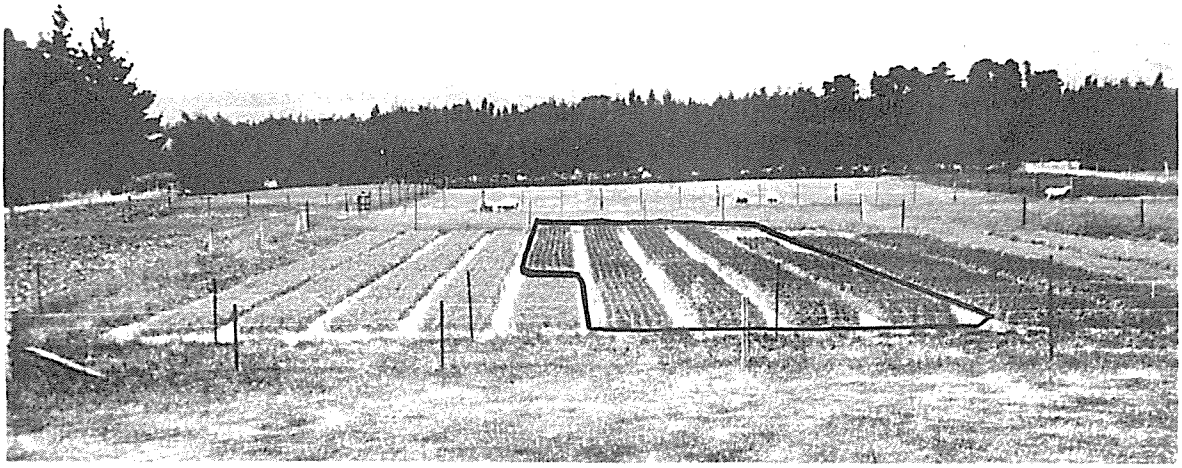
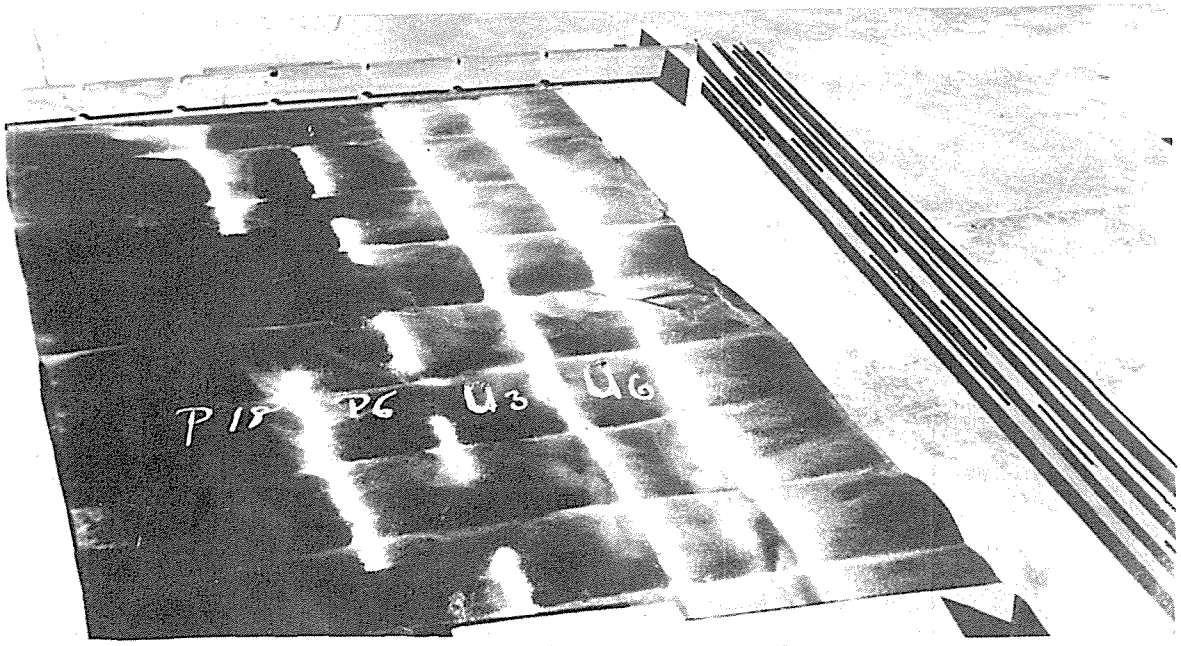


FIGURE 5

Fertilizer Application Equipment And
Distribution Patterns



Poor illustration of precision distribution

P = Periodic

U = Uniform

figure 1. as quickly as possible using the apparatus described in B below. The laying down of the trial was completed by sowing the seed with a "Planet Junior" drill into the furrows sown with fertilizer.

Each experiment shown in figure 2. was laid down separately using this procedure.

See figure 4. for a general view of the trial area.

B. FERTILIZER APPLICATION

Rods of timber 6 feet long with a saw groove along their length were used to apply the fertilizer to the plots. The depth of the saw groove determined the sowing rate which was accurately measured in a preliminary test of the apparatus. The rods two sowing rates were

(1) 0.87 ± 0.04 grams per 6 inches for approximately 3 cwt per acre and (2) 1.76 ± 0.05 grams per 6 inches for approximately 6 cwt per acre. This is equal to 333 ± 15 lbs and 674 ± 19 lbs per acre respectively. The grooves on the rods for the U3 treatment sowed at a rate equal to (1) above while U6, S6, A6, S18 and A18 treatment rods all sowed at the (2) rate. Blanking off the grooves on the (S6,A6) and (S18, A18) rods with putty along alternate 6 inch and 18 inch sections respectively applied the fertilizer at an average of approximately 3 cwt per acre for these treatments. This simulated a 1 foot and 3 feet period in the impulse delivery of a star wheel distributor.

Special jigs were constructed to enable accurate deposition of the fertilizer from the rods into the furrows. They were wooden frames 4 feet 6 inches long with 7 slots on top spaced at 6 inch intervals. A piece of dowling inserted into each end of the rods acted as a pivot for the inversion of the rods.

A trough 10 feet long 5 inches wide and 4 inches deep filled with fertilizer was used to fill the rods employing a constant reciprocating and rolling action, tipping off any surplus before transfer to the plots. The fertilizer had previously been screened retaining that which passed through a

twelve mesh sieve but did not pass a twenty mesh sieve. This ensured even filling of the grooves on the rods.

The simultaneous patterns were produced by maintaining the applicating rod in the same direction for every row across the plot while the alternate pattern was obtained by turning the rod end for end in adjacent rows.

See figure 5. for an illustration of the equipment described above and the patterns of fertilizer application:

C. SEEDING EQUIPMENT

A "Planet Junior Seeder" was used to sow the seed into the furrows after the fertilizer had been applied. The barley was sown at an average rate of 240 lbs per acre.

This machine enabled the seed to be covered sufficiently by the soil to protect it from the birds. It also deposited the seed in a reasonably uniform pattern of distribution along the row. (See page 24)

D. MAINTENANCE OF THE EXPERIMENT

The whole area was watered with a sprinkler the day after sowing to lay the dust and prevent damage from birds dust bathing.

Successful measures to prevent bird damage to the experiment included the use of bird scarers and cages coupled with a constant vigil using firearms as a deterrent both during the establishment period and after heading until harvest .

Control of weeds was effected by use of 24D weedicide and hand weeding the plots.

Control of an invasion of army worm on the 27.2.61 was successful when Dieldrin was applied.

V SAMPLING METHODS AND EXPERIMENTAL TECHNIQUE

A. GENERAL

Each plot was sampled to determine the following:-

(1) Establishment rate

(2) Number of leaves per primary tiller

(3) Tillering

(4) Height per plant

(5) Heading rate

(6) Yield of Grain and Straw.

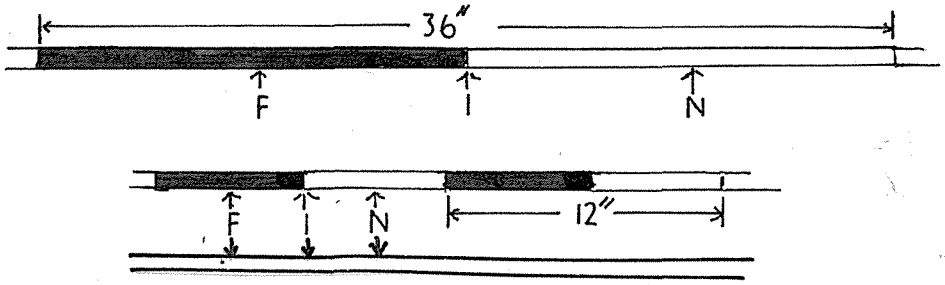
The measuring sites for the above included:-

(a) The 3 feet sections of each of the centre 3 sampling rows, randomly selected within each plot, to determine (1) (2) and (3).

(b) Six individual sampling sites within each plot. At each site plants were measured in the "F" "I" and "N" positions for (3) (4) and (5).

(see figure 6)

Figure 6
Sections of rows with F I and N positions indicated.



Two sets of sites on the centre 3 sampling rows were randomly selected for each plot.

(c) Nine feet of the centre 3 sampling rows of each plot was harvested to determine (6).

The same sampling sites were used at each sampling date.

B. ESTABLISHMENT RATE

One week after the emergence of the plants a count of the number of plants per 3 feet of row was taken. The fertilizer applicating rods were used to locate the sampling site and a 3 foot rule used to measure the length of row sampled.

C. NUMBER OF LEAVES PER PRIMARY TILLER

As well as being of value in indicating the stage of growth of the plants leaf number was used as a criterion for determining the time at which floral initiation occurred. The primary tiller was defined as the culm arising from the first shoot to emerge after germination of the seed.

This measurement involved the counting of all leaves whether dead or growing the final leaf to emerge being classed as early intermediate or advanced in its growth and recorded as follows:-

X .25 last leaf in an early stage of growth

X . 5 last leaf in an intermediate stage of growth

X .75 last leaf in an advanced stage of growth

The figures taken were transposed to quarter units for ease of analysis, $4X + 1$ $4X + 2$ and $4X + 3$ being the respective expressions for the above classification.

D. TILLERING

Two measurements were made for the tillering rate

(a) the number of tillers, excluding the primary tillers, per 3 feet of row

(b) The number of tillers, excluding the primary tiller, per plant in the F I and N positions as per A (b) above.

The primary tillers were excluded as the measurements of B, the establishment rate, did not show any treatment differences - see Chapter IV section II.

Only three counts of the number of tillers per 3 feet of row were

taken as the number and size of tillers after the 31.12.60 made it impracticable to obtain an accurate count. The dates of these measurements were 16.12.60 24.12.60 31.12.60. The number of tillers per plant was recorded when taking measurements at the F I and N positions (see A(b)) for height and number of leaves per plant. These were done at 14 28 35 42 and 56 days after the emergence of the crop.

E. FLORAL INITIATION INVESTIGATION

Samples of barley plants from a plot of Proctor barley sown 3 weeks prior to this experiment were examined for the development of double ridges on the primordial apex which indicated the initiation of inflorescence. The plants were dissected longitudinally into two halves and the stems stained with "fast green" for microscopic examination using a binocular microscope. A count of the number of leaves per primary tiller was made so as to indicate the stage at which the plants from the experiment should be examined.

It was found from this preliminary investigation that initiation of flowering occurred at approximately the five leaf stage in growth. Plants from all plots in every position were examined at the 4, 5, 6 and 7 leaf stage of growth.

F. HEIGHT PER PLANT MEASUREMENTS

The height of each plant at the F I and N positions as described in A(b) were measured by taking the distance from ground level to the tip of the plant which was gathered to the erect position. A 3 foot rule was used, the measurements being taken to the nearest $\frac{1}{4}$ inch. The ground surface was reasonably level and firm but care was taken not to exert any downward pressure on the rule and to ensure the lower end was as near to the plant as possible.

G. HEADING RATE

Using the same procedure as for B the number of heads emerged per 3 feet of row were counted every day, after the appearance of the first heads on the 17.1.61, for 7 days and then every 2 days till the 3.2.61 and again on the

10.2.61 and 23.2.61 giving a total of 14 counts. Only 12 of these were analysed statistically due to zero results on the first two days.

H. YIELD OF GRAIN AND STRAW

The centre 9 feet of the 3 central sampling rows was harvested from each plot and stored to allow the samples to dry to a satisfactory threshing condition because heavy rain on January 20th had caused secondary shooting and heading in the Co plots and the N positions of the non-uniform plots.

The treatments were harvested individually as the average moisture content of the grain reached 20% - 21%. This resulted in cutting the U3 and U6 plots on the 7.3.61, the S6, A6, S18 and A18 plots on the 10.3.61 and the Co plots on the 17.3.61.

The samples were weighed and threshed in May 1961 using an Andrews and Bevan stationary mill which had been modified to prevent grain loss. The straw was rethreshed to ensure a complete extraction of grain. A check was also kept on the tailings. Due to the inefficiency of the mill to separate all the awns and light straw the threshed grain was cleaned in a small seed cleaning machine designed by Grasslands Division D.S.I.R. for handling small samples. The cleaned grain was then weighed and samples were taken, ground to a meal and dry matter determinations carried out. These were done using a Mettler B6 balance for weighing the samples which were placed in a Wilco oven at 80°C for 24 hours and, after removal to a dessicator for 1 hour, reweighed.

During threshing operations composite samples of straw and tailings were taken, weighed on a Mettler K7 balance dried for 24 hours at 100°C and reweighed to determine the dry matter content.

From the figures obtained in the above operations yield of grain and straw, expressed in grams (to 0.1 gm) of dry matter, basis, was calculated.

CHAPTER IV

RESULTS

This chapter is presented under the following sections:-

I Statistical Techniques

II Establishment Rate Counts.

III Floral Initiation Investigations

IV Number of Leaves per Primary Tiller

V Tiller Counts

VI Height Measurements

VII Heading Counts

VIII Dry weight Yield of Grain and Straw

I STATISTICAL TECHNIQUES

It was assumed that the layout was completely randomised with no blocking of treatments when the results were analysed Glenday (1962).

For measurements IV V VI and VII a full analysis was performed on all the data collected for the first sampling date. A test on the accuracy of sampling (see appendices, 3, 5, 6, 8 and 10) indicated that 3 and 6 sampling sites for the measurements per 3 feet of row and of the individual plants in the F I and N positions respectively, were warrented. Below is the equation used to test the accuracy of sampling.

SE of the mean for x samples

$$= \sqrt{\frac{S^2s + n S^2_{op}}{5n}}$$ for 5 replicates

Where S^2s is the sample variance

Sp^2 is the plot variance

n is the number of samples per treatment.

Each character was analysed separately at each sampling date. One analysis of variance per character was performed for II V(a) and VII while there were three for IV V(b) and VII, one for each of the F I and N positions. After the first sampling date analyses were done on condensed data using the means of the 3 and 6 sampling sites per plot.

In the measurements IV (number of leaves per primary tiller) and VI (height per plant) the figures were coded to quarter units for ease of analysis.

Where treatment effects were near to being significantly different in the overall analysis, a partitioning of the analysis according to Cochrane and Cox (1954) was employed to obtain a more accurate result (see appendix 11).

The "t" test as per Snedecor (1959) was performed on all means to determine the significant differences.

Least significant difference $\bar{d} = t\ 28df\ {0.05 \atop 0.01} \sqrt{\frac{2x\ EMS}{n}}$

n = number of samples per treatment

II ESTABLISHMENT RATE COUNTS

The number of plants per 3 feet of row one week after emergence on 5.12.60 are presented in table 2. with the result of the analysis of variance.

Table 2

Number of plants per 3 feet of row @ 5.12.60

Treatment	Co	U3	U6	S6	A6	S18	A18	
Means	74.9	73.9	78.4	76.6	75.7	77.8	76.8	± 2.3
Result of Analysis of Variance		F. value		0.47				
		F. required		2.44				
		Result		N.S.				
d 0.05	6.7							
0.01	9.1							

There were no significant effects of treatment on the rate of establishment. The spacing between plants was reasonably even averaging 0.49".

III FLORAL INITIATION INVESTIGATIONS

Barley plants taken from a demonstration plot of the same variety and from the trial plots were examined for initiation of inflorescence. From a microscopic study of the primordial ridges on the short apex the results presented in table 3. were obtained.

Table 3

State of the Shoot Apex according to the Stage of growth in terms of Number of leaves

Key Ru (V) = primordial ridges undivided - vegetative

Rd (F) = primordial ridges divided - floral

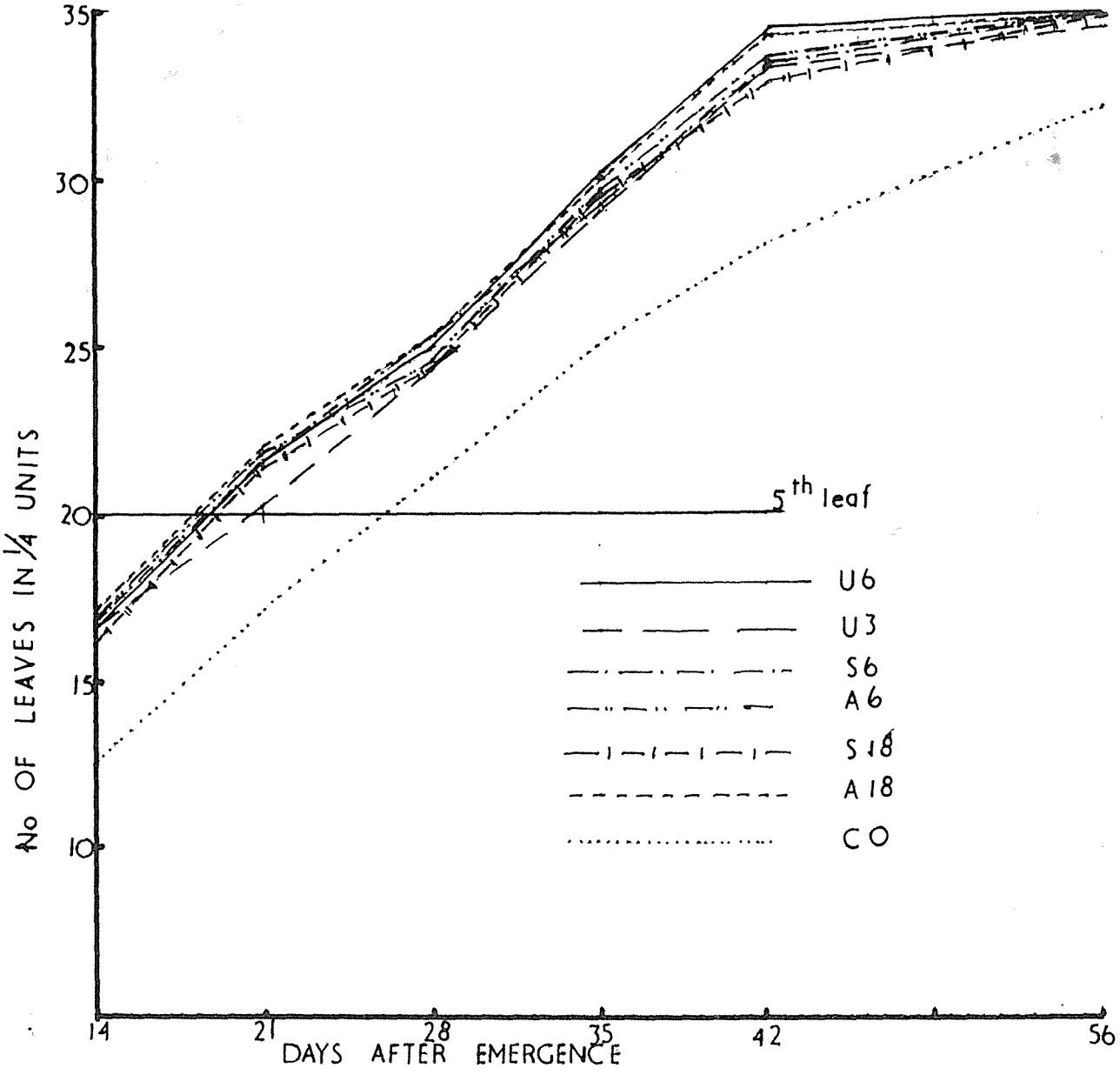
No. of Plants	No. of Leaves per Primary Tiller	No. in the Ru(V) state	No. in the Rd(F) state	% Initiated
8	3	8	0	0.0%
33	4	32	1	3.1%
50	5	1	49	98.0%
9	6	0	9	100.0%

The results indicate that emergence of the fifth leaf can be taken as a reliable criterion for the intitiation of inflorescence. The plant in the 4th leaf Rd(F) state was very near to emerging to the 5th leaf while the 5th leaf plant in the Ru(V) state had just emerged to the 5th leaf.

