CERTIFICATE

I hereby certify that the work submitted in this thesis for the degree of Magister in Scientia of the University of Wales is the result of my own investigations, except where acknowledgement is made in the text.

....
Candidate

....
Supervisor

D E C L A R A T I O N

I hereby declare that the work in this thesis has not already been submitted for any degree, and is not being concurrently submitted in candidature for any degree.

Signature ....

Date .4/IX/73....................

Variation in Response of *Lolium* *Species* and Hybrids to Different Nitrogen, Phosphorus and Potassium Levels.

a thesis

submitted in part candidature

for the degree of

Magister in Scientia

of the

University of Wales

by

Heliodoro Pastor Figueredo

Welsh Plant Breeding Station,
Plas Gogerddan,
Aberystwyth,
Cardiganshire.

April 1973.

CONTENTS

FIGURE INDEX

Experiment A

Experiment B

Experiment C

INDEX TO TABLES

ACKNOWLEDGEMENT

The candidate wishes to express his sincere gratitude to his research director, Dr. P. J. Goodman, for his careful supervision, advice and encouragement throughout the period of research and during the preparation of this thesis. Thanks are also due to Professor P. T. Thomas, C.B.E., for providing the facilities at the W.P.B.S. which enabled this work to be carried out; also to Mr. D. M. Hughes and Mr. M. Collison for their valuable technical assistance.

The candidate wishes to acknowledge the assistance of the British-Colombo Plan Technical Co-operation Programme in giving him a scholarship to attend the University College of Wales in Aberystwyth, Great Britain. Also he is extremely grateful to the Instituto Colombiano Agropecuario (I.C.A.) for giving him the opportunity to receive this grant.

The candidate also expresses his gratitude to Dr. G. M. Evans, director of the M.Sc. course for his advice and encouragement throughout the period of studies, and to the Professor H. Rees of the Agricultural Botany Department for providing the facilities for the M.Sc. course.

<u>Plate 1</u>

The interaction between nitrogen levels and populations of *Lolium* spp.

CHAPTER I. INTRODUCTION

Most grass breeding programmes have developed the variation and combination of characters in natural ecotypes or cultivated varieties. Cooper and Breese (1971) have shown that a more long term approach lies in deliberately combining characteristics from different climatic and agronomic populations, in accordance with a well defined physiological or morphological model.

Model hybridization has been used both within species or, more ambitiously, between related species. Interspecific hybridization has been used most often between *Lolium perenne* L. and *L.multiflorum* Lam. Stabilization has been needed and this has been achieved either by back crossing (Corkill, 1957) or by inducing polyploidy (Breese and Lewis, 1969). The hybrids used in the present experiments are the progeny of a half diallel between selected climatic and agronomic populations of *L.perenne* and *L.multiflorum* produced by Dr. J. P. Cooper at the Welsh Plant Breeding Station.

Deliberate selection for characters of mineral nutrition is also a recent innovation (Vose, 1963). Much unconscious selection for performance at different levels of nutrition must have occurred during the development of successful varieties in different parts of the world. Indeed, Jain and Bradshaw (1966) found a high degree of natural selection among Agrostis plants near lead mines. These plants had evolved very sophisticated mechanisms of tolerance of lead, copper and zinc. Similarly, in agricultural conditions, variations and adaptations occur. Butler et al (1962) found that individual plants varied in their content of many nutrients. Like the development of new varieties for increased yield, the study of variation in characters of mineral nutrition for agronomic purposes began with the use of ecotypes (Antonovics et al, 1966; Goodman 1969). More recently the nutrient studies, like the yield studies, have turned to using model diallel crosses between L.perenne and L.multiflorum. The variations found in nutrition of L.perenne ecotypes have been greatly increased by using the model diallel (Bowerman and Goodman, 1971; Owen, 1972).

Variations in characters of mineral nutrition may take several forms. Firstly there is variation in the expression of deficiency symptoms, and variation in tolerance of shortage or toxic levels of minerals (Jain and Bradshaw, 1966; Randall, 1963). Secondly, there is variation in content of different nutrients (Butler et al, 1962). Thirdly, there is variation in growth response to applied nutrient or fertilizer.

Yield response to applied fertilizer is an important economic attribute. It represents the marketable return for fertilizer application. Yield response may be expressed in several ways. Total yield may be found to vary at different fertilizer levels, or the nutrient rate giving optimal growth may very, or the shape of the yield response curve to fertilizer may vary. In practice there is variation in all three of these characters, as shown in a group of eight pasture species studied by Ozanne, Keay and Biddiscombe (1969). Even within the single species Hordeum vulgare Boken (1970) found small but consistent variations in maximal yield and response curve shape.

Boken (1970) and earlier, Vose and Breese (1964) had concluded that "efficiency" or "utilization" of nutrient (g.dry matter per g.fertilizer applied) was a meaningful measure of response. This value measures the agricultural significance of selections made for nutrient response.

Work on the half diallel used in these experiments has already been done in sand culture (Goodman and Hughes 1972). Consistent and significant differences were found in response of different varieties and progenies to nitrogen, phosphorus and potassium. There were two problems in applying this work to pots of soil. Firstly, suitable rates of application had to be found for nitrogen, phosphorus and potassium. Those for phosphorus were already known from the work of Lawas and Goodman (1970). Secondly, these rates are known to depend to some extent on interactions with other nutrients (Goodman, 1969), with light intensity, temperature and cutting regime (Hughes, 1970).

The rates of application were judged from somewhat limited prior experience especially of nutrient interaction and cutting effects. Doses of fertilizer varying one nutrient at a time were made to increase logarithmically from a basal formula. Separate experiments were carried out measuring response to nitrogen, phosphorus and potassium, as previous experience had shown that factorial experiments were too large to handle satisfactorily and the interactions between nutrients were too complex for simple interpretation (Goodman, 1969).

This work represents an intermediate stage between measuring response of diallel progenies to different nutrient conditions in sand culture and the ultimate testing of these varieties for fertilizer response in the field, which still remains to be done.

CHAPTER II. MATERIALS AND METHODS

MATERIALS

Three similar experiments were carried out to investigate the effect of nitrogen (Exp.A); phosphorus (Exp.B) and potassium (Exp.C) on eight selected populations of *Lolium* Species (Table 1).

Table 1. - Selected populations of *Lolium species*.

Code Number	Species	Variety	Origin
1 x 1	L.multiflorum	Liscate (Bb1277)	Italy
5 x 5	L.multiflorum	S.22	Aberystwyth
4 x 4	L.perenne	Ba6280	Normandy
3 x 3	L.perenne	S.23	Aberystwyth
1 x 5	L.multif x L.multif	Liscate x S.22	
1 x 3	L.multif x L.perenne	Liscate x S.23	
4 x 5	L.perenne x L.multif	Ba6280 x S.22	
4 x 3	L.perenne x L.perenne	Ba6280 x S.23	

The particular interest was to find whether the varieties responded differently to increasing fertilizer levels. Thus, the eight populations were treated with a basal addition of macro and micronutrients.

Macronutrients:

Sodium Nitrate pure cryst $NaNO_3$;

Potassium Nitrate KNO_3;

Calcium Nitrate $Ca(NO_3)_2$;

Sodium Dihydrogen orthophosphate NaH_2PO_4;

Potassium Chroride KCL;

Calcium Chloride $CaCL_2.6H_2O$;

Magnesium Sulphate $MgSO_4.7H_2O$;

Micronutrients:

Ferric EDTA solution

Micronutrient solution as described by Shive and Robbins (1942)

The population seedlings were planted in John Innes compost with 20% sand to which no fertilizer had been added.

METHODS

One hundred and eighty seeds of each population were placed on wet fine sand in Petri dishes, set into two groups of 90 seeds and left to germinate under shade for a week. The sand was kept damp throughout this period. Strong seedlings about one inch tall of each population were selected and transplanted to 12 pots of compost.

Each 5-inch pot, with 9 seedlings, contained a basal nutrient mixture of macro and micronutrients mixed dry with the soil.

To determine the response of the eight populations to different nitrogen, phosphorus and potassium levels, in each experiment one of these three major nutrients was supplied at four levels while the other two were standardized.

There were three replicates of these 4 levels at random over the 12 pots per population. The three replicates were fully randomised within three blocks. Thus each block contained 32 treatments (8 populations x 4 nutrient levels). The pots were placed in saucers and watered from above twice daily.

Fifteen days from transplanting the plants were thinned down to five plants per pot.

Four harvests were carried out within each experiment. The leaf variates (number, area and dry matter) were recorded at each harvest time. At the last harvest each plant was removed from the soil by washing, then separated into its three parts: leaves, stem and roots. The leaf variates, stem dry matter and root dry matter were each then recorded. Finally after all harvests had been taken, the plant variates, total leaf number, total leaf area, total leaf dry matter and plant total dry matter were estimated from all the harvests combined.

The leaf area was measured on a fresh leaf sample in the "Hayashi Denko Leaf Area Machine". The dry matter was estimated using an oven at 100°C for 24 hpurs, then weighing.

The analysis of variance for each variate was worked out as for the random blocks. Since the analyses of variance all had the same pattern and numbers of degrees of freedom, sample analyses are presented (Appendix D) to illustrate the method used. Significance was determined by the Duncan's New Multiple Range and Least Significant Difference tests. Statistical analyses was carried out for individual and combined harvests.

Experiment (A). Nitrogen Treatment

On May 15th, 1972, seedlings of the eight populations grown on wet fine sand in Petri dishes were transplanted to 5-inch pots which contained the following basal nutrient mixture:

4.0g. NaH_2PO_4;

3.0g. KCL;

8.8g. $CaCL_2.6H_2O$;

2.6g. $MgSO_4.7H_2O$;

5 ml. of ferric EDTA solution;

5 ml. of micronutrient solution;

$NaNO_3$:

N_0 = 0g.

N_1 = 0.5g.

N_2 = 2.0g.

N_3 = 8.0g.

nitrogen levels.

To avoid replanting, nine seedlings were planted per pot. Only five were allowed to grow through the experiment which was carried out in the greenhouse. The pots were placed in saucers and watered from above twice daily for 70 days.

Four harvests were carried out at 32, 44, 56 and 70 days after planting. The leaf variates, number and area were not recorded at 44 days after planting.

Experiment (B). Phosphorus Treatment

On December 14th, 1971, seedlings of the eight populations grown on wet fine sand in Petri dishes were transplanted to 5-inch pots which contained the following basal nutrient mixture:

$4.0g.\ KNO_3$;

$9.5\ Ca(NO_3)_2$;

$2.1g.\ MgSO_4.7H_2O$;

5 ml. of ferric EDTA solution;

5 ml. of micronutrients solution;

NaH_2PO_4:	P_0 = 0g.		
	P_1 = 1.0g.	phosphorus levels.	
	P_2 = 4.0g.		
	P_3 = 16.0g.		

To avoid replanting, nine seedlings were planted per pot. Only 5 were allowed to grow through the experiment.

The experiment carried out in a controlled environment (growth room) at 75 Wm^{-2} for 16 hours daylength at 20^oC. The pots were placed in saucers and watered from above twice daily for 86 days.

Four harvests were carried out at 41, 58, 70 and 86 days after planting. The leaf variates, number and area were not recorded at 58 days after planting.

Experiment (C). Potassium Treatment

On July 5th, 1972, seedlings of the eight populations grown on wet fine sand in Petri dishes were transplanted to 5-inch pots which contained the following basal nutrient mixture:

4.0g. $NaNO_3$;

4.0g. NaH_2PO_4;

8.8g. $CaCL_2.6H_2O$;

2.6g $MgSO_4 . 7H_2O$

5 ml. of ferric EDTA solution;

5 ml. of micronutrients solution;

KCL: K_0 = 0g.

K_1 = 0.5g. potassium levels.

K_2 = 2.0g.

K_3 = 8.0g.

To avoid replanting, nine seedlings were planted per pot. Only 5 were allowed to grow through the experiment.

The experiment was carried out in the greenhouse. The pots were placed in saucers and watered from above twice daily for 78 days.

Four harvests were carried out at 30, 42, 58 and 78 days after planting.

CHAPTER III. RESULTS

EXPERIMENT (A). - NITROGEN TREATMENT

The results are summarized in Appendices A, B and C. Sample analyses of variance are shown in Appendix D.

The material and methods used in the nitrogen experiment have already been described in Chapter II "Materials and Methods".

1. Effect of Different Nitrogen Levels.

(i) Total Yields for all Harvests Combined.

(a) Leaf number per plant (Table 2).

The total leaf number increased as nitrogen supply increased over the whole range from N_0 to N_3. From N_0 to N_1 and from N_1 to N_2 the differences were significant. From N_0 to N_2 the leaf number increased about six times as much as from N_2 to N_3.

(b) Leaf area per plant. (Table 2).

The total leaf area increased uniformly as nitrogen supply increased over the whole range from N_0 to N_3. The leaf area increment between treatment levels was significant over the whole range.

(c) Leaf dry matter per plant. (Table 2).

The total leaf dry matter increased as nitrogen supply increased over the whole range from N_0 to N_3. The yield at N_3 was about three times that at N_0. The largest increment was from N_1 to N_2, but the other increments between the treatment levels N_0 and N_1, N_2 and N_3 were also significant.

(d) Stem dry matter per plant. (Table 2).

The stem dry matter increased significantly only over the range N_1 to N_2. The N_2 and N_3 yield exceeded by three times that of N_0 and N_1.

Table 2. - Mean Yield, Standard Error, Least Significant Difference and Duncan's New Multiple Range Tests of Nitrogen Levels for all Harvests Combined.

Variate (Per Plant)	Nitrogen Levels. Mean values for all variates				Stand. Error $S\bar{x}$	L.S.D. At 5% level	probability
	N_0	N_1	N_2	N_3			
Leaf number.	39.0	48.6	76.1	82.9	2.68	7.58	$<$ 1%
Leaf area (cm^2/pl)	8.4	13.4	21.9	30.1	0.86	2.45	$<$ 1%
Leaf dry matter (g./pl)	0.4	0.5	0.9	1.1	0.03	0.08	$<$ 1%
Stem dry matter (g./pl)	0.1	0.1	0.3	0.3	0.01	0.03	$<$ 1%
Root dry matter (g./pl)	0.3	0.3	0.3	0.2	0.01	0.04	$<$ 1%
Plant total dry matter (g./pl)	0.8	0.9	1.5	1.6	0.05	0.17	$<$ 1%

All means underscored by a single line do not differ significantly in the Duncan's Multiple Range Test at 5% level.

(e) Root dry matter per plant. (Table 2).

The root dry matter decreased significantly fron N_2 to N_3. There was no difference between the yield means in the range from N_0 to N_2.

(f) Total dry matter per plant (Table 2, and Appendix D)

The plant total dry matter increased over the whole range from N_0 to N_3, but significantly only from N_1 to N_2. The yield at N_3 was double that at N_0.

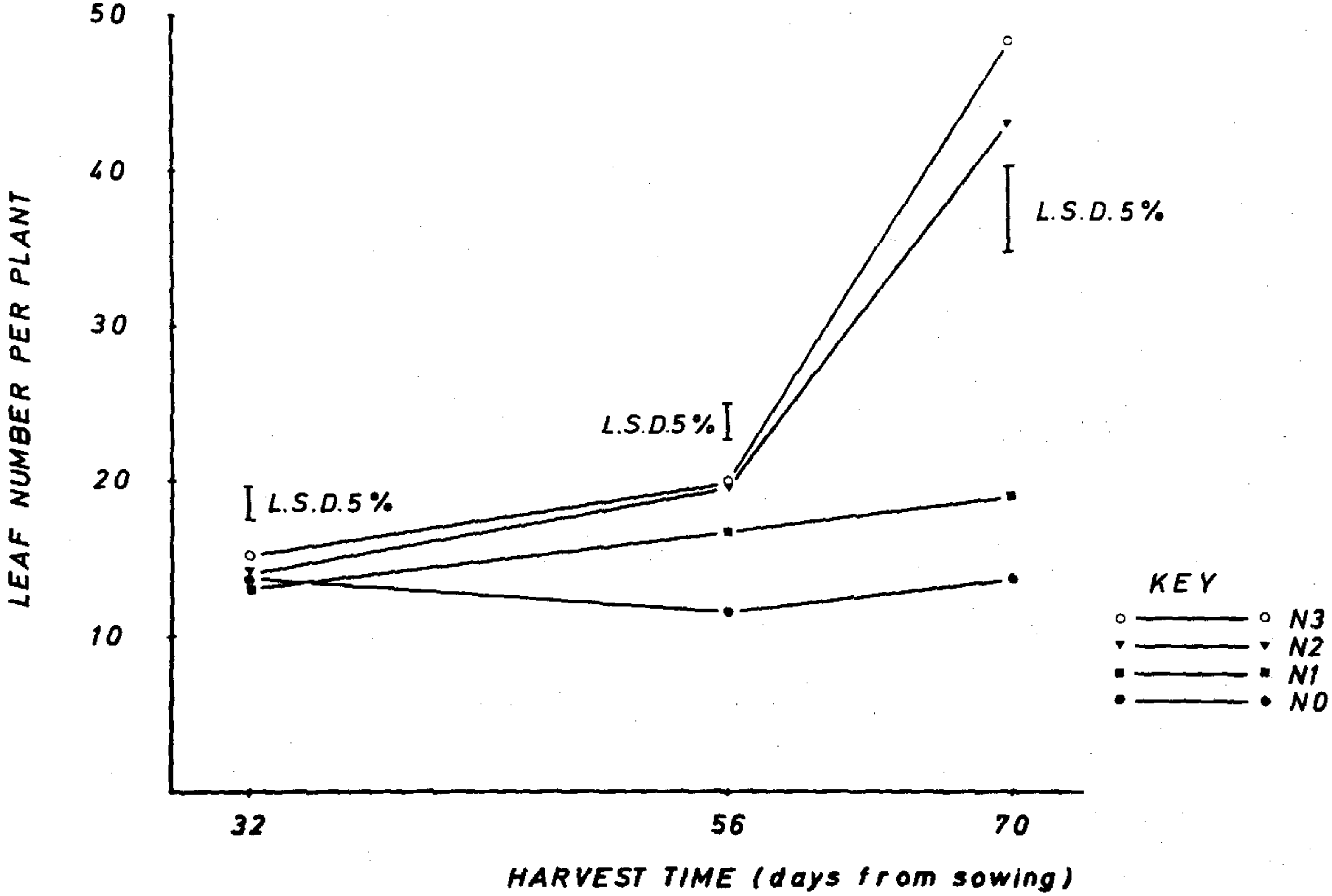
(ii) Effect of Different Nitrogen Levels on Individual Harvest Yields.

The data for individual harvests are presented as graphs. The yield varied according to the harvest interval and thus, the variations in absolute values are not important. What is important is the ranking of the yields at the different nitrogen levels. The variates leaf number and leaf area were recorded only at the first, third and fourth harvest, while leaf dry matter was recorded at the first (41st day), second (58th day), third (70th day) and fourth harvest (86th day after sowing).

(a) Leaf number per plant. (Figure 1).

Each increment of nitrogen supply from N_1 to N_3 increased the leaf number per plant while N_0 remained almost the same at each successive harvest. N_3 produced the largest yield throughout the experiment but it did not differ significantly from N_2. N_1 and N_0 differed at the third (56th day) and fourth harvest (70th day). N_0 and N_1 "crossed over" at the first harvest (32nd day after sowing) when N_0 leaf number slightly exceeded N_1. The progress of mean leaf number throughout the experiment was calculated as

FIGURE 1. EFFECT OF NITROGEN ON LEAF NUMBER AT INDIVIDUAL HARVESTS.



(mean value per plant): First harvest, $\bar{x} = 14.0$; third harvest, $\bar{x} = 16.8$; fourth harvest, $\bar{x} = 30.7$.

(b) Leaf Area per pot. (Figure 2).

The leaf area increments varied significantly over the following ranges: First harvest (32nd day) each increment from N_1 to N_3; third harvest (56th day) each increment from N_0 to N_2 and fourth harvest (70th day) each increment from N_0 to N_3. The mean leaf area values per pot, were: First harvest $\bar{x} = 30.8\ cm^2$; third harvest, $\bar{x} = 22.2\ cm^2$; fourth harvest, $\bar{x} = 38.3\ cm^2$.

(c) Leaf dry matter per pot. (Figure 3).

At all harvests each increment of nitrogen supply increased the leaf dry matter. Most but not all of the increases were significant. The leaf dry matter increased throughout the experiment and it was calculated as the mean value for each harvest per pot as follows: First harvest (32 days), $\bar{x} = 0.9$g.; second harvest (44 days) $\bar{x} = 0.5$g.; third harvest (56 days), $\bar{x} = 0.6$g.; fourth harvest (70 days). $\bar{x} = 1.5$g.

2. <u>Effect of Different Populations</u>

(i) Genotype Differences for all Harvests Combined.

(a) Leaf number per plant (Table 3).

The smallest leaf number was found in <u>Lolium multiflorum</u> Liscate, while the largest leaf number was found in <u>L.multiflorum</u> variety S.22. The <u>Lolium perenne</u> parents were intermediate in leaf number, and not significantly different from each other. The differences between the <u>L.multiflorum</u> and the <u>L.perenne</u> parents were significant. The hybrids did not differ significantly in total leaf

FIGURE 2. EFFECT OF NITROGEN ON LEAF AREA AT INDIVIDUAL HARVESTS.

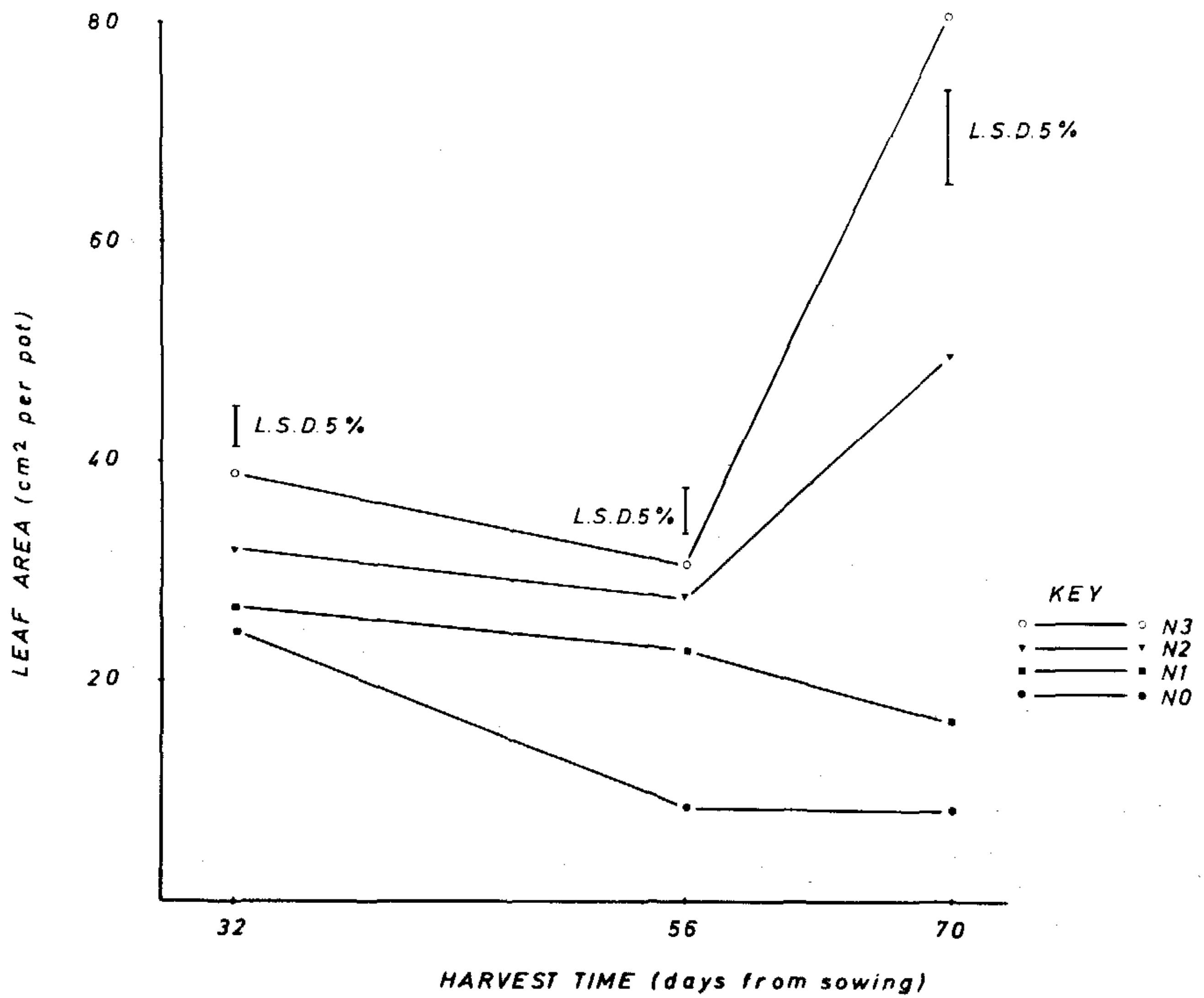
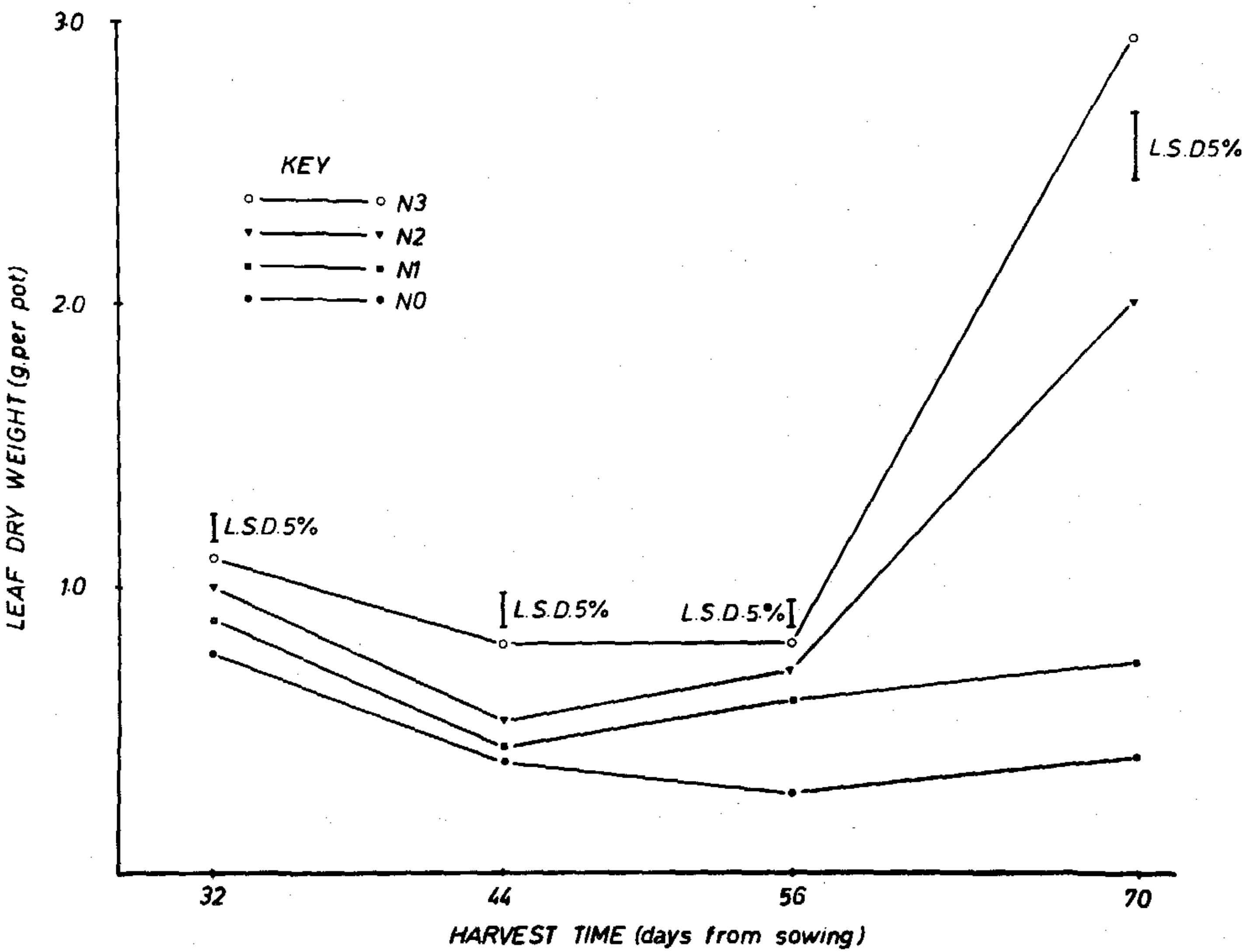


FIGURE 3. EFFECT OF NITROGEN ON LEAF DRY WEIGHT AT INDIVIDUAL HARVESTS



number.

