Competition Studies in *Linum*

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In order to investigate competition in *Linum*, two experiments were laid out during 1962 and 1963. The first experiment had four varieties (two linseed and two flax) grown in five proportions and three densities in three replications. The second experiment included six varieties (three linseed and three flax) grown in two densities and two proportions in two replications.

The results of both the experiments indicate that in most of the cases, the yields of the mixture are greater than the pure stands. This is common both for dry weight and seed number. Individual and relative crowding coefficients of both linseed and flax change with density and proportion.

Individual and relative coefficients are higher when the components are in low frequencies in a mixture. The ratio diagrams show that the varieties, at least for some time, do not crowd for the same space. Both the components perform better when they are in low frequency in a mixture as compared to their pure stands.

As the ultimate output of the mixed cultures is better than the pure stands, and the components do not appear to interfere, hence there is a good degree of independence in their relationship in a mixture. There appears to be no effect of competition in final height of the main stem, shoot number and seed number per capsule, but there is a profound effect of competition on capsule number and seed index, which can be due to the fact that in a mixture of linseed and flax, the flax plants, as a result of early maturation, release the habitat in later stages and linseed plants utilize it partly in increasing capsule number and partly by increasing seed index.

INTRODUCTION

Struggle for existence, the universal biological phenomenon as enunciated by Darwin, or the survival of the fittest is also applicable in a narrower sense to individuals within a species, and has been termed competition by various writers, although the exact definition of this term varies with various workers according to the extent of competition between individuals within a species for the same space and source of food. The phenomenon can be observed by

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putting together individuals in a species with varying characteristics and keeping a record of the growth and development of the plant in various components.

Efforts have been made in the present studies to demonstrate this phenomenon amongst the varieties of flax (*Linum usitatissium*). Linseed and flax types within *Linum usitatissium* have been bred for different purposes, and consequently they have developed different morphologies. A stidy of their growth in mixture of different combinations