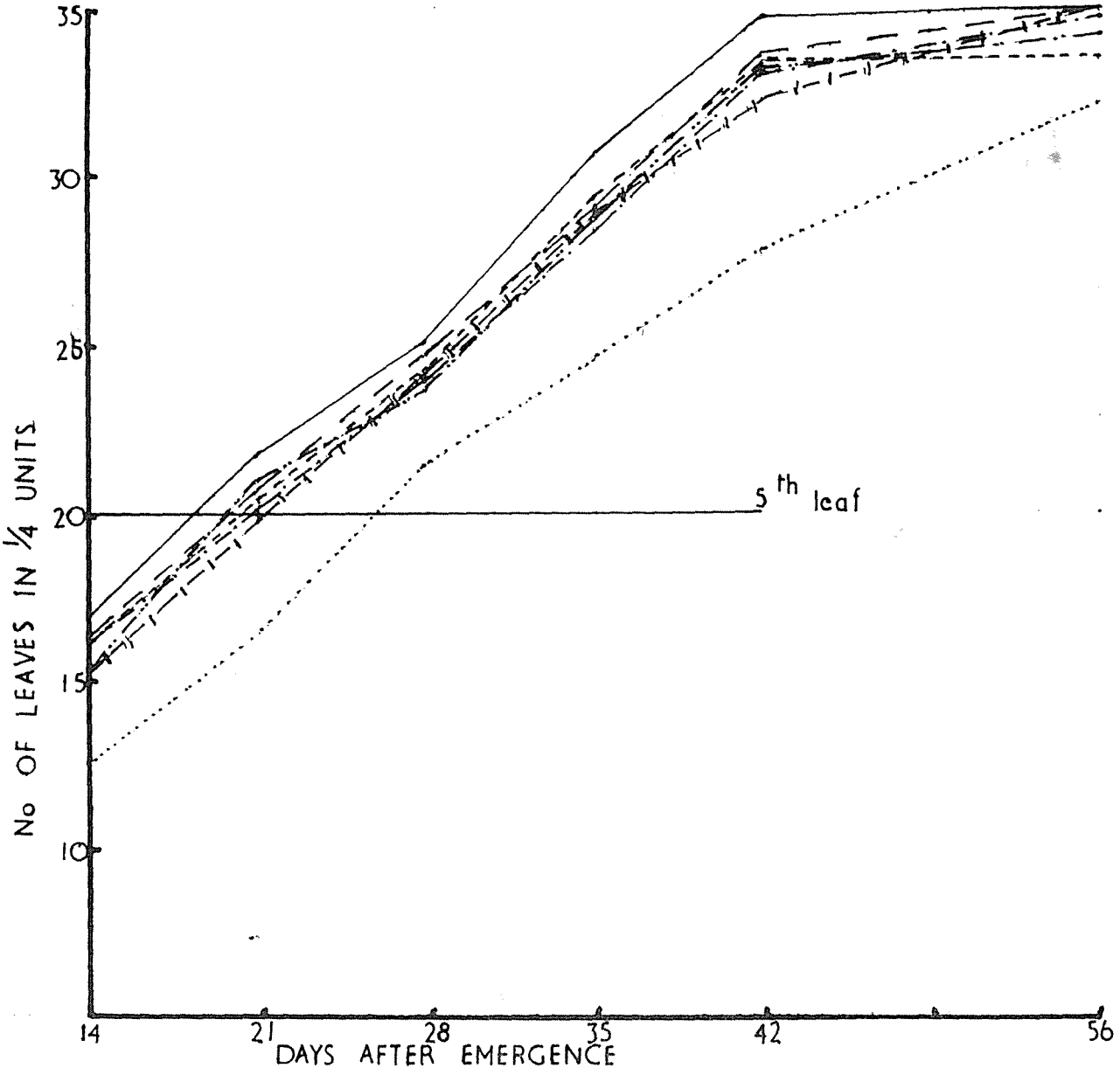
FIGURE .7

Number Of Leaves Per Primary Tiller

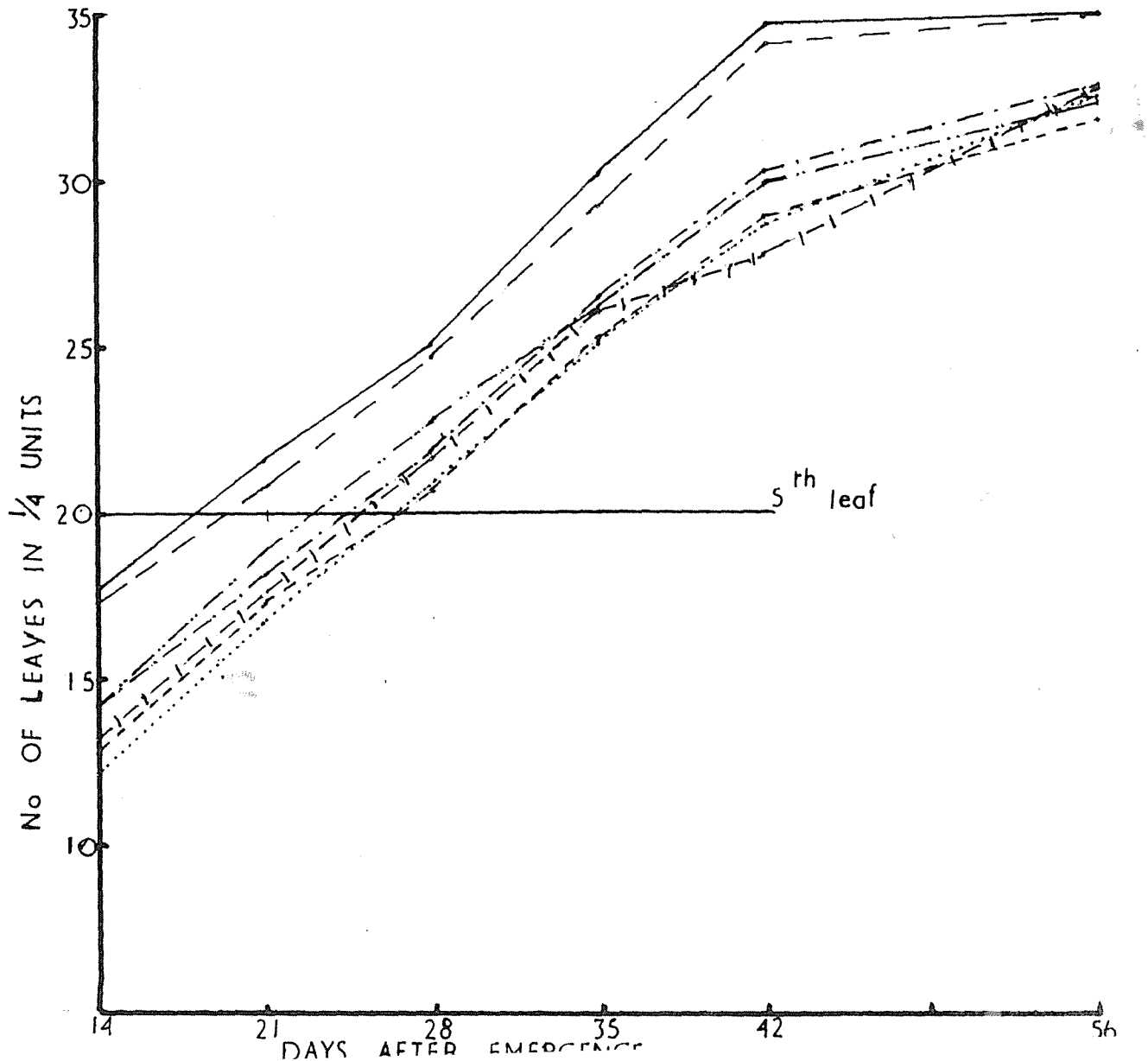
(a) Position F



(b) Position I


35
30
25
20
15
10
No OF LEAVES IN 1/4 UNITS
5th leaf
14
21
28
35
42
56
DAYS AFTER EMERGENCE

(c) Position N


35
30
25
20
15
10
No OF LEAVES IN 1/4 UNITS
5th leaf
14
21
28
35
42
56
DAYS AFTER EMERGENCE

VI NUMBER OF LEAVES PER PRIMARY TILLER

The effect of the treatments on the rate of leaf emergence is shown by the graphs presented in figure 7. The means of the number of leaves in quarter units are plotted for each sampling date (see appendix 4 for further details). These graphs show that all plants in the F and I positions followed a similar pattern of leaf emergence although the I plants were slightly slower. After 42 days the number of leaves on these plants remained constant while the number on the unfertilized plants in the N positions continued to increase. Considering all three graphs collectively indicates the uniformity in rate of leaf emergence. All Co U3 and U6 plants did not vary greatly at any one sampling date while S6, A6, S18 and A18 did. The N plants were 5 - 6 days behind the F plants and 3 - 5 behind the I plants. The differences were not bridged at the final sampling date.

The 5th leaf stage indicated by the horizontal line at 20 units on the x - axis indicates the effect of treatment on the date at which floral initiation occurred. All plants in U3, U6 and those in the F position of S6, A6, S18 and A18 reached this stage at approximately 19 days after emergence. The plants in the I position of S6, A6, S18 and A18 reached it at approximately 20 days, while all the plants of Co did not produce 5 leaves until approximately 26 days and the plants in the N position of S6, A6, S18 and A18 till approximately 23, 22, 24 and 27 days respectively. Therefore the initiation of inflorescence was uniform in Co, U3 and U6 but very uneven in S6, A6, S18 and A18.

A summary of "t" test results is presented in table 4. Further details of the analyses of variance and "t" test results are given in appendices 3 and 4.

Table 4

Summary of "t" test results presented in appendix 4.

Differences significant at the 1% level

Position	14 days	21 days	28 days	35 days	42 days	56 days
F	$Co<U_3U_6S_6A_6S_{18}$	ditto →				
I	$Co<U_3U_6S_6A_6S_{18}$	ditto →				
		$U_6>S_6S_{18}A_{18}$			$U_6>S_{18}$	$U_6>A_{18}$
						$U_3>A_{18}$
N	$Co<U_3U_6S_6A_6$	$Co<U_3U_6$	ditto →			
	$U_3>S_6A_6S_{18}A_{18}$	$U_3>S_6S_{18}A_{18}$	$U_3>S_6A_6S_{18}A_{18}$	ditto →		
	$U_6>S_6A_6S_{18}A_{18}$	ditto →				

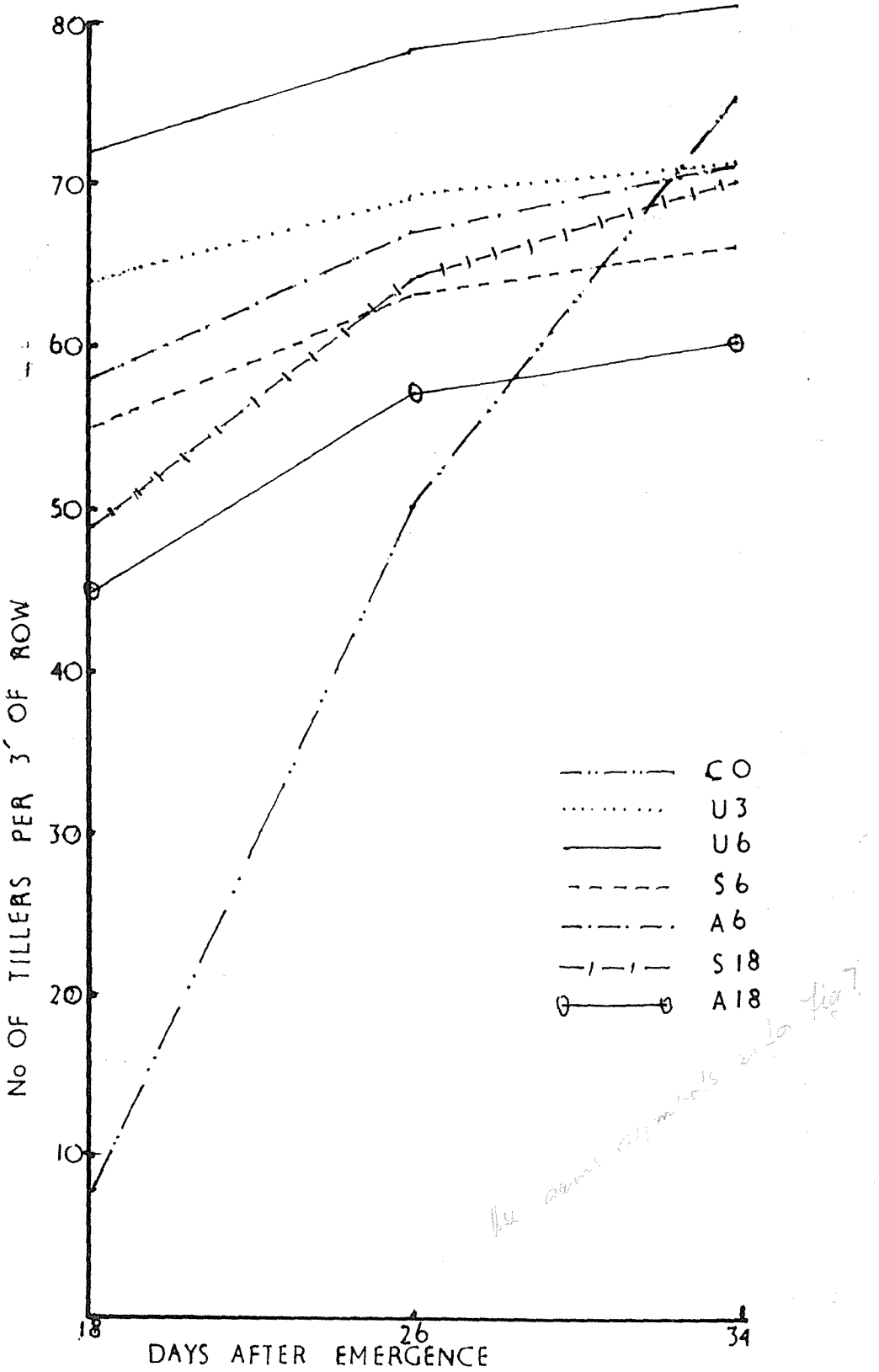
Differences significant at the 5% level only

F		$U_3<A_6$			$U_6>S_{18}$
I	$U_6>A_6S_{18}$		$U_6>S_6A_6$	$U_6>S_6A_6S_{18}$	$U_6>S_6A_6A_{18}$
N	$S_6>A_{18}$	$Co<A_6$	$Co<A_6$	$Co<S_6$	$Co<S_6$
		$U_3>A_6$		$S_6>A_{18}$	

The above results indicate the significance of the relationships drawn from the graphs of figure 7.

FIGURE 8.

Number Of Tillers Per 3feet Of Row



V TILLER COUNTS

(a) per 3 feet of row on 3 sampling dates

(b) per plant in the F I and N positions on 6 sampling dates.

(a) Tillers per 3 feet of row

The mean number of secondary tillers as given in appendix 5 have been plotted in the graphs of figure 8. For all three sampling dates U6 was superior to all other treatments. The Co treatment was significantly poorer (at 1%) on the first sampling, but at the final sampling its number of tillers was significantly greater (at 5%) than A18 and not significantly different from all other treatments. Apart from Co all treatments produced a similar pattern of tiller emergence. The S18 and A18 treatments were generally lower than U3, U6, and A6 during the period of measurement. A summary of the "t" test results obtained from the means is given in table 5.

Table 5

Summary of the "t" test results presented in Appendix 5 (3)

Differences significant at the 1% level		
Sampling Date - days after emergence		
18 days	26 days	34 days
Co < U3 U6 S6 A6 S18 A18	Co < U6	U6 > S18 A18
U3 > S18 A18	U6 > A18	
U6 > S6 A6 S18 A18		
S6 > A18, A6 > A18		
Differences significant at the 5% level only		
A6 > S18	Co < U3 A6	Co > S18 A18
	U6 > S6	U6 > S6

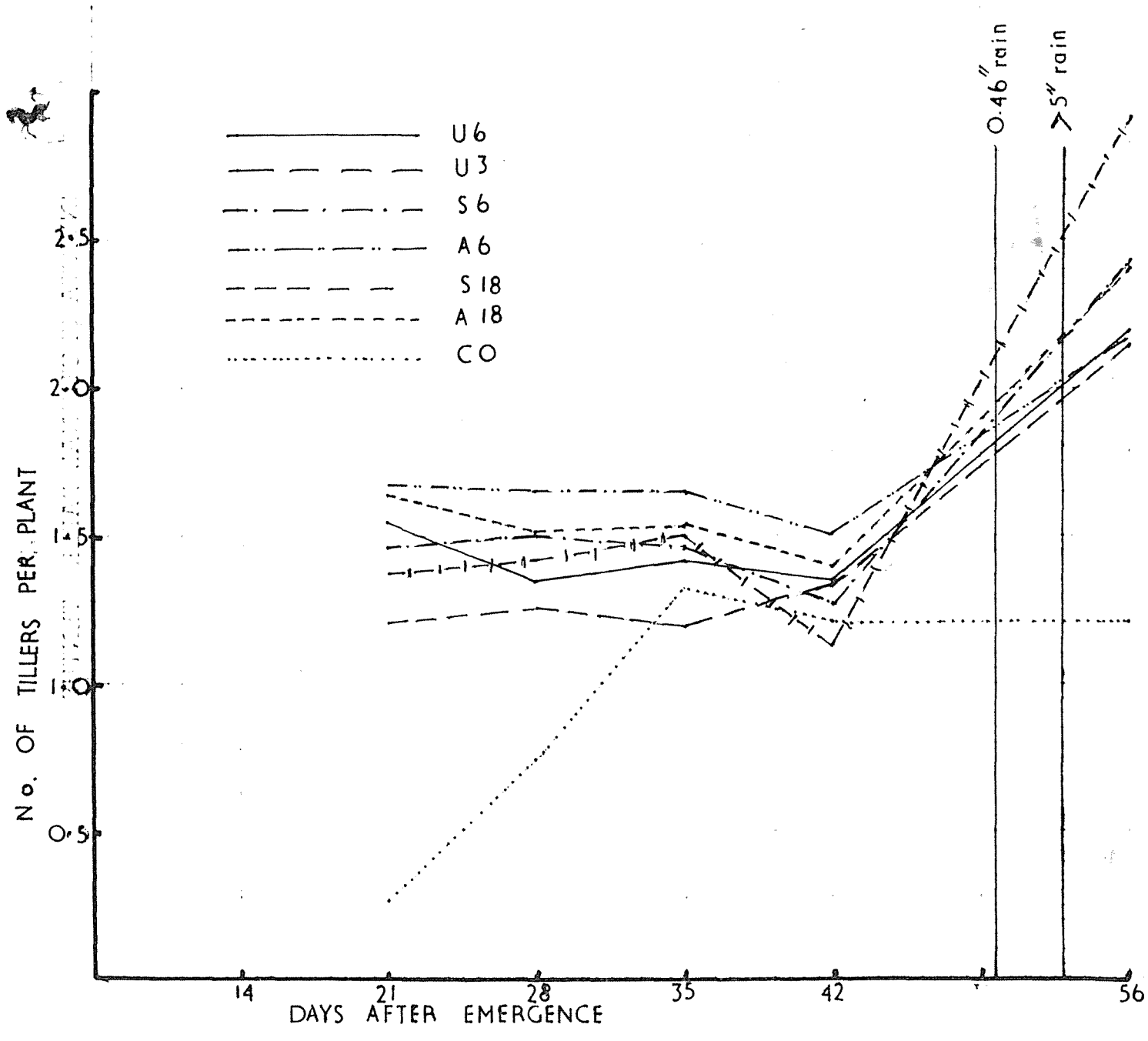
Measurement on a 3 feet section of row was discontinued 34 days after emergence due to the difficulty encountered in distinguishing secondary from the primary tillers on the fertilized plants.