(b) Leaf area per plant (Table 3).

The largest leaf area was found in L.multiflorum variety S.22. This was significantly greater than the leaf area of L.multiflorum Liscate. The L.perenne parents had significantly less leaf area than the L.multiflorum Liscate but were not significantly different from each other.

In the progenies, the L.multiflorum Liscate x L.multiflorum S.22 yielded more leaf area than the two inter-specific hybrids which did not differ significantly. The L.perenne hybrid Ba6280xS.23 yielded less than the interspecific hybrids, and did not differ significantly from its parents. The L.multiflorum hybrid Liscate x S.22 did not differ significantly from its parents.

(c) Leaf dry matter per plant (Table 3).

The L.multiflorum parents yielded significantly more than the L. perenne parents. The Lolium multiflorum hybrid Liscate x S.22 yielded significantly more than the interspecific hybrids Ba6280x S.22 and Liscate x S.23 and even greater than its parents but not significantly so. The interspecific hybrids differed significantly from their parents but not between themselves; they yielded intermediately between the population. The L.perenne hybrid Ba6280 x S.23 did mot differ significantly from its parents or from the other hybrids.

(d) Stem dry matter per plant (Table 3).

In the parents, stem dry matter was greater in L.multiflorum S.22 amd smaller in L.perenne S.23 than in the other parents, from which they differed significantly. The parents *L.multiflorum* Liscate and *L.perenne* Ba6280 as well as the hybrids Liscate x S.22, Liscate x S.23 and Ba6280 x S.22 did not differ significantly from each other. All of them yielded intermediately between the parents *L.multiflorum* S.22 and *L.perenne* S.23 from which they differed significantly. The *L.perenne* progeny Ba6280 x S.23 differed significantly from its parents Ba6280 and from the other progenies but not from its parent S.23.

(e) Root dry matter per plant (Table 3).

In the parents, root dry matter was significantly greater in *L. multiflorum* than in *L.perenne*, but there was no significant difference between the *L.multiflorum* parents or between the *L.perenne* parents.

In the progenies, root dry matter was significantly greater in the *L.multiflorum* progeny Liscate x S.22 and significantly smaller in the *L.perenne* progeny Ba6280 x S.23 and in the interspecific hybrid Ba6280 x S.22. The interspecific hybrid Liscate x S.23 yielded intermediately between the other progenies and did not differ significantly from its parent Liscate. The greatest yield in the population was found in the *L.multiflorum* hybrid "Liscate x S.22".

(f) Total dry matter per plant. (Table 3).

The greatest yield was in the *L.multiflorum* hybrid Liscate x S.22 and the smallest yield was in the *L.perenne* parent S.23. There was no significant difference between the *L.multiflorum* parents Liscate and S.22 or between them and their hybrid Liscate x S.22.

Table 3. Mean Yield, Standard Error, Least Significant Difference and Duncan's New Multiple Range Tests of the Populations for all Harvests Combined.

Populations, L. S. D., Probability	Mean values for each variate per plant.					
	Leaf number	Leaf area (cm^2/pl)	Leaf dry matter (g./pl)	Stem dry matter (g./pl)	Root dry matter (g./pl)	Plant total dry matter (g./pl)
Liscate (L.multifl.)	44.9	22.8 b c	0.9 a	0.2 a	0.3 a	1.4 a
S. 22 (L.multifl.)	86.2	28.8 a	0.9 a	0.3	0.3 a	1.5 a
Ba6280 (L.perenne)	57.2 a	12.7 ef	0.5 c	0.2 a	0.2 b	0.9 c
S. 23 (L. perenne)	62.4 a	11.0 f	0.5 c	0.1 b	0.2 b	0.8 c
Liscate x S.22 (L.m. x L.m.)	59.3 a	26.1 ab	1.0 a	0.2 a	0.4	1.6 a
Liscate x S.23 (L.m. x L.p.)	59.7 a	19.1 cd	0.7 b	0.2 a	0.3 a	1.2 b
Ba6280 x S.22 (L.p. x L.m.)	66.3 a	16.1 de	0.7 b	0.2 a	0.2 b	1.1 b
Ba6280 x S.23 (L.p. x L.p.)	57.2 a	11.0 f	0.5 c	0.1 b	0.2 b	0.8 c
Standard Error, $S\bar{x}$.	3.79	1.22	0.04	0.01	0.02	0.06
L. S. D. At 5% level	10.71	3.46	0.12	0.04	0.07	0.18
Probability	$\leq$ 1%	$\leq$ 1%	$\leq$ 1%	$\leq$ 1%	$\leq$ 1%	$\leq$ 1%

All means marked with the same letter do not differ in the Duncan's Multiple Range Test at 5% level.

There was no significant difference between the L.perenne parents Ba6280 and S.23 or between them and their hybrid Ba6280 x S.23. The interspecific hybrids yielded intermediately between the parents differing significantly from the parents but not differing between themselves.

(ii) Population Differences at Individual Harvests.

The data for individual harvests are presented as graphs. The values varied according to the harvest interval and thus, the variations in absolute values are not important. What is important is the ranking of the different populations in yield.

(a) Leaf number per plant. (Figure 4).

The greatest leaf number at all harvests was found in the L. multiflorum S.22, which differed significantly from the other parents and from the progenies. The smallest leaf number was that of L.multiflorum Liscate at most harvests. The other parents and progenies did not vary significantly.

(b) Leaf area per pot. (Figure 5).

The L.multiflorum S.22 gave the greatest yield at the last harvest exceeding significantly the other L.multiflorum parent and the hybrid between them. However, the L.multiflorum Liscate gave less yield than the hybrid L.multiflorum 'Liscate x S.22' and one of the interspecific hybrids L.multiflorum Liscate x L.perenne S.23 at the last harvest. The smallest leaf area increments were given by the L.perenne parents and their hybrid which did not differ significantly.

FIGURE 4. EFFECT OF DIFFERENT GENOTYPES ON NUMBER OF LEAVES AT INDIVIDUAL HARVESTS.

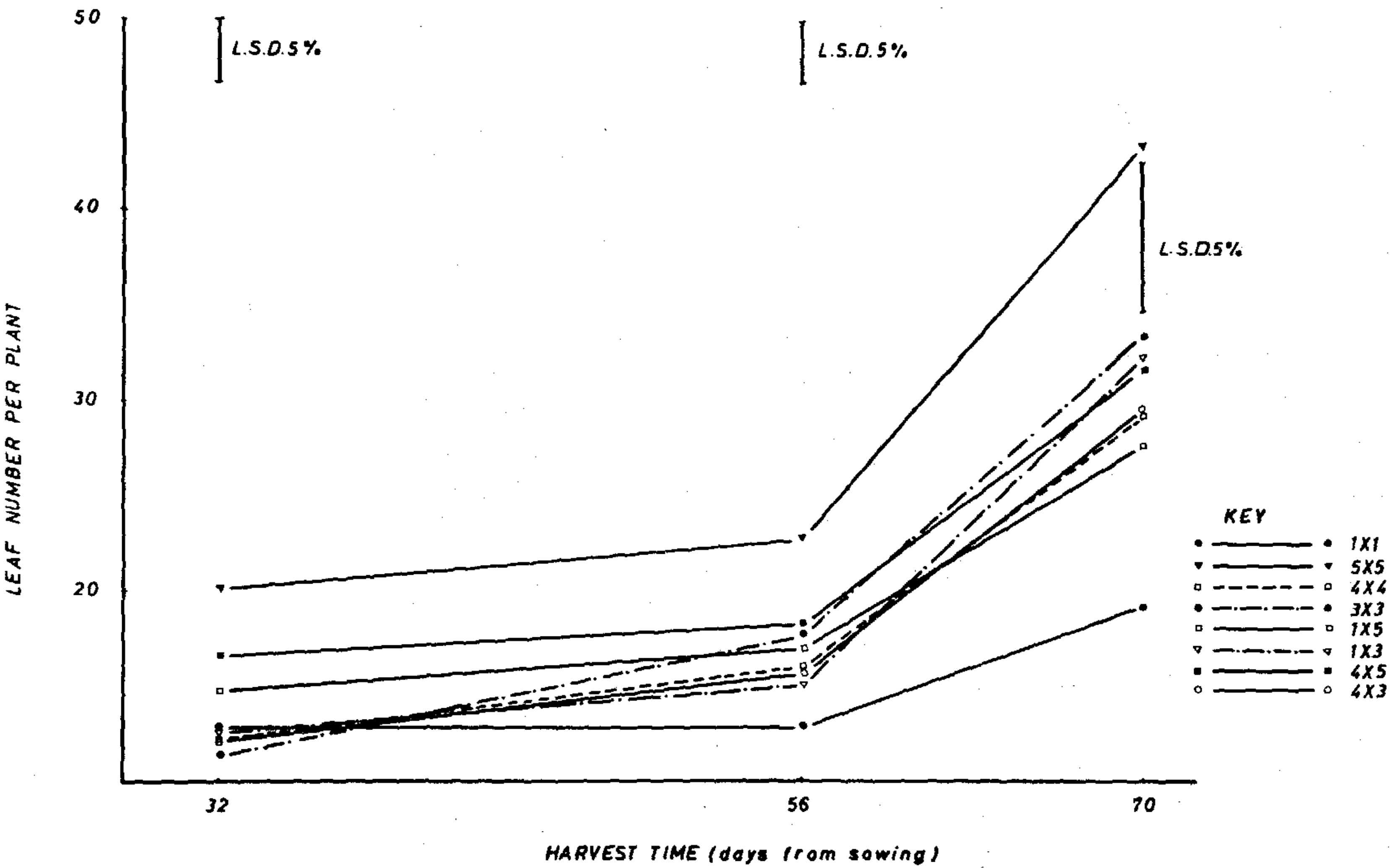
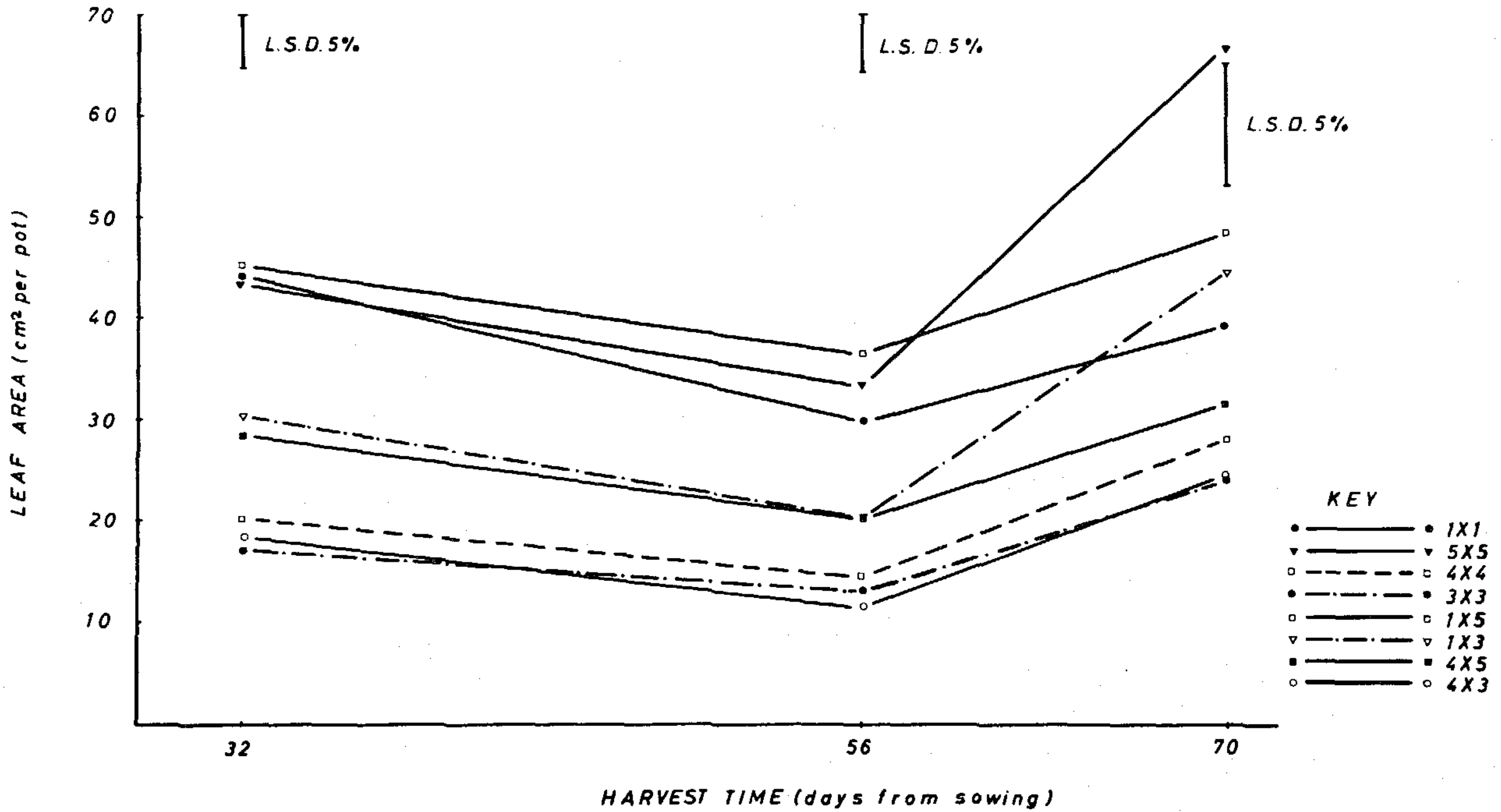


FIGURE 5. EFFECT OF DIFFERENT GENOTYPES ON LEAF AREA AT INDIVIDUAL HARVESTS



(c) Leaf dry matter per pot. (Figure 6)

The L.multiflorum parents greatly changed their yielding characteristics over the duration of the experiment. At the first harvest they yielded most dry matter, butat the fourth harvest they yielded least dry matter of all the populations.

Apart from the last harvest when the parent L.multiflorum yield had declined, the L.perenne parent and hybrids yielded least dry matter. The interspecific hybrids yielded intermediately between their parents in dry matter. However, the greatest dry matter was consistently given by the L.multiflorum Liscate x L.multiflorum S.22. This is a most interesting hybrid in that the sharp decline in yield of the Liscate and S.22 parents relative to L.perenne presumably caused by frequent cutting did not occur in this hybrid.

3. Populations x Nitrogen Interaction.

(i) Populations x Nitrogen Interaction for all Harvests Combined.

(a) Leaf area per pot. (Figure 7)

In the parents, the increase in total leaf area caused by increasing the nitrogen supply was significantly greater in the L.multiflorum parents than in the L.perenne parents at N_2 and N_3 levels. In the L.multiflorum parents, the total leaf area increment in S.22 exceeded significantly that in Liscate and in its hybrid at N_3. The L.perenne parents did not differ significantly. In the progenies, the total leaf area increment was significantly greater in L.multiflorum progeny Liscate x S.22 than in the other progenies at N_2 and N_3. The interspecific hybrids always occupied an intermediate position between the L. multiflorum hybrid and the L.perenne hybrid, so, they were ranked in order thus: Liscate x S.22;

FIGURE 6. EFFECT OF DIFFERENT GENOTYPES ON LEAF DRY WEIGHT AT INDIVIDUAL HARVESTS.

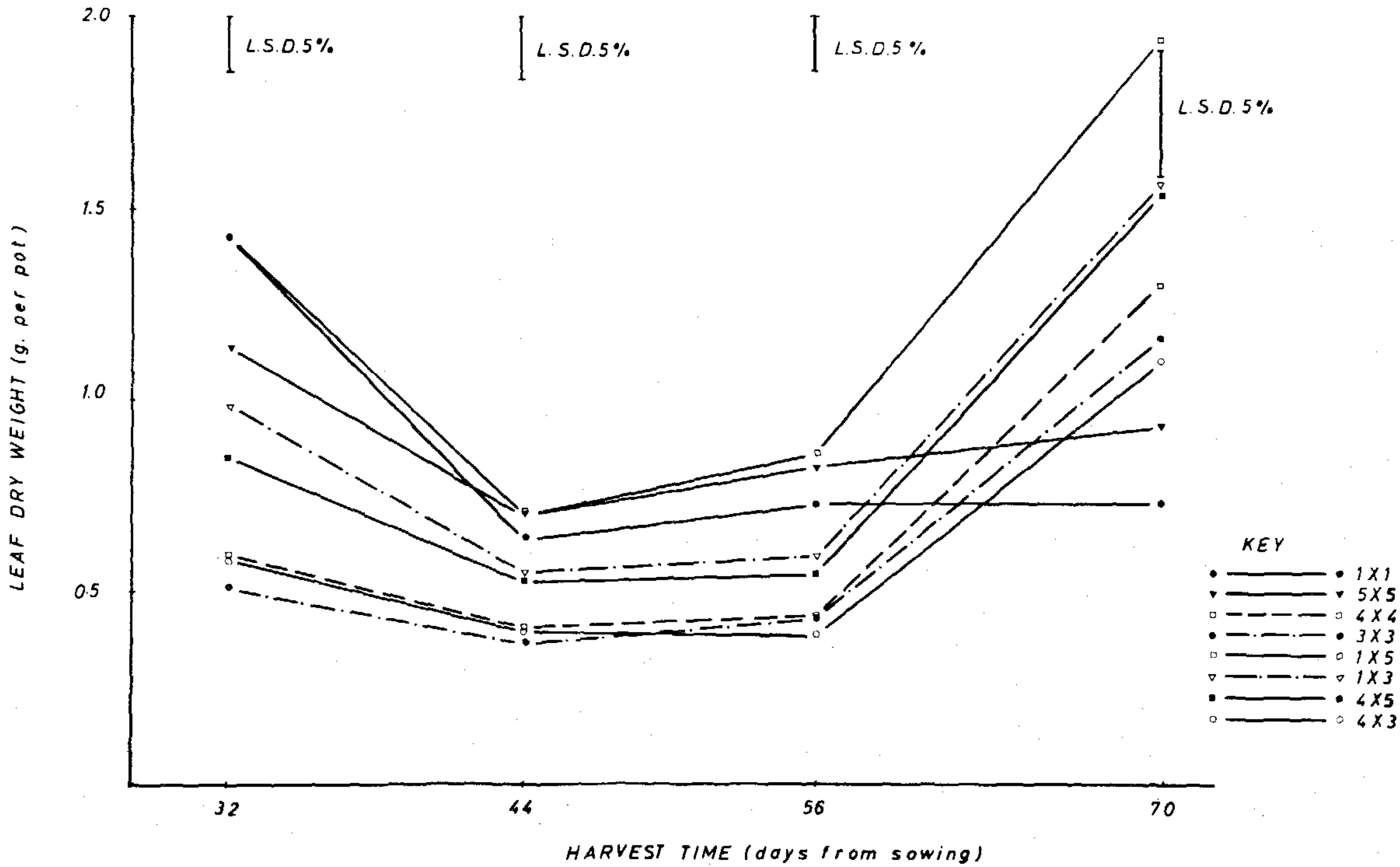
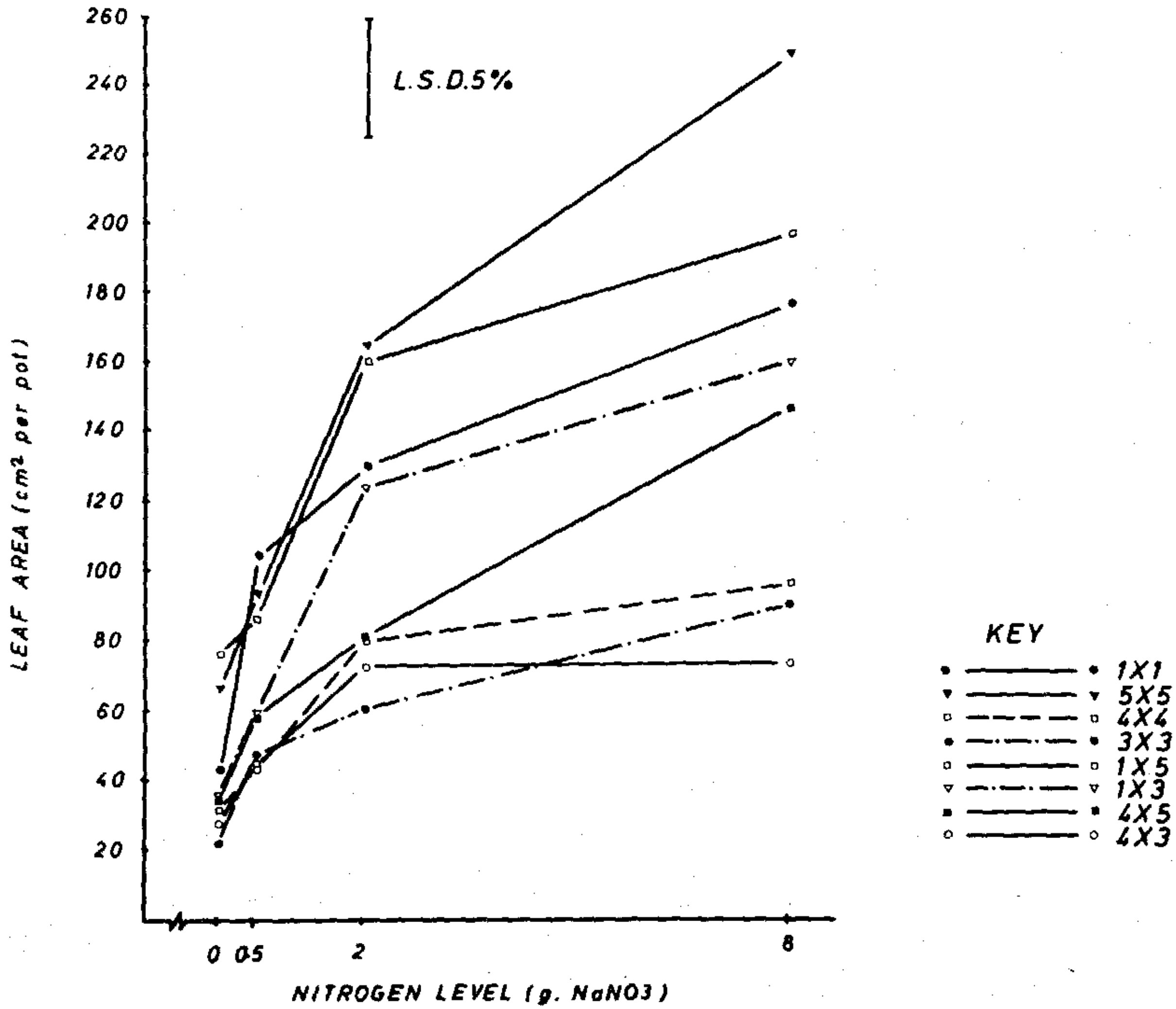


FIGURE 7. EFFECT OF GENOTYPES X NITROGEN LEVELS INTERACTION ON TOTAL LEAF AREA.



Liscate x S.23; Ba6280 x S.22 and Ba6280 x S.23. Each one differed significantly from the other at N_3. The leaf area increased as the nitrogen supply increased in all populations.

(b) Leaf dry matter per pot. (Figure 8).

In the parents, the total leaf dry matter increase caused by increasing the nitrogen supply was significantly greater in the L.multiflorum parents and their hybrid than in the L.perenne parents and their hybrid at N_2 and N_3. There was no significant difference in total dry matter between the L.multiflorum parents and their hybrid or between the L.multiflorum parents and their hybrid throughout the range of nitrogen supply.

In the progenies, the total leaf dry matter increment was significantly greater in the L.multiflorum hybrid Liscate x S.22 than in the other progenies. Thus, the interspecific hybrids occupied an intermediate position between L.multiflorum hybrid Liscate x S.22 and the L.perenne hybrid Ba6280 x S.23, so, the populations were ranked in order thus: Liscate x S.22; Ba6280 x S.22; Liscate x S.23 and Ba6280 x S.23. The interspecific hybrids differed significantly from the other progenies but they did not differ between themselves at N_3.

(c) Total dry matter per pot (Figure 9).

In the parents, the increase in plant total dry matter caused by increasing the nitrogen supply was greater in L.multiflorum than in L.perenne parents throughout the range of the nitrogen supply. L.multiflorum parents yielded significantly differently from the L.perenne parents at N_2 and N_3 levels.

FIGURE 8. EFFECT OF GENOTYPES X NITROGEN LEVEL INTERACTION ON TOTAL LEAF DRY WEIGHT.