Further details of the analyses of variance and "t" tests for the number of secondary tillers per 3 feet of row appear in appendix 5.

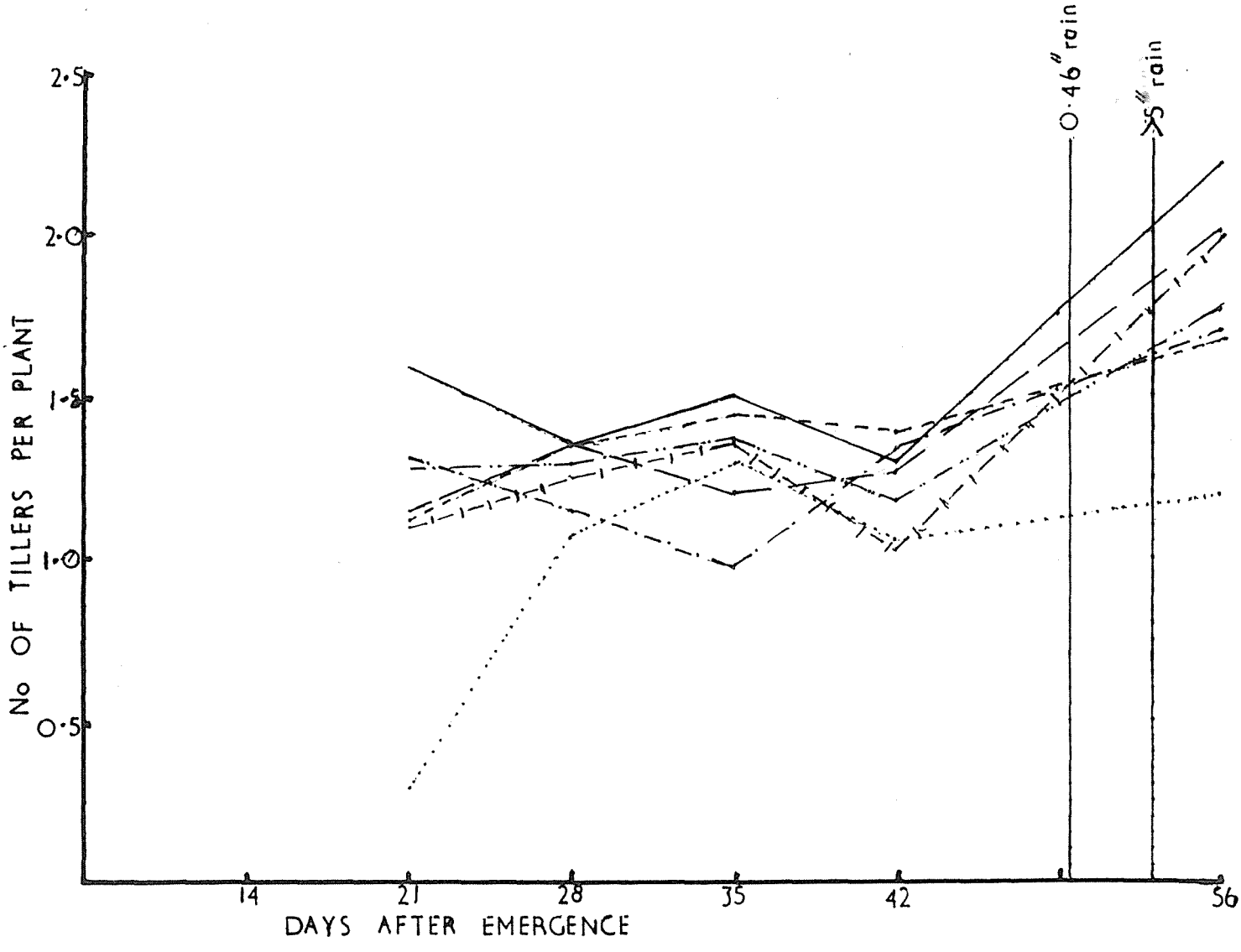
FIGURE .9.

Number Of Tillers Per Plant

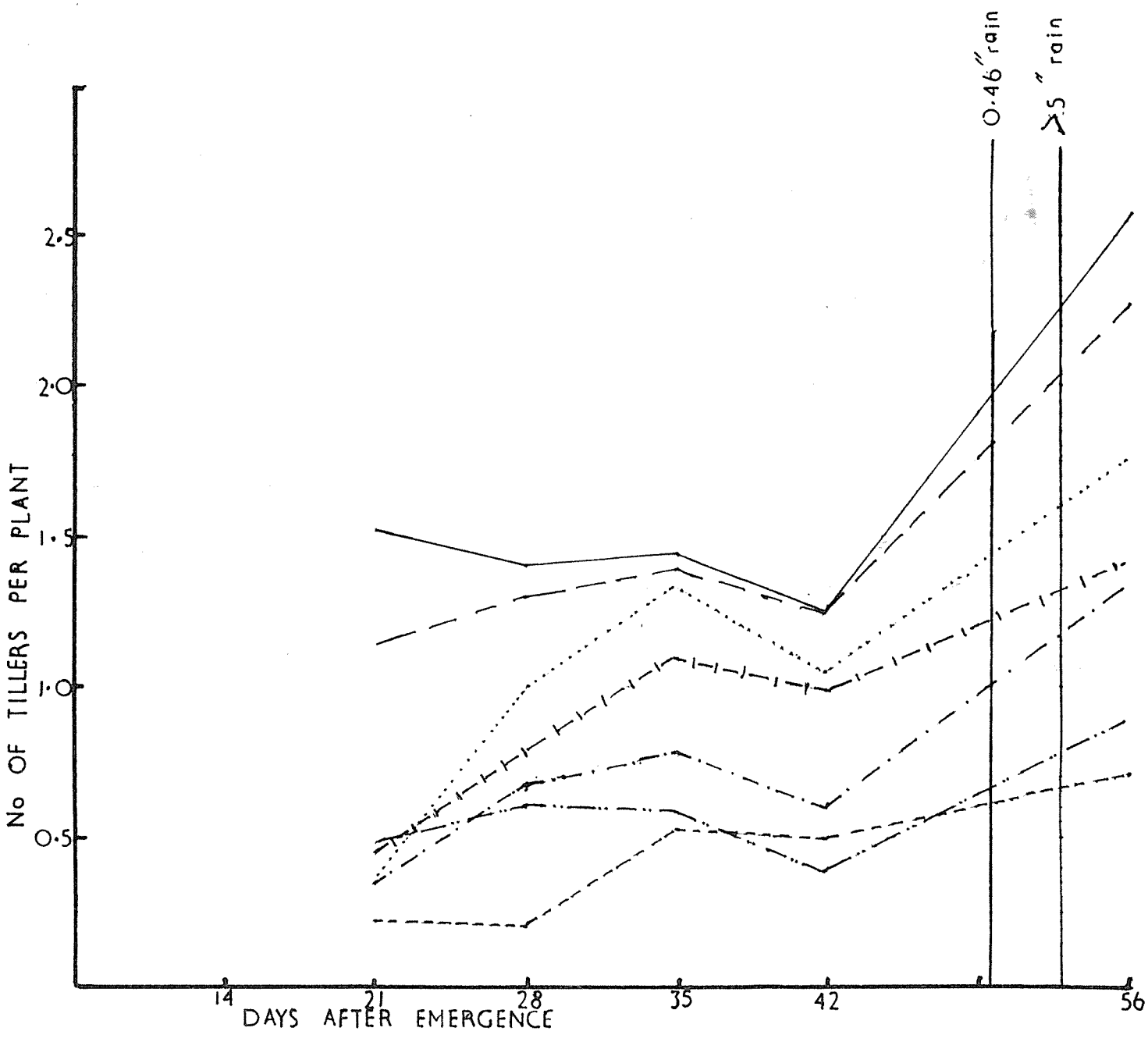
(a) Position F



(b) Position I


2·5
2·0
1·5
1·0
0·5
No OF TILLERS PER PLANT
0·46" rain
>5" rain
14
21
28
35
42
56
DAYS AFTER EMERGENCE

(c) Position N


0·46" rain
≥.5 " rain
2·5
2·0
1·5
1·0
0·5
No OF TILLERS PER PLANT
14
21
28
35
42
56
DAYS AFTER EMERGENCE

(b) Tiller counts per plant in the F I and N position

The number of secondary tillers per plant measurement commenced just prior to the second sampling for the number per 3 feet of row. The means of 30 samples per treatment in each of the F I and N positions are plotted for each sampling date in the graphs of figure9.

All plants receiving fertilizer developed more tillers per plant in the earlier stages of growth than those unfertilized. The U3 plants were slightly poorer tillerers than those receiving 6 cwt per acre in U6 and the F position of S6, A6, S18 and A18. The general pattern of tillering for the fertilized plants was similar in all cases with a stable period from 21 days till 35 days after emergence, a depression at 42 days and a marked increase at 56 days. The plants in the I position of S6, A6, S18 and A18 were slightly poorer tillerers than the F position plants. The only marked differences in the F and I positions occurred on the first sampling date when Co, U3, S18 and A18 were poorer than U6, S6 and A6 and at the final sampling when Co was poorer than all other treatments and S18 was better than U6, U3 and A6 in tiller production. The same general pattern applies for I plants as for F, the Co plants being poorer at the first and last sampling dates. The unfertilized plants were all lower than U3 and U6 at first and only Co and the N plants of S18 showed any marked increase over the measurement period. The pattern of tillering for these unfertilized plants shows a marked increase until the 35 days sampling date and then a similar depression at 42 days as with all the fertilized ones and an increase at 56 days.

A summary of the "t" test results is presented in table 6. Further details of analyses of variance, means and "t" test results appear in appendix 6 and 7.

Table 6

Summary of the "t" test results presented in Appendix 7(6) for number of secondary tillers per plant.

Position	21	28	35	42	56
Differences significant at the 1% level					
	Days after emergence				
F	$Co < U_3U_6S_6A_6S_{18}A_{18}$	$Co < U_6S_6A_6S_{18}A_{18}$			$Co < U_3U_6S_6A_6S_{18}A_{18}$
I	$Co < U_3U_6S_6A_6S_{18}A_{18}$ $U_3 < U_6$ $U_6 > S_{18}A_{18}$				$Co < U_3U_6S_{18}$
N	$Co < U_3U_6$ $U_3 > S_6A_6S_{18}A_{18}$ $U_6 > S_6A_6S_{18}A_{18}$	$Co > A_{18}$ $U_3 > S_6A_6A_{18}$ $U_6 > S_6A_6S_{18}A_{18}$	$Co > A_6A_{18}$ $U_3 > S_6A_6A_{18}$ $U_6 > S_6A_6A_{18}$	$Co > A_6$ $U_3 > S_6A_6A_{18}$ $U_6 > S_6A_6A_{18}$	$Co > A_6A_{18}$ $U_3 > S_6A_6S_{18}$ $U_6 > S_6A_6S_{18}A_{18}$
Differences significant at the 5% level only					
F	$U_3 < A_6A_{18}$	$U_3 < A_6$	$U_3 < A_6$	$A_6 > S_{18}$	$U_3 < S_{18}$ $U_6 < S_{18}$ $A_6 < S_{18}$
I			$U_6 > S_6$ $S_6 < A_{18}$	$Co < S_6A_{18}$ $S_6 > S_{18}$ $S_{18} < A_8$	$Co < A_6$
N		$U_3 > S_{18}$ $S_6 > A_{18}$ $S_{18} > A_{18}$	$Co > S_6$ $A_6 > S_{18}$ $S_{18} > A_{18}$	$Co > S_6A_{18}$ $S_{18} > A_{18}$	$S_6 > A_{18}$ $S_{18} > A_{18}$

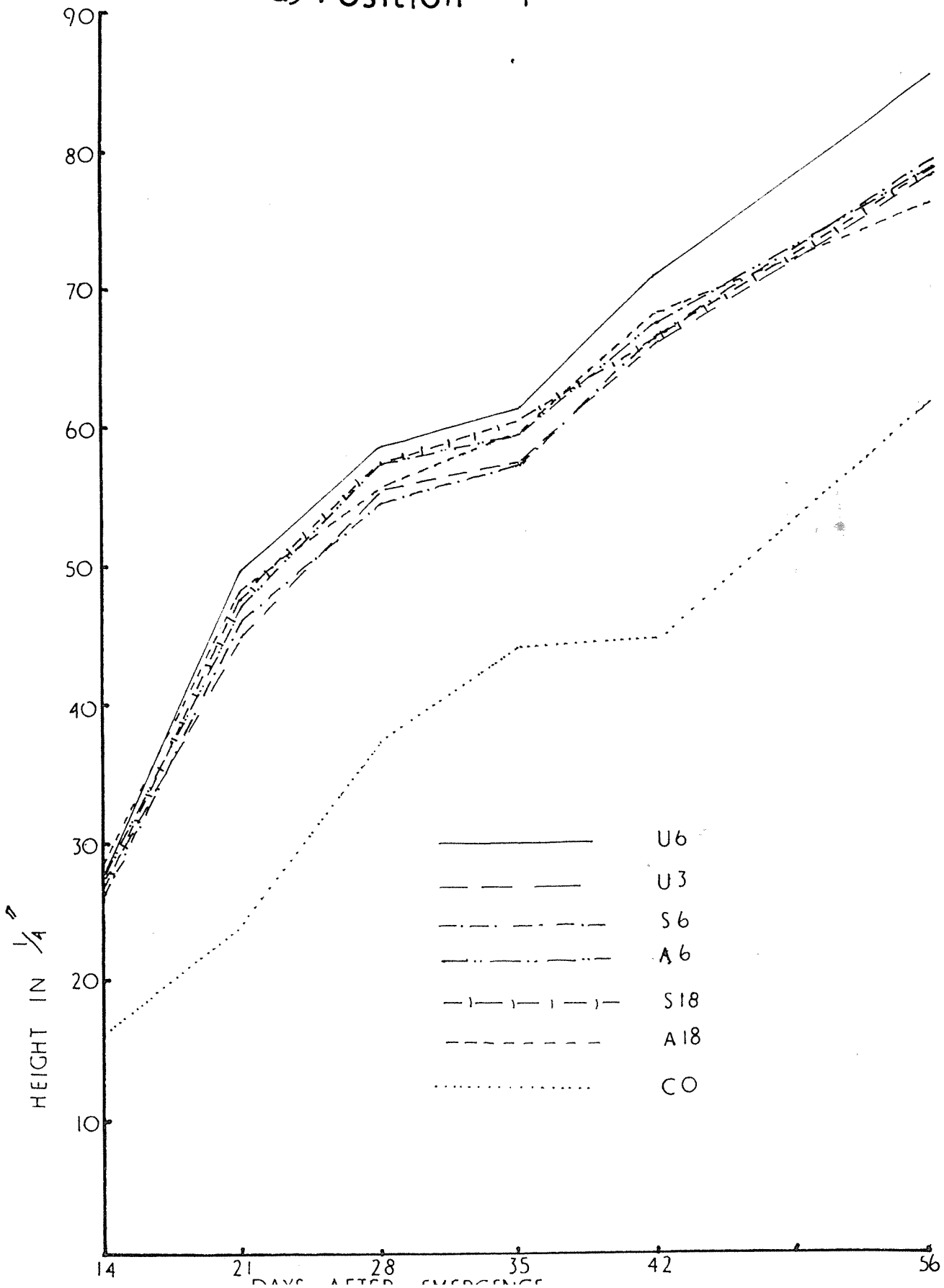
Table 6 indicates that all fertilized plants possessed significantly more tillers (at 1%) than the unfertilized ones at the first three measurements, and A6 plants were much better (at 5%) than the U3 plants in the F position. After the first sampling Co plants developed a significantly greater number of tillers (at 1%)

than those in the N position of A6 and A18. The A18 treatment was a significantly poorer tillerer (at 5%) than S18 for all measurements except the first. Plants in the I position of S6, A6, S18 and A18 demonstrated an intermediate trend very similar to U3.

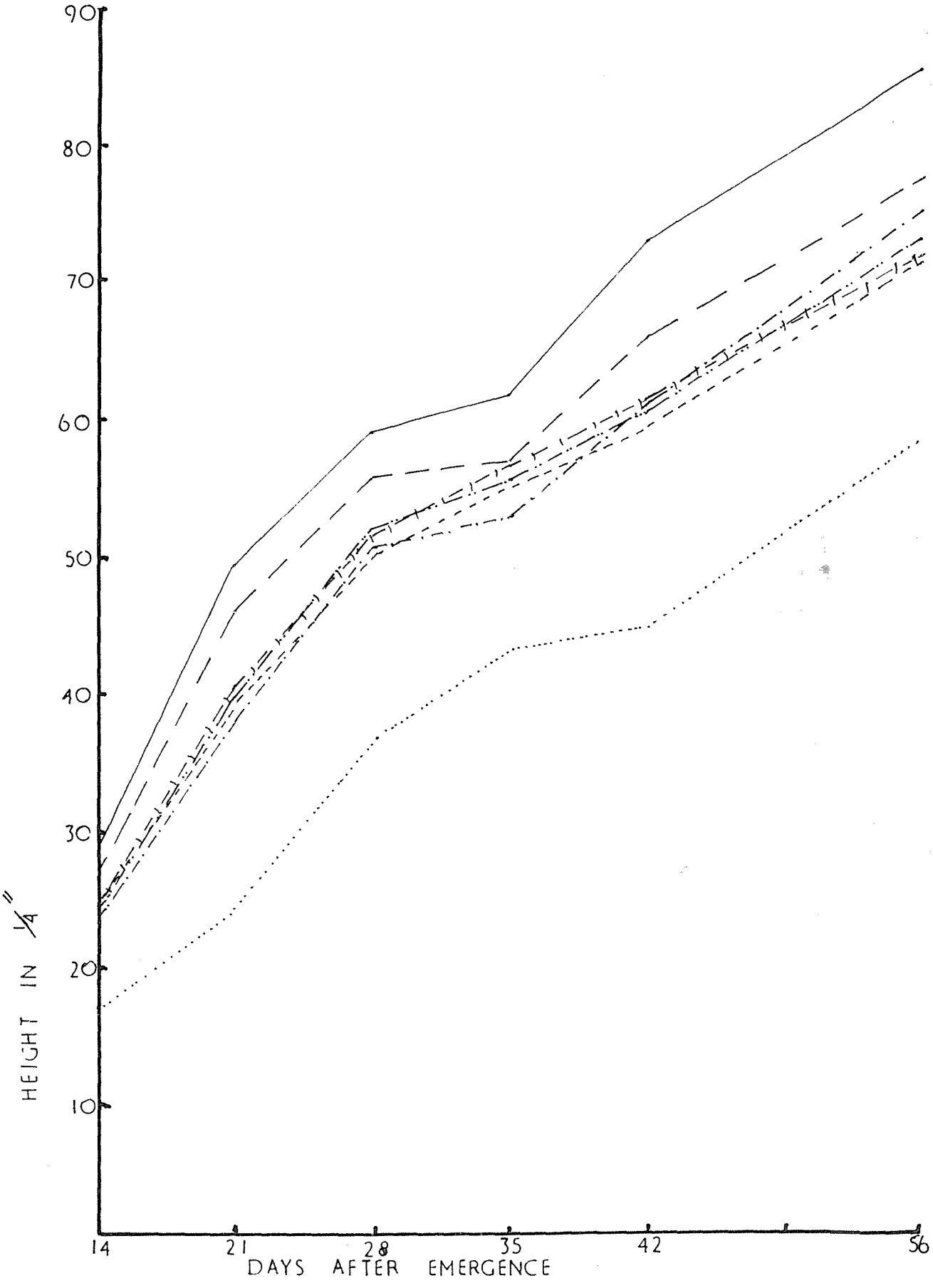
FIGURE 10

Height Measurements Per Plant In 1/4"

(a) Position F



(b) Position I


90
80
70
60
50
40
30
20
10
HEIGHT IN 1/4"
14
21
28
35
42
56
DAYS AFTER EMERGENCE

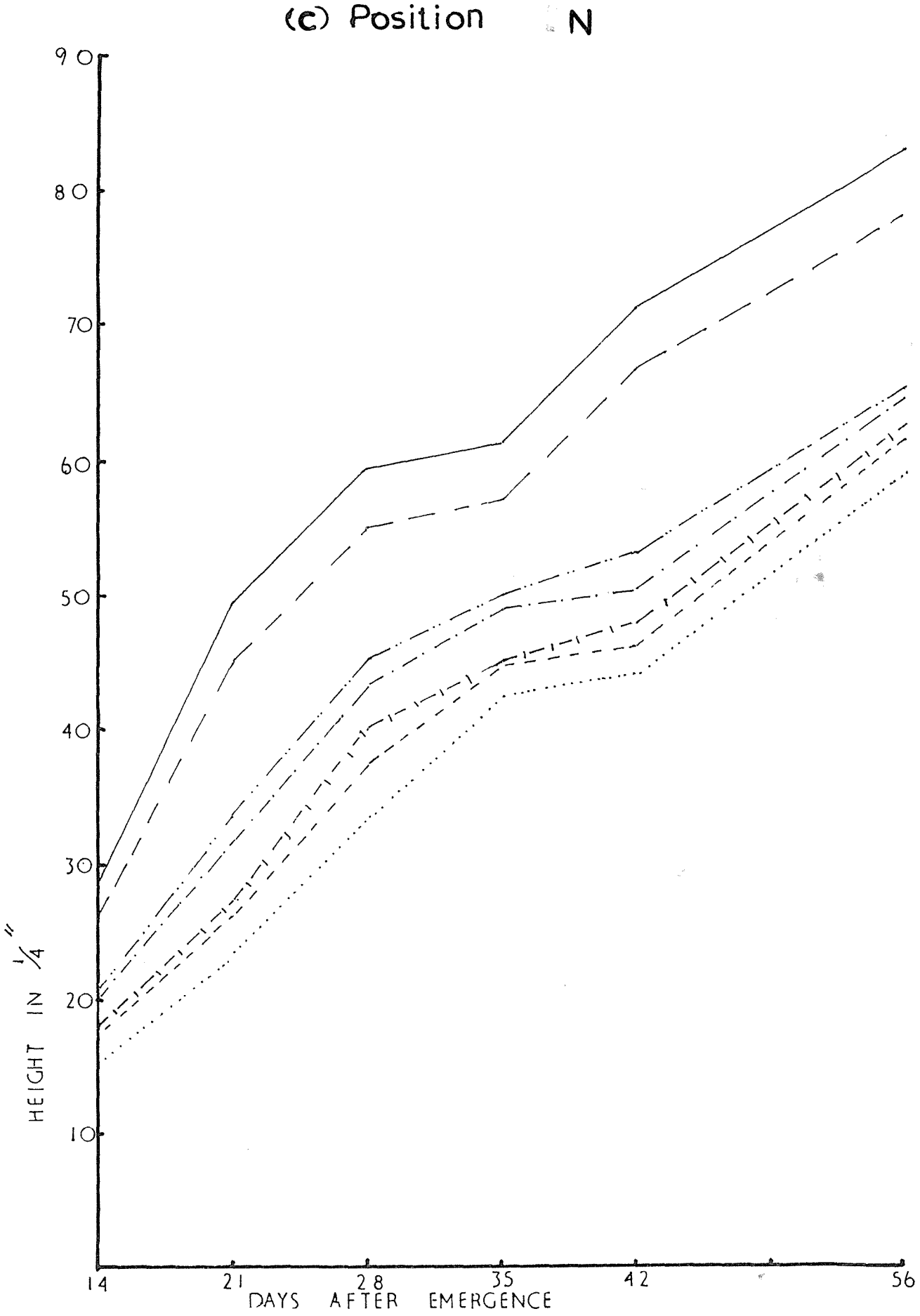
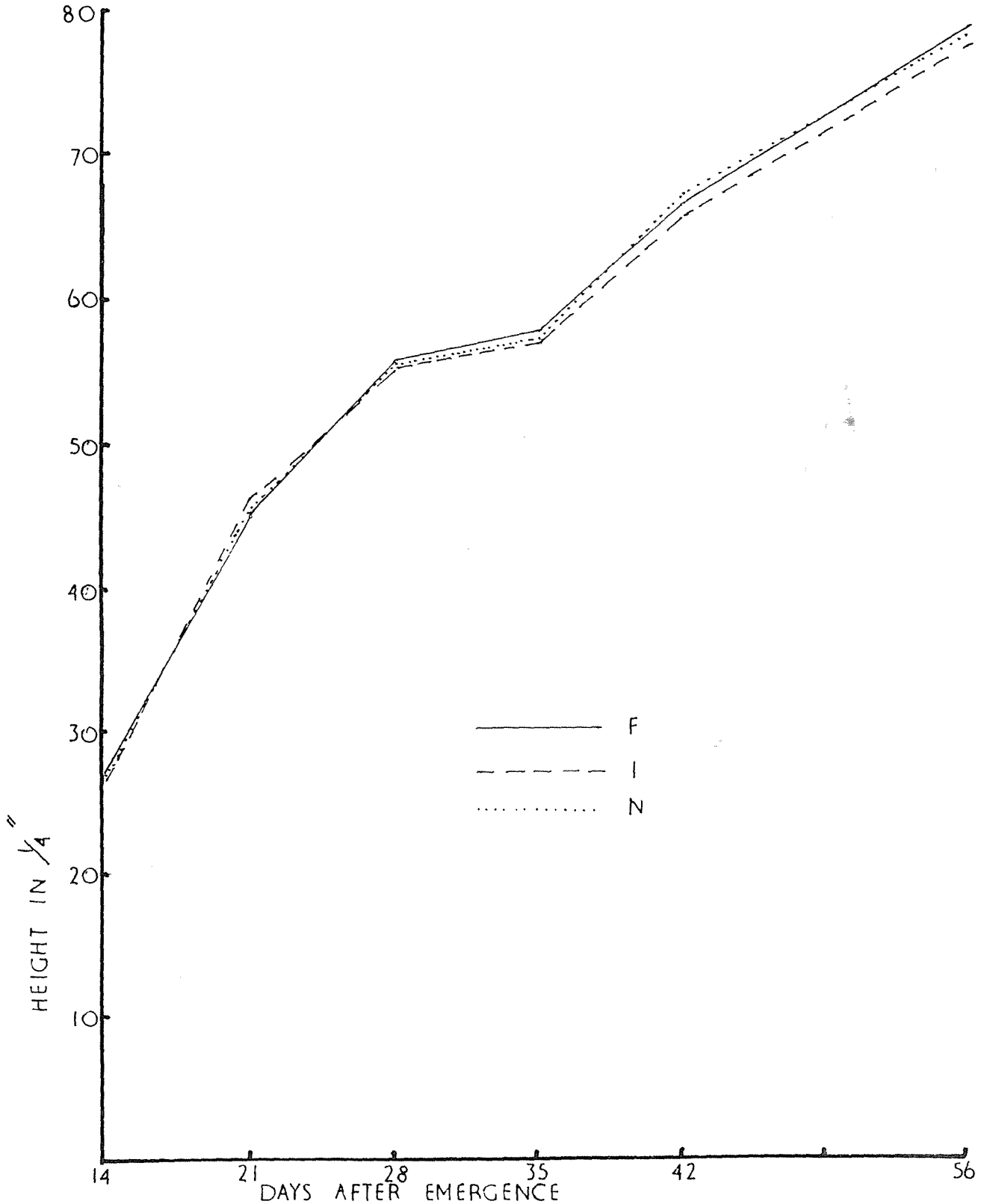

(c) Position N
90
80
70
60
50
40
30
20
10
HEIGHT IN 1/4"
14
21
28
35
42
56
DAYS AFTER EMERGENCE

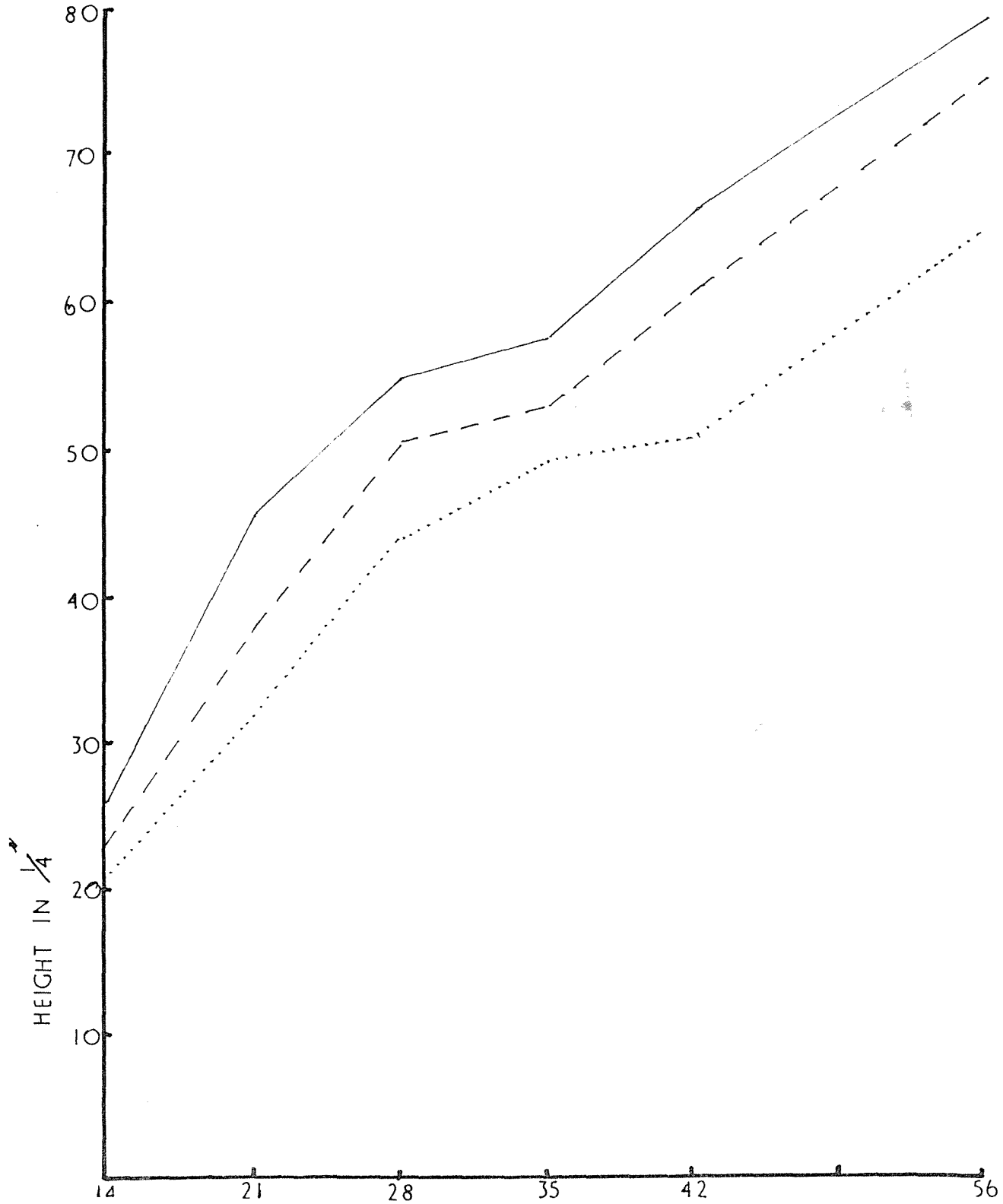
FIGURE .11.

Height Measurements Per Plant In 1/4"

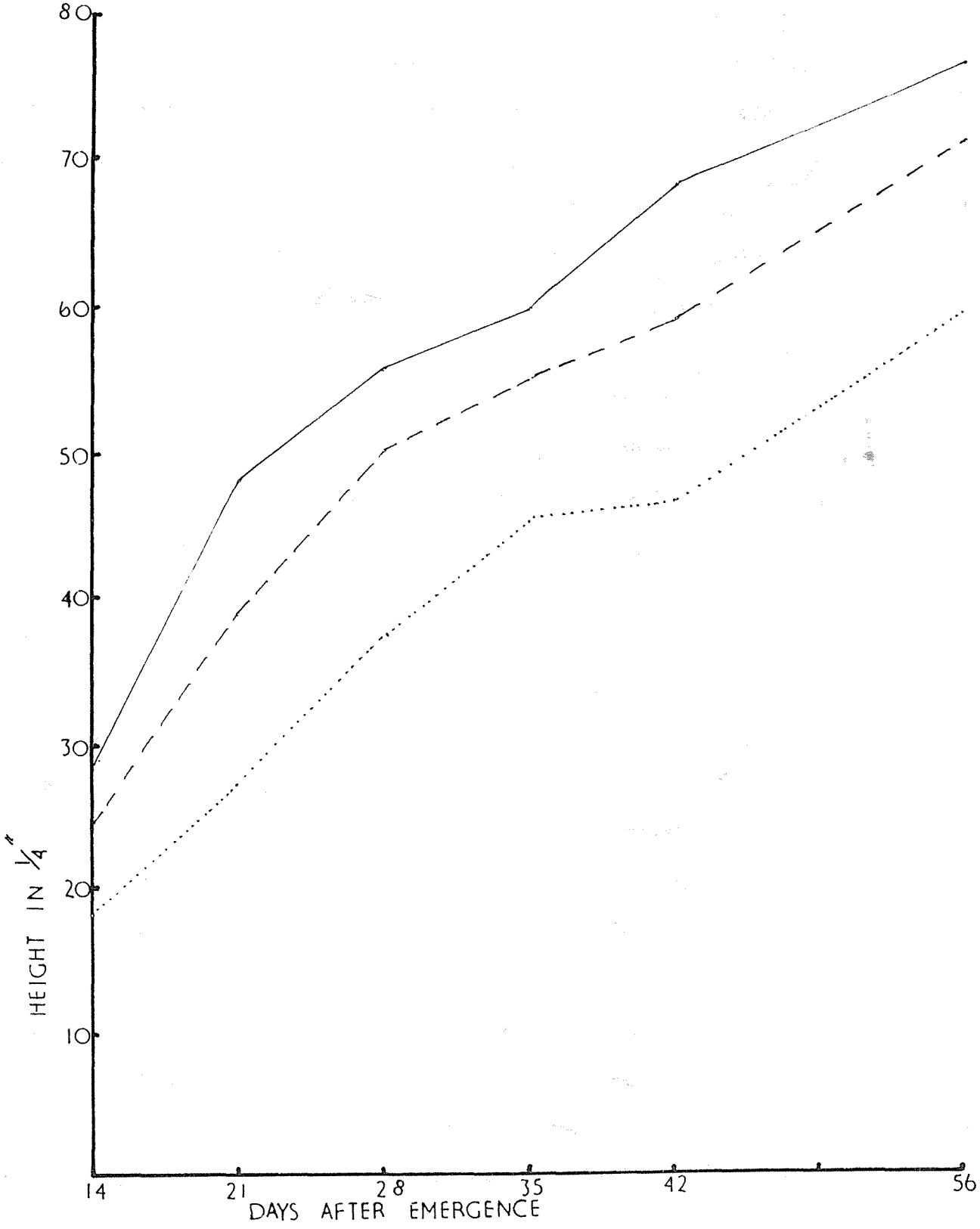
(a) U3



(b) S 6



(c) A 18


80
70
60
50
40
30
20
10
HEIGHT IN 1/4"
14
21
28
35
42
56
DAYS AFTER EMERGENCE

VI HEIGHT MEASUREMENTS

These measurements were taken concurrently with those of the number of leaves per primary tiller and number of secondary tillers per plant in the F I and N positions. The means of 30 samples per treatment at each sampling date are plotted for each position in figure 10, the x axis being calibrated in ½" units as presented in the analyses of variance in appendix 8.

The growth of all fertilized plants in terms of height was greater and faster than those unfertilized. The I position plants of S6, A6, S18 and A18 were slighlty slower and did not reach the same height as those in the middle of a fertilized zone, but were better than the unfertilized plants.

There are three phases in the pattern of height increase over the period of measurement

(1) a rapid increase in height followed by

(2) a period of slow growth and

(3) a final rapid increase in height.