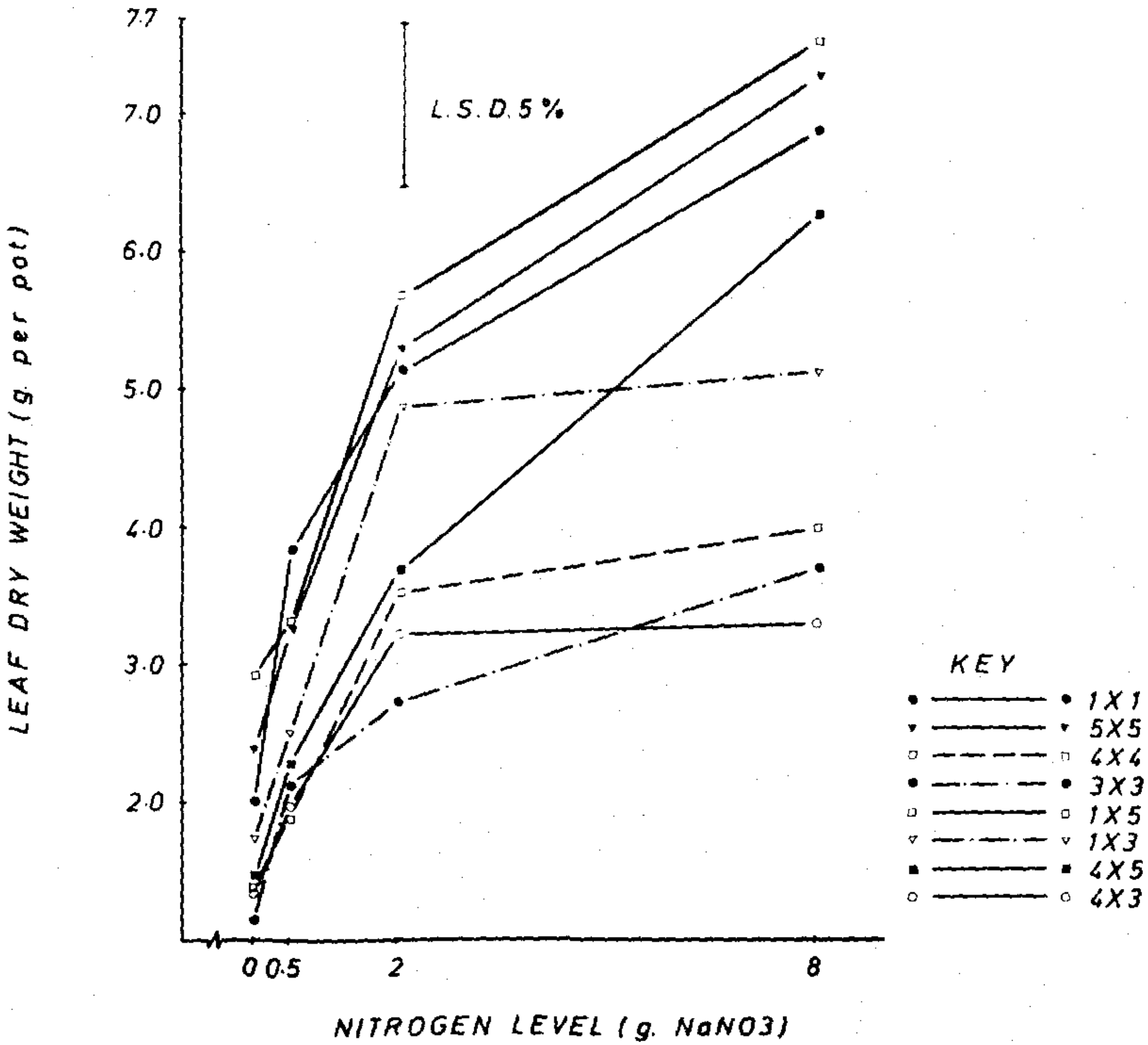
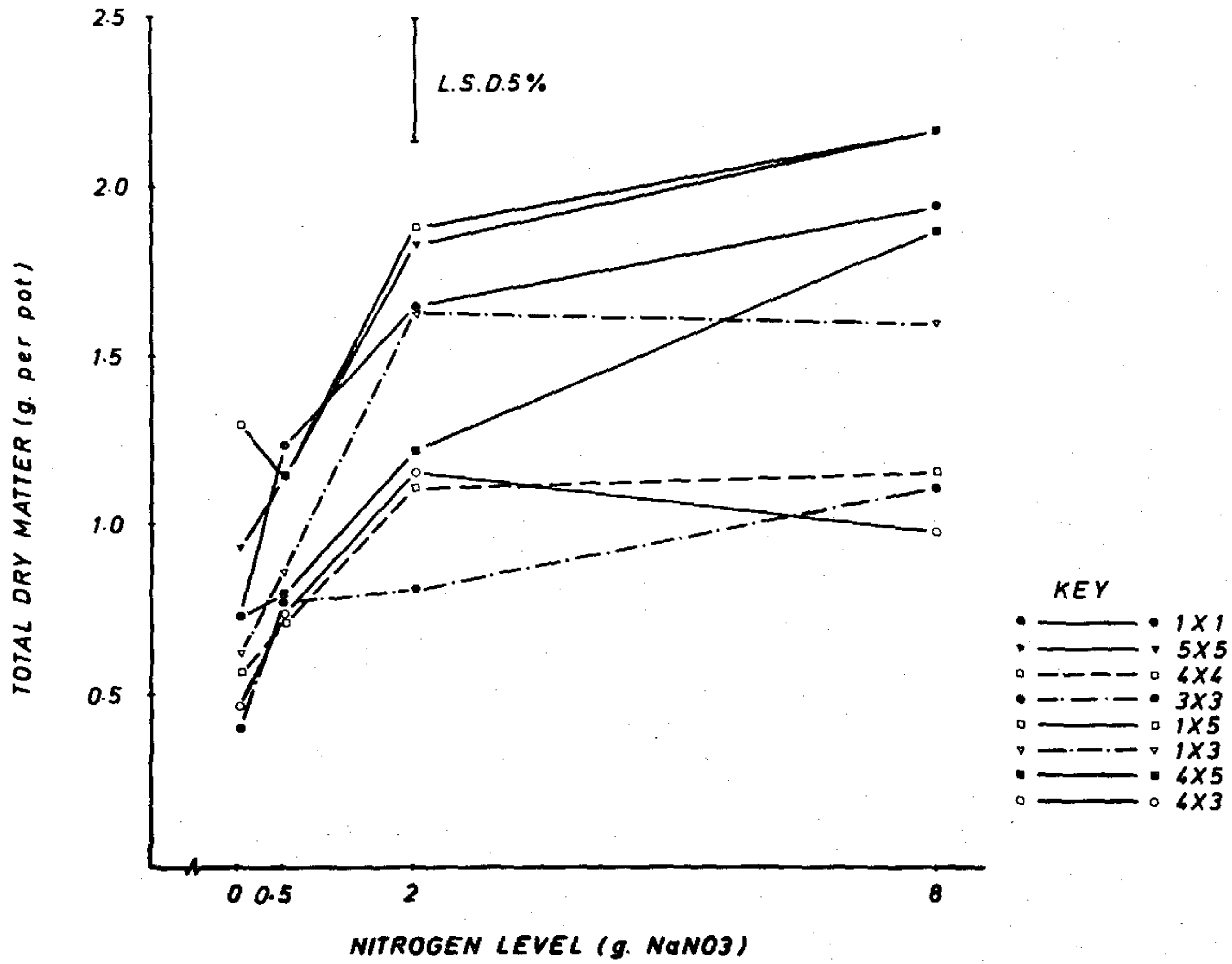


FIGURE 9. EFFECT OF GENOTYPES X NITROGEN LEVEL INTERACTION ON PLANT TOTAL DRY MATTER FOR ALL HARVESTS COMBINED.



In the progenies, the interspecific hybrids Ba6280 x S.22 and Liscate x S.23 yielded intermediately between the L.multiflorum hybrid Liscate x S.22 and the L.perenne hybrid Ba6280 x S.23, but did not differ significantly from them throughout the range of nitrogen supply. The interspecific hybrid Liscate x S.23 yielded significantly differently from the other interspecific hybrid Ba6280 x S.22 and from the L.multiflorum hybrid Liscate x S.22 at the N_2 level and also differed significantly from this last one at N_3 level. (Table 2). There were no significant interaction in the following characters: Total leaf number per plant, stem dry matter and root dry matter for all harvests combined.

(ii) Population x Nitrogen Interaction at the Individual Harvests.

(a) Leaf area per pot. (Figures 10, 11 and 12).

The populations and nitrogen levels interacted significantly in leaf area in the first (32nd day), third (56th day) and fourth (70th day) harvest. In the parents, the leaf area was consistently and significantly greater in the L.multiflorum than in the L. perenne at all harvests. The ranking of the parents throughout the experiment was in the order: S.22; Liscate; Ba6280 and S.23. The greatest leaf area was in the S.22 and the smaller was in the S.23. The L.perenne parents did not differ significantly between themselves throughout the experiment. The L.multiflorum parents only differed significantly at N_3 in the last harvest.

In the progenies, the leaf area was significantly greater in the L.multiflorum Liscate x S.22 than in the others at the first (32nd day) and third harvest (56th day after sowing). The inter-

FIGURE 10. EFFECT OF GENOTYPES X NITROGEN LEVEL INTERACTION ON LEAF AREA AT FIRST HARVEST.

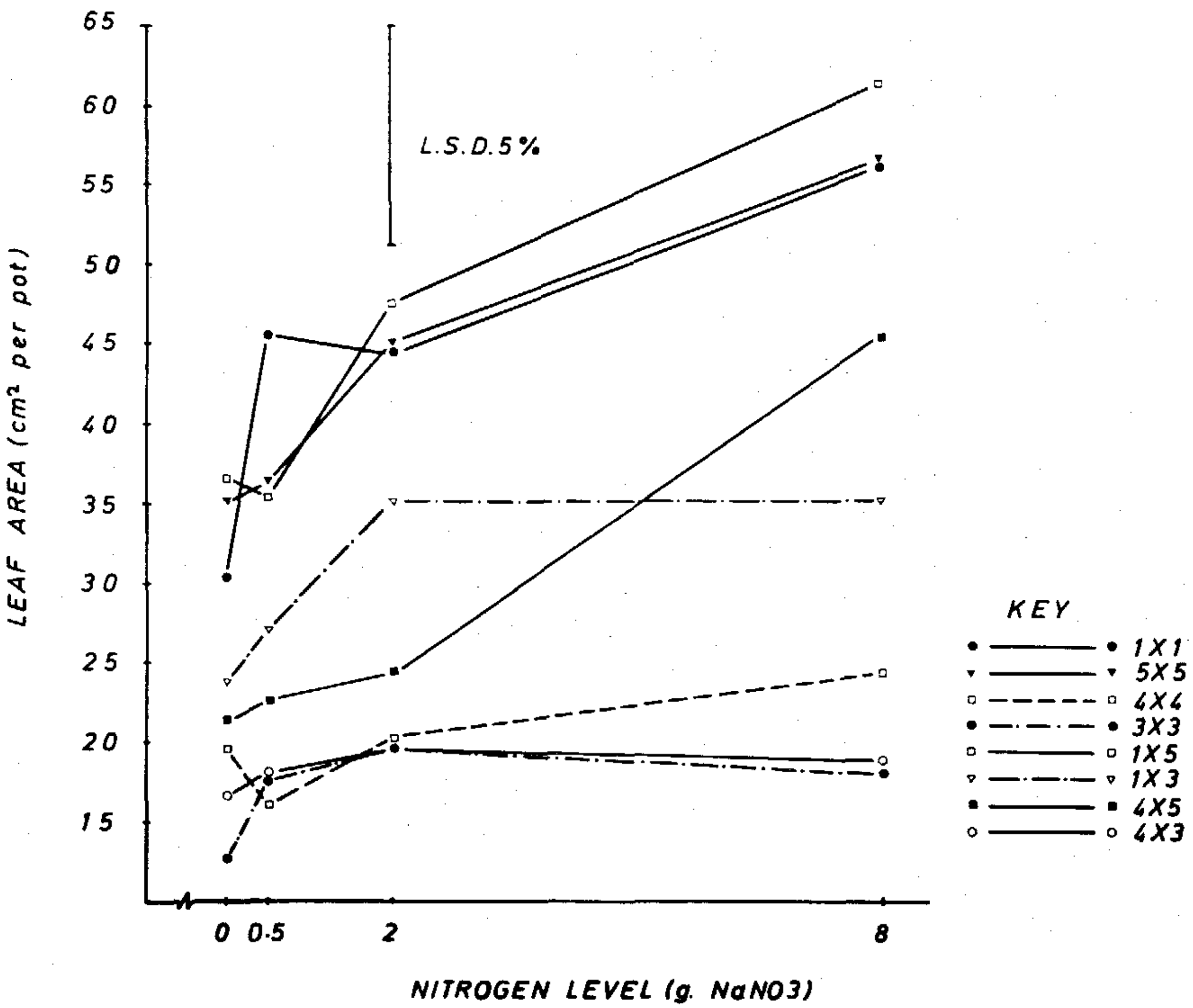


FIGURE 11. EFFECT OF GENOTYPES X NITROGEN LEVEL INTERACTION ON LEAF AREA AT THE THIRD HARVEST

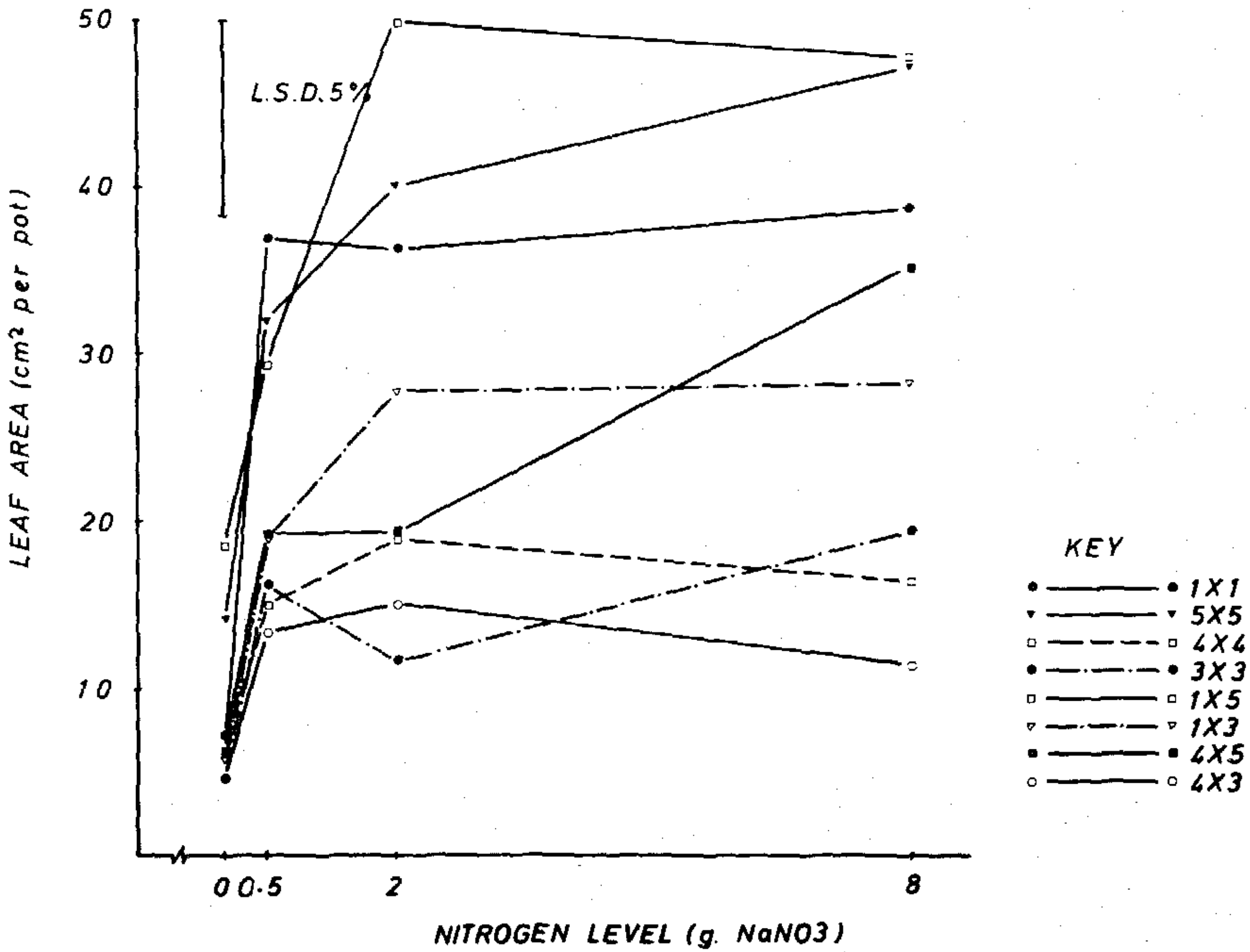
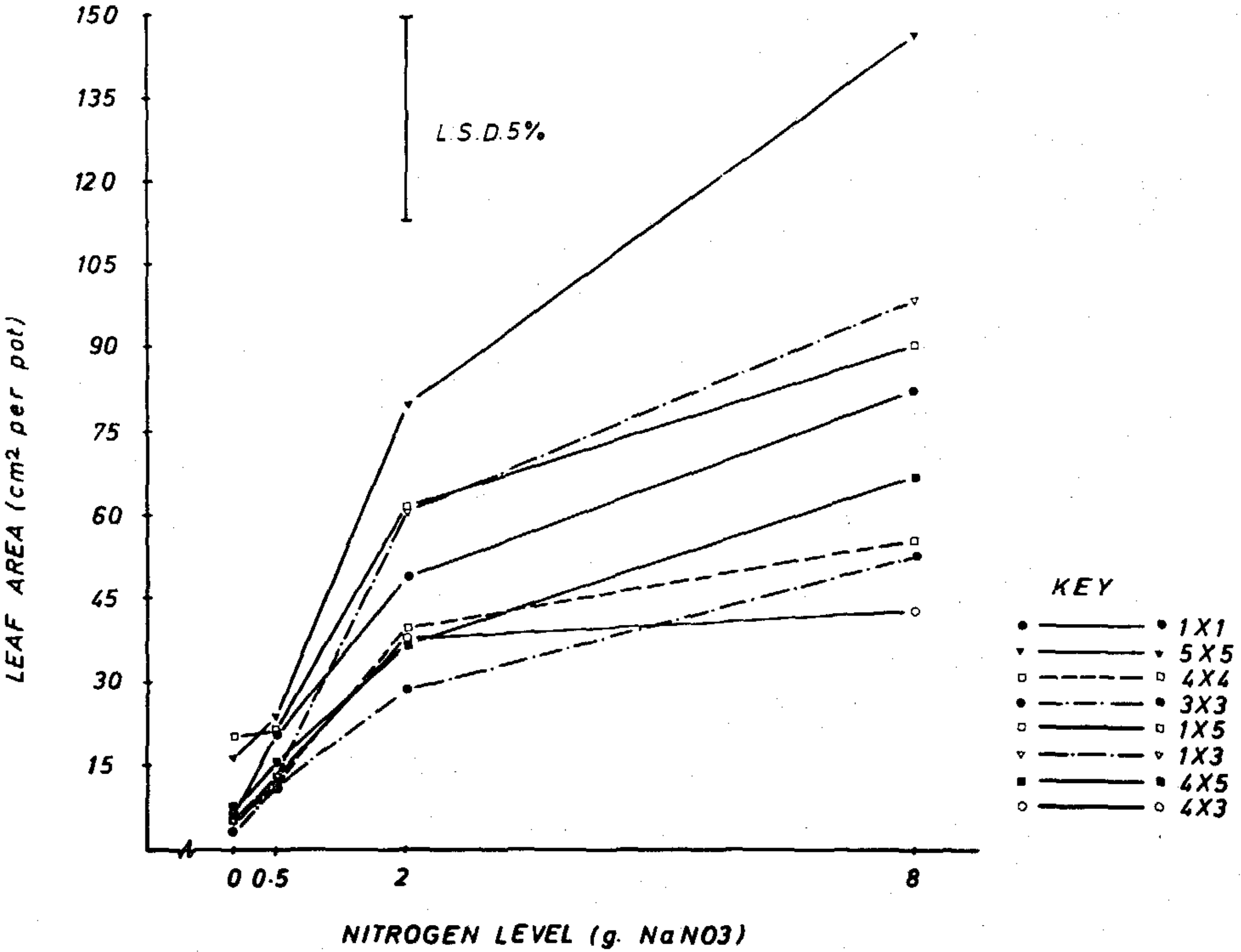


FIGURE 12. EFFECT OF GENOTYPES X NITROGEN LEVEL INTERACTION ON LEAF AREA AT THE FOURTH HARVEST



specific hybrids occupied an intermediate position between L.multiflorum parents and their hybrid on the one hand and the L.perenne parents and their hybrid on the other hand at most harvests. The greatest leaf area in all the populations was always at N_3 level. The leaf area in the two interspecific hybrids "crossed over" in the range N_1 to N_3 in most harvest.

(b) Leaf dry matter per pot. (Figures 13 and 14)

There was a significant interaction between populations and nitrogen levels at the first and fourth harvest. The ranking of populations was similar at the two different times. The L.multiflorum parents and their hybrid yielded significantly more than the L.perenne parents and their hybrid in response to nitrogen supply especially at N_3 level. The interspecific hybrids occupied on intermediate position between the other populations. The greatest nitrogen response was in the hybrid Liscate x S.22

4. Heritability

Estimation of heritability in this experiment is complicated by the shortage of material taken from the original half diallel cross. Thus, nutrient treatment was given to only 4 parents and 4 hybrids, which were selected as follows:

L.multiflorum variety 'Liscate' (1x1);

L.multiflorum variety 'S.22' (5x5);

L.perenne variety 'Ba6280' (4x4);

L.perenne variety 'S.23' (3x3);

L.multiflorum hybrid 'Liscate x S.22' (1x5);

Interspecific hybrid 'Liscate x S.23' (1x3);

FIGURE 13. EFFECT OF GENOTYPES X NITROGEN LEVEL INTERACTION ON LEAF DRY WEIGHT AT THE FIRST HARVEST

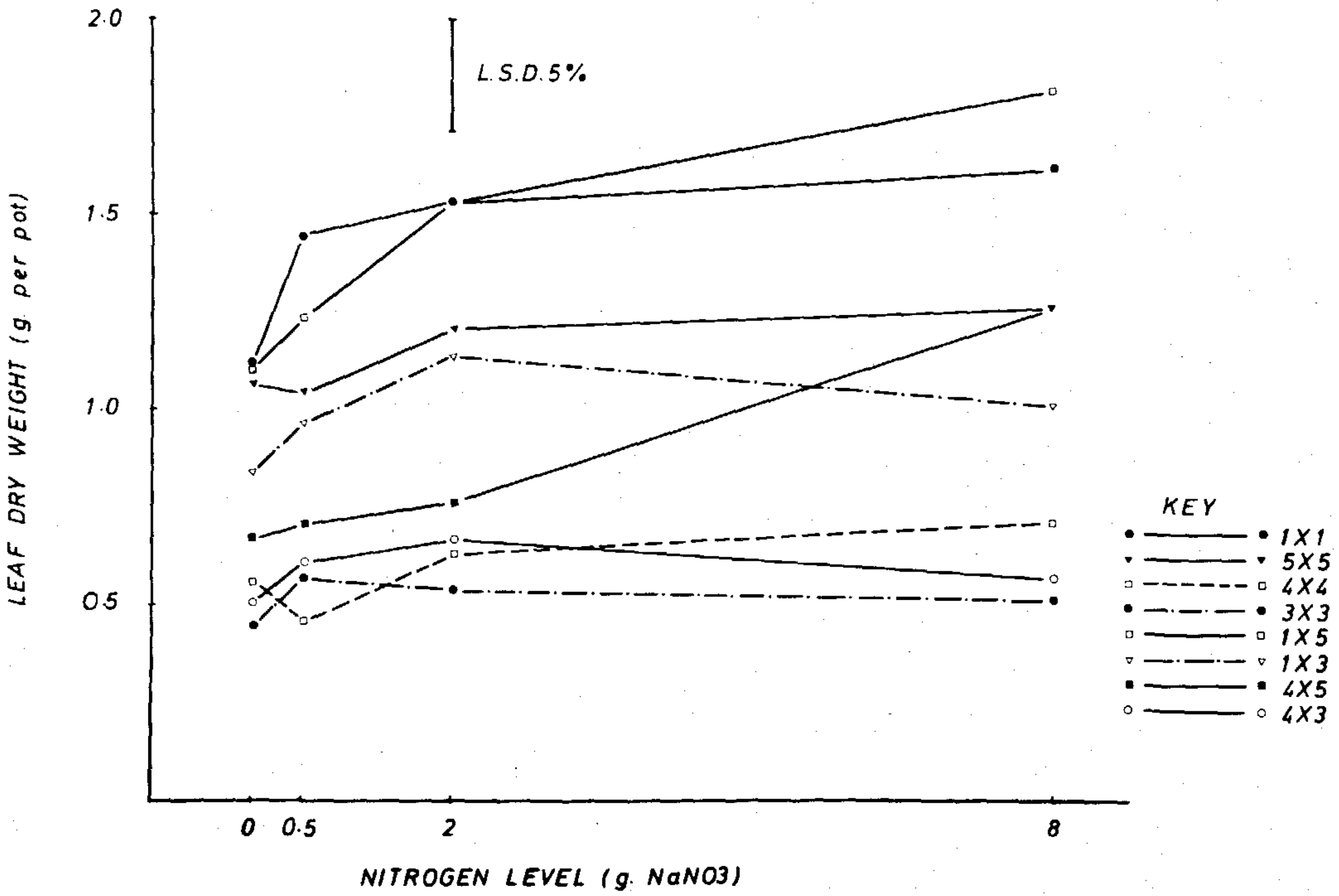
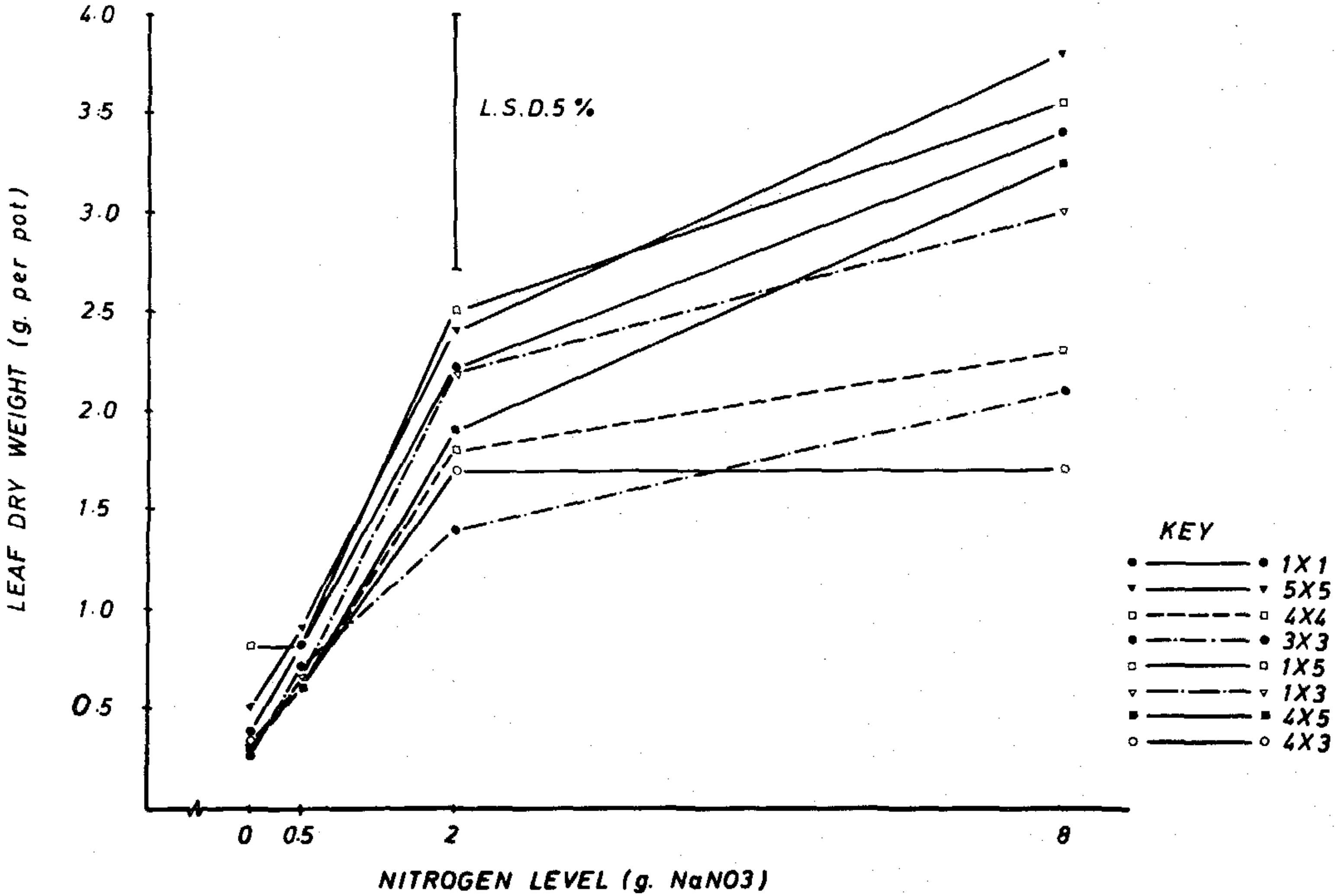


FIGURE 14. EFFECT OF GENOTYPES X NITROGEN LEVEL INTERACTION ON LEAF DRY WEIGHT AT THE FOURTH HARVEST.