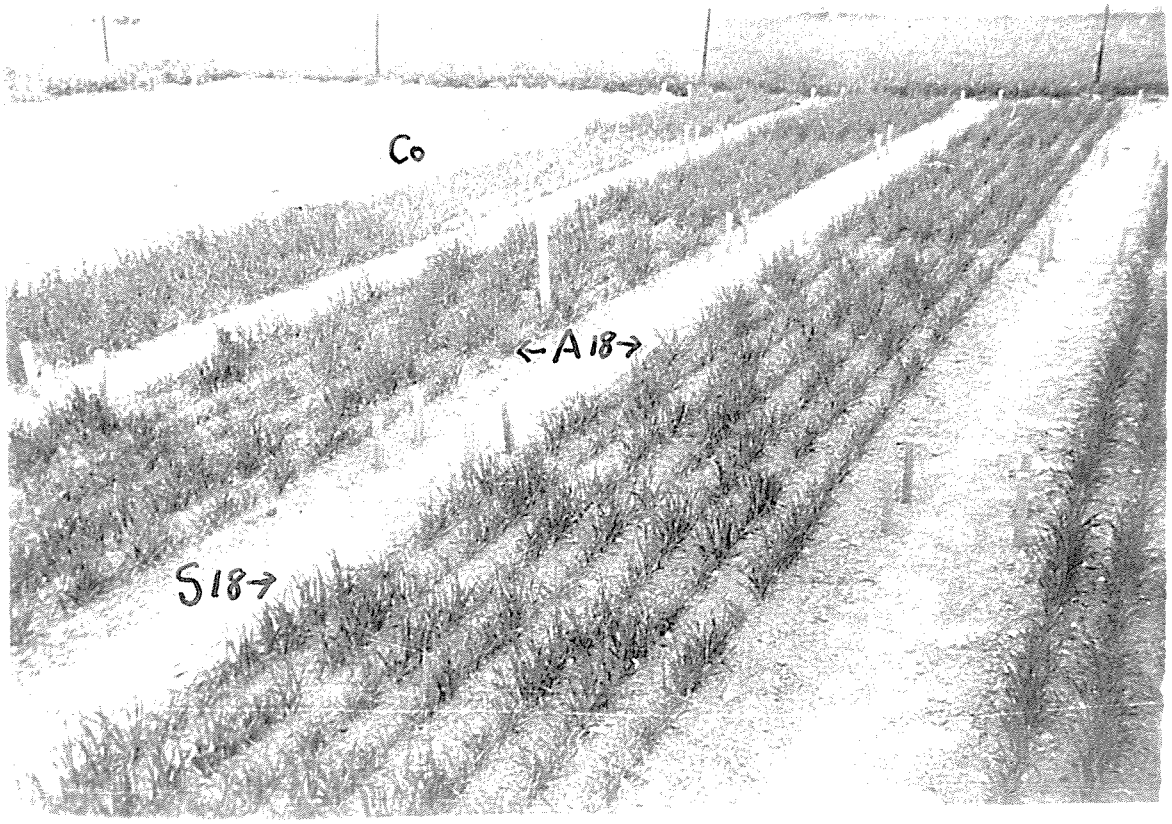
The fertilized plants and those in the I position of A6, S6, S18 and A18 completed the first phase by 28 days with the second phase lasting until 35 days when the final phase commenced. The unfertilized plants took till 35 days to complete phase (1) and did not commence phase (3) until 42 days.

The uniformity of growth pattern is illustrated by the graphs in figure 11 representing U3, S6 and A18. Treatment U3 was extremely uniform while S6 gave a moderate unevenness in height (maximum difference of the means 3.9") and A18 was extremely uneven in height (maximum difference of the means 5.5"). The S6 and A18 treatments did not complete the three phases described above as uniformly as U3.

Figures 12, 13, 14, 15 and 16 are a series of photographs illustrating the various treatments from 12 days till 57 days after emergence when a majority of plants had completed heading. There is a definite colour difference between fertilized and unfertilized plants as well as height differences being evident

FIGURE 12

(a) A18 12 Days After Emergence



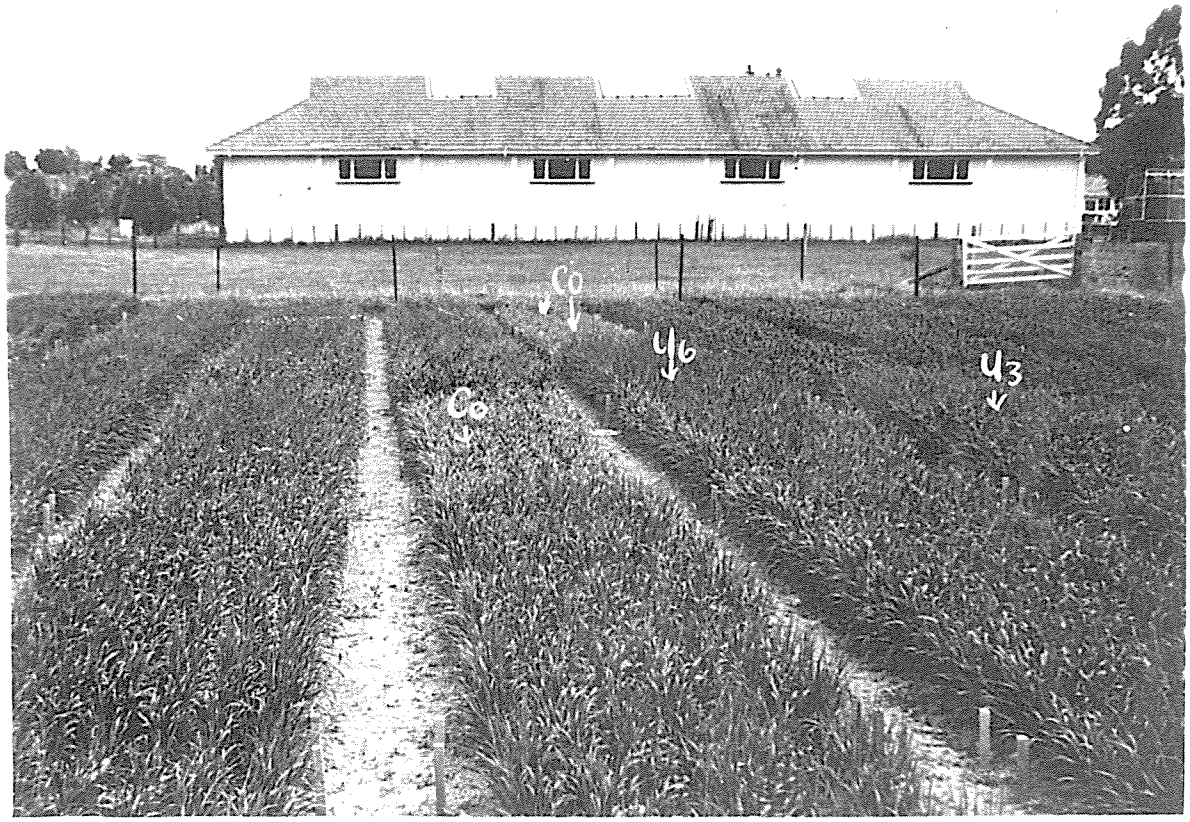
(b) A18 12 Days After Emergence
Co + S18

FIGURE 13

(a) The Whole Trial 16 Days After Emergence

(b) S18 and A6 At 16 Days

FIGURE 14



(a) Co, U6 and U3 37 Days After Emergence

(b) S18 At 37 Days.

FIGURE 14

(c) Close Up Of S18 At 37 Days

FIGURE 15

(a) U3 And A6 55 Days After Emergence

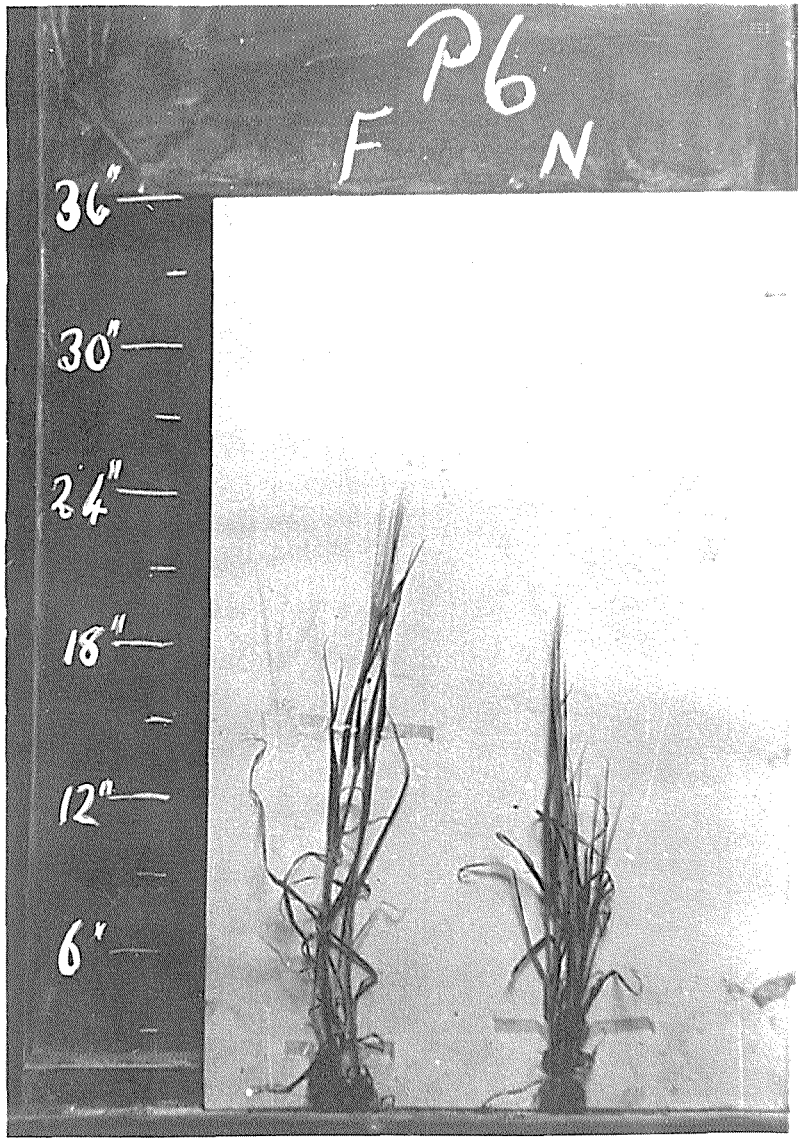
FIGURE 15

(b) S18 and A6 At 55 Days

(c) A18 At 55 Days

FIGURE 16

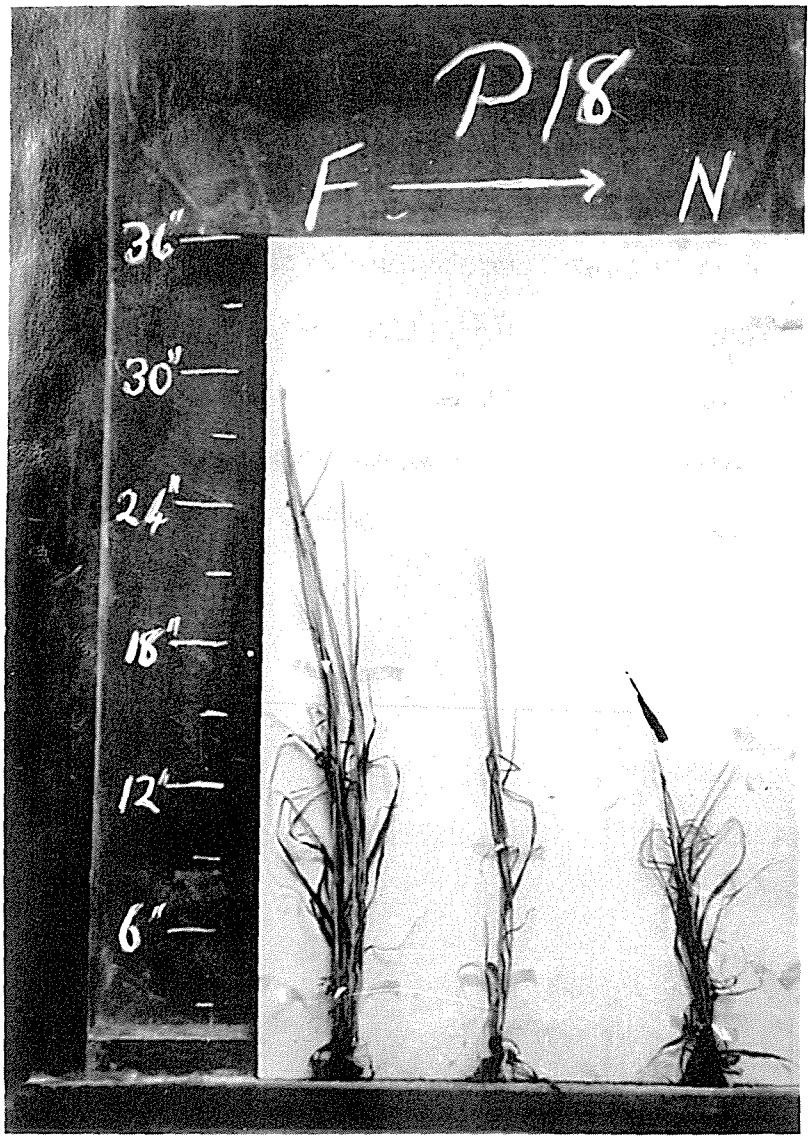
(a) Random Plants of U6, U3 and Co At 57 Days



(b) Random Plants of P6 (S6 and A6) At 57 Days

P_6 = Periodic 6" gaps - a combination of S_6 & A_6.

FIGURE 16



(c) Random Plants of P18 (S18 and A18) At 57 Days

P_{18} = Periodic 18" gaps - a combination of S_{18} & A_{18}

(d) S18 57 Days After Emergence

especially in the S18 and A18 plots. The differences are more pronounced in the earlier photographs but are still present in figure 16. In figure 14 the fertilized plants are beginning to shoot while the unfertilized plants are purely vegetative. Heading is well advanced in the fertilized plants in figures 15 and 16 while the unfertilized ones are only in the early shooting stage. The S18 and A18 plots demonstrate a great variability in height shooting and heading. Note the undulations of S18 in line across the plots while those in A18 plots create a diagonal strip effect.

A summary of results of the "t" tests on height per plant is presented in table 7. Further details of the analyses of variance, means and "t" test results appear in appendices 8 and 9.

Table 7

Summary of the "t" test results presented in Appendix 9 (7) for the height measurements.

Position	Days after emergence: 14	21	28	35	42	56
Difference significant at the 1% level						
F	$Co < U_3U_6S_6A_6S_{18}A_{18}$	ditto →				
I	$Co < U_3U_6S_6A_6S_{18}A_{18}$	ditto →				
	$U_3 > S_6$	$U_3 > S_6A_6A_{18}$	$U_6 > S_6A_{18}$	$U_6 > S_6$	$U_6 > S_6A_6S_{18}A_{18}$	$U_6 > A_{18}$
	$U_6 > S_6A_6S_{18}A_{18}$	ditto →				
N	$Co < U_3U_6S_6A_6$	$Co < U_3U_6A_6$	$Co < U_3U_6S_6A_6$	$Co < U_3U_6$	ditto →	
	$U_3 > S_6A_6S_{18}A_{18}$	ditto →		$U_3 > S_{18}A_{18}$	$U_3 > S_6A_6S_{18}A_{18}$	ditto →
	$U_6 > S_6A_6S_{18}A_{18}$	ditto →				
Differences significant at the 5% level only						
F						$U_6 > A_{18}$
I	$U_3 > A_6S_{18}A_{18}$	$U_3 > S_{18}$	$U_6 > A_6S_{18}$	$U_6 > A_{18}$	$U_3 > A_{18}$ $U_3 < U_6$	$U_6 > S_6A_6S_{18}$
N	$Co < S_{18}$	$Co < S_6$	$A_6 > A_{18}$	$Co < A_6$	$Co < A_6$	
	$S_6 > A_{18}$	$A_6 > S_{18}A_{18}$		$U_3 > S_6A_6$		
	$A_6 > A_{18}S_{18}$					

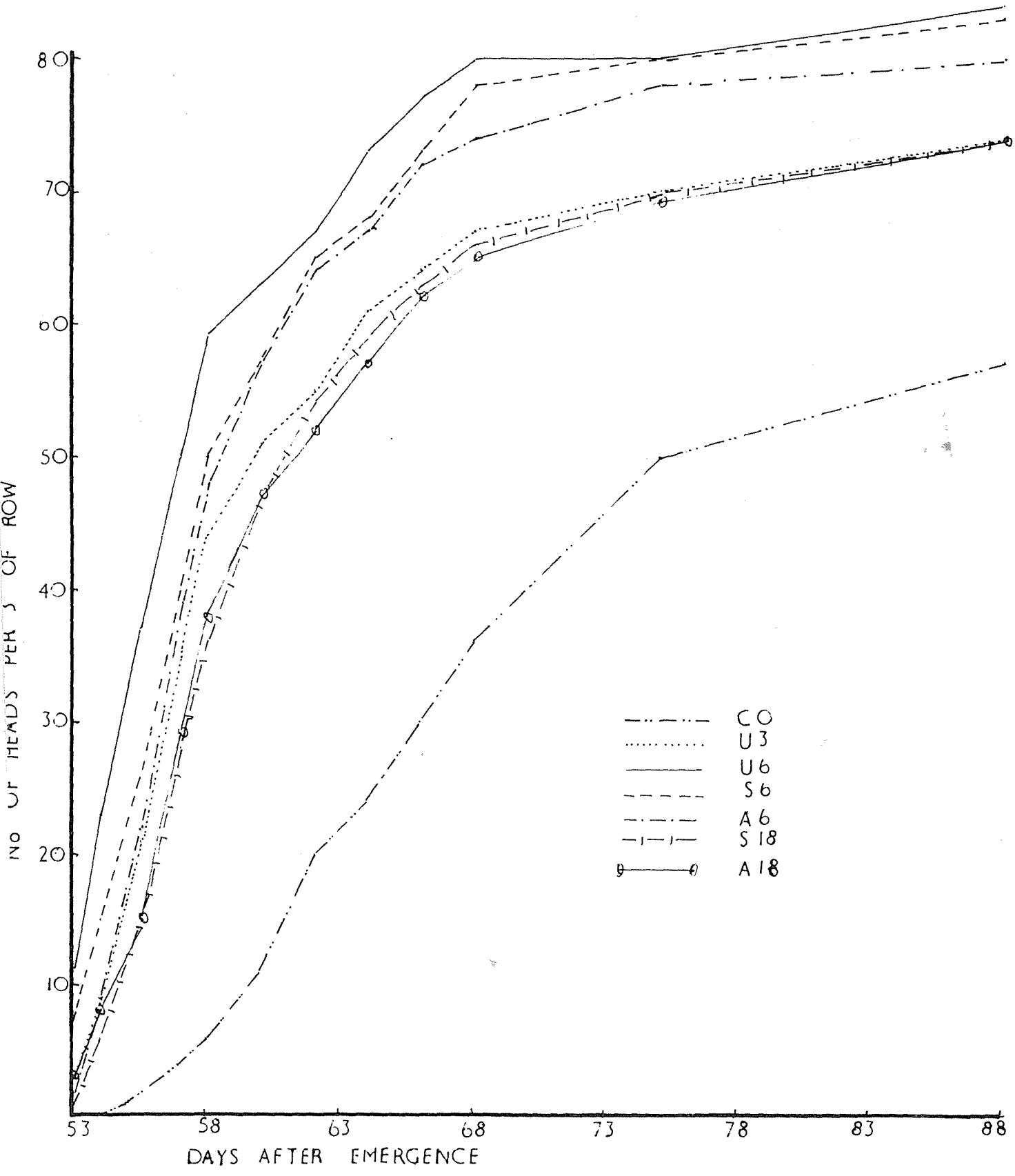
From table 7 it can be seen that the Co plants were significantly shorter (at 1%) than all plants in the F and I positions over the entire period of measurement. The unfertilized plants of S6 and A6 were significantly taller (at 1%) than all the other unfertilized plants up until 35 days after emergence, after which A6 only maintained a significant difference at the 5% level. All unfertilised plants did not differ significantly in height at the final sampling. The significant difference between A6 and A18 (at 5%) disappeared after the 28 days sampling and U3 plants were only significantly taller than those in the I position of S6, A6,

S18 and A18 treatments at the first two samplings.

All unfertilized plants of Co_3 $S6_3S18$ and A18 in the N position were significantly shorter than U3 and U6 plants at all sampling dates.

FIGURE .17.

Number Of Heads Per 3feet Of Row



VII HEADING COUNTS

The effect of the treatments on heading is illustrated by figure 17 graphing the mean number of heads per 3 feet of row at each sampling date from figures given in appendix 10. The control, Co, was definitely slower and poorer in its heading rate, not even reaching an average of 60 heads per 3 feet of row at the final sampling date. The patterns and rates of U3, S18 and A18 were almost identical, with the S18 and A18 tending to be slightly lower. The U6, S6 and A6 treatments were grouped together, with S6 and A6 slightly slower and lower in their heading rate, but much better than the other three fertilized treatments which received the same quantity of fertilizer. There was, however, no great difference between all the 3 cwt per acre treatments until after the sampling at 55 days after emergence. The graph also shows that after the beginning of heading there was a rapid increase for 10 days in all treatments but control, Co, which demonstrated a much more gradual build up in number of heads per 3 feet of row.

The results of applying the "t" test to the means is summarised in table 8. Further details of analyses of variance, means and "t" test results appear in appendix 10.

Table 8

Summary of the "t" test results presented in Appendix 10 (3) for number of heads emerged per 3 ft of row

Days after Emergence	Differences
Differences at the 1% level	
53	$U_6 > A_6 S_{18}$
54	$Co < U_6 S_6$. $U_3 < U_6$* $U_6 > A_6 S_{18} A_{18}$
55	$Co < U_3 U_6 S_6 A_6 S_{18} A_{18}$. $U_3 < U_6$* $U_6 > A_6 S_{18} A_{18}$
57	" . " . $U_6 > S_{18} A_{18}$* $S_6 > S_{18}$
58	" . " . " . $S_6 > S_{18} A_{18}$. $A_6 > S_{1}$
60	" . " . " .
62	" . $U_6 > A_{18}$.
64	" . $U_6 > A_{18}$*
66	" .
68	" . $U_6 > A_{18}$*
75	" .
88	" .
Differences at the 5% level	
53	$U_3 < U_6$* $U_6 > A_{18}$
54	-
55	$U_6 > S_6$* $S_6 > S_{18} A_{18}$
57	" $S_6 > A_{18}$* $A_6 > S_{18} A_{18}$ $U_6 > A_6$
58	" $A_6 > A_{18}$* $U_6 > A_6$
60	$S_6 > S_{18} A_{18}$* $A_6 > S_{18} A_{18}$
62	$U_3 < U_6$* $U_6 > S_{18}$* $S_6 > S_{18} A_{18}$* $A_6 > A_{18}$
64	$U_3 < U_6$* $U_6 > S_{18}$*
66	$U_6 > A_{18}$
68	$U_3 < U_6$* $U_3 < S_6$* $U_6 > S_{18}$* $S_6 > S_{18} A_{18}$*
75	$U_6 > A_{18}$* $S_6 > S_{18}$*
88	$U_3 < U_6$* $U_6 > S_{18} A_{18}$

Control Co was not included in the first sampling date results due to zero results. The U6 and S6 treatments were the only ones significantly greater at (1%) than Co at 54 days, but all treatments were at every subsequent sampling date. As well U6 was significantly greater than U3, S18 and A18 from 54 days onwards. Significant differences at the 5% level generally occurred between (S6, A6) and (S18, A18), and U6 was significantly greater at the 1% level at first but later only at the 5% level of probability. No significant differences occurred between S6 and A6 nor between S18 and A18.

VIII DRYWEIGHT YIELD OF GRAIN AND STRAW

The mean yields and standard errors of grain and straw, in grams dry-weight per plot and in bushels and hundred weight (cwt.), are presented in tables 9 and 10 along with a summary of "t" test results in table 11. Further details of analyses of variance, "t" test results and yield figures are given in appendix 11.

Table 9

Mean dryweight yields of grain and straw

Treatment	Co	U3	U6	S6	A6	S18	A18	
Grain weight per plot in grams.	259.0	321.1	381.4	328.8	312.7	273.5	296.1	±29.6
Straw weight per plot in grams.	439.3	575.8	597.8	541.4	556.8	558.4	508.2	±22.4

Table 10

Mean yield of grain and straw in bushels and cwts. per acre

Treatment	Co	U3	U6	S6	A6	S18	A18
Grain weight in bushels/acre.	30.67	38.02	45.87	38.95	37.02	32.38	35.06
Straw weight in cwts/acre	27.85	36.50	37.89	34.32	35.29	35.40	32.21

Table 11

Summary of "t" test results presented in Appendix 11 (4) for yield measurements of grain and straw.

Measurements	Differences
Differences at the 1% level	
Grain	Co < U6
Straw	Co < U3 U6 S6 A6 S18 ; U6 > A18
Differences at the 5% level	
Grain	U6 > S18 A18
Straw	Co < A18 ; U3 > A18

For yield of grain no significant differences resulted except where Co was lower than U6 (at 1%) and U6 greater than S18 and A18 (at 5%).

The straw yield of Co was significantly lower (at 1%) than all treatments except A18 which was only significantly greater at the 5% level. Treatment A18 was significantly lower in straw yield than U6 and U3 (at 5%).

In terms of bushels per acre all the fertilized treatments gave an average increase of 7.21 bushels, the U6 at 6 cwt of fertiliser and the 3 cwt plots raising the yield by 15.20 and 5.61 bushels respectively. Straw yield was increased by fertilizing by an average of 7.42 cwts per acre, the 6 cwt and 3 cwt plots raising it by 10.04 and 6.85 cwt respectively.

CHAPTER V

DISCUSSION AND CONCLUSIONS

A. DISCUSSION

I ESTABLISHMENT

II FLORAL INITIATION

III NUMBER OF LEAVES PER PRIMARY TILLER

IV TILLERING

V HEIGHT

VI HEADING

VII YIELD OF GRAIN AND STRAW

VIII GENERAL

B. CONCLUSIONS

A. DISCUSSION

I ESTABLISHMENT

The crop emerged evenly on the 29.11.60 six days after sowing. There was no sign of any germination injury, as was expected with the use of surpentine super phosphate. The plants were in the two leaf stage on the 5.12.60 when counts of the number of plants established per 3 feet of row were taken. The lack of significant differences due to treatment was due to there being no germination injury by the fertilizer. There was no loss from bird damage. There was no visible effects on growth at this stage probably because the plants had not grown sufficiently to benefit from the fertilizer.

II FLORAL INITIATION

The microscopic examination of the primordial apices of barley plants indicates that the number of leaves on the primary tiller is a reasonably reliable criterion for the initiation of inflorescence. This is in line with Cooper's findings (1951) that annual species of Lolium change from vegetative to floral primordia once a set number of leaves have appeared.

Initiation was found to take place on the emergence of the fifth leaf and from a consideration of the results on the number of leaves per primary tiller at each sampling date an evaluation of rate and uniformity of initiation as affected by treatment can be made.

The application of phosphate increased the speed of initiation. The plants receiving 6 cwt per acre reached the stage of floral initiation first, those receiving 3 cwt second, the S6 and A6 unfertilized plants third, and all the other unfertilized plants last. It appears that the unfertilized plants in S6 and A6 may have benefitted from the extension of their rooting systems into the fertilized zone at either end of the gaps.

The Co, U3 and U6 treatments were quite uniform in the speed of initiation all plants reaching this stage within a period of 2 days. The S18 and A18 treatments

were the most uneven, the date of initiation ranging from 19 - 26 days as the plants in the fertilised zone received the benefit of an application equivalent to 6 cwt per acre while the plants in the unfertilised zone were as slow as the Co plants as no benefit would be derived from fertiliser zones near by due to lack of sufficient extension of the rooting systems. The plants in the I position in the non-uniform treatments are all slightly slower than those in the F position but equal to the U3 plants in their speed of initiation. This may be due to these plants having to compete with those plants from the unfertilised zone plus only half their own rooting systems being in contact with the fertilised zone.

The effect of speeding up the initiation was reflected in the date of heading and maturity of the crop the Co plots being a week behind in each instance.

III NUMBER OF LEAVES PER PRIMARY TILLER

As well as being an index of floral initiation this character is one of those which indicates the vegetative growth of the plant.

The uniformly fertilised treatments U3 and U6 produce leaves at a more rapid rate than Co and a more uniform rate than S6, A6, S18 or A18. The pattern of response shown at the fifth leaf stage as described above in III persisted till maturity. All the fertilised plants had reached their maximum at 42 days at which stage they were well advanced towards heading that commenced at about 50 days after emergence. The unfertilised plants on the other hand did not reach their maximum until later at 56 days. The maximum number of leaves for all primary tillers was 8. The variation in the final count in figure 7 is due to the stage of growth of the final leaf.

The A18 treatments slightly slower leaf emergence than S18 in the N position may have been caused by the shading incurred by the flanking fertilised plants in adjacent F positions plus the competition of the more vigorous plants for moisture, but this is very doubtful.

IV TILLERING

As found by McLeod (1960) the tillering of cereals is increased by the application of phosphate to spring sown crops. The rapid increase brought about by phosphate in the early stages of growth is of particular importance in that it increased the number of heading tillers at maturity thereby increasing the yield. The tillering rate increased with an increase in the rate of fertilizer application U6 being the best of all treatments. Although unfertilised plants of Co did produce as many tillers, the crop canopy eventually shaded the base of the plants and prevented further tiller development. Those already emerged were in many cases too small to survive the severe shading and there was a marked depression in tiller numbers as the crop got taller. The fertilised plants tillered earlier and the secondary tillers grew along with the primaries and prevented the shading from killing them. The fertilized plants also continued to tiller until shading from the canopy prevented further tiller development and the smaller younger tillers died, causing a depression in tiller numbers as per figure 9. Another contributing cause to the depression in tiller numbers could have been the dying off of the smaller tillers due to the poorer moisture conditions caused by the drought after sowing the trial. The obvious increase in tiller numbers at the last sampling date is attributed to the effect of very heavy rainfall, indicated by the vertical lines in figure 9, following a prolonged period of dry weather when there was a great decrease in the water balance (see appendix 12). The new tillers were very late and a majority of the crop was heading and the shading effect from the canopy prevented any extensive growth and many died. It therefore appears that the drought conditions prevailing from the time of sowing until mid January had a deleterious effect on the tillering rate.

The unevenness in fertilizer distribution of treatments S6, A6, S18 and A18 was reflected in the lack of uniformity of tillering within these plots. It was extremely uneven in all these treatments at first but only in S6, A6 and A18 throughout the measurement period, A18 being the worst. The extreme unevenness of

A18 is attributed to the very low tillering rate of plants in the N position. The cause of this lower tillering is that the more vigorous plants on all sides of the lower growing N plants intercepted the light to such an extent that shading prevented tillering. This accounts for the significantly lower tillering of A18 in the number of tillers per 3 feet of row measurements. The S18 treatment produced significantly more tillers per plant in the N position because of the lack of light interception as can be seen from figures 12 - 16. In both S18 and A18 the majority of tillers in the number per 3 feet of row counts occurred in the fertilised sections at first but there was a uniform pattern at the final sampling.

V HEIGHT

Height measurements were used as an index of growth, other indexes being too laborious for the number of samples or insufficient plots were available for significant sampling. Height was also used to determine the onset of heading.

Up until 8 days after emergence no signs of differences in growth developed. By the 10th day however, marked differences in height were evident as seen in figure 12. The Co, U3 and U6 treatments were uniform in height the Co being much shorter, but the S6, A6, S18 and A18 were very uneven, the fertilised sections much taller than the unfertilised ones. This uneven pattern in the height of the crop was most evident in the S18 and A18 treatments although measurements and close examination of S6 and A6 plots detected differences but not as great, and there were not so many plants affected. The graphs in figures 10 and 11 indicate the gradation in height from the fertilised to the unfertilised zones in the non-uniform treatments, and that the heavier application increased the growth of the crop. The variation in height persisted till maturity, the greatest occurring (1) at 21 days after emergence when the response of the fertilised plants, then in their rapid growth phase, were well ahead of those unfertilised and (2) again at 42 days when the fertilised plants had commenced to shoot and the unfertilised ones were in the final stages of

the growth phase when there is no great increase in height for a short period just prior to shooting.

All plants followed the same general pattern of height increase which included three distinct phases described in page 37 Chapter III. The final phase of rapid increase occurred when the plants were shooting i.e. in a developmental state. The first phase was purely vegetative when there was an increase in height due to a build up in the bulk of the plants. The second phase of slow height increase can be attributed to the change from a vegetative to a developmental state when the flowering stem was not tall enough to affect the height.

There was no sharp line of demarcation between the fertilized and unfertilized zones of the non-uniform plots but a gradual gradient in height. It is assumed that this is caused by the plants in the unfertilized zone close to the end of the fertilized section having extended their rooting systems sufficiently to benefit from the applied phosphate. No horizontal diffusion of fertilizer would be responsible in view of the work cited in Chapter II. The lower height of plants in the I position of the non-uniform treatments is probably due to competition for nutrients from unfertilized plants and not all of their own rooting systems being in contact with the applied fertilizer.

There was probably a greater response to the application of phosphate because of the drought conditions prevailing during the post emergence period until heading in mid January (see Appendix 13). The cause of this may be that the fertilized plants receiving an initial boost early in the season enabled them to utilize the available moisture more efficiently then, and also to develop an extensive rooting system which later supplied the plant with a greater quantity of nutrients and moisture than the unfertilized plants.

VI HEADING

The average heading rate per 3 feet of row showed a definite response to phosphate and was best for the heaviest application. This confirms McLeod's findings (1960) with spring sown cereals.

The fertilized plots were earlier than the unfertilized ones by 5-6 days reflecting the time interval between floral initiation in the respective plots. All unfertilized plants were slower to head than those fertilized. It appears that the phosphate response in heading is related to the response in floral initiation.

The number of heads per 3 feet of row in Co was at all times significantly lower than all other treatments probably because of the poorer tillering in the early stages of growth and the resultant effect of drought conditions. Although the number of heads in the unfertilized section of S18 and A18 were low the extra number produced in the fertilized section balanced the figures on a 3 feet of row basis to slightly less than those for U3. The S6 and A6 treatments probably produced more heads than U3, S18 or A18 because the plants in the 6" fertilized sections at 6 cwt per acre headed at a rate equivalent to U6 and those in the unfertilized 6" section benefited to some extent by the extension of their rooting systems to the fertilized zone.

In the Co, U3, S18 and A18 treatments there was some secondary heading due to rain on the 20th January 53 days after emergence. This accounts for their increase in the final counts taken. The increase in U6, S6 and A6 was not as great.

The final figures given are an indication of the range of grain yield.

VII YIELD OF GRAIN AND STRAW

There was a definite grain yield response to the rate of application of phosphate, 6 cwt per acre producing a greater yield increase than 3 cwt per acre. There was also a tendency for U3, S6 and A6 to yield 3 - 5 bushels per acre more than S18 or A18, but the differences were not significant. Only U6 shows a significant difference in this trial. The trends occurring in the 3 cwt non-uniform treatments when compared with U3 are in part, in agreement with Cashmore's results (1939) also obtained under drought conditions i.e. there is no difference between S6, A6 and U3 (a slight increase from S6) and only a tendency for a reduction in yield with S18 and A18.

The straw yield was definitely increased by fertiliser application but there was only a slight increase with 6 cwt over 3 cwt per acre. All the non-uniform treatments yielded slightly lower than the uniform U3 treatment. A18 was much lower than any of the other 3 cwt treatments probably because of the smaller plants in the unfertilized sections which were affected by shading and competition for moisture by the surrounding fertilized plants.

Overall the yield of grain and straw was much lower than expected due to the drought conditions prevailing after sowing the crop. There was a considerable variation in the yield of plots within treatments which can be attributed to the effect of variable soil moisture content caused by the tile drains. The plots between the drains yielded much better than those over or in close proximity to the drains.

VIII GENERAL

There was a general lack of vigour in the unfertilized plants after responses in height, leaf number, and tillering became evident. Probably this was mostly due to lack of sufficient moisture uptake resulting from insufficient root extension under the dry conditions. This applies especially to plants in the N positions of A18 where they had to compete for moisture and light with the better developed plants in the F positions. The fertilized treatments matured far more quickly than Co and the uniform treatments far more evenly than the non-uniform ones.

The "simultaneous" treatments as opposed to the "alternate" ones only produced differences in the treatments with a periodic impulse amplitude of 36" (18" fertilized, 18" gap). The alternate pattern caused a decrease in tillering height and straw yield. There was no differences between the two patterns for number of leaves, heading rate, or yield of grain.

The tile drains traversing the experiment created variability in the soil moisture conditions and this affected both the growth of the crop (in terms of height) and the yield of grain and straw. There was much more growth and greater yield between the drains than near and over top of them.

In the layout of the experiment lack of precision is evident because a radomised block design was not used which would have overcome the variability due to moisture conditions to some extent and would have made the analyses more accurate.

B. CONCLUSIONS

When using serpentine superphosphate the establishment of barley is not affected by non-uniform distribution or the application of various rates.

The rate of growth of the crop in terms of leaf number and height is markedly affected by non-uniform distribution, the most uneven distributions being the most variable. Uneven distribution could affect the herbage yield of the crop in a dry season, if grown for forage.

The development of barley is affected by the lack of uniformity of distribution at the stage of floral initiation and the unevenness of poor distribution is persistant till maturity, the unfertilized sections being slow to head and mature. This effect could have some significance in harvesting operations in districts where the climate is unreliable.

The yield appears to be maintained and not decreased by a slight variability in distribution, but greater variabilities tend to decrease it. This implies that very precise mechanisms are not necessary to ensure a complete uniformity in distribution. Therefore the patterns of the star wheel at high speeds are acceptable, but where periodic impulses with an amplitude of 36" or more occurs then adjustments to the machine are necessary.

There is no benefit from the practice of phasing the stars to avoid peaks occurring in adjacent rows when barley is grown as a grain crop and it may be detrimental where it is grown for forage.

The number of replicates per treatment would have sufficed for accurate results if a randomised block design had been employed.

Future work in this field should include:-

(a) A study of the effect of non-uniform distribution on the herbage yield for a forage crop.

(b) A study of the marginal effect of the fertilized section on the unfertilized section considering rooting systems and uptake of phosphate using radioactive tracers.

(c) A study of the effects of non-uniform distribution using nitrogenous fertilisers.

The experiment reported here was carried out under drought conditions and the results obtained are not necessarily applicable to a normal season.

CHAPTER VI

SUMMARY

1. A study was made of the effect of seven fertilizer treatments, including non-uniform patterns of fertilizer distribution along the row, on the establishment, growth, development and yield of barley.

2. The treatments applied simulated uniform distribution at 3 and 6 cwt of fertilizer per acre, two degrees of variability in distribution (12" and 36" periodic impulses) in two patterns (alternate and simultaneous), and a control receiving no fertilizer.

3. There was no effect of treatment upon the establishment of the crop.

4. Growth was very uneven in the non-uniform treatments especially the 36" ones, all tillering, leaf number and height being affected. There was a marked improvement in growth with application of fertilizer.

5. Floral initiation occurred with the emergence of the 5th leaf in this variety of barley (Proctor).

6. The uniformity of development was poor where fertilizer was applied unevenly the date of floral initiation, shooting, heading and maturity being affected.