Interspecific hybrid 'Ba6280 x S.22' (4x5);

L.perenne hybrid 'Ba6280 x S.23' (4x3).

As can be seen, the interspecific hybrids: Liscate x Ba6280 (1x4) and S.22 x S.23 (5x3) were omitted on the grounds of shortage of space. Therefore analysis of heritability on the F_1 alone is not possible. In fact virtually the only test of heritability possible with this material is a mid parent-progeny regression. Obviously, this has to be applied with caution for two reasons: firstly, because there are so few hybrids (4), and secondly, because the crosses are between two quite different species. Nevertheless, regression analysis of yields and nutrient responses was necessary to investigate the breeding potential and appeared to be worthwhile on material which differed so widely.

(i) Yield.

Estimation of heritability based on mid parent-progeny regression with only 4 hybrids allows only two degrees of freedom, so that very few of the variates measured showed significant heritability. Table 3 shows that the correlation coefficient of the variate total leaf dry matter was significant at 1% level of probability and the plant total dry matter correlation coefficient was significant at 5% level, therefore, their estimated heritabilities of (h^2 = 1.25) and(h^2 = 1.27) respectively are assumed to be significant too.

There are very few points on the regressions, and this, together with the considerable species difference between the two set of parents, suggests that these heritability estimates may not be completely accurate.

Table 4. Mean Yield of Hybrids, Mid Parent-Progeny Regression and Correlation Coefficients.

Populations, Regression and Correlation Coefficients.	Mean Yield of variates per Plant.					
	Total leaf number	Total leaf area (cm^2)	Total leaf dry matter (g.)	Stem dry matter (g.)	Root dry matter. (g.)	Plant total dry matter (g.)
Mid parent value, $\bar{P}$.	65.55	25.80	0.90	0.25	0.30	1.45
Liscate x S.22	59.30	26.10	1.00	0.20	0.40	1.60
Mid parent value, $\bar{P}$.	53.65	16.90	0.70	0.15	0.25	1.10
Liscate x S.23	59.70	19.10	0.70	0.20	0.30	1.20
Mid parent value, $\bar{P}$.	71.70	20.75	0.70	0.25	0.25	1.20
Ba6280 x S.22	66.30	16.10	0.70	0.20	0.20	1.10
Mid parent value, $\bar{P}$.	59.80	11.85	0.50	0.15	0.20	0.85
Ba6280 x S.23	57.20	11.00	0.50	0.10	0.20	0.80
Regression Coefficient	0.36	0.95	1.25	0.50	2.00	1.27
Correlation Coefficient	0.71	0.89	0.99^{xx}	0.57	0.85	0.95^{x}

Key: x = 0.05 level of significance at *t* table

xx = 0.01 level of significance at *t* table

(ii) Nutrient response

None of the nutrient response regressions of mid parent and progeny was significant when tested at two degrees of freedom. When tested at 10 degrees of freedom, using replicates, the variates total leaf area and total leaf dry matter had a significant heritability, thus total leaf area response (leaf area at N_3 - leaf area at N_0) had a correlation coefficient of ($r = 0.68$) and a heritability of ($h^2 = 0.68$); total leaf dry matter response (leaf dry matter at N_3 - leaf dry matter at N_0) had a correlation coefficient of ($r = 0.62$) and a heritability of ($h^2 = 0.83$). These values are given as indications rather than proof of heritability of response.

EXPERIMENT (B). PHOSPHORUS TREATMENT

The results are summarized in Appendices A, B and C. The materials and methods used in the phosphorus experiment have already been described in Chapter II "Material and Methods".

1. Effect of Different Phosphorus Levels.

(i) Total Yield for all Harvests Combined.

(a) Leaf number per plant. (Table 5).

The total leaf number increased as phosphorus supply increased over the whole range from P_0 to P_3, but was significant only from P_0 to P_1. From P_0 to P_1 the leaf number increased about 11 times as much as from P_2 to P_3.

(b) Leaf area per plant. (Table 5).

The total leaf area increased uniformly as phosphorus supply increased over the whole range from P_0 to P_3. The leaf area increment between treatment levels was significant only between P_0 and P_1. The leaf area increment between P_0 and P_1 was three times larger than that between P_1 and P_2.

(c) Leaf dry matter per plant (Table 5).

The total leaf dry matter increased as phosphorus supply increased over the whole range from P_0 to P_3. The increase was significant only from P_0 to P_1. The leaf dry matter increment from P_0 to P_1 was three times greater than that between P_1 and P_2. The leaf dry matter increased uniformly from P_1 to P_3.

(d) Stem dry matter per plant. (Table 5).

The stem dry matter increased significantly only over the range from P_0 to P_1. The treatment levels P_1, P_2 and P_3 all yielded double that of P_0.

(e) Root dry matter per plant (Table 5).

The root dry matter increased from P_0 to P_3, but not uniformly, since the yield at P_1 exceeded that at P_2. However, the yield at P_0 and P_3 differed significantly both in the least significant difference and the Duncan's New Multiple Range Test.

(f) Total dry matter per plant (Table 5)

The plant total dry matter increased as the phosphorus supply increased over the whole range from P_0 to P_3, but significantly only from P_0 to P_1. The total dry matter increment between P_0 and P_1 was three times greater than that between P_1 and P_2.

(ii) Effect of Different Phosphorus Levels on Individual Harvest Yields.

The data for individual harvests are presented as graphs. As in the case of nitrogen so for phosphorus the yield varied according to the harvest interval, and thus, the variations in absolute values are not important. What is important is the ranking of the yields at different phosphorus levels. The variates leaf number and leaf area were recorded only at the first, third and fourth harvests. While leaf dry matter was recorded at the first (41st day), second (58th day), third (70th day) and fourth harvests (86th day after sowing).

(a) Leaf Number per plant (Figure 15).

The leaf number increased as phosphorus supply increased over the whole range from P_0 to P_3 at all harvests. The greatest leaf number was found at P_3 and the smallest at P_0. These differed significantly throughout the experiment. There was no significant difference between P_1 and P_2; they differed significantly from

FIGURE 15. EFFECT OF PHOSPHORUS ON LEAF NUMBER AT INDIVIDUAL HARVESTS

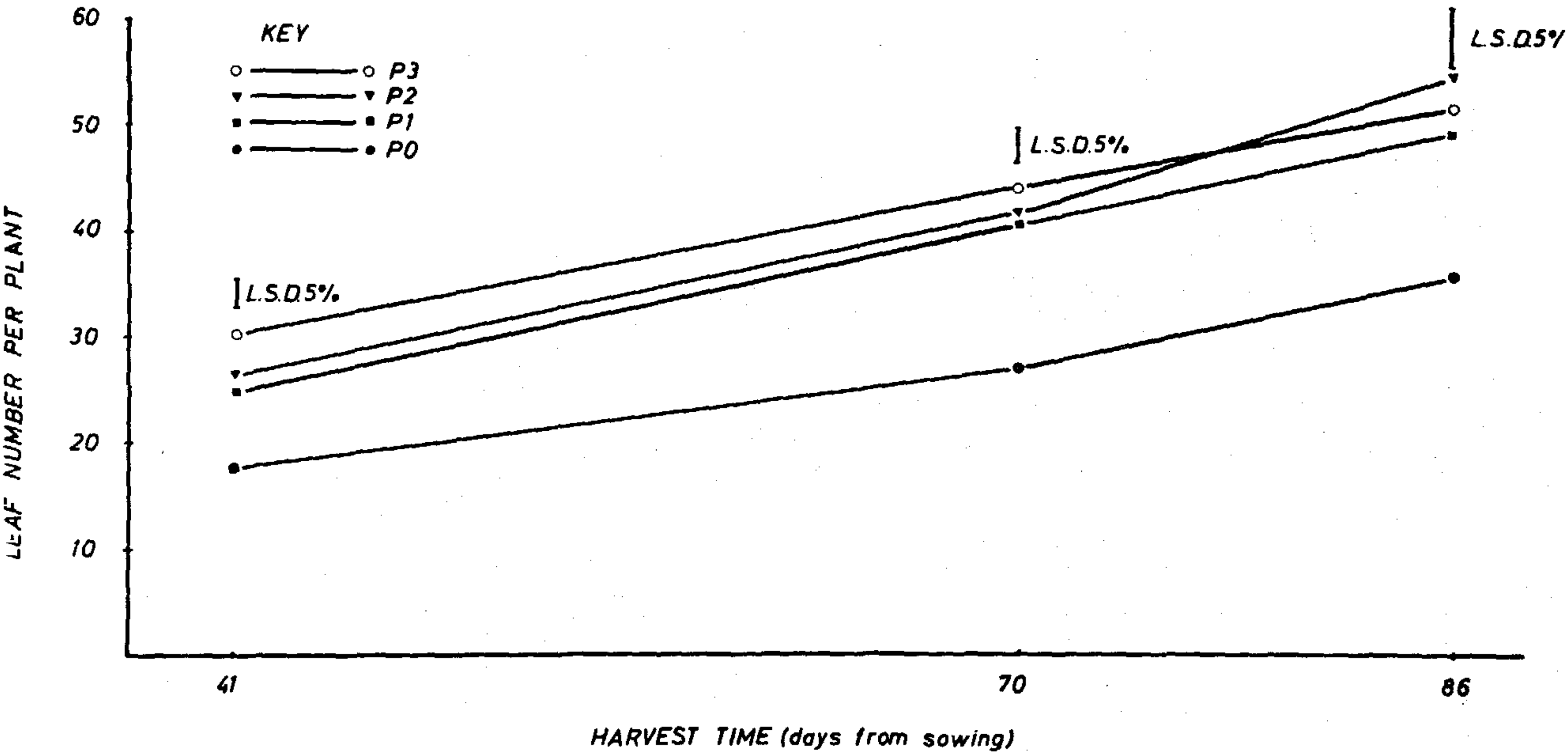


Table 5. Mean Yield, Standard Error, Least Significant Difference and Duncan's New Multiple Range Tests of Phosphorus Levels for all Harvests Combined.

Variate (per plant)	Phosphorus Levels. Mean values for all variates				Stand Error $S\bar{x}$	L.S.D. at 5% level	Probability
	P_0	P_1	P_2	P_3			
Leaf number	79.4	113.5	121.4	124.6	6.50	18.39	< 1%
Leaf area (cm^2/pl)	28.6	47.3	53.4	60.6	2.76	7.83	< 1%
Leaf dry matter (g./pl)	1.2	1.8	2.0	2.2	0.10	0.31	< 1%
Stem dry matter (g./pl)	0.2	0.4	0.4	0.4	0.02	0.07	< 1%
Root dry matter (g./pl)	0.2 a	0.3 b	0.2 a	0.3 b	0.03	0.08	< 1%
Plant Total dry matter (g./pl)	1.6	2.5	2.6	2.9	0.15	0.43	< 1%

All means underscored by a single line or given the same letter do not differ significantly in the Duncan's Multiple Range Test at 5% level.

P_0 throughout the experiment but only differed significantly from P_3 at the first harvest (41 days after sowing). The leaf number increased uniformly from the first harvest (41st day) to the last harvest (86th day) as can be seen by the smooth slopes of the curves in Figure 15.

Mean leaf numbers in this experiment were: First harvest, $\bar{x} = 24.6$; third harvest, $\bar{x} = 38-0$; fourth harvest, $\bar{x} = 47-0$.

P_2 and P_3 "crossed over" at the last harvest (86th day), but the total production was greater at P_3 than at P_2.

(b) Leaf area per pot. (Figure 16).

The leaf area increased from the first to the fourth harvest, showing a small increase between the first and the third harvest while there was a large increase between the third and the fourth harvest. The leaf area increased as phosphorus supply increased throughout the experiment.

The mean leaf areas per pot at the individual harvests were: First harvest, $\bar{x} = 58.6\ cm^2$; third harvest, $\bar{x} = 61.8 cm^2$; fourth harvest, $\bar{x} = 116.8 cm^2$.

P_0 differed significantly from P_1, P_2 and P_3 throughout the experiment. There was no significant difference between P_1 and P2. The leaf area was significantly greater at P_3 than at P_1 in the first and third harvest and just significantly greater than P_2 in the third harvest.

(c) Leaf dry matter per pot. (Figure 17).

The leaf dry matter harvested at the second and fourth harvests was greater than that at the first or third harvest. These

FIGURE 16. EFFECT OF PHOSPHORUS ON LEAF AREA AT INDIVIDUAL HARVESTS

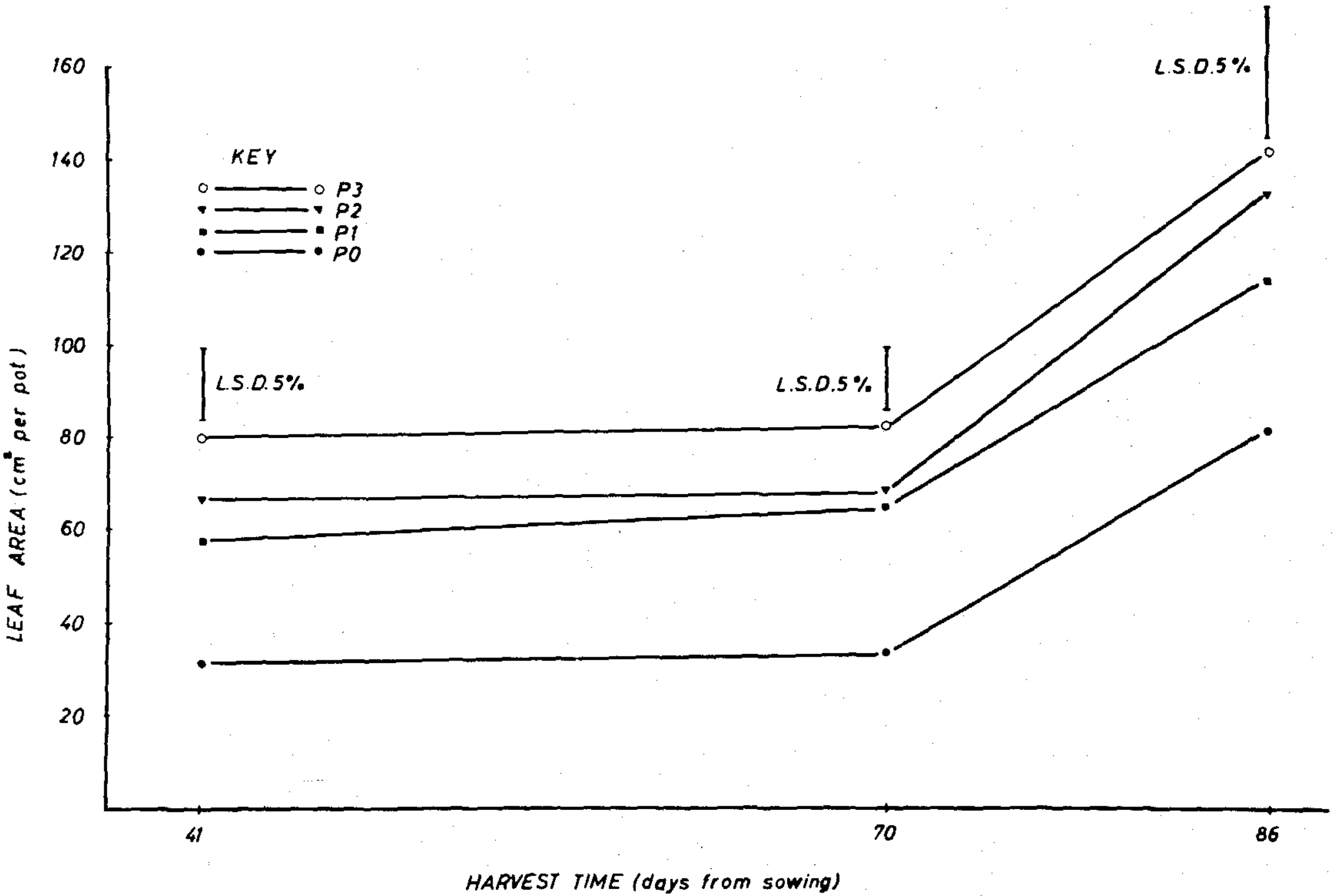
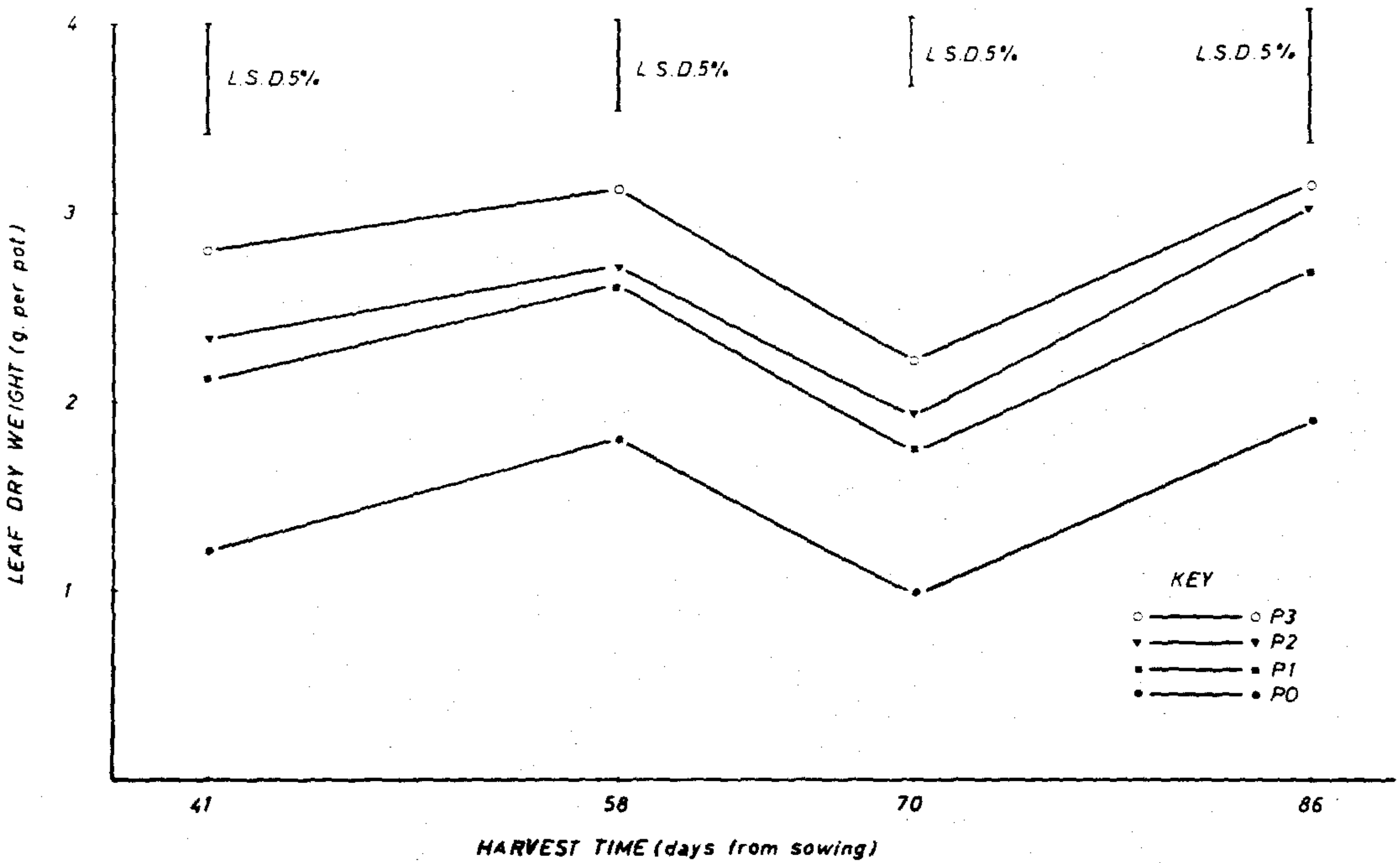


FIGURE 17. EFFECT OF PHOSPHORUS ON LEAF DRY WEIGHT AT INDIVIDUAL HARVESTS



differences were caused by slower growth rates (before the first harvest) and short harvest interval (before the third harvest). The leaf dry matter yield increased as phosphorus supply increased from P_0 to P_3 throughout the experiment.

The mean leaf dry weights at each harvest were: First harvest, $\bar{x}$ = 2.1g.; second harvest, $\bar{x}$ = 2.6g.; third harvest, $\bar{x}$ = 1.7g.; fourth harvest, $\bar{x}$ = 2.7g.

The yield at the treatment levels P_1, P_2 and P_3 varied significantly from P_0 throughout the experiment. There was no significant difference between P_1 and P_2 at any time. P_3 differed significantly from P_1 at most harvests, but did not differ from P_2 at any time.

2. Effect of Different Populations

(i) Population Differences for all Harvests Combined.

(a) Leaf number per plant (Table 6).

In the parents, the greatest leaf number per plant was in the *L.multiflorum* S.22 and the smallest leaf number was in the *L. perenne* Ba6280. There was no significant difference between the *L.multiflorum* S.22 and the *L.perenne* S.23 or between the *L.multiflorum* Liscate and the *L.perenne* Ba6280 parents.

In the progenies, the greatest leaf number was in the interspecific hybrid Liscate x S.23 and the smallest leaf number was in the *L.perenne* hybrid Ba6280 x S.23. The leaf number was not significantly different between the interspecific hybrids Liscate x S.23 and Ba6280 x S.22 and the *L.multiflorum* hybrid Liscate x S.22, but there was a significant difference between them and the *L. perenne* hybrid Ba6280 x S.23.

The greatest leaf number per plant was found in the interspecific hybrid Liscate x S.23 and the smallest in the *L.perenne* parent Ba6280.

(b) Leaf Area per plant (Table 6).

In the parents, the greatest total leaf area was found in the *L.multiflorum* Liscate and the smallest leaf area in the *L.perenne* Ba6280. There was no significant difference between *L.multiflorum* parents Liscate and S.22 or between the *L.perenne* parents Ba6280 and S.23. The *L.multiflorum* parents yielded significantly more than the *L.perenne* parents.

In the progenies, the greatest leaf area was found in the *L. multiflorum* hybrid Liscate x S.22 and the smallest leaf area in the *L.perenne* hybrid Ba6280 x S.23. In the total leaf area the interspecific hybrids occupied an intermediate position differing significantly from the other hybrids.

The greatest leaf area was found in the *L.multiflorum* hybrid 'Liscate x S.22' and the smallest in the *L.perenne* parent Ba6280.

(c) Leaf dry matter per plant. (Table 6).

In the parents, the greatest leaf dry matter was found in the *L.multiflorum* Liscate and the smallest in the *L.perenne* Ba6280 and S.23. The *L.multiflorum* parents yielded significantly more than the *L.perenne* parents. There was a significant difference between the *L.multiflorum* parents and S.22, but there was no significant difference between the *L.perenne* parents Ba6280 and S.23.

In the progenies, the greatest leaf dry matter was found in the <u>L.multiflorum</u> hybrid Liscate x S.22 and the smallest in the <u>L.perenne</u> hybrid Ba6280 x S.23. In leaf dry matter the interspecific hybrids again occupied an intermediate position differing significantly from the other hybrids. There was no significant difference between the interspecific hybrids.

The greatest leaf dry matter was found in the <u>L.multiflorum</u> hybrid 'Liscate x S.22' and the smallest in <u>L.perenne</u> parent Ba6280.

(d) Stem dry matter per plant (Table 6).

In the parents, the greatest stem dry matter was found in the <u>L.multiflorum</u> Liscate and the least in the <u>L.perenne</u> Ba6280. The <u>L.multiflorum</u> parents Liscate and S.22 yielded significantly more than the <u>L.perenne</u> parents Ba6280 and S.23. There was a significant difference between the <u>L.multiflorum</u> but not between the <u>L.perenne</u> parents.

In the progenies, the greatest stem dry matter was in the <u>L.multiflorum</u> hybrid 'Liscate x S.22' and the least was in the <u>L.perenne</u> hybrid Ba6280 x S.23. The interspecific hybrids yielded intermediately between the other hybrids differing significantly from them but not between themselves.

The greatest stem dry matter in the population was found in the <u>L.multiflorum</u> hybrid 'Liscate x S.22' and the smallest in the <u>L.perenne</u> parent Ba6280 and in the hybrid Ba6280 x S.23.