7. No great differences in yield resulted from the various treatments at 3 cwt per acre. There was a tendency only, for the most non-uniform treatment to reduce yield. Yield was related to the heading rate.

8. The drought conditions prevailing created a variability in soil moisture which reduced the accuracy of the experimental layout used.

9. The evidence obtained indicates that there may be no necessity to increase the precision of current star wheel distributors.

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APPENDIX I

List of Conventional Abbreviations

NS.	result not statistically significant
*	result statistically significant at the 5% level
**	result statistically significant at the 1% level
F	the variance ratio for specified conditions
SS	sum of squares
MS	mean square
df	degrees of freedom
ΣX	sum of the replicates
$\bar{X}$	mean value
SE	standard error of the mean
d. 0.05	difference at the 5% level to be significant
d. 0.01	difference at the 1% level to be significant

"F"	Fertilized Section	See page 23
"I"	Intersection between "F & N"	
"N"	Non Fertilized Section	

APPENDIX 2

Analysis of variance at the rate of establishment.

No. of plants per 3 ft. of row at 7 days after emergence.

Source	SS	df	M.S.	F value	F required	Result
Treatment	75.9	6	12.65	0.47	2.44	N.S.
Error	760.5	28	27.16		3.53	
Total	836.4	34				

APPENDIX 3

Analyses of Variance of number of leaves per Primary Tiller of each sampling date.

1(a) 24 days after emergence Position "F"

Source	SS	df	M.S.	F value	F required	Result
Treatment	431.0	6	71.8	12.82	2.44 3.53	* *
Plots within Treatments E(1)	156.0	28	5.6		3.53	
Samples within plots E(2)	248.0	175	1.4			
Total	835	209				

SE of means for 1 - 6 samples

1 sample	$= \sqrt{0.42}$	=	0.65
2 "	$= \sqrt{0.28}$	=	0.53
3 "	$= \sqrt{0.23}$	=	0.48
4 "	$= \sqrt{0.21}$	=	0.46
5 "	$= \sqrt{0.20}$	=	0.45
6 "	$= \sqrt{0.19}$	=	0.44

1(b) 14 days after emergence Position "I"

Source	SS	df	M.S.	F value	F required	Result
Treatment	346	6	57.6	9.93	2.44 3.53	* *
Plots within Treatments E(1)	164	28	5.8		3.53	
Samples within plots E(2)	463	175	2.6			
Total	973	209				

SE of means for 1 - 6 samples

1 sample	$= \sqrt{0.63}$	=	0.79
2 "	$= \sqrt{0.37}$	=	0.61
3 "	$= \sqrt{0.28}$	=	0.53
4 "	$= \sqrt{0.24}$	=	0.49
5 "	$= \sqrt{0.21}$	=	0.46
6 "	$= \sqrt{0.19}$	=	0.44

APPENDIX 3 (Continued)

1(c) 14 days after emergence — Position "F"

Source	SS	df	M.S.	F value	F required	Result
Treatment	819	6	136.5	24.82	2.44 3.53	* *
Plots within Treatment E (1)	155	28	5.5			
Samples within plots E (2)	496	175	2.8			
Total	1470	209				

SE of means for 1 - 6 samples

1 sample	$= \sqrt{0.65}$	$= 0.80$
2 "	$= \sqrt{0.37}$	$= 0.61$
3 "	$= \sqrt{0.28}$	$= 0.53$
4 "	$= \sqrt{0.23}$	$= 0.48$
5 "	$= \sqrt{0.20}$	$= 0.45$
6 "	$= \sqrt{0.18}$	$= 0.43$

2(a) 21 days after emergence — Position "F"

Source	SS	df	M.S.	F value	F required	Result
Treatment	82.9	13.82	13.68	13.68	2.44 3.53	* *
Error	28.2	28	1.01			
Total	111.1	34				

2(b) 21 days after emergence — Position "I"

Source	SS	df	M.S.	F value	F required	Result
Treatment	82.5	6	13.75	25.46	2.44 3.53	* *
Error	15.0	28	0.54			
Total	97.5	34				

APPENDIX 3 (Continued)

2(c) 21 days after emergence — Position "N"

Source	SS	df	M.S.	F value	F required	Result
Treatment	97.2	6	16.20	9.26	2.44 3.53	* *
Error	48.9	28	1.75			
Total	146.1	34				

3(a) 28 days after emergence — Position "F"

Source	SS	df	M.S.	F value	F required	Result
Treatment	60.6	6	10.1	16.03	2.44 3.53	* *
Error	17.6	28	0.63			
Total	78.2	34				

3(b) 28 days after emergence — Position "I"

Source	SS	df	M.S.	F value	F required	Result
Treatment	39.3	6	6.55	8.73	2.44 3.53	* *
Error	21.1	28	0.75			
Total	60.4	34				

3(c) 28 days after emergence — Position "N"

Source	SS	df	M.S.	F value	F required	Result
Treatment	85.6	6	14.27	9.98	2.44 3.53	* *
Error	40.0	28	1.43			
Total	125.6	34				

APPENDIX 3 (Continued)

4(a) 35 days after emergence — Position "F"

Source	SS	df	M.S.	F value	F required	Result
Treatment	92.0	6	15.33	31.94	2.44 3.53	* *
Error	13.4	28	0.48			
Total	105.4	34				

4(b) 35 days after emergence — Position "I"

Source	SS	df	M.S	F value	F required	Result
Treatment	100.3	6	16.72	11.61	2.44 3.53	* *
Error	40.2	28	1.44			
Total	140.5	34				

4(c) 35 days after emergence — Position "N"

Source	SS	df	M.S.	F value	F required	Result
Treatment	131.5	6	21.92	29.23	2.44 3.53	* *
Error	21.1	28	0.75			
Total	152.6	34				

5(a) 42 days after emergence — Position "F"

Source	SS	df	M.S.	F value	F required	Result
Treatment	151.0	6	25.17	20.30	2.44 3.53	* *
Error	34.6	28	1.24			
Total	185.6	34				

APPENDIX 3 (Continued)

5(b) 42 days after emergence — Position "I"

Source	SS	df	M.S.	F value	F required	Result
Treatment	151.0	6	25.17	20.30	2.44 3.53	* *
Error	34.4	18	1.23			
Total	185.4	34				

5(c) 42 days after emergence — Position "M"

Source	SS	df	M.S.	F value	F required	Result
Treatment	218.4	6	36.40	25.82	2.44 3.53	* *
Error	39.3	28	1.41			
Total	257.7	34				

6(a) 56 days after emergence — Position "F"

Source	SS	df	M.S.	F value	F required	Result
Treatment	33.1	6	5.52	30.67	2.44 3.53	* *
Error	5.0	28	0.18			
Total	38.1	34				

6(b) 56 days after emergence — Position "I"

Source	SS	df	M.S.	F value	F required	Result
Treatment	33.0	6	5.50	13.09	2.44 3.53	* *
Error	11.6	28	0.42			
Total	44.6	34				

APPENDIX 3 (Continued)

6(c) 56 days after emergence

Source	SS	df	M.S.	F value	F required	Result
Treatment	50.6	6	8.43	7.21	2.44 3.53	* *
Error	32.7	28	1.17			
Total	83.3	34				

APPENDIX 4

Means at the number of leaves per primary tiller at each sampling date.

1. 14 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	12.5	16.5	16.5	16.6	16.6	16.2	16.9	±0.4	1.3 1.7
I	12.6	16.4	16.8	16.1	15.3	15.2	16.1	±0.4	1.3 1.7
N	12.1	17.3	17.5	14.1	14.1	13.1	12.8	±0.4	1.3 1.7

2. 21 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	17.0	20.1	21.3	21.3	21.6	21.1	21.7	±0.5	1.3 1.8
I	16.5	20.6	21.6	20.1	20.9	19.9	20.3	±0.4	1.0 1.3
N	16.7	20.7	21.5	18.1	18.6	17.5	17.2	±0.6	1.7 2.3

3. 28 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	21.1	24.4	25.0	25.1	24.8	24.3	25.1	±0.4	1.0 1.4
I	21.5	24.7	25.0	23.9	23.7	24.0	24.2	±0.4	1.1 1.5
N	20.9	24.7	24.8	21.7	22.6	21.7	20.7	±0.5	1.5 2.1

APPENDIX 4 (Continued)

4. 35 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	25.1	29.2	30.1	29.3	29.7	29.4	30.1	±0.3	0.9 1.2
I	24.7	29.1	30.6	28.5	28.6	28.9	29.4	±0.5	1.5 2.1
N	25.0	29.2	30.4	26.5	26.1	26.0	25.1	±0.4	1.1 1.5

5. 42 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	28.2	33.5	34.7	34.1	34.1	33.0	34.5	±0.5	1.4 2.0
I	27.8	33.6	34.8	33.2	33.2	32.3	33.4	±0.5	1.4 1.9
N	28.7	34.1	34.6	30.2	29.9	27.8	28.8	±0.5	1.5 2.1

6. 56 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	32.20	34.9	35.0	35.0	35.0	35.0	35.0	±0.2	0.6 0.7
I	32.2	35.0	35.0	34.9	34.3	35.0	33.5	±0.3	0.8 1.1
N	32.5	35.0	35.0	32.9	32.4	32.6	31.8	±0.5	1.4 1.9

APPENDIX 4 (Continued)

7. Results of "t" tests on number of leaves per primary tiller.

Comparison	Sampling Date and Position																	
	14			21			28			35			42			56		
	F	I	N	F	I	N	F	I	N	F	I	N	F	I	N	F	I	
Co V U3	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	
Co V U6	*	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	
Co V S6	**	**	**	**	**	NS	**	**	NS	**	**	*	**	**	*	**	**	
Co V A6	**	**	**	**	**	*	**	**	*	**	**	NS	**	**	NS	**	**	
Co V S18	**	**	NS	**	**	NS	**	**	NS	**	**	NS	**	**	NS	**	**	
Co V A18	**	**	NS	**	**	NS	**	**	NS	**	**	NS	**	**	NS	**	**	
U3 V U6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
U3 V S6	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	
U3 V A6	NS	NS	**	*	NS	*	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	
U3 V S18	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	**	NS	*	**	NS	NS	
U3 V A18	NS	NS	**	*	NS	**	NS	NS	**	*	NS	**	NS	NS	**	NS	**	
U6 V S6	NS	NS	**	NS	**	**	NS	*	**	NS	*	**	NS	*	**	NS	NS	
U6 V A6	NS	*	**	NS	NS	**	NS	*	**	NS	*	**	NS	*	**	NS	NS	
U6 V S18	NS	*	**	NS	**	**	NS	NS	**	NS	*	**	*	**	**	NS	NS	
U6 V A18	NS	NS	**	NS	**	**	NS	NS	**	NS	NS	**	NS	*	**	NS	**	
S6 V A6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
S6 V S18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
S6 V A18	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	**	
A6 V S18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
A6 V A18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
S18 V A18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	**	

APPENDIX 5

1. Means of the number of tillers per 3 ft. of row at each sampling date.

	Treatment								
Days after emergence	Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
18 days	8.2	64.1	72.5	56.9	58.4	48.9	45.3	±3.3	9.5 12.8
26 days	53.6	68.6	78.1	62.6	67.2	64.9	57.2	±4.6	13.4 18.1
34 days	75.4	70.6	80.7	66.1	70.5	59.7	61.1	±4.3	12.5 16.9

2. Analyses of variance of the number of tillers per 3 ft of row on the average o 3 samples per plot.

2.(a) 18 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	38618.3	6	6436.3	39.92	2.44 3.53	**
Plots within Treatments E (1)	4514.0	28	161.21			
Samples within Plots E (2)	6019.1	70	85.98			
Total	49151.4	104				

SE of means for 1 - 3 samples

1 sample = $\sqrt{22.21}$ = 4.71
2 " = $\sqrt{13.61}$ = 3.69
3 " = $\sqrt{10.75}$ = 3.28

2.(b) 26 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	1916.0	6	319.33	2.96	2.44 3.53	*
Error	3020.7	28	107.88			
Total	4936.7	34				

2(c) 34 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	1177.0	6	196.1	2.10	2.44 3.53	NS
Error	2619.6	28	93.56			
Total	3796.6	34				

3 Results of "t" tests on the means of No. of tillers per 3 ft of row

Comparison	Days after Emergence		
	18	26	34
Co V U5	**	*	NS
Co V U6	**	**	NS
Co V S6	**	NS	NS
Co V A6	**	*	NS
Co V S18	**	NS	*
Co V A18	**	NS	*
U3 V U6	NS	NS	NS
U3 V S6	NS	NS	NS
U3 V A6	NS	NS	NS
U3 V S18	**	NS	NS
U3 V A18	**	NS	NS
U6 V S6	**	*	*
U6 V A6	**	NS	NS
U6 V S18	**	NS	**
U6 V A18	**	**	**
S6 V A6	NS	NS	NS
S6 V S18	NS	NS	NS
S6 V A18	**	NS	NS
A6 V S18	*	NS	NS
A6 V A18	**	NS	NS
S18 V A18	NS	NS	NS

APPENDIX 6

Analyses of Variance of the Number of secondary tillers per plant at each sampling date.

1(a) 21 days after emergence — Position "F"

Source	SS	df	MS	F value	F required	Result
Treatment	42.3	6	7.05	12.58	2.44 3.53	**
Plots within treatments E (1)	15.8	28	0.56			
Samples within plots E (2)	52.4	175	0.29			
Total	110.5	209				

SE of means for 1-6 samples

1 sample	=	0.25
2 sample	=	0.19
3 "	=	0.16
4 "	=	0.15
5 "	=	0.14
6 "	=	0.13

1(b) 21 days after emergence — Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	29.5	6	4.92	13.30	2.44 3.53	**
Plots within treatments E (1)	10.4	28	0.37			
Samples within plots E (2)	61.4	175	0.35			
Total	101.3	209				

SE of means for 1-6 samples

1 sample	=	0.28
2 "	=	0.19
3 "	=	0.15
4 "	=	0.13
5 "	=	0.12
6 "	=	0.11

APPENDIX 6 (Continued)

1(c) 21 days after emergence — Position "N"

Source	SS	df	MS	F value	F required	Result
Treatment	42.7	6	7.12	9.49	2.44 3.53	**
Plots within treatments E (1)	21.0	28	0.75			
Samples within Plots E (2)	54.0	175	0.38			
Total	117.7	209				

SE of means for 1-6 samples

1 sample = 0.29
2 " = 0.22
3 " = 0.19
4 " = 0.17
5 " = 0.16
6 " = 0.15

2(a) 28 days after emergence — Position "F"

Source	SS	df	Ms	F value	F required	Result
Treatment	2.56	6	0.427	4.49	2.44 3.53	**
Error	2.66	28	0.095			
Total	5.22	34				

2(b) 28 days after emergence — Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	0.37	6	0.062	0.427	2.44 3.53	NS
Error	4.10	28	0.146			
Total	4.47	34				

APPENDIX 6 (Continued)

2(c) 28 days after emergence — Position "N"

Source	SS	df	MS	F value	F required	Result
Treatment	5.28	6	0.88	8.07	2.44 3.53	**
Error	3.06	28	0.109			
Total	8.34	34				

3(a) 35 days after emergence — Position "F"

Source	SS	df	MS	F value	F required	Result
Treatment	0.64	6	0.107	1.31	2.44 3.53	NS
Error	2.29	28	0.082			
Total	2.93	34				

3 (b) 35 days after emergence — Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	0.92	6	0.153	1.26	2.44 3.53	NS
Error	3.39	28	0.121			
Total	4.31	34				

3(c) 35 days after emergence — Position "N"

Source	SS	df	MS	F value	F required	Result
Treatment	4.5	6	0.75	6.63	2.44 3.53	**
Error	3.16	28	0.113			
Total	7.66	34				

APPENDIX 6 (Continued)

4(a) 42 days after emergence — Position "F"

Source	SS	df	MS	F value	F required	Result
Treatment	0.46	6	0.092	1.64	2.44 3.53	NS
Error	1.53	28	0.056			
Total	1.99	34				

4(b) 42 days after emergence — Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	0.61	6	0.102	1.89	2.44 3.53	NS
Error	1.51	28	0.0539			
Total	2.12	34				

4(c) 42 days after emergence — Position "N"

Source	SS	df	MS	F value	F required	Result
Treatment	3.81	6	0.635	5.57	2.44 3.53	**
Error	3.18	28	0.114			
Total	6.99	34				

5(a) 56 days after emergence — Position "F"

Source	SS	df	MS	F value	F required	Result
Treatment	7.34	6	1.22	6.25	2.44 3.53	**
Error	5.45	28	0.195			
Total	12.79	34				

APPENDIX 6 (Continued)

5(b) 56 days after emergence — Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	3.24	6	0.54	2.73	2.44 3.53	*
Error	5.54	28	0.198			
Total	8.78	34				

5(c) 56 days after emergence — Position "M"

Source	SS	df	MS	F value	F required	Result
Treatment	14.21	6	2.368	11.33	2.44 3.53	*
Error	5.85	28	0.209			
Total	20.06	34				

APPENDIX 7

Means of the number of secondary tillers per plant at each sampling date.

1. 21 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	0.26	1.20	1.53	1.46	1.66	1.36	1.63	±0.13	0.39 0.52
I	0.30	1.16	1.60	1.33	1.30	1.10	1.13	±0.11	0.32 0.43
N	0.36	1.16	1.53	0.33	0.50	0.46	0.23	±0.15	0.46 0.62

2. 28 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	0.74	1.24	1.34	1.48	1.64	1.42	1.50	±0.14	0.39 0.54
I	1.08	1.36	1.36	1.16	1.32	1.26	1.36	±0.17	0.49 0.67
N	1.02	1.32	1.42	0.68	0.62	0.78	0.22	±0.15	0.43 0.58

3. 35 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	1.32	1.18	1.42	1.46	1.64	1.48	1.52	±0.13	0.37 0.50
I	1.32	1.22	1.52	0.98	1.38	1.36	1.44	±0.15	0.45 0.61
N	1.36	1.42	1.44	0.80	0.60	1.12	0.54	±0.15	0.44 0.59

4. 42 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	1.20	1.32	1.34	1.26	1.50	1.12	1.38	±0.11	0.31 0.41
I	1.06	1.28	1.30	1.36	1.18	1.04	1.40	±.10	0.30 0.41
N	1.06	1.26	1.26	0.62	0.40	1.0	0.52	±0.11	0.44 0.59

5. 56 days after emergence

Position	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	1.20	2.14	2.18	2.42	2.16	2.90	2.40	±0.20	0.57 0.77
I	1.22	2.04	2.24	1.72	1.82	2.02	1.70	±0.20	0.58 0.78
N	1.78	2.30	2.60	1.36	0.92	1.44	0.72	±0.21	0.59 0.80

6. Result of "t" tests on the mean number of secondary tillers per plant.

Comparison	Sampling Date and Position														
	21			28			35			42			56		
	F	I	N	F	I	N	F	I	N	F	I	N	F	I	N
Co V U3	**	**	**	**	NS	NS	NS	NS	NS	NS	NS	NS	**	**	NS
Co V U6	**	**	**	**	NS	NS	NS	NS	NS	NS	NS	NS	**	**	**
Co V S6	**	**	NS	**	NS	NS	NS	NS	*	NS	*	*	**	NS	NS
Co V A6	**	**	NS	**	NS	NS	NS	NS	**	NS	NS	**	**	*	**
Co V S18	**	**	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	**	**	NS
Co V A18	**	**	NS	**	NS	**	NS	NS	**	NS	*	*	**	NS	**
U3 V U6	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
U3 V S6	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	**
U3 V A6	*	NS	**	*	NS	**	*	NS	**	NS	NS	**	NS	NS	**
U3 V S18	NS	NS	**	NS	NS	*	NS	NS	NS	NS	NS	NS	*	NS	**
U3 V A18	*	NS	**	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	NS
U6 V S6	NS	NS	**	NS	NS	**	NS	*	**	NS	NS	**	NS	NS	**
U6 V A6	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	**
U6 V S18	NS	**	**	NS	NS	**	NS	NS	NS	NS	NS	NS	*	NS	**
U6 V A18	NS	**	**	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	**
S6 V A6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S6 V S18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
S6 V A18	NS	NS	NS	NS	NS	*	NS	*	NS	NS	NS	NS	NS	NS	*
A6 V S18	NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS	**	*	NS	NS
A6 V A18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S18 V A18	NS	NS	NS	NS	NS	*	NS	NS	*	NS	*	*	NS	NS	*

APPENDIX 8

Analyses of Variance of the height per plant at each sampling date.