(e) Root dry matter per plant (Table 6).

In the parents, the greatest root dry matter was in the

Table 6. Mean Yields, Standard Error, Least Significant Difference and Duncan's New Multiple Range Tests of the Populations for all Harvests Combined.

Populations L. S. D., Probability	Mean values for each variate per plant					
	Total leaf number (L.No.)	Total leaf area (cm^2)	Total leaf dry matter (g.)	Stem dry matter (g.)	Root dry matter (g.)	Plant total dry matter (g.)
Liscate (L.multifl.)	90.2 c d	66.5 ab	2.7 a	0.5	0.4 a	3.6 a
S. 22 (L.multifl.)	122.0 a	54.8 bc	1.8 b	0.4 a	0.2 b	2.4 b
Ba6280 (L.perenne)	80.6 d	25.2 d	1.1 c	0.2 b	0.1 b	1.4 c
S. 23 (L.perenne)	105.5 ab	26.8 d	1.1 c	0.2 b	0.1 b	1.4 c
Liscate x S.22	126.4 a	75.8 a	2.7 a	0.6	0.5 a	3.8 a
Liscate x S.23	132.3 a	53.1 c	1.9 b	0.4 a	0.2 b	2.5 b
Ba6280 x S.22	127.9 a	50.9 c	1.8 b	0.4 a	0.2 b	2.4 b
Ba6280 x S.23	92.7 bc	26.7 d	1.2 c	0.2 b	0.1 b	1.5 c
Standard Error, $S\bar{x}$	9.19	3.91	0.15	0.03	0.04	0.22
L.S.D. At 5% level	26.02	11.07	0.44	0.11	0.12	0.61
Probability	$<$1%	$<$1%	$<$1%	$<$1%	$<$1%	$<$1%

All means marked with the same letter do not differ in the Duncan's New Multiple Range Test at 5% level.

L.multiflorum Liscate and the least was in the _L.perenne_ Ba6280 and S.23. The _L.multiflorum_ parents Liscate and S.22 differed significantly, but there was no significant difference between the _L.perenne_ parents Ba6280 and S.23 or even between them and the _L.multiflorum_ S.22.

In the progenies, the greatest root dry matter was in the _L. multiflorum_ hybrid Liscate x S.22 and the least was in the _L. perenne_ hybrid Ba6280 x S.23. The interspecific hybrids occupied an intermediate position between the _L.multiflorum_ and _L.perenne_ hybrids. There was no significant difference between the interspecific hybrids Ba6280 x S.22 and Liscate x S.23 or even between them and the _L.perenne_ hybrid Ba6280 x S.23, but there was a significant difference between these and the _L.multiflorum_ hybrid 'Liscate x S.22'.

The greatest yield was found in the L.multiflorum hybrid 'Liscate x S.22' and the least in the _L.perenne_ parent.

(f) Total dry matter per plant. (Table 6)

In the parents, the _L.multiflorum_ Liscate and S.22 yielded significantly more than the _L.perenne_ parents Ba6280 and S.23. Liscate differed significantly from S.22 but there was no significant difference between Ba6280 and S.23.

In the progenies the greatest plant total dry matter was in the _L.multiflorum_ hybrid Liscate x S.22 and the least in the _L.perenne_ hybrid Ba6280 x S.23. The interspecific hybrids did not differ significantly but occupied an intermediate position between the

L.multiflorum and L.perenne hybrids, differing significantly from them.

The greatest yield in the population was found in the L.multiflorum hybrid Liscate x S.22 and the least in the L.perenne parents Ba6280 and S.23.

(ii) Population Differences at Individual Harvests

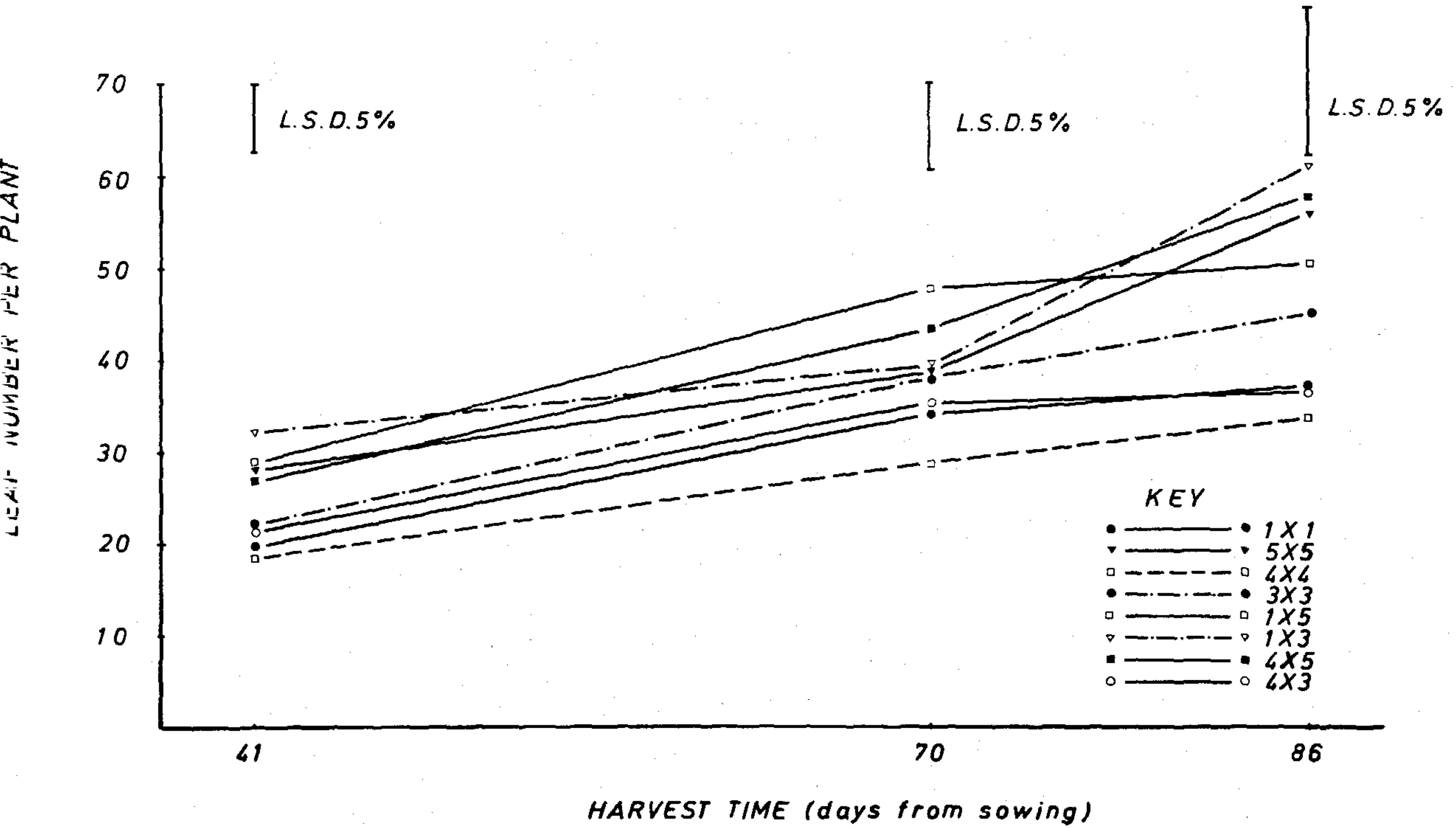
The data for population differences at individual harvests are presented as graphs. As stated in the nitrogen experiment, what is important is the ranking of the populations for the different variates, rather than the absolute values which depend on the length of the harvest interval.

(a) Leaf number per plant. (Figure 18)

The leaf number was recorded only three times, 41, 70 and 86 days after sowing. In the parents, the greatest leaf number at all harvests was found in the L.multiflorum S.22 and the least was in the L.perenne Ba6280. The L.perenne S.23 yielded intermediately between the L.multiflorum parents S.22 and Liscate but it did not differ significantly from them. At almost all the harvests there was a significant difference between the L.multiflorum parents in leaf number. The L.perenne parents did not differ significantly in this character.

In the progenies, the leaf number was greater in the interspecific hybrids Liscate x S.23 and Ba6280 x S.22 than in the other hybrids. There was no significant difference between the interspecific hybrids. The L.multiflorum hybrid Liscate x S.22 did not differ significantly from the interspecific hybrids. The L.perenne hybrid Ba6280 x S.23 had the smallest leaf number per plant. The L.

FIGURE 18. EFFECT OF DIFFERENT GENOTYPES ON NUMBER OF LEAVES AT INDIVIDUAL HARVESTS.



multiflorum and L.perenne hybrids differed significantly in leaf number at most harvests. The L.perenne parent S.23 and the interspecific hybrid Ba6280 x S.22 increased their leaf number substantially at each harvest in contrast to the other parents and progeny which scarcely increased their leaf number after cutting.

(b) Leaf area per pot. (Figure 19).

The leaf area was measured three times at 41, 70 and 86 days after sowing. In the parents, the greatest leaf area was found in the L.multiflorum Liscate or S.22 at the last harvest and the least in L.perenne Ba6280 or S.23. The Liscate was slightly more adversely affected by successive harvests than the other parents. The L.multiflorum parents had a significantly greater leaf area than the L.perenne throughout the experiment. Up to the third harvest (70th day) there was a significant difference between the L.multiflorum parents Liscate and S.22 but this later disappeared. The L.perenne parents Ba6280 and S.23 did not differ significantly at any harvest.

In the progenies, the greatest leaf area at all the harvests was in the L.multiflorum hybrid Liscate x S.22 and the least in the L.perenne hybrid Ba6280 x S.23. The interspecific hybrids Liscate x S.22 and Ba6280 x S.22 occupied an intermediate position between the other hybrids in this character differing significantly from them at most of the harvests. There was a significant difference throughout the experiment between the L.multiflorum and L.perenne hybrids, but there was none between the interspecific hybrids.

(c) Leaf dry matter per pot. (Figure 20).

FIGURE 19. EFFECT OF DIFFERENT GENOTYPES ON LEAF AREA AT INDIVIDUAL HARVESTS.

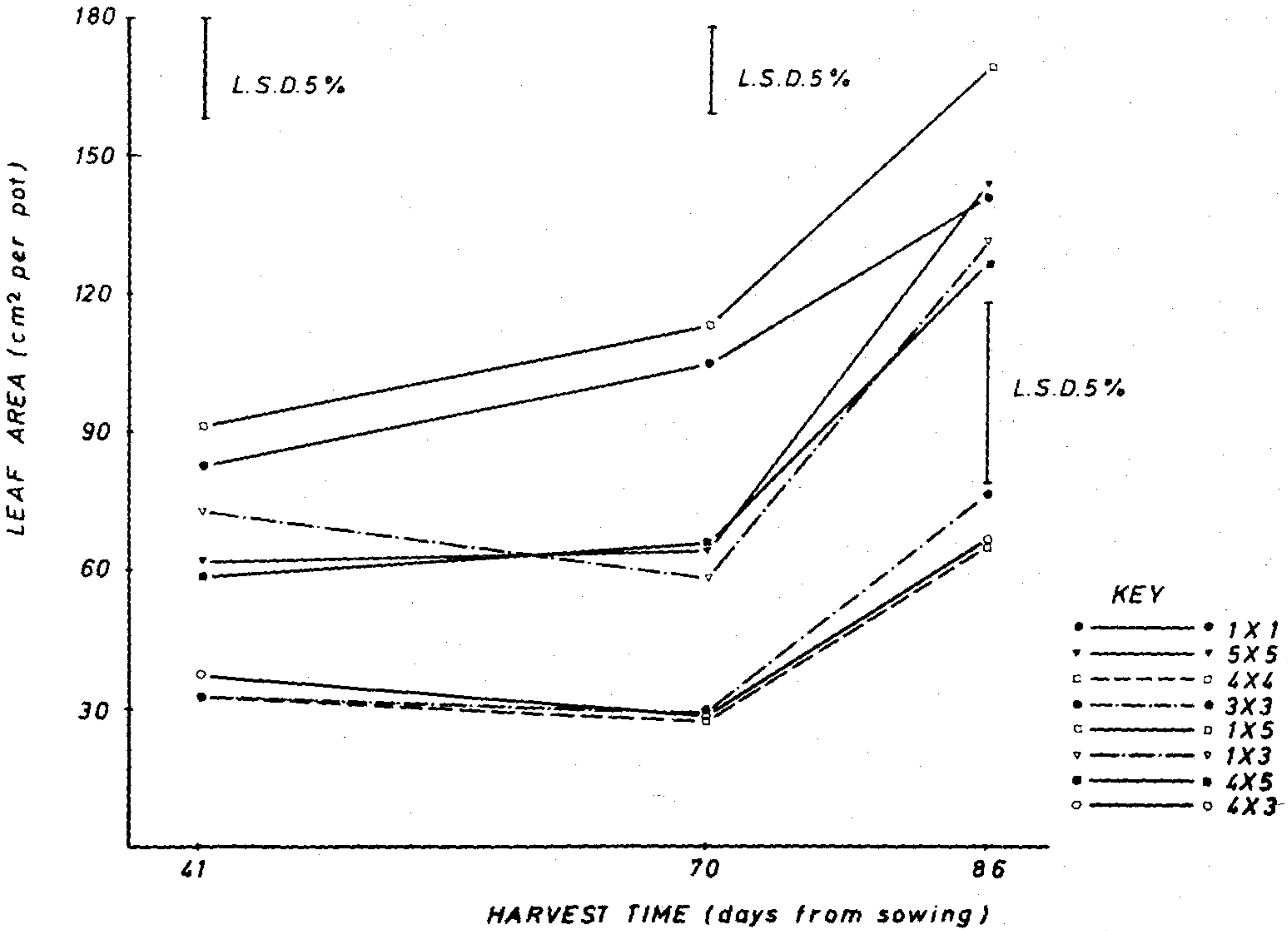
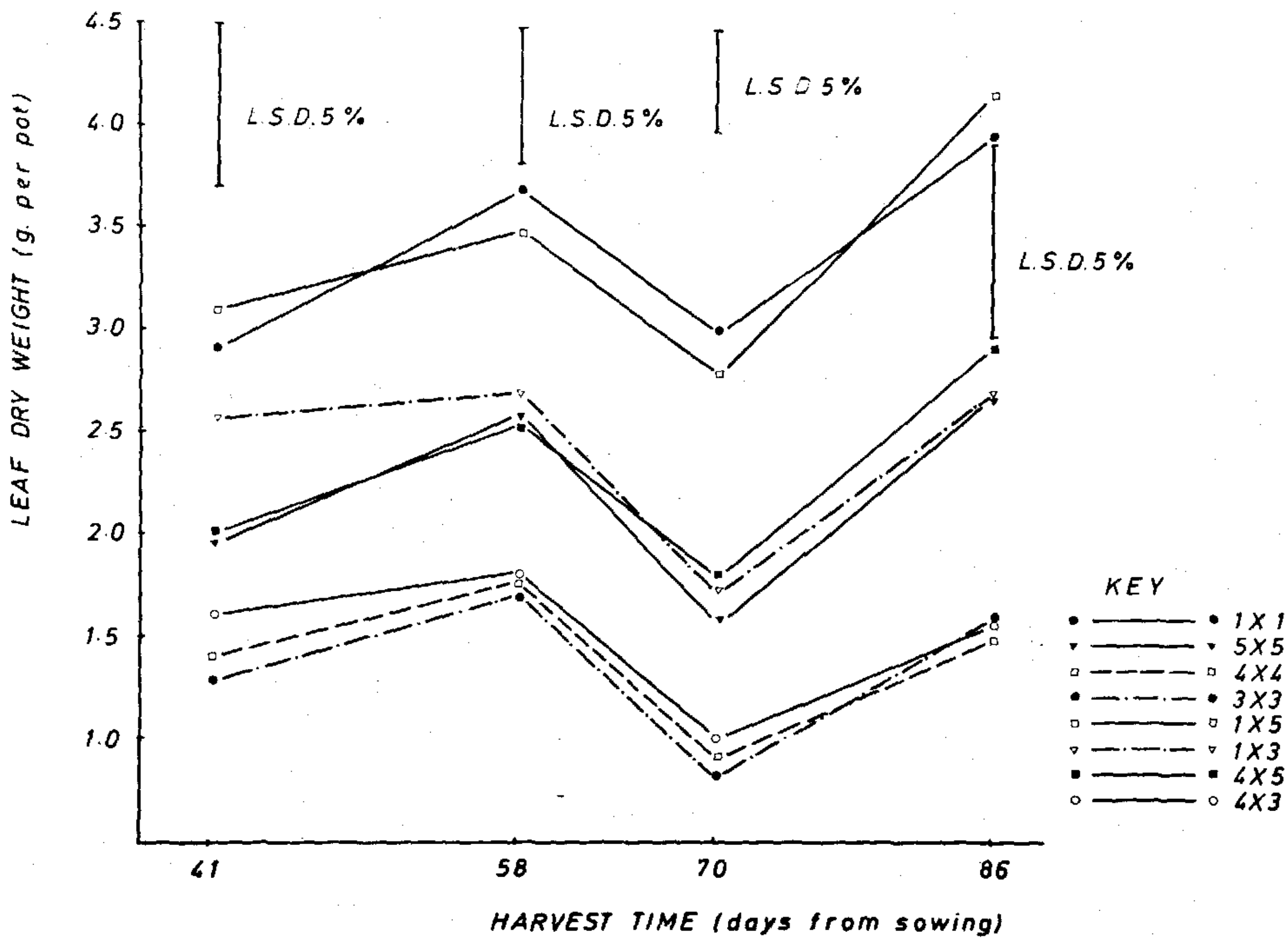


FIGURE 20. EFFECT OF DIFFERENT GENOTYPES ON LEAF DRY WEIGHT AT INDIVIDUAL HARVESTS.



In the parents, the greatest leaf dry matter was in the L.multiflorum Liscate and the least in L.perenne S.23. The L.multiflorum parents Liscate and S.22 differed significantly throughout the experiment and they yielded more than the L.perenne parents at all harvests. There was no significant difference between the L.perenne parents Ba6280 and S.23, but they differed significantly from the L.multiflorum Liscate at all harvests and from the L. multiflorum S.22 at the third (70th day) and fourth (86th day) harvests.

In the progenies, the greatest leaf dry matter was in the L. multiflorum hybrid Liscate x S.22 and this differed significantly from the others at all harvests. The interspecific hybrids did not differ significantly. They occupied an intermediate position between the other hybrids, differing significantly from the L.multiflorum hybrid Liscate x S.22 at all harvests and from the L.perenne hybrid Ba6280 x S.23 at most harvests. The smallest leaf dry matter in the progenies was in the L.perenne hybrid at all harvests.

3. Populations x Phosphorus Interaction.

(i) Populations x Phosphorus Interaction for all Harvests Combined.

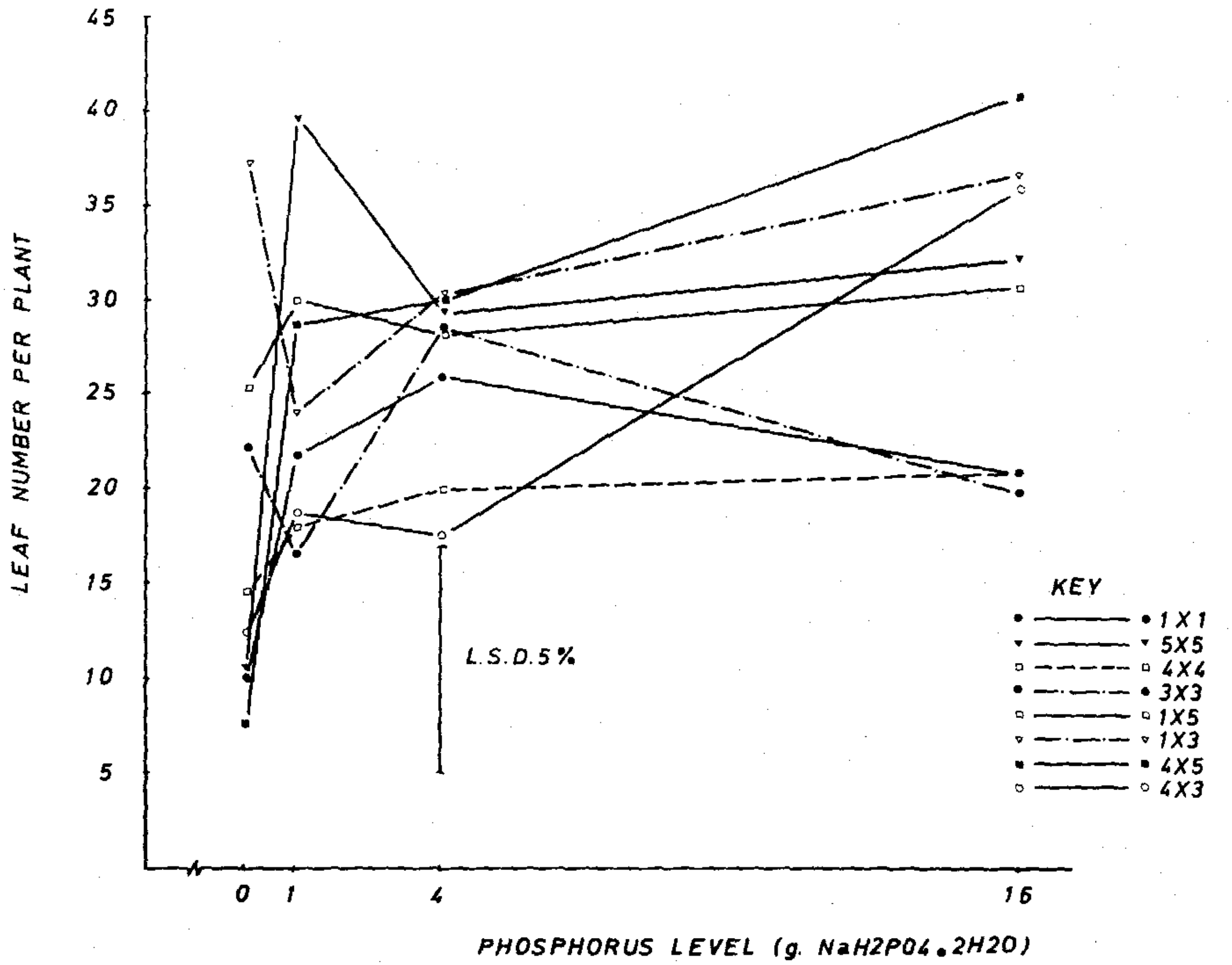
There was no significant interaction between populations and the phosphorus levels in any character for all harvests.

(ii) Populations x Phosphorus Interaction at the Individual Harvests.

(a) Leaf number per plant (Figure 21).

Populations and phosphorus levels interacted significantly on leaf number per plant at the first harvest (41st day). In the parents,

FIGURE 21. EFFECT OF GENOTYPES X PHOSPHORUS LEVEL INTERACTION ON LEAF NUMBER AT THE FIRST HARVEST.



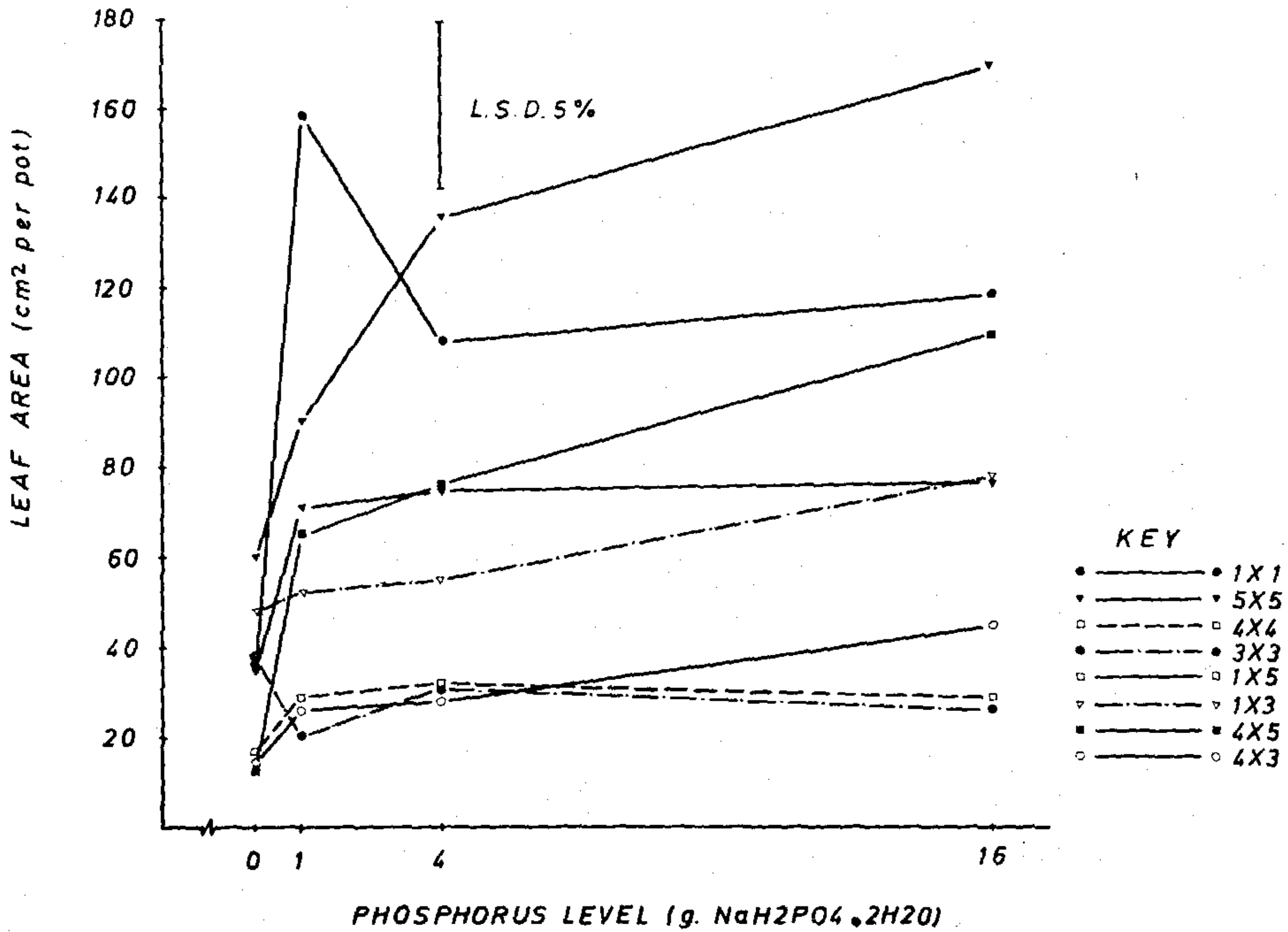
the *L.multiflorum* Liscate leaf number increased significantly from P_0 to P_2 and then declined from P_2 to P_3. The *L.multiflorum* S.22 leaf number increased significantly from P_0 to P_1, but declined from P_1 to P_2. It then increased slightly from P_2 to P_3. The *L. perenne* Ba6280 leaf number increased very little from P_0 to P_3. The *L.perenne* S.23 leaf number decreased from P_0 to P_1 and P_2 to P_3. P_1 did not differ significantly from P_2.

In the progenies, the *L.multiflorum* hybrid Liscate x S.22 increased slightly in leaf number from P_0 to P_3. There was a slight decrease from P_1 to P_2 but then an increase from P_2 to P_3. The interspecific hybrid Liscate x S.23 leaf number decreased from P_0 to P_1 but then increased to P_3. The interspecific hybrid Ba6280 x S.22 leaf number increased significantly from P_0 to P_3. The *L.perenne* hybrid Ba6280 x S.23 leaf number showed a significant increase from P_0 to P_3 although there was a slight decrease from P_1 to P_2.

(b) Leaf area per pot (Figure 22).

Populations and phosphorus levels interacted significantly at the third harvest (70 days after sowing). In the parents, leaf area increased as phosphorus supply increased. This was significant in the *L.multiflorum* Liscate from P_0 to P_1 but then it decreased significantly from P_1 to P_2. It increased slightly from P_2 to P_3 The *L.multiflorum* S.22 leaf area increased very little from P_0 to P_3 The *L. perenne* Ba6280 increased its leaf area very little from P_0 to P_3. The *L.perenne* S.23 leaf area decreased from P_0 to P_3. This parent showed little increase in leaf area from P_1 to P_2 In the progenies, leaf area increased significantly in the *L.*

FIGURE 22. EFFECT OF GENOTYPES X PHOSPHORUS INTERACTION ON LEAF AREA AT THIRD HARVEST.



multiflorum hybrid Liscate x S.22 from P_0 to P_3. The increase was very marked from P_1 to P_3. The interspecific hybrid Liscate x S.23 leaf area increased very little from P_0 to P_1. The interspecific hybrid Ba6280 x S.22 leaf area increased uniformly and significantly from P_0 to P_3. The *L.perenne* hybrid Ba6280 x S.23 increased very little in leaf area from P_o to P_3.

(c) Leaf dry matter per pot (Figure 23).

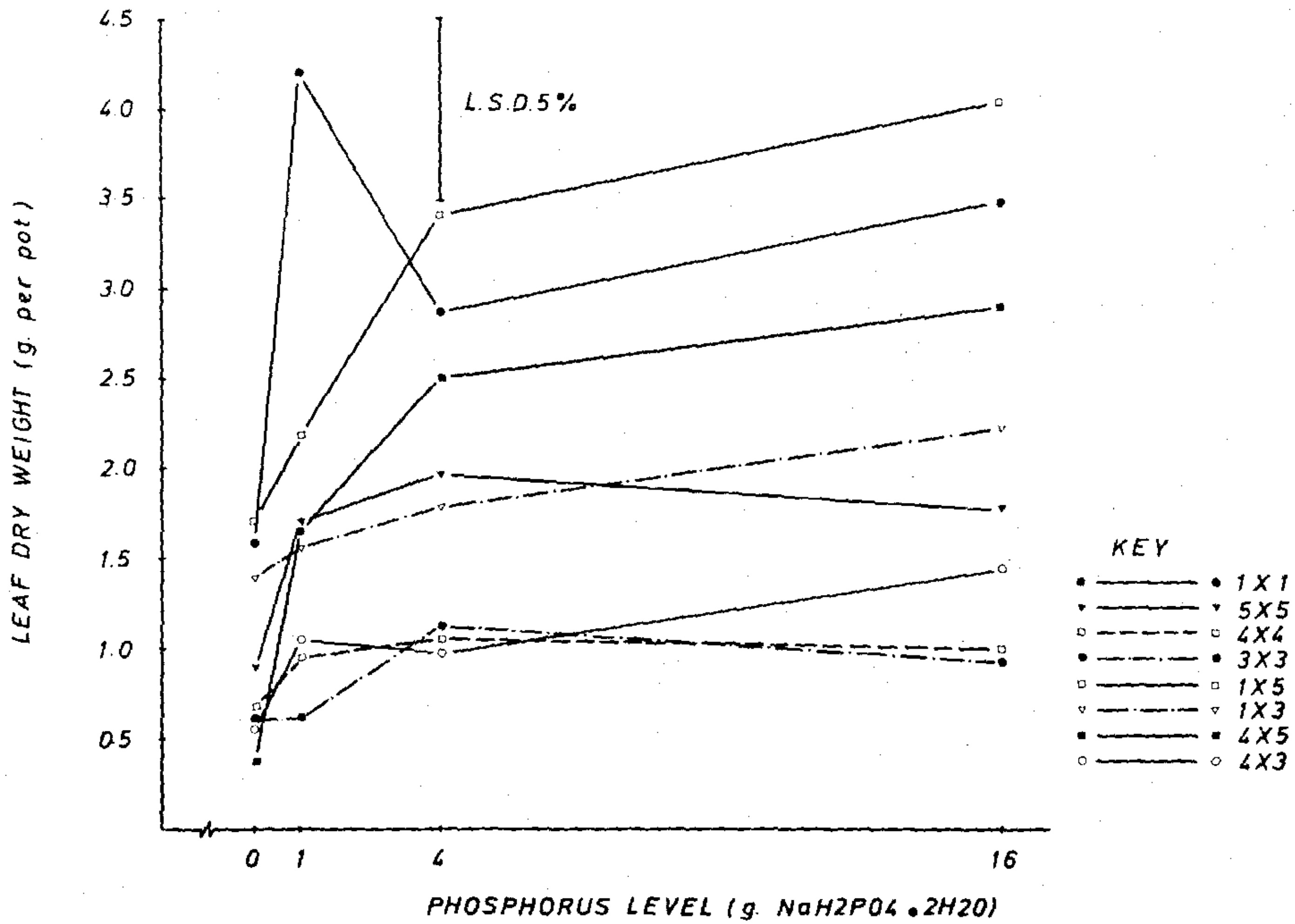
The populations and the phosphorus levels interacted significantly at the third harvest (70th day after sowing). In the parents, the *L.multiflorum* Liscate leaf dry matter increased from P_0 to P_1, but then decreased significantly from P_1 to P_2, increasing again from P_2 to P_3 though not significantly. The *L.multiflorum* S.22 increased significantly in leaf dry matter from P_0 to P_2 and then declined from P_2 to P_3. The *L.perenne* Ba6280 increased very little in leaf dry matter from P_0 to P_3. The *L.perenne* S.23 increased in leaf dry matter from P_1 to P_3 but then declined from P_2 to P_3.

In the progenies, the leaf dry matter increased significantly from P_0 to P_3 in the *L.multiflorum* hybrid. There was a large increase from P_1 to P_2. The interspecific hybrid Liscate x S.23 did not significantly increase in leaf dry matter from P_0 to P_3. The interspecific hybrid Ba6280 x S.22 increased in leaf dry matter from P_0 to P_3.

4. Heritability

As in nitrogen and potassium experiments, the estimation of heritability is complicated by the shortage of material from the original half diallel cross. The only possible test of heritability with this material is a

FIGURE 23. EFFECT OF GENOTYPES X PHOSPHORUS LEVEL INTERACTION ON LEAF DRY WEIGHT AT THE THIRD HARVEST.



mid parent-progeny regression as was shown in experiment A.

(i) Yield

Very few variates measured showed significant heritability at the two degrees of freedon allowed by the mid parent-progeny regression. Table 7 shows that the regression coefficients of the variates, total leaf area, total leaf dry matter and stem dry matter were significant at 5% level of probability, so that those characters are heritable Total leaf area had a regression coefficient of ($r = 0.98$) and a heritability of ($h^2 = 1.37$); total leaf dry matter, $r = 0.95$ and $h^2 = 1.16$; stem dry matter, $r = 0.98$ and $h^2 = 1.53$. As in the nitrogen experiment, so with phosphorus, the h^2 values appear to be over estimated unless there is much heterosis.

(ii) Nutrient Response.

None of the nutrient response regressions of mid parent and progeny was significant when tested either at 2 degrees of freedom or at 10 degrees of freedom.

Table 7. Mean Yield of Hybrids, Mid Parent-Progeny Regression and Correlation Coefficients.

Populations, Regression and Correlation Coefficients	Mean yield of variates per Plant.					
	Leaf number	Leaf area (cm^2/pl)	Leaf dry matter (g./pl)	Stem dry matter (g./pl)	Root dry matter (g./pl)	Plant total dry matter (g./pl)
Mid parent value, $\bar{P}$.	106.10	60.65	2.25	0.45	0.30	3.00
Liscate x S.22	126.40	75.80	2.70	0.60	0.50	3.8
Mid parent value, $\bar{P}$.	97.85	46.65	1.90	0.35	0.25	2.5
Liscate x S.23	132.30	53.10	1.90	0.40	0.20	2.5
Mid parent value, $\bar{P}$.	101.30	40.00	1.45	0.30	0.15	1.9
Ba6280 x S.22	127.90	50.90	1.80	0.40	0.20	2.4
Mid parent value, $\bar{P}$.	93.05	26.00	1.10	0.20	0.10	1.4
Ba6280 x S.23	92.70	26.70	1.20	0.20	0.10	1.5
Regression Coefficient	2.33	1.37	1.16	1.53	1.60	1.28
Correlation Coefficient	0.70	0.98^x	0.95^x	0.98^x	0.84	0.94

Key: x = 0.05 level of significance at t table.

EXPERIMENT C. - POTASSIUM TREATMENT.

The results are summarized in Appendices A, B and C. The materials and methods used in the potassium experiment have already been described in chapter II " "Materials and Methods".

1. Effect of Different Potassium Levels.

(i) Total Yield for all Harvests Combined.

(a) Leaf number per plant (Table 8)

The total leaf number decreased as potassium supply increased over the whole range from K_0 to K_3. There was thus an over supply or an imbalance of potassium. Despite this negative potassium response what is important for genetic purposes is the ranking of the variety mean yields at the different treatment levels. Before the variety means can be discussed, it is necessary to examine the mean effects of potassium for all varieties. (Table 8). Thus the greatest leaf number per plant was at K_0 level while the smallest leaf number was at K_3 which had the greatest potassium supply. There was no significant difference in the leaf number between the levels K_0, K_1 and K_2, but there was a significant decrease between K_2 and K_3 in the mean leaf number.

(b) Leaf area per plant (Table 8)

Like the total leaf number, the total leaf area decreased as the potassium supply increased from K_0 to K_3. The ranking of the leaf area means in the treatment levels can be seen in table 8. The greatest leaf area per plant was at K_0 while the smallest leaf area was at K_3. There was no significant difference in the leaf area at K_0, K_1 and

and K_2 but there was a significant decrease to K_3.

(c) Leaf dry matter per plant (Table 8)

There was no significant difference between K_0, K_1 and K_2 but there was a significant decrease between them and K_3.

(d) Stem dry matter per plant (Table 8).

The stem dry matter decreased significantly from K_0 to K_1, thus the stem dry matter yield of the levels K_0 and K_2 was significantly greater than that at K_1 and K_3 levels.

(e) Root dry matter per plant (Table 8).

The greatest root dry matter per plant was at K_2, with a smaller yield at K_0 and K_1 and also at K_3. The K_2 level yielded the greatest root dry matter which declined then at K_3.

(f) Total dry matter per plant (Table 8)

The greatest total dry matter yield was at K_2 level and the smallest yield was at K_3 level. These differences were significant. There was no significant difference between K_1, K_0 and K_2 levels.

(ii) Effect of Different Potassium Levels on Individual Harvest Yields.

The data for individual harvests are presented as graphs. As in the case of nitrogen and phosphorus so for potassium the yield varied according to the harvest interval, the variation in absolute values are not important. What is important is the ranking of the yields at different potassium levels. The variates, leaf number, leaf area and leaf dry weight were measured 30, 42, 58 and 78 days after sowing.

(a) Leaf number per plant. (Figure 24).

Increasing potassium supply generally decreased the leaf number per plant

FIGURE 24 EFFECT OF POTASSIUM ON LEAF NUMBER AT INDIVIDUAL HARVESTS

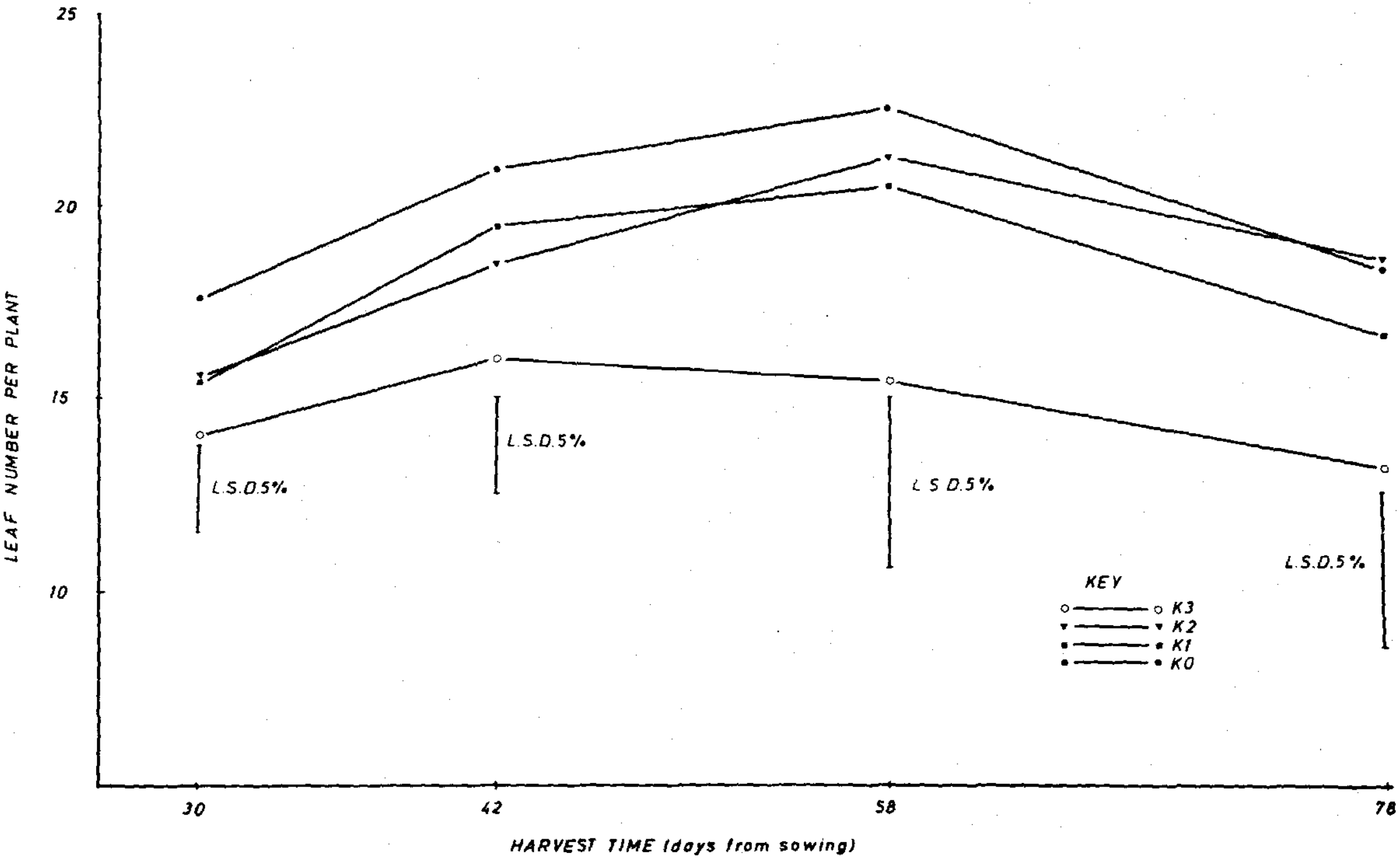


Table 8. Mean Yield, Standard Error, Least Significant Difference and Duncan's New Multiple Range Tests of Potassium Levels for all Harvests Combined.

Variate (per plant)	Potassium Levels Mean values for all variates				Stand Error $S\bar{x}$	L.S.D. At 5% Level	Probability
	K_0	K_1	K_2	K_3			
Leaf Number	79.1	71.6	73.6	58.5	3.03	8.56	< 1%
Leaf area (cm^2/pl)	29.6	27.2	28.6	20.3	1.51	4.28	< 1%
Leaf dry matter (g./pl)	0.9	0.8	0.9	0.6	0.04	0.11	< 1%
Stem dry matter (g./pl)	0.3 a	0.2 b	0.3 a	0.2 b	0.01	0.04	< 1%
Root dry matter (g./pl)	0.4 a b	0.4 a b	0.5 a	0.3 b	0.04	0.11	< 5%
Plant Total dry matter (g./pl)	1.6 a b	1.4 b	1.7 a	1.1	0.09	0.25	< 1%

All means underscored by a single line or given the same letter do not differ significantly in the Duncan's Multiple Range Test at 5% level.

over the whole harvest period. The greatest leaf number was found at K_0 while the smallest was found at K_3. There was a significant difference between K_0 and K_3 but not between K_0, K_1 and K_2 at any harvests. K_1 differed significantly from K_3 at the second (42nd day) and third harvest (58th day).

The leaf number means for the different harvests were: First harvest (30th day), $\bar{x} = 15.5$; second harvest (42nd day), $\bar{x} = 18.7$) third harvest (58th day), $\bar{x} = 19.9$ and fourth harvest (78th day after sowing), $\bar{x} = 16.5$.

(b) Leaf area per pot. (Figure 25).

Increasing potassium supply generally decreased the leaf area per pot thus the greatest leaf area was at K_0, while the smallest was at K_3. K_0 and K_3 as well as K_1 and K_3 differed significantly at all harvests. K_2 and K_3 differed significantly at the second, third and fourth harvests.

The leaf area means per pot for the different harvests were: First harvest (30th day), $\bar{x} = 32.7$ cm^2; second harvest (42nd day), $\bar{x} = 31.6$ cm^2; third harvest (58th day), $\bar{x} = 40.3$ cm^2; fourth harvest (78th day), $\bar{x} = 26.2$ cm^2.

(c) Leaf dry matter per pot. (Figure 26)

Increasing potassium supply generally decreased the leaf dry matter per pot. Thus, the smallest leaf dry matter was at K_3 and it differed significantly from the other levels at the second (42nd day) and at the third harvest (58th day). At the first harvest (30th day) there was a significant difference between K_0 and K_3. At the fourth harvest

FIGURE 25. EFFECT OF POTASSIUM ON LEAF AREA AT INDIVIDUAL HARVESTS

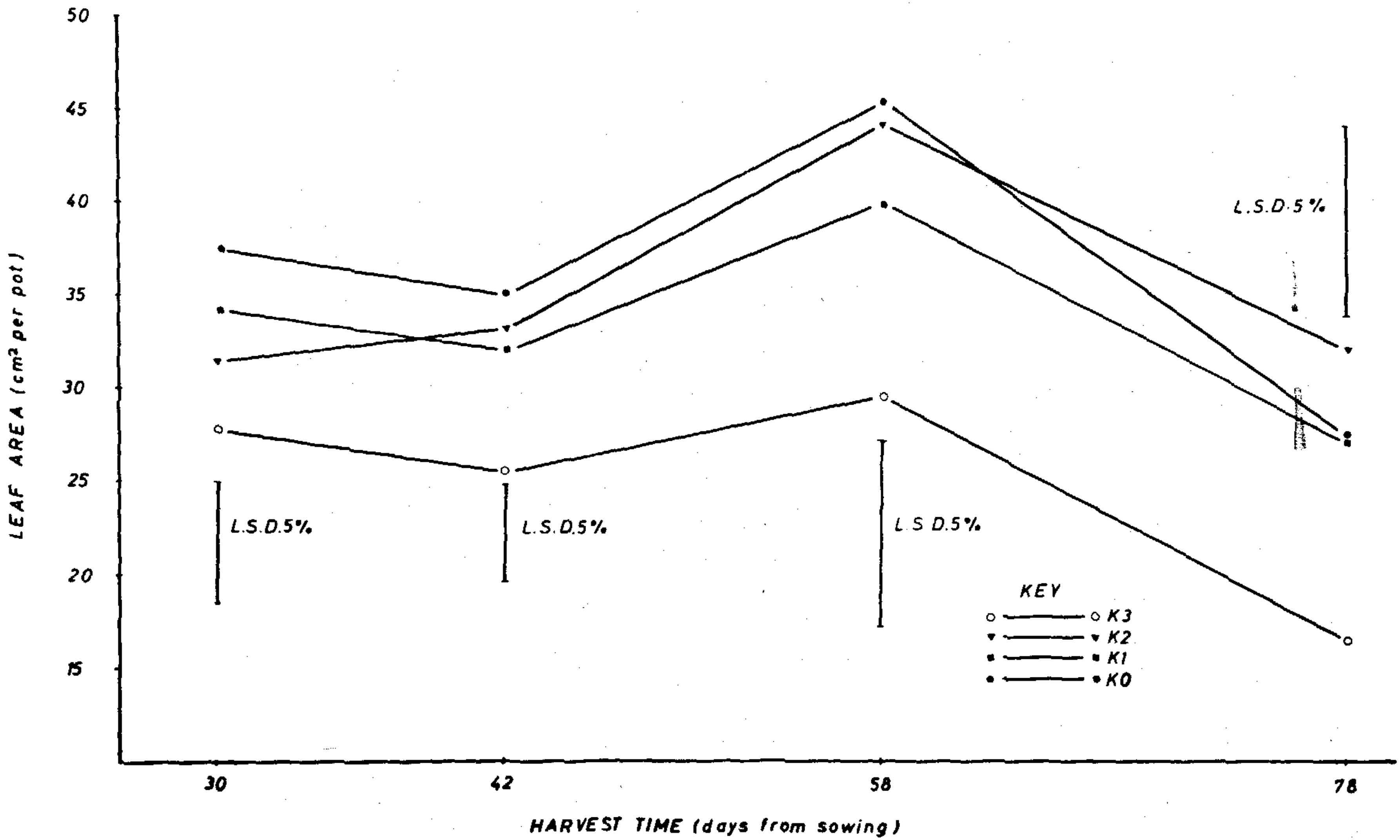
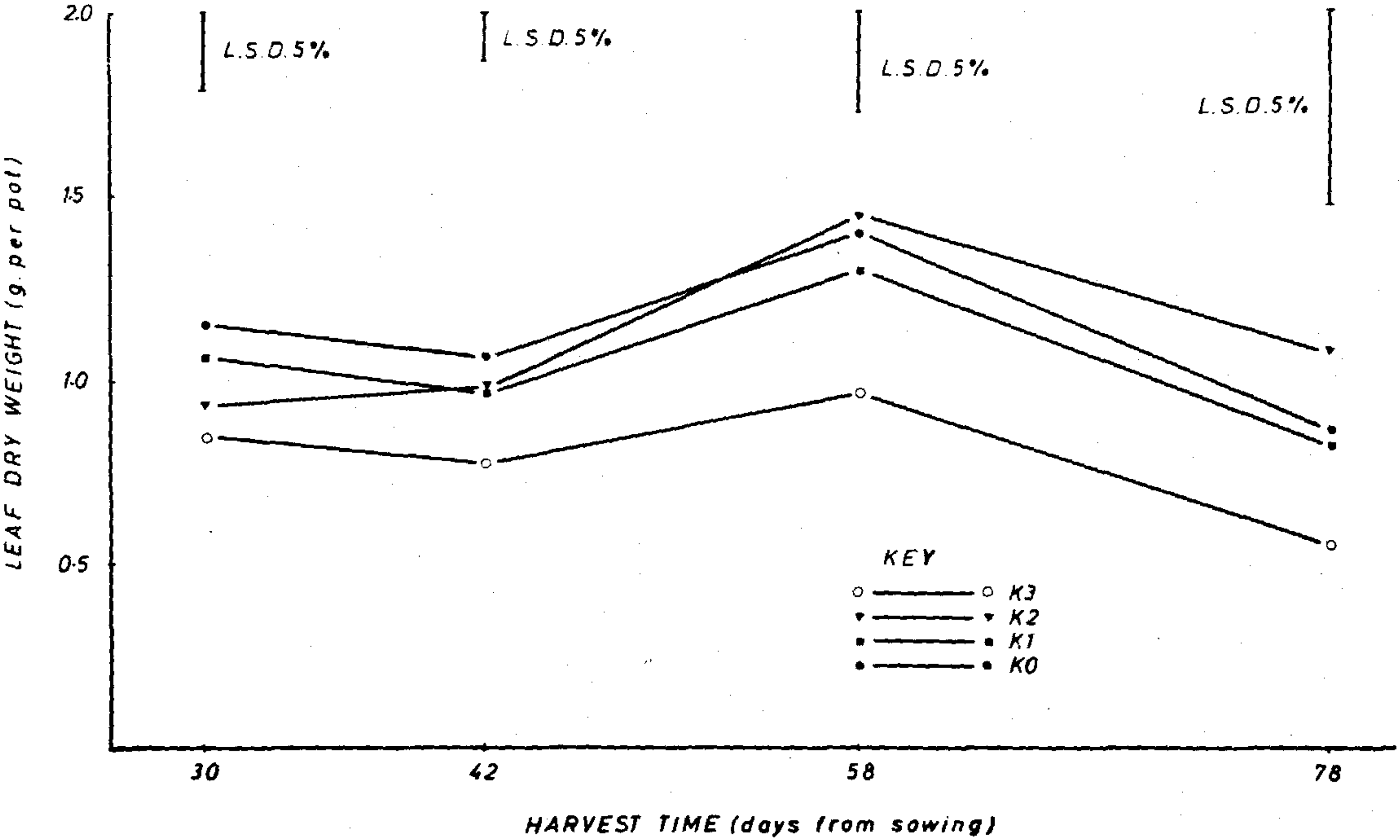


FIGURE 26. EFFECT OF POTASSIUM ON LEAF DRY WEIGHT AT INDIVIDUAL HARVESTS



(78th day) there was no significant difference between any levels of potassium.

The leaf dry matter means per pot for the different harvests were: First harvest (30th day), $\bar{x} = 1.0$ g., second harvest (42nd day), $\bar{x} = 0.9$ g., third harvest (58th day), $\bar{x} = 1.3$ g., fourth harvest 78th day), $\bar{x} = 0.8$ g.

2. Effect of Different Populations.

(i) Population Differences for all Harvests Combined.

(a) Leaf number per plant (Table 9).

In the parents, the greatest leaf number per plant was in *L.multiflorum* S.22 and the smallest in *L.multiflorum* Liscate. These differed significantly. The parents *L.perenne* Ba6280 and S.23 occupied an intermediate position between the *L.multiflorum* parents. They did not differ significantly from each other or from the *L.multiflorum* Liscate. The *L.multiflorum* S.22 differed significantly from all the other parents.