1(a) 14 days after emergence — Position "F"

Source	SS	df	MS	F value	Frequired	Result
Treatment	2889	6	481.5	22.50	2.44 3.53	**
Plots within treatments E (1)	599	28	21.4			
Samples within Plots E (2)	934	175	5.3			
Total	4422	209				

SE of means for 1-6 samples

1 sample	=	1.26
2 "	=	1.03
3 "	=	0.94
4 "	=	0.89
5 "	=	0.86
6 "	=	0.84

1(b) 14 days after emergence — Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	2231	6	371.8	19.67	2.44 3.53	**
Plots within treatments E (1)	530	28	18.9			
Samples within Plots E (2)	1615	175	9.2			
Total	4376	209				

SE of means for 1-6 samples

1 sample	=	1.47
2 "	=	1.11
3 "	=	0.97
4 "	=	0.88
5 "	=	0.83
6 "	=	0.79

APPENDIX 8 (Continued)

1(c) 14 days after emergence Position "M"

Source	SS	df	MS	F value	F required	Result
Treatment	4096	6	682.7	29.68	2.44 3.53	**
Plots within treatments E (1)	644	28	23.0			
Samples within Plots E (2)	1195	175	6.8			
Total	5935	209				

SE of means for 1-6 samples

1 sample = 1.38
2 " = 1.11
3 " = 0.99
4 " = 0.94
5 " = 0.90
6 " = 0.87

2(a) 21 days after emergence Position "F"

Source	SS	df	MS	F value	F required	Result
Treatment	2342.5	6	390.4	25.45	2.44 3.53	**
Error	429.5	28	15.3			
Total	2772.0	34				

2(b) 21 days after emergence Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	1903.0	6	317.2	28.07	2.44 3.53	**
Error	316.5	28	11.3			
Total	2219.5	36				

APPENDIX 8 (Continued)

2(c) 21 days after emergence Position "N"

Source	SS	df	MS	F value	F required	Result
Treatment	2827.0	6	471.2	25.82	2.44 3.53	**
Error	511.0	28	18.3			
Total	3338.0	34				

3(a) 28 days after emergence Position "F"

Source	SS	df	MS	F value	F required	Result
Treatment	1605.2	6	267.53	23.92	2.44 3.53	**
Error	312.9	28	11.18			
Total	1918.1	34				

3(b) 28 days after emergence Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	1502.4	6	250.40	12.09	2.44 3.53	**
Error	580.0	28	20.71			
Total	2082.4	34				

3(c) 28 days after emergence Position "N"

Source	SS	df	MS	F value	F required	Result
Treatment	2625.2	6	437.53	14.14	2.44 2.53	**
Error	866.7	28	30.95			
Total	3491.9	34				

APPENDIX 8 (Continued)

4(a) 35 days after emergence — Position "F"

Source	SS	df	MS	F value	F required	Result
Treatment	1055.9	6	175.98	15.37	2.44 3.53	**
Error	320.5	28	11.45			
Total	1376.4	34				

4(b) 35 days after emergence — Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	967.0	6	161.17	6.96	2.44 3.53	**
Error	648.1	28	23.15			
Total	1615.1	34				

4(c) 35 days after emergence — Position "N"

Source	SS	df	MS	F value	F required	Result
Treatment	1434.8	6	239.13	9.09	2.44 3.53	**
Error	736.9	28	26.32			
Total	2171.7	34				

5(a) 42 days after emergence — Position "F"

Source	SS	df	MS	F value	F required	Result
Treatment	2379.9	6	396.65	15.29	2.44 3.53	**
Error	726.4	28	25.94			
Total	3106.3	34				

APPENDIX 8 (Continued)

5(b) 42 days after emergence — Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	2180.3	6	363.38	17.26	2.44 3.53	**
Error	589.4	28	21.05			
Total	2769.7	34				

5(c) 42 days after emergence — Position "N"

Source	SS	df	MS	F value	F required	Result
Treatment	3429.5	6	571.58	17.18	2.44 3.53	**
Error	931.6	28	33.27			
Total	4361.1	34				

6(a) 56 days after emergence — Position "F"

Source	SS	df	MS	F value	F required	Result
Treatment	1526.1	6	254.35	6.66	2.44 3.53	**
Error	1069.4	28	38.19			
Total	2595.5	34				

6(b) 56 days after emergence — Position "I"

Source	SS	df	MS	F value	F required	Result
Treatment	1996.1	6	332.68	5.77	2.44 3.53	**
Error	1614.7	28	57.67			
Total	3610.8	34				

APPENDIX 8 (Continued)

6(c) 56 Days after emergence Position "N"

Source	SS	df	MS	F value	F required	Result
Treatment	2434.6	6	405.76	8.45	2.44 3.53	**
Error	1344.1	28	48.00			
Total	3778.7	34				

APPENDIX 9

Means of the height per plant at each sampling date.

1. 14 days after emergence

Position	Treatments Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	15.9	26.4	26.5	25.6	26.3	25.8	27.6	±0.8	2.4 3.3
I	16.3	26.0	27.7	22.8	23.2	23.6	23.6	±0.8	2.3 3.1
N	15.4	26.2	28.5	20.2	20.5	18.0	17.5	±0.9	2.5 3.4

2. 21 days after emergence

Position	Treatments Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	23.9	44.8	49.5	45.4	46.9	47.2	47.6	±1.8	5.1 6.8
I	23.7	45.6	48.9	37.3	39.3	39.9	38.4	±1.5	4.4 5.9
N	24.4	45.1	49.5	31.7	33.8	27.1	26.5	±1.9	5.5 7.5

3. 28 days after emergence

Position	Treatments Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	37.2	55.2	58.5	54.4	57.1	57.0	55.1	±1.5	4.3 5.8
I	36.1	55.2	58.7	50.1	51.6	51.6	49.9	±2.0	5.9 7.9
N	33.4	55.2	59.4	43.6	45.4	40.2	37.8	±6.2	7.2 9.7

4. 35 days after emergence

Position	Treatments Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	44.1	57.4	61.5	57.2	59.4	60.5	59.4	±1.5	4.4 5.9
I	42.9	56.6	61.4	52.5	55.3	56.0	54.6	±2.2	6.2 8.4
N	42.8	57.2	61.5	49.1	50.2	45.1	45.0	±2.3	6.7 8.9

APPENDIX 9 (Continued)

5. 42 days after emergence

Position	Treatments								
	Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	44.5	66.5	71.1	66.4	67.3	66.7	68.2	±2.3	6.6 8.9
I	44.7	65.8	72.9	60.9	60.6	64.4	59.0	±2.1	5.9 8.0
N	44.3	67.3	71.7	50.8	53.1	48.3	46.3	±2.6	7.5 10.1

6. 56 days after emergence

Position	Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
F	62.3	78.8	85.7	79.2	78.6	78.8	76.7	±2.8	8.0 10.8
I	58.1	77.3	85.3	75.1	72.9	71.9	71.6	±3.4	9.9 13.5
N	62.6	78.5	83.1	64.9	65.3	61.9	59.9	±3.1	8.9 12.1

7. Result of "t" tests on the mean height per plant

Comparison	Sampling Date and Position																	
	14			21			28			35			42			56		
	F	I	N	F	I	N	F	I	N	F	I	N	F	I	N	F	I	I
Co V U3	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	
Co V U6	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	
Co V S6	**	**	**	**	**	*	**	**	**	**	**	NS	**	**	NS	**	**	
Co V A6	**	**	**	**	**	**	**	**	**	**	**	*	**	**	*	**	**	
Co V S18	**	**	*	**	**	NS	**	**	NS	**	**	NS	**	**	NS	**	**	
Co V A18	**	**	NS	**	**	NS	**	**	NS	**	**	NS	**	**	NS	**	**	
U3 V U6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	
U3 V S6	NS	**	**	NS	**	**	NS	NS	**	NS	NS	*	NS	NS	**	NS	NS	
U3 V A6	NS	*	**	NS	**	**	NS	NS	**	NS	NS	*	NS	NS	**	NS	NS	
U3 V S18	NS	*	**	NS	*	**	NS	NS	**	NS	NS	**	NS	NS	**	NS	NS	
U3 V A18	NS	*	**	NS	**	**	NS	NS	**	NS	NS	**	NS	*	**	NS	NS	
U6 V S6	NS	**	**	NS	**	**	NS	**	**	NS	**	**	NS	**	**	NS	*	
U6 V A6	NS	**	**	NS	**	**	NS	*	**	NS	NS	**	NS	**	**	NS	*	
U6 V S18	NS	**	**	NS	**	**	NS	*	**	NS	NS	**	NS	**	**	NS	*	
U6 V A18	NS	**	**	NS	**	**	NS	**	**	NS	*	**	NS	**	**	*	**	
S6 V A6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
S6 V S18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
S6 V A18	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
A6 V S 18	NS	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
A6 V A18	NS	NS	*	NS	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	
S18 V A18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

APPENDIX 10

1. Means of the number of heads emerged per 3 ft of row at each sampling date.

Sampling Date	Treatment								
Days after emergence	Co	U3	U6	S6	A6	S18	A18	S.E.	d 0.05 0.01
53 days		3	11	7	2	1	3	±2	7 9
54 "	0	9	23	15	9	6	8	±3	10 14
55 "	1	21	37	26	22	15	15	±4	11 14
57 "	4	35	50	40	39	28	29	±3	9 12
58 "	6	44	59	50	48	36	38	±3	9 12
60 "	11	51	63	57	57	47	47	±3	9 12
62 "	20	55	67	65	64	54	52	±4	11 15
64 "	24	61	73	68	67	59	57	±4	12 16
66 "	30	64	77	73	72	64	62	±5	14 15
68 "	36	67	80	78	74	66	65	±4	11 15
75 "	50	70	80	80	78	70	69	±4	11 15
88 "	57	74	84	83	80	74	74	±4	10 14

2. Analyses of variance of the number of heads emerged per 3 ft of row at each sampling date.

2(a) 53 days after emergence (Treatment Co excluded because of zero results)

Source	SS	df	MS	F value	F required	Result
Treatment	992.9	5	198.58	2.14	2.62 3.90	NS
Plots within treatments E (1)	2222.3	24	92.59			
Samples within PlotsE(2)	480.0	60	8.0			
Total	3695.2	89				

SE of means for 1-3 samples

1 sample = 2.78
2 " = 2.64
3 " = 2.48

APPENDIX 10 (Continued)

2(b) 54 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	1011.6	6	202.32	3.04	2.44 3.53	*
Error	1598.2	28	66.59			
Total	2609.8	34				

2(c) 55 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	3809.5	6	634.92	10.38	2.44 3.53	**
Error	1712.6	28	61.16			
Total	5522.1	34				

2(d) 57 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	6364.0	6	1060.66	22.24	2.44 3.53	**
Error	1335.0	28	47.68			
Total	7699.0	34				

2(e) 58 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	8674.2	6	1445.7	31.73	2.44 3.53	**
Error	1275.7	28	45.56			
Total	9949.9	34				

2(f) 60 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	8911.5	6	1485.25	30.62	2.44 3.53	**
Error	1358.1	28	48.50			
Total	10269.6	34				

2(g) 62 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	7948.6	6	1324.77	18.96	2.44 3.53	**
Error	1956.5	28	69.88			
Total	9905.1	34				

2(h) 64 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	7864.6	6	1310.76	16.00	2.44 3.53	**
Error	2293.5	28	81.91			
Total	10158.1	34				

2(i) 66 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	7207.6	6	1201.27	10.25	2.44 3.53	**
Error	3282.1	28	117.22			
Total	10489.7	34				

2(j) 68 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	6433.4	6	1072.23	14.89	2.44 3.53	**
Error	2015.6	28	71.99			
Total	8449.0	34				

2(k) 75 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	3372.1	6	562.01	7.48	2.44 3.53	**
Error	2103.4	28	75.12			
Total	5475.5	34				

2(l) 88 days after emergence

Source	SS	df	MS	F value	F required	Result
Treatment	2455.7	6	409.28	6.48	2.44 3.53	**
Error	1769.0	28	63.17			
Total	4224.7	34				

APPENDIX 10 (Continued)

3. Results of "t" tests on the number of heads emerged per 3 ft of row at each sampling date.

Comparison	Sampling Date - Days after emergence										
	53	54	55	57	58	60	62	64	66	68	75
Co V U3		NS	**	**	**	**	**	**	**	**	**
Co V U6	**	**	**	**	**	**	**	**	**	**	**
Co V S6		**	**	**	**	**	**	**	**	**	**
Co V A6		NS	**	**	**	**	**	**	**	**	**
Co V S18		NS	**	**	**	**	**	**	**	**	**
Co V A18		NS	**	**	**	**	**	**	**	**	**
U3 V U6	*	**	**	**	**	**	*	*	NS	*	NS
U3 V S6	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
U3 V A6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
U3 V S18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
U3 V A18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
U6 V S6	NS	NS	*	*	*	NS	NS	NS	NS	NS	NS
U6 V A6	**	**	**	*	*	NS	NS	NS	NS	NS	NS
U6 V S18	**	**	**	**	**	**	*	*	NS	*	NS
U6 V A18	*	**	**	**	**	**	**	**	*	**	*
S6 V A6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S6 V S18	NS	NS	*	**	**	*	*	NS	NS	*	NS
S6 V A18	NS	NS	*	*	**	*	*	NS	NS	*	*
A6 V S18	NS	NS	NS	*	**	*	NS	NS	NS	NS	NS
A6 V A18	NS	NS	NS	*	*	*	*	NS	NS	NS	NS
S18 V A18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

APPENDIX 11

Yield measurements of grain and straw

1. Yield of Grain in grams of clay matter per plot.

Treatment	Replicate 1	2	3	4	5	ΣX	$\bar{X}$
Co	278.9	172.1	264.3	276.8	303.1	1295.2	259.0 ±22.4
U3	346.9	321.0	275.9	360.0	283.5	1587.3	321.1 ±16.7
U6	465.3	341.5	441.4	287.5	401.3	1937.0	387.4 ±37.8
S6	279.1	463.8	330.8	216.0	354.4	1644.1	328.8 ±41.3
A6	360.4	229.6	312.7	279.9	380.6	1563.2	312.7 ±27.3
S18	265.9	296.5	227.2	376.4	201.6	1367.6	273.5 ±30.4
A18	225.4	280.2	284.2	283.4	407.1	1480.5	296.1 ±29.9

2 Yield of Straw in grams of dry matter per plot.

Treatment	Replicate 1	2	3	4	5	ΣX	$\bar{X}$
Co	414.2	344.2	367.7	488.0	582.1	2196.2	439.3 ±13.7
U3	584.5	524.0	589.2	576.5	604.9	2879.1	575.8 ±13.7
U6	594.0	684.2	516.0	653.5	577.4	3025.1	597.8 ±29.5
S6	575.4	732.9	445.0	464.8	488.6	2706.7	541.4 ±52.8
A6	581.3	579.6	481.3	567.5	574.2	2783.9	556.8 ±19.0
S18	584.0	507.2	549.8	584.4	566.6	2792.0	558.4 ±14.3
A18	524.0	529.6	512.6	499.1	475.8	2541.1	508.2 ± 9.6

3 Means of Grain and Straw yield.

Measurement	Treatment Co	U3	U6	S6	A6	S18	A18	S.E.	0.05 & 0.01
Grain	259.0	321.1	387.4	328.8	312.7	273.5	296.1	±29.6	85.6 115.4
Straw	439.3	575.8	597.8	541.4	556.8	558.4	508.2	±22.4	65.4 88.3

4. Results of "t" tests on the yield of Grain and Straw.

Comparison	Measured Character	
	Grain	Straw
Co V U3	NS	**
Co V U6	**	**
Co V S6	NS	**
Co V A6	NS	**
Co V S18	NS	**
Co V A18	NS	*
U3 V U6	NS	NS
U3 V S6	NS	NS
U3 V A6	NS	NS
U3 V S18	NS	NS
U3 V A18	NS	*
U6 V S6	NS	NS
U6 V A6	NS	NS
U6 V S18	*	NS
U6 V A18	*	**
S6 V A6	NS	NS
S6 V S18	NS	NS
S6 V A18	NS	NS
A6 V S18	NS	NS
A6 V A18	NS	NS
S18 V A18	NS	NS

APPENDIX 12

1. Analysis of variance of Grain yield per plot.

Source	SS	df	MS	F value	F required	Result
Treatments	52636	6	8773	2.01	2.44 3.53	NS
Error	122396	28	4731			
Total	175032	34				

2 Partitioned Analysis of Variance of Grain yield

Source of Variation	SS	df	MS	F value	F required	Result
Treatments	52636	6	8772.6	2.01	2.44 3.53	NS
U3 V (S6 A6 S18 A18)	865.5	1	865.5	0.198	4.20 7.64	NS
U6 V (S6 A6 S18 A18)	28648.9	1	28648.9	6.55	4.20 7.64	*
U6 V Co	41190.7	1	41190.7	9.42	4.20 7.64	**
U3 V (S18 A18)	3559.9	1	3559.9	0.82	4.20 7.64	NS
U6 V (S6 A6)	14811.7	1	14811.7	3.38	4.20 7.64	NS
U6 V A18	20848.4	1	20848.4	4.77	4.20 7.64	*
U6 V S18	32421.4	1	32421.4	7.42	4.20 7.64	*
Error	122396	28	4371			

The above analysis is performed on data not orthogonal and therefore the total SS and df are not identical to 1. The variance used in each source may have been used in another.

3. Analysis of Variance of Straw yield.

Source	SS	df	MS	F value	F required	Result
Treatment	86517	6	14,419.5	3.16	2.44 3.53	*
Error	127700	18	4560.7			
Total	214217	34				

APPENDIX 12 (Continued)

4. Partitioned analysis of Variance of Grain Yield

Source	SS	df	MS	F value	F required	Result
Treatment	86517	6	14419.5	3.16	2.44 3.53	*
U3 V (S6 A6 S18 A18)	4803.9	1	4803.9	1.05	4.20 7.64	NS
U6 V (S6 A6 S18 A18)	16299.6	1	16299.6	3.57	4.20 7.64	NS
U6 V Co	68690.9	1	68690.9	15.06	4.20 7.64	**
U6 V A18	23425.6	1	23425.6	5.14	4.20 7.64	*
U3 V A18	11431.2	1	11431.2	2.51	4.20 7.64	NS
Error	127700	28	4560.7			

The same conditions apply for this analysis as for 12 (2).

APPENDIX 13

Meteorological Records November 1960 - March 1961