In the progenies, the interspecific hybrid Ba6280 x S.22 was significantly greater than the other hybrids. There was no significant difference between the following progenies: *L.multiflorum* hybrid Liscate x S.22; interspecific hybrid 'Liscate x S.23' and the *L.perenne* hybrid' Ba6280 x S.23'.

The greatest and the least leaf number in the populations were found in the *L.multiflorum* parents S.22 and Liscate respectively.

(b) Leaf area per plant (Table 9)

In the parents, the greatest total leaf area was in the *L.multiflorum*

S.22 and the least in L.perenne S.23. The L.multiflorum and the L.perenne parents differed significantly.

In the progenies, the greatest leaf area was in the L.multiflorum hybrid Liscate x S.22 and the smallest in the L.perenne hybrid Ba6280 x S.23. There was no significant difference between the interspecific hybrids Ba6280 x S.22 and Liscate x S.23, but they differed significantly from the L.multiflorum hybrid Liscate x S.22 and from the L.perenne hybrid Ba6280 x S.23.

The greatest and the least leaf area in the populations were found in the L.multiflorum hybrid 'Liscate x S.22' and in the L.perenne parent 'S.23' respectively.

(c) Leaf dry matter per plant (Table 9)

In the parents, the greatest total leaf dry matter was in the L.multiflorum 'Liscate' and the least in the L.perenne Ba6280 and S.23; this difference was significant. There was no significant difference between the L.multiflorum parents Liscate and S.22 nor between the L.perenne parents Ba6280 and S.23. However the two species were significantly different.

In the progenies, the L.multiflorum hybrid Liscate x S.22 significantly out yielded the L.perenne hybrid Ba6280 x S.23. The interspecific hybrids Ba6280 x S.22 and Liscate x S.23 did not differ significantly. However, they did differ significantly from the hybrids Liscate x S.22 and Ba6280 x S.23. The greatest yield in the population was found in the L.multiflorum 'Liscate x S.22' and the least in the L.perenne parent 'Ba6280'.

(d) Stem dry matter per plant (Table 9).

In the parents, the L.multiflorum S.22 yielded significantly more than the others which did not differ significantly. In the progenies, the L.multiflorum hybrid Liscate x S.22 and the interspecific hybrid Ba6280 x S.22 yielded significantly more than the other hybrids or parents.

(e) Root dry matter per plant (Table 9)

In the parents, the greatest root dry matter per plant was in the L.multiflorum S.22 and the smallest in the L.perenne S.23. The difference between them was significant. The L.multiflorum parents Liscate and S.22 did not differ significantly nor did the L.perenne parents Ba6280 and S.23.

In the progenies, the L.multiflorum hybrid Liscate x S.22 significantly out yielded the L.perenne hybrid Ba6280 x S.23. The L.multiflorum hybrid 'Liscate x S.22' did not differ significantly from the interspecific hybrid Ba6280 x S.22 neither did the interspecific hybrid Liscate x S.23 differ from the L.perenne hybrid Ba6280 x S.23. The greatest yield in the population was found in the L.multiflorum hybrid 'Liscate x S.22' and the least in the L.perenne parent S.23.

(f) Total dry matter per plant (Table 9).

In the parents, there was no significant difference between the L. multiflorum variaties Liscate and S.22 or between the L.perenne variaties Ba6280 and S.23. However, the species L.multiflorum and L.perenne differed significantly.

In the progenies, there was no significant difference between the inter-

Table 9. Mean Yield, Standard Error, Least Significant Difference and Duncan's New Multiple Range Tests of the Populations for all Harvests Combined.

Populations, L.S.D., and Probability	Mean values for each variate per Plant					
	Total leaf number (T.L.N.)	Total leaf area (cm^2)	Total leaf dry matter (g.)	Stem dry matter (g.)	Root dry matter (g.)	Plant Total dry matter (g.)
Liscate (L.multifl)	56.20 b	31.40 b c	1.06 ab	0.20 b	0.50 ab	1.76 ab
S. 22 (L.multifl.)	94.90 a	37.10 ab	0.90 b	0.30 a	0.60 a	1.80 ab
Ba6280 (L.perenne)	59.90 b	16.60 d	0.50 c	0.20 b	0.30 cd	1.00 c
S. 23 (L.perenne)	62.70 b	14.20 d	0.50 c	0.20 b	0.20 d	0.90 c
Liscate x S. 22	69.70 b	39.20 a	1.10 a	0.30 a	0.60 a	2.00 a
Liscate x S. 23	69.30 b	26.30 c	0.90 b	0.20 b	0.40 b c	1.50 b
Ba6280 x S. 22	85.08 a	29.80 c	0.90 b	0.30 a	0.50 ab	1.70 ab
Ba6280 x S. 23	67.70 b	17.20 d	0.60 c	0.20 b	0.30 cd	1.10 c
Standard Error, $S\bar{x}$	4.28	2.14	0.05	0.02	0.05	0.12
L.S.D. At 5% level	12.10	6.05	0.16	0.06	0.16	0.35
Probability	$<$ 1%	$<$ 1%	$<$ 1%	$<$ 1%	$<$ 5%	$<$ 1%

All means marked with the same letter do not differ in the Duncan's Multiple Range Test at 5% level.

specific hybrids and the L.multiflorum hybrid 'Liscate x S.22'. However, the L.perenne hybrid Ba6280 x S.23 yielded significantly less than the other hybrids.

The greatest yield in the population was found in the L.multiflorum hybrid 'Liscate x S.22' and the least in the L.perenne parent S.23.

(ii) Population Differences at Individual Harvests.

The data for the population differences at individual harvests are presented as graphs. As stated in the previous experiments, the values varied according to the harvest interval, and thus the variations in absolute value are not important. What is important is the ranking of the different populations in yield.

(a) Leaf number per plant. (Figure 27)

In the parents, the greatest leaf number at all the harvests was in the L.multiflorum S.22 which differed significantly from the other parents. After the first harvest the smallest leaf number was in L.multiflorum Liscate. The L.perenne parents Ba6280 and S.23 differed significantly from the L.multiflorum S.22 but not from the L.multiflorum Liscate or from each other.

The progenies did not differ significantly at any harvest. They yielded intermediately between the L.multiflorum parents and did not differ significantly from them.

(b) Leaf area per pot. (Figure 28)

In the parents, the L.multiflorum S.22 significantly out yielded the L.perenne S.23 at all harvests. There was no significant difference between the L.multiflorum parents Liscate and S.22 or between the

FIGURE 27. EFFECT OF DIFFERENT GENOTYPES ON LEAF NUMBER PER PLANT AT INDIVIDUAL HARVESTS.

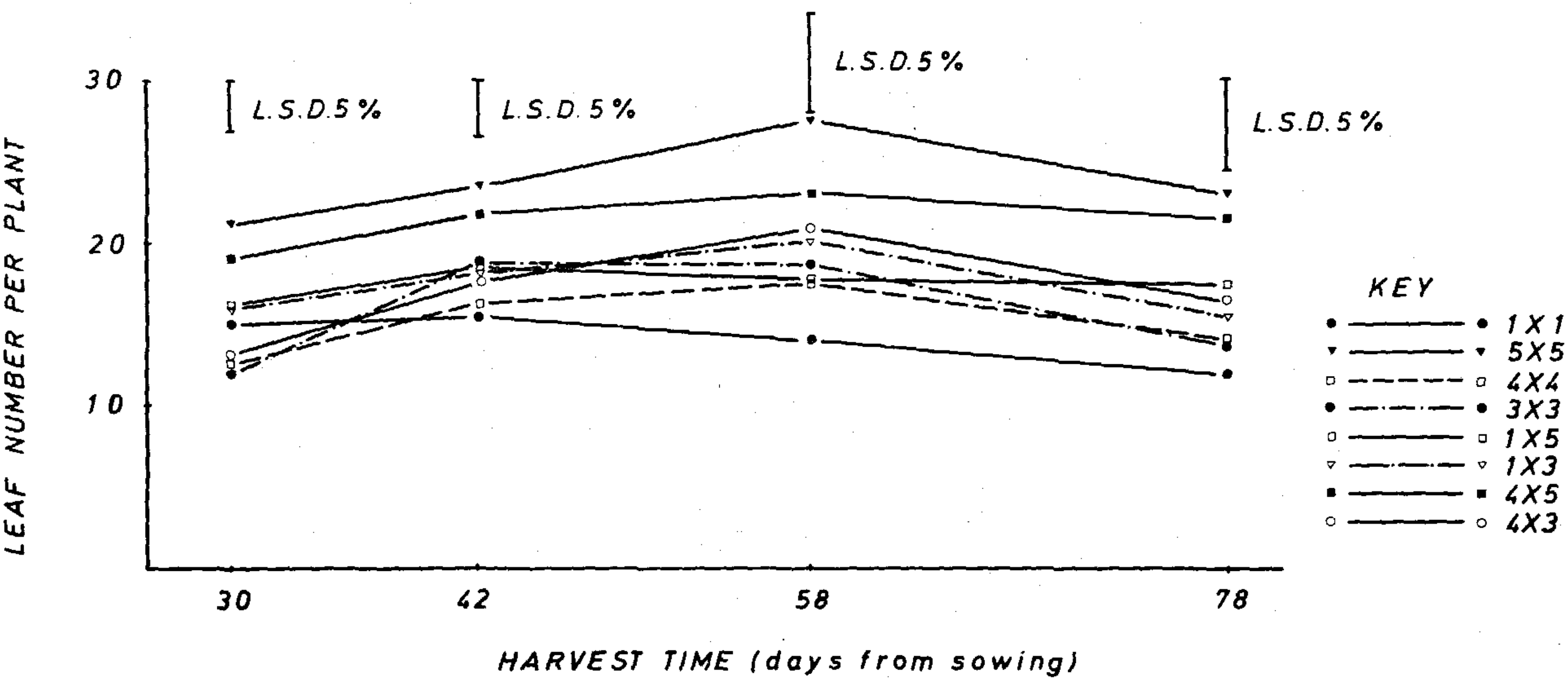
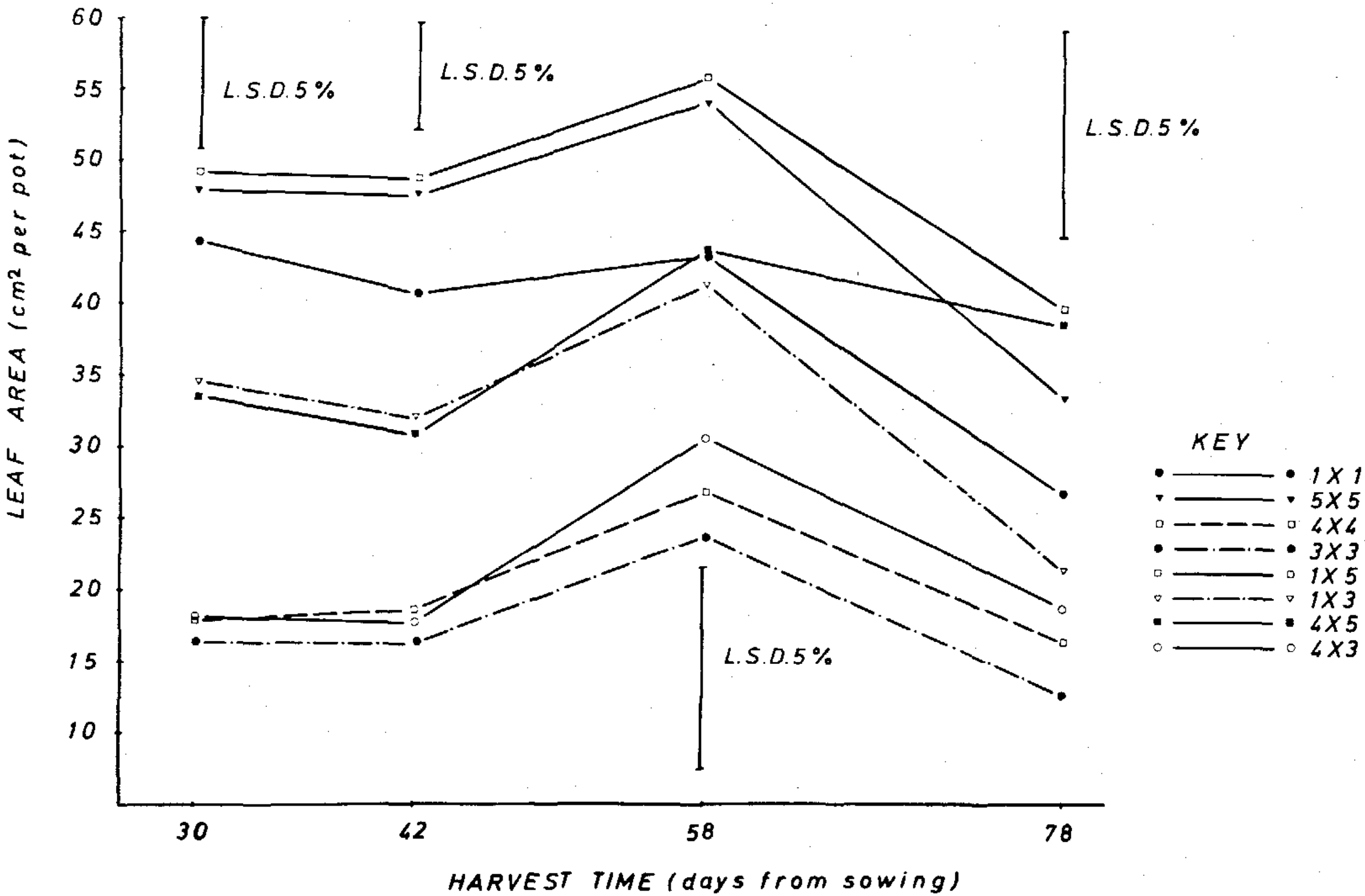


FIGURE 28. EFFECT OF DIFFERENT GENOTYPES ON LEAF AREA AT INDIVIDUAL HARVESTS.



L.perenne parents Ba6280 and S.23 throughout the experiment. The L. multiflorum and L.perenne parents differed significantly at the first (30th day), second (42nd day) and third (30th day) harvests.

In the progenies, the L.multiflorum Liscate x S.22 significantly out yielded the other hybrids at the first (30th day) and second harvest (42nd day after sowing). The L.perenne hybrid Ba6280 x S.23 yielded significantly less than the L.multiflorum Liscate x S.22. The interspecific hybrids Liscate x S.23 and Ba6280 x S.22 differed significantly only at the fourth (78th day) harvest, there was a significant difference between them and the other hybrids at the first and second harvest.

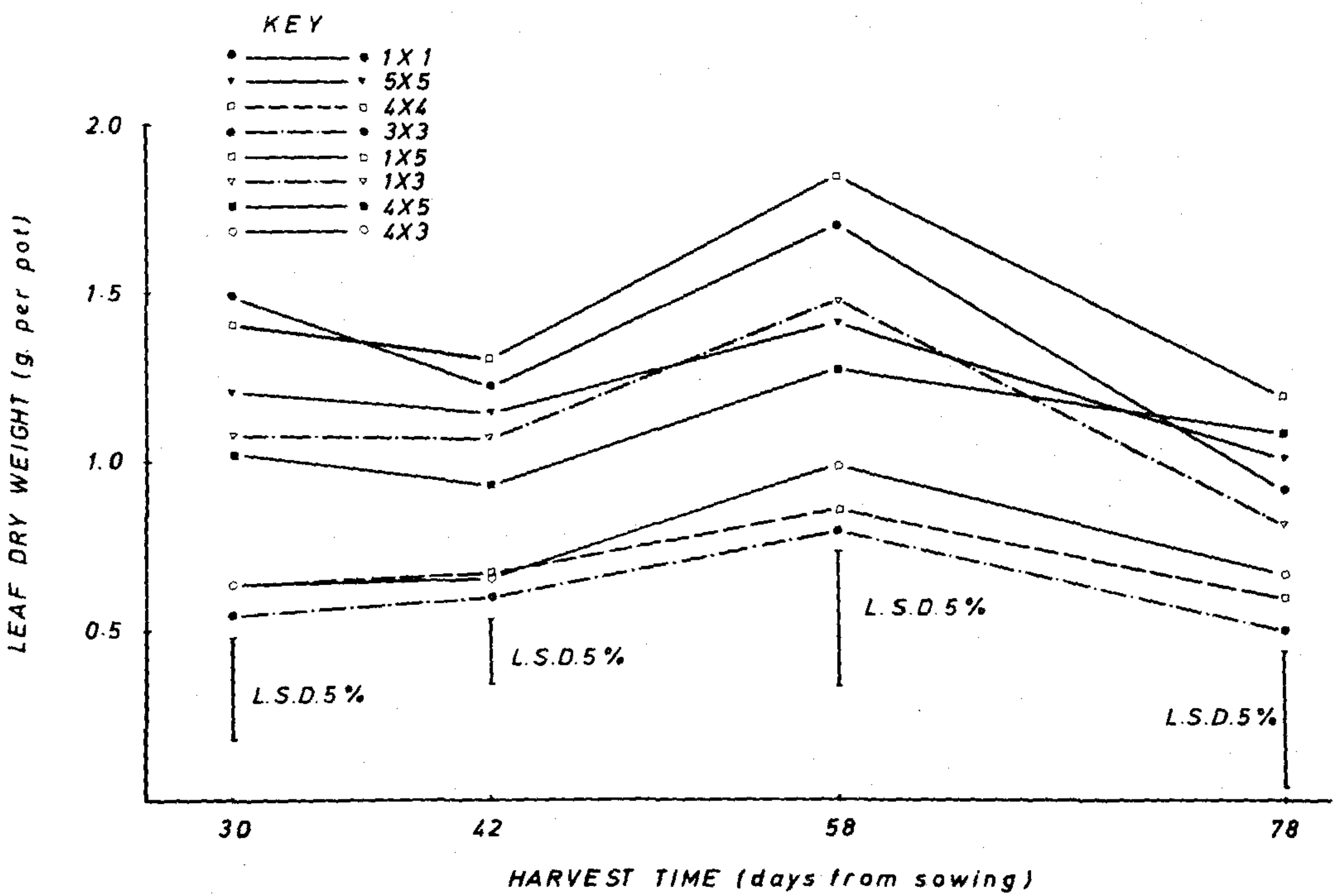
(c) Leaf dry matter per pot. (Figure 29).

In the parents, there as a significant difference between the L.multiflorum and L.perenne parents at the first (30th day), second (42nd day) and third (58th day) harvest.

In the progenies, the greatest leaf dry matter at all the harvests was in the L.multiflorum hybrid Liscate x S.22 which differed from all the other hybrids at the first and second harvest. The lowest leaf dry matter at all harvests was in the L.perenne hybrid Ba6280 x S.23 which differed significantly from the other hybrids at the first and second harvest. The interspecific hybrids Liscate x S.23 and Ba6280 x S.22 were not significantly different, but occupied an intermediate position between the other hybrids differing significantly from them only at the first harvest.

Between parents and progenies, the greatest yield at all harvests

FIGURE 29. EFFECT OF DIFFERENT GENOTYPES ON LEAF DRY WEIGHT AT INDIVIDUAL HARVESTS.



was given by the L.multiflorum hybrid Liscate x S.22 and the least by L.perenne parent S.23.

3. Populations . Potassium Interaction.

There was no significant interaction between populations and potassium in any of the characters studied either for all harvests combined or for individual harvests.

4. Heritability.

As in the experiments A and B, the heritability of the characters in the progenies was tested by Mid Parent - Progeny regression using two degrees of freedom.

(i) Yield.

Most of the variates measured showed significant heritability at the two degrees of freedom. In Table 10 can be seen that the variates, total leaf area, stem dry matter and root dry matter had a correlation coefficient significant at 1% level. The variates total leaf dry matter and plant total dry matter had a correlation coefficient significant at 5% level. Therefore, all these variates showed a significant heritability estimated by the regression coefficient.

(ii) Nutrient Response.

None of the nutrient response regressions of mid parent and progeny was significant when tested either at 2 or 10 degrees of freedom.

Table 10. Mean Yield of Hybrids, Mid Parent-Progeny Regression and Correlation Coefficients.

Populations, Regression and Correlation Coefficients	Mean Yield of variates per Plant					
	Leaf number	Leaf area (cm^2/pl)	Leaf dry matter (g./pl)	Stem dry matter (g./pl)	Root dry matter (g./pl)	Plant total dry matter (g./pl)
Mid parent value, $\bar{P}$.	75.55	34.25	0.98	0.25	0.55	1.78
Liscate x S.22	69.70	39.20	1.10	0.30	0.60	2.00
Mid parent value, $\bar{P}$.	59.45	22.80	0.78	0.20	0.35	1.33
Liscate x S.23	69.30	26.30	0.90	0.20	0.40	1.50
Mid parent value, $\bar{P}$.	77.00	26.60	0.70	0.25	0.45	1.40
Ba6280 x S.22	85.08	29.80	0.90	0.30	0.50	1.70
Mid parent value, $\bar{P}$.	60.90	15.15	0.50	0.20	0.25	0.95
Ba6280 x S.23	67.70	17.20	0.60	0.20	0.30	1.10
Regression Coefficient	0.58	1.14	1.01	2.00	1.00	1.09
Correlation Coefficient	0.67	0.99^{xx}	0.97^{x}	0.99^{xx}	0.99^{xx}	0.98^{x}

Key: x = 0.05 level of significance at _t_ table
xx = 0.01 level of significance at _t_ table

CHAPTER IV DISCUSSION AND CONCLUSIONS.

The results are summarised in Appendices A, B and C.

Effects of nutrients.

The effects of nutrients depend entirely on the chosen range. At low levels, deficiencies occur, often marked by visual symptoms. At intermediate levels, over a wide range, growth is affected. Finally, at the highest level, growth is unchanged by fertilizer increments, or there is an adverse effect.

The nitrogen levels given in these experiments were apparently in growth-promoting ranges. Nitrogen affected leaf size more than other plant parts. Leaf area per plant and leaf dry matter per plant were increased over the whole range from N_0 to N_3. Leaf number, stem dry matter and total plant dry matter were increased significantly by nitrogen only up to N_2. Nitrogen at the highest level (N_3) decreased the amount of root.

Phosphorus levels seems to have been rather high, because phosphorus affected leaves, roots and stems only up to the P_1 level. Phosphorus at the P_2 level decreased root dry matter.

Potassium levels were much too high. Increase in potassium caused a decrease in all parameters measured.

Effects of population.

The mean effects of population over all nutrients showed that the L.multiflorum parents Liscate (Bb1277) and S.22 yielded similarly in leaf area, leaf dry matter, stem dry matter, root dry matter and plant total dry matter. However, the leaf number in Liscate was consistently smaller than in S.22. This implies that the individual leaves of Liscate were larger than those of S.22. The L.perenne parents Ba6280 and S.23 differed significantly from the L.multiflorum parents but not from each other. In leaf number Ba6280 and S.23 were usually greater than Liscate but always less than S.22.

In the progenies, the L.multiflorum hybrid Liscate x S.22 always yielded most, in leaf area, leaf dry matter, stem dry matter, root dry matter and plant total dry matter. The interspecific (L.multiflorum x L.perenne) hybrids yielded intermediately in these characters and the L.perenne hybrid Ba6280 x S.23 yielded least. Leaf number did not vary consistently among the hybrids in the three (NPK) experiments.

At individual harvests, the later harvests showed a relative decline in leaf number and leaf area, less markedly in leaf dry matter, in Liscate compared with S.22 and L.perenne. Apparently there was less recovery after cutting in Liscate than in the other parents. Interestingly, the interspecific hybrids withstood cutting better than Liscate or S.22 in leaf number. In leaf area and leaf dry matter the L.multiflorum hybrid Liscate x S.22 withstood cutting better than the interspecific hybrids which was unexpected.

Interaction effects - Population x nutrient

The L.multiflorum parents consistently responded more in leaf area and leaf dry matter to nitrogen and phosphorus than the L.perenne parents. There was no interaction between potassium and populations.

In the progenies the L.multiflorum hybrid Liscate x S.22 was more responsive in leaf area and dry matter to nitrogen and phosphorus than the other hybrids. Usually the L.perenne hybrid Ba6280 x S.23 was significantly less responsive to nitrogen and phosphorus than other hybrids.

An interesting observation on population x nutrient level interaction is that the ranking of populations in these experiments was very consistent (Appendices B and C) in contrast to the observations of Thomson and Wright (1971) who found much variation. These different results may be caused by the number of different interactions which occur in Thomson and Wrights' field experiments, and which may vary between sites and seasons more than pot experiments will vary.

The importance and the consistency of the interactions has provided material for further analysis. Boken (1970) expressed the interactions between populations and nutrients as percentages of maximum yield. The results for leaf dry matter response to nitrogen and phosphorus by individual populations have been analysed in this way (Figs. 30 and 31).

The percentage maximum yield curve for nitrogen (Fig.30) shows that response declines with increasing fertilizer dose, most noticeable in the populations 4 x 3 and 1 x 3 (Ba6280 x S.23 and Liscate x S.23). Population 4 x 5 (Ba6280 x S.22) responded strongly throughout the range of nitrogen application.

The percentage maximum yield curve for phosphorus (Fig.31) was interesting in that the parents reached maximum yield at P_1 or P_2 while the progeny yielded most at P_3. There is no obvious explanation for this. Thus several new points arise from using the percentage maximum yield analysis of Boken (1971), which concentrates on the shape of response curves rather than their absolute values. Similarly, both Boken (1971) and Vose and Breese (1964) suggest analysis of "utilization" or "efficiency" of nutrient. This analysis of the dry matter produced per unit weight of fertilizer supplied, has agricultural significance as it represents the yield return for fertilizer outlay.

FIGURE 30. % RESPONSE OF DIFFERENT GENOTYPES TO NITROGEN (leaf drymatter)

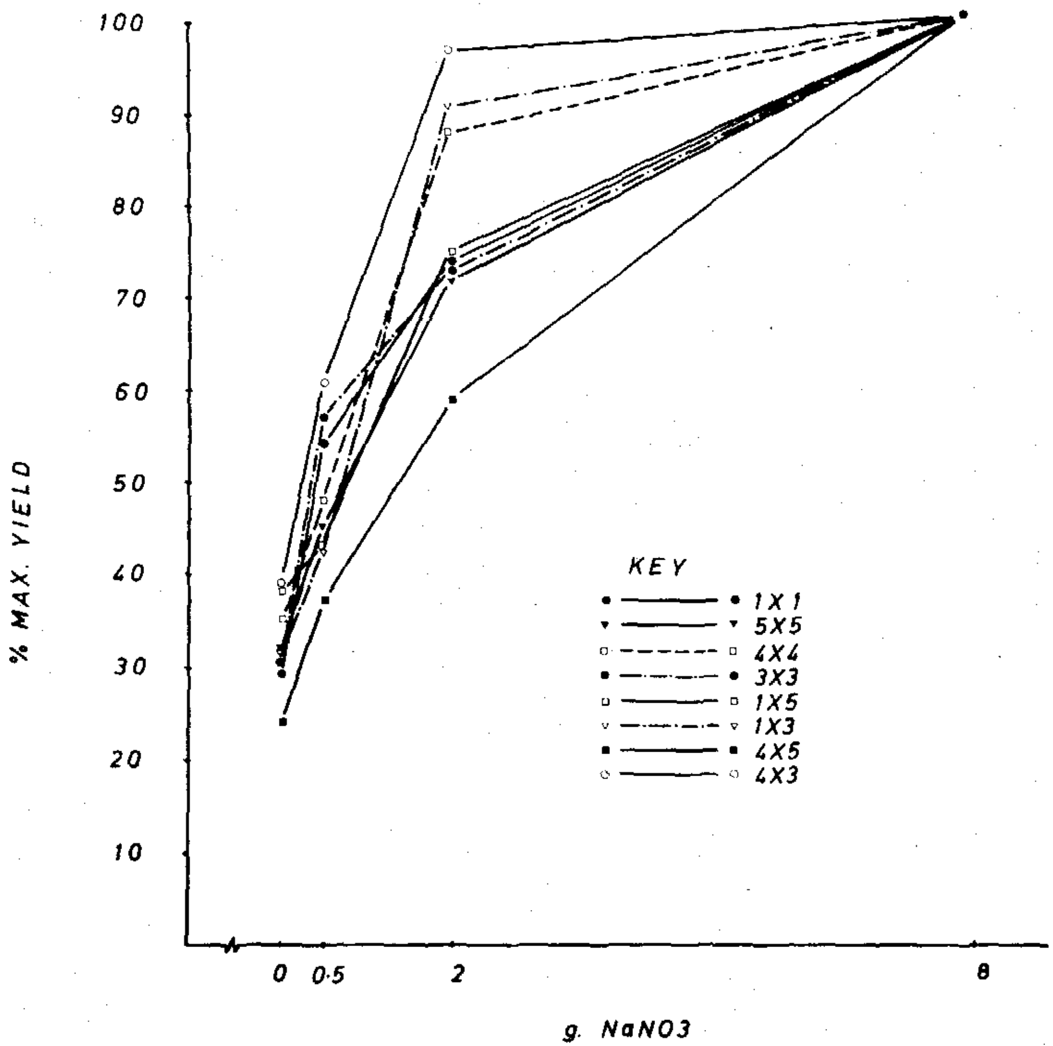
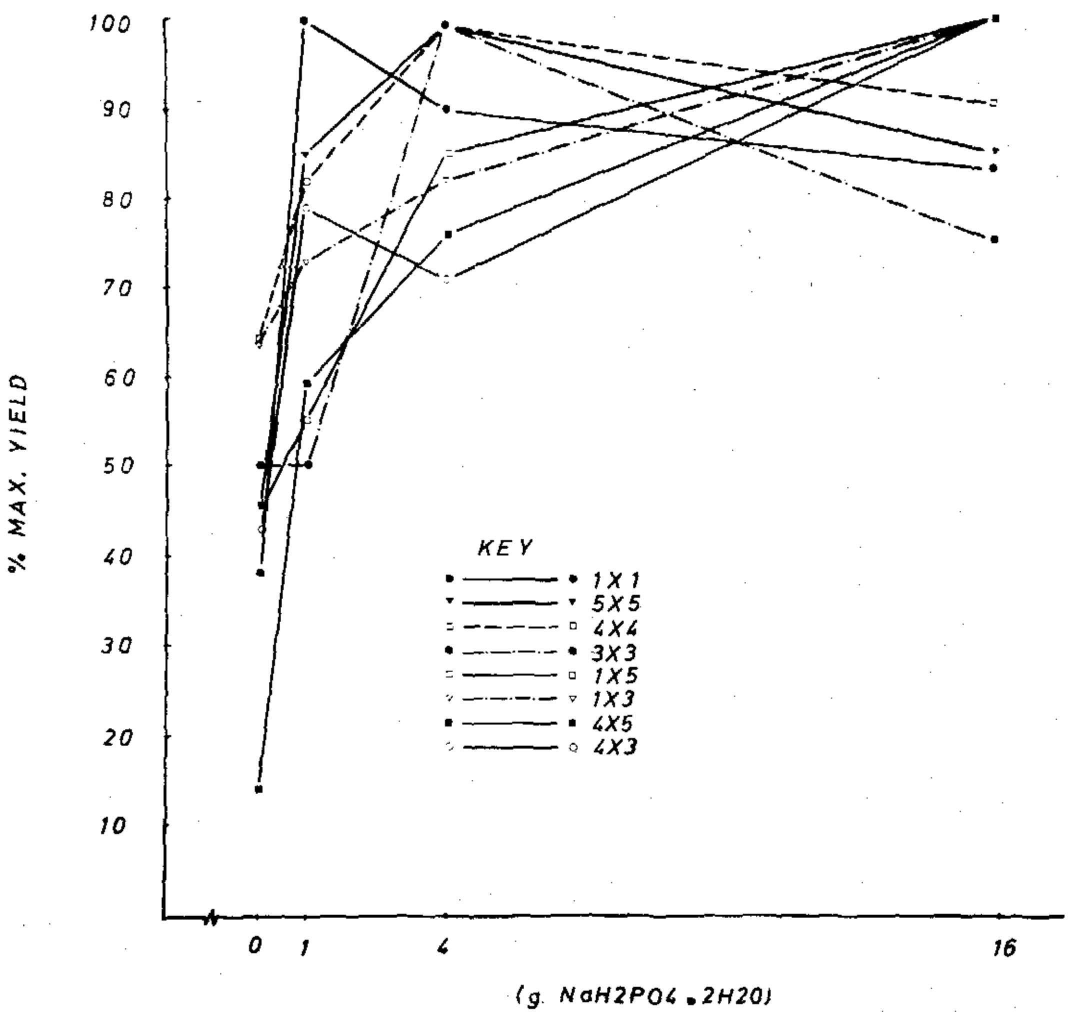


FIGURE 31. % RESPONSE OF DIFFERENT GENOTYPES TO PHOSPHORUS (leaf dry matter)



The values of leaf dry matter response per fertilizer supplied are shown in tables 11 and 12. As a consequence of the sigmoid growth, the return is least from the final fertilizer increment. It is noteworthy that all values are positive, and thus some return, however small, occurs from the whole range of fertilizer application. Loluim perenne gives noticeably smaller returns for fertilizer outlay than does L.multiflorum at the higher levels of fertilizer application. At low levels however, the differences are much less obvious particularly among the hybrids. Thus it may be that higher levels of fertilization will increase the advantage of L.multiflorum over L.perenne. The "utilization" or "efficiency" concept is thus a helpful one in defining the agricultural potential of selections made for characters of mineral nutrition.

Heritability - yield characters.

Significant correlation coefficients occurred in mid parent-progeny regressions involving most of the yield parameters. This observation has limited value when based on only two degrees of freedom, but suggests, since the regression coefficients are large ($h^2 \geq 1$) that this material is valuable for breeding purposes. In particular, leaf dry matter which is the most important yield character measured was significantly heritable ($h^2 \geq 1$) in all three experiments (N.P.K.) obviously, much larger numbers of progeny (perhaps 50) are needed to give accurate heritability estimates but the effect is none-the-less significant.

Heritability - response characters.

Although significant differences occurred in response, as mentioned earlier, none of these was significantly heritable. Again, larger numbers of progeny need to be tested to obtain a completely reliable result.

Table 11. The "efficiency" of nitrogen use by different populations (g. leaf dry matter produced, above the "no fertilizer" level, per g. nutrient supplied)

Code	N_1-N_0	N_2-N_0	N_3-N_0
1 x 1	20.0	8.9	3.5
5 x 5	10.0	8.1	3.5
3 x 3	11.1	4.4	1.8
4 x 4	5.6	5.8	2.5
1 x 5	4.4	7.8	3.3
4 x 5	8.9	6.1	3.3
1 x 3	6.7	8.9	2.6
4 x 3	7.8	3.3	1.4

Table 12. The "efficiency" of phosphorus use by different populations (g.leaf dry matter produced, above the "no fertilizer" level, per g. nutrient supplied)

Code	P_1-P_0	P_2-P_0	P_3-P_0
1 x 1	13.0	2.8	0.6
5 x 5	4.0	1.4	0.3
3 x 3	0.0	0.8	0.1
4 x 4	1.0	0.5	0.1
1 x 5	2.0	2.0	0.7
4 x 5	6.5	2.3	0.8
1 x 3	1.0	0.5	0.3
4 x 3	2.5	0.5	0.3

CONCLUSIONS

The <u>L.multiflorum</u> parents Liscate and S.22 gave larger yields and responded more to nutrient level than <u>L.perenne</u> Ba6280 and S.23. However, the <u>L. multiflorum</u>, especially Liscate, declined in yield after cutting relative to the other parents. The disadvantages of the parents were considerably offset in the progeny, which yielded more than the <u>L.perenne</u>,declined in yield less than the <u>Liscate</u> and gave favourable responses to nitrogen and phosphorus, whether measured as arithmetic response, percentage of maximal yield, or return for nitrogen and phosphorus supply.

Although the nutrient responses were not significantly heritable, useful heritabilities were found in yield characters. Leaf dry matter, in particular, was significantly heritable in all three experiments.

These experiments agree well with results obtained in sand culture (Goodman and Hughes, 1972). There is need to repeat these trials in the field to assess the agronomic potential of the genotype x environment interaction found and to increase this potential by selection within the hybrids.

Present opinion (Thomson and Wright, 1971) favours the use of interspecific rather than intraspecific crosses in the production of new synthetic grass varieties. The material used in these experiments is far from being ideal hybrid material, and its hybrid nature brings problems in analysis of results as well as in agronomic use. In mid parent-progeny regressions the very diverse parent material may itself influence the type of regression obtained.
Despite these problems the material in this diallel appears to be almost ideal for studies on the physiological basis of yield, as shown by work on canopy

structure (Rhodes, 1972) on biochemical attributes (Treharne and Lloyd, 1972) and on nutrient physiology. The physiological principles discovered by using this material can then be applied to other material, perhaps less diverse, which will provide agronomically desirable herbage grasses for the future.

CHAPTER V SUMMARY

Four parents and four progeny from a half diallel between populations of Lolium perenne L. and L.multiflorum Lam. were tested for response to nitrogen, phosphorus and potassium, in three separate experiments. There were four levels of nutrient in each experiment, a basal dressing without the variable nutrients, and three fertilizer additions arranged in a logarithmic sequence, all in pots of soil. Measurements were made of leaf number, leaf area and leaf dry weight at four harvests; of stem dry weight and root dry weight at a final harvest, after ten to twelve weeks.

Nitrogen supply up to 8g. $NaNO_3$/pot increased leaf size. Other plant parts were increased by N up to 2g. $NaNO_3$/pot. Roots were decreased by 8g. $NaNO_3$/pot. Phosphorus supply up to 1 g. NaH_2PO_4/pot increased leaves, roots and stems. 4g.NaH_2PO_4/pot caused a decrease in roots. Potassium supply of 0.5g. KCL/pot decreased all plant parameters.

The Lolium multiflorum parents Bb1277 (Liscate) and S.22 significantly outyielded the L.perenne parents Ba6280 and S.23 in all characters except leaf number. Among the progenies, the L.multiflorum hybrid Bb1277 x S.22 always yielded most in leaf area, leaf, stem, root and total dry matter. The interspecific hybrids yielded intermediately, and the L.perenne hybrid Ba6280 x S.23 yielded least. Several characters, notably leaf dry matter, were heritable.

Lolium multiflorum parents and their hybrid responded more to nitrogen and phosphorus than L.perenne parents or their hybrid. These responses were not significantly heritable, probably because the progeny numbers were so small.

CHAPTER VI REFERENCES CITED

ANTONOVICS, J., LOVETT, J. & BRADSHAW, A.D. (1966).

The evolution of adaptation to nutritional factors in populations of herbage plants. The use of isotopes in plant nutrition and physiology. IAEA, Vienna.

BOKEN, ELSE, 1970).

Studies on methods for determining varietal utilization of nutrients. II. Barley variaties and phosphorus. Pl. soil 33, 645-652.

BOWERMAN, A. & P. J. GOODMAN, (1971)

Variation in Nitrate Reductase Activity in Lolium. Ann. Bot. 35, 353-66.

BREESE, E. L. & LEWIS, E. J. (1969)

'Grasses,species and hybrids' Occ. Sym. Br. Grassld Soc., 5, 15-20.

BUTLER, G.W., BARCLAY, P.C. & GLENDAY, A.C. (1962).

Genetic and environmental differences in the mineral composition of ryegrass herbage', Pl. soil. 16, 214-28.

COOPER, J. P. & EL BREE, (1971)

Plant Breeding: 'Forage grasses and legumes', in potential crop Production, London: Heinemann, pp.295-318.

CORKILL, L., (1957)

Pasture plant breeding in New Zealand', Agric. Rev. Lond., 3, (6) 31-7.

GOODMAN, P. J., (1969)

Intra-specific variation in mineral nutrition of plants from different habitats. Ecological aspects of mineral nutrition of plants. B.E.S. Symp. IX, Ed. I.H.Rorison, Oxford and Edinburgh: Blackwill Sci. Publ.

GOODMAN, P. J. & D. M. HUGHES, (1972)

'Plant nutrition', in Report of the Welsh Plant Breeding Station for 1971. Aberystwyth. pp. 12-14.

HUGHES, D. M., (1970).

Studies on potassium and sodium nutrition of the Gramineae with particular reference to Lolium perenne. M.I.B. thesis, University of Wales, Aberystwyth.

JAIN, S. K. & BRADSHAW, A. D. (1966).

Evolutionary divergence among adjacent plant populations. I The evidence and its theoretical analysis. Heredity, 21, 407-441.

LAWAS, O. M. & P. J. GOODMAN, (1970).

The effect of phosphorus levels and previous cropping on seedling growth of Lolium selection lines. Pl. Soil 32, 103-112.

OWEN, C. M., (1972).

Variation in phosphorus and response in Lolium spp. M.Sc. thesis, University of Wales, Aberystwyth.

OZANNE, P. G., J. KEAY & E. F. BIDDISCOMBE, (1969).

The comparative applied phosphate requirements of eight annual pasture species. Aust. J. Agric. Res., 20, 809-18.

RANDALL, P. J. (1963).

Studies on aluminium and manganese toxicities in some herbage grasses. Ph.D. thesis, University of Wales, Aberystwyth.

RHODES, I., (1972)

Canopy structures and light utilization in Report of the Welsh Plant Breeding Station for 1971, Aberystwyth, pp.8-9.

THOMSON, A. J. & A. J. WRIGHT, (1971).

'Principles and problems in grass breeding', in Annual Report of the Plant Breeding Institute, Cambride for 1971, pp. 31-67

TREHARNE, K. J. & E. J. LLOYD, (1972)

'Genetic variation in isoenzyme activity', in Report of the Welsh Plant Breeding Station for 1971, Aberystwyth, p.12

VOSE, P. B., (1963).

Varietal differences in plant nutrition. Herbage Abstracts, 33, (1), 1-13.

VOSE, P. B. & E. L. BREESE, (1964).

Genetic variation in the utilization of nitrogen by Ryegrass species <u>Lolium perenne</u> and <u>L.multiflorum</u>. Ann. Bot. <u>28</u>, 251-270.

CHAPTER VII APPENDICES

APPENDIX (A) - Summary of the main significant effects of nutrient levels.

1. All harvests combined

<u>Leaf number per plant.</u>

$N_2 > N_1 > N_0$ $\qquad N_2 - N_0 = 6x\ (N_3 - N_2)$

$P_1 > P_0$ $\qquad P_1 - P_0 = 11x\ (P_3 - P_2)$

$K_3 < K_2$

<u>Leaf area per plant</u>

$N_3 > N_2 > N_1 > N_0$ $\qquad N_3 = 3\frac{1}{2} \times N_0$

$P_1 > P_0$ $\qquad P_1 - P_0 = 3 \times (P_2 - P_1)$

$K_3 < K_2$

<u>Leaf dry matter per plant</u>

$N_3 > N_2 > N_1 > N_0$ $\qquad N_3 = 3 \times N_0$

$P_1 > P_0$ $\qquad P_1 - P_0 = 3 \times (P_2 - P_1)$

$K_3 < K_2$

<u>Stem dry matter per plant</u>

$N_3 = N_2 > N_1 = N_0$: $\quad N_3 = N_2 = 3 \times (N_1 = N_0)$

$P_1 > P_0$ $\quad P_1 = P_2 = P_3 = 2 \times P_0$

$K_1 < K_0$ $\quad$ but $K_0 = K_2$ and $K_1 = K_3$

<u>Root dry matter per plant</u>

$N_3 < N_2 = N_1 = N_0$

$P_2 < P_1$ $\qquad$ but $P_0 = P_2$ and $P_1 = P_3$

$K_3 < K_2$ $\qquad$ but $K_0 = K_1 = K_3$

Total dry matter per plant

$N_2 > N_1$ $\qquad$ $N_3 = 2 \times N_0$

$P_1 > P_0$ $\qquad$ $P_1 - P_0 = 3 \times (P_3 - P_2)$

$K_3 < K_2$

2. Individual harvests.

Leaf number per plant.

$\overset{III,IV}{N_1 > N_0}$; $\qquad$ $\overset{IV}{N_2 > N_1}$;

$P_3 \overset{I}{>} P_2 = P_1 \overset{I-IV}{>} P_0$;

$K_0 \overset{I-IV}{>} K_3$; $\qquad$ $K_2 = K_1 \overset{II,III}{>} K_3$;

Leaf area per pot

$N_3 \overset{I,IV}{>} N_2 \overset{I,III,IV}{>} N_1 \overset{I,III}{>} N_0$

$P_3 \overset{I,III}{>} P_2 = P_1 \overset{I,III}{>} P_0$

$K_3 \overset{I,II,III,IV}{<} K_0 = K_1$; $\qquad$ $K_3 \overset{II,III,IV}{<} K_2$

Leaf dry matter per pot

$N_3 > N_2 > N_1 > N_0$ (mostly significant)

$P_3 \overset{overall}{=} P_2 = P_1 > P_0$; $P_3 > P_1$ (most harvests)

$K_3 \overset{I,II,III}{<} K_0 = K_1 = K_2$

Key:
I = First harvest
II = Second harvest
III = Third harvest
IV = Fourth harvest

APPENDIX (B). Summary of the main significant effects of populations.

1. Population differences at all harvests combined.

	Parents	Hybrids
	<u>Leaf number per plant</u>	<u>Leaf number per plant</u>
N	Liscate < S.23 = 6280 < S.22	All hybrids equal
P	S.22 = S.23 > Liscate = 6280	Liscate x S.23 = 6280 x S.22 = Liscate x S.22 > 6280 x S.23
K	Liscate = 6280 = S.23 < S.22	Liscate x S.22 = Liscate x S.23 = 6280 x S.23 < 6280 x S.22
	<u>Leaf area per plant.</u>	
N	S.22 > Liscate > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
P	Liscate = S.22 > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
K	Liscate = S.22 > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
	<u>Leaf dry matter per plant</u>	
N	Liscate = S.22 > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
P	Liscate > S.22 > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
K	Liscate > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
	<u>Stem dry matter per plant</u>	
N	S.22 > Liscate = 6280 > S.23	Other hybrids > 6280 x S.23
P	Liscate > S.22 > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
K	S.22 > Liscate = 6280 = S.23	Liscate x S.22 = 6280 x S.22 > other hybrids

	Parents	Hybrids
	Root dry matter per plant	
N	S.22 = Liscate > 6280 = S.23	Liscate x S.22 > Liscate x S.23 > 6280 x S.22 = 6280 x S.23
P	Liscate > S.22 = 6280 = S.23	Liscate x S.22 > other hybrids
K	S.22 = Liscate > 6280 = S.23	Liscate x S.22 = 6280 x S.22 > Liscate x S.23 = 6280 x S.23
	Total dry matter per plant	
N	S.22 = Liscate > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
P	Liscate > S.22 > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
K	Liscate = S.22 > 6280 = S.23	Liscate x S.22 = 6280 x S.22 > Liscate x S.23 > 6280 x S.23

2. Population differences at individual harvests.

	Parents	Hybrids
	Leaf number per plant	**Leaf number per plant**
N	S.22 > other parents	Progenies Not significant
P	S.22 = Liscate > 6280 = S.23 (Note A)	most harvests (Note B) Liscate x S.23 = 6280 x S.22 = Liscate x S.22 > 6280 x S.23
	Harvest II,III,IV	
K	S.22 > other parents	Progenies not Significant
	Leaf area per pot	**Leaf area per pot**
	Harvest IV	
N	S.22 > Liscate > 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
	Harvest I,III	
P	Liscate > S.22 = 6280 = S.23	Liscate x S.22 > interspecifics > 6280 x S.23
	Harvest I,II,III I,II,III,IV I,II,III	Harvest I,II I,II
K	Liscate = S.22 > S.23 = 6280	Liscate x S.22 > interspecifics > 6280 x S.23

	Parents	Hybrid
	<u>Leaf dry matter per pot</u>	
	Harvest I I,II,III (Note A)	Harvest I I,III
N	Liscate > S.22 > S.23 = 6280	Liscate x S.22 > interspecifics > 6280 x S.23
		Harvest II,III II,III II,III,IV
P	Liscate > S.22 > S.23 = 6280	Liscate x S.22 > Liscate x S.23 > S.22 x 6280 > 6280 x S.23
	I,II,III	I,II I,II
K	Liscate = S.22 > S.23 = 6280	Liscate x S.22 > interspecifics > 6280 x S.23

<u>Key</u>:

I = First harvest
II = Second harvest
III = Third harvest
IV = Fourth harvest

<u>Note A</u> Liscate was affected adversely by cutting in the experiments - in leaf dry matter so also was S.22 affected adversely by cutting.

<u>Note B</u> S.22 x 6280 and Liscate x S.23 were less adversely affected by cutting than other hybrids.

APPENDIX (C). Summary of the main interaction effects (population x nutrient level)

Leaf number per plant

Parents

Differences not consistent

Hybrids

Differences not consistent.

Leaf area per pot

Parents

N x populations at combined harvests,

at N_2, N_3

S.22 > Liscate > Ba6280 = S.23

Hybrids

N x populations at combined harvests.

at N_2

Lisc. x S.22 > Lisc. x S.23 > Ba6280 x S.22 = Ba6280 x S.23

at N_3

Lisc. x S.22 > Lisc. x S.23 = Ba6280 x S.22 > Ba6280 x S.23

Parents

N x populations at individual harvests,

at N_1,N_2,N_3 in I,III

S.22 = Liscate > Ba6280 = S.23

at N_3 in IV

S.22 > Liscate > Ba6280 = S.23

Hybrids

N x populations at individual harvests,

at N_3 in I, III

Lisc. x S.22 > Ba6280 x S.22 = Lisc. x S.23 > Ba6280 x S.23

Parents

P x populations at individual harvests,

at P_1 in I

S.22 > Liscate = Ba6280 = S.23

at P_1,P_3 in III

Liscate > S.22 > Ba6280 = S.23

Hybrids

P x populations at individual harvests.

at P_2, P_3 in III

Lisc. x S.22 > Ba6280 x S.22 = Lisc. x S.23 = Ba6280 x S.23

Parents

K x populations: Not significant

Hybrids

K x populations: Not significant

Leaf dry matter per pot

Parents

N x populations at combined harvests.

at N_2, N_3

S.22 = Liscate > Ba6280 = S.23

Hybrids

N x populations at combined harvests

at N_3

Lisc x S.22 > Ba6280 x S.22 = Lisc. x S.23 > Ba6280 x S.23

Parents

N x populations at individual harvests,

at N_1,N_2,N_3 in I

Liscate > S.22 > Ba6280 = S.23

at N_3 in IV

Liscate = S.22 > Ba6280 = S.23

Hybrids

N x populations at individual harvests,

at N_2 in I

Lisc. x S.22 > Lisc. x S.23 > Ba6280 x S.22 = Ba6280 x S.23

at N_3 in I

Lisc. x S.22 > Ba6280 x S.22 = Lisc. x S.23 > Ba6280 x S.23

at N_3 in IV

Lisc. x S.22 = Ba6280 x S.22 = Lisc. x S.23 > Ba6280 x S.23

Parents

P x populations at individual harvests

at P_1,P_3 in III

Liscate > S.22 = Ba6280 = S.23

Hybrids

P x populations at individual harvests

at P_3,

Lisc. x S.22 > Ba6280 x S.22 = Lisc. x S.23 = Ba6280 x S.23

Parents

K x populations: Not significant.

Hybrids

K x populations: Not significant

Plant total dry matter per plant

Parents

at N_2, N_3

S.22 = Liscate > Ba6280 = S.23

Hybrids

at N_0

Lisc. x S.22 > Ba6280 x S.22 = Lisc. x S.23 = Ba6280 x S.23

at N_2

Lisc. x S.22 = Lisc. x S.23 > Ba6280 x S.22 = Ba6280 x S.23

at N_3

Lisc. x S.22 = Ba6280 x S.22 = Lisc. x S.23 > Ba6280 x S.23

Key:

I = First harvest

II = Second harvest

III = Third harvest

IV = Fourth harvest

APPENDIX (D) Analysis of Variance of the plant total dry matter in experiments A, B and C.

1. Sample Anova - Experiment A - plant total dry matter (g/plant)

Source of Variance	S.S.	df	M.S.	V.R.	P.	Signific. Level.
Total	668.57	95				
Replicates	1.26	2	0.63	0.53	>5%	N S
Nitrogen levels	326.33	3	108.78	91.41	<1%	* * *
Populations	215.03	7	30.72	25.82	<1%	* * *
N x populations	52.18	21	2.48	2.08	< 5%	*
Error	73.77	62	1.19			

2. Sample Anova - Experiment B - plant total dry matter (g/plant)

Source of Variance	S.S.	df	M.S.	V.R.	P.	Signific level
Total	3772.38	95				
Replicates	214.34	2	107.17	7.83	< 1%	* * *
Phosphorus levels	563.62	3	187.87	13.73	< 1%	* * *
Populations	1731.48	7	247.35	18.08	< 1%	* * *
P x populations	414.67	21	19.75	1.44	> 5%	N S
Error	848.27	62	13.68			

3. Sample Anova - Experiment C - plant total dry matter (g/plant)

Source of Variance	Sum of Squares	df	M.S.	V.R.	P	Signific. Level
Total	905.30	95				
Replicates	7.45	2	3.73	0.84	≥5%	N S
Potassium levels	87.08	3	29.03	6.54	≤1%	* * *
Populations	394.14	7	56.31	12.68	≤1%	* * *
K x populations	141.57	21	6.74	1.52	≥5%	N S
Error	275.06	62	4.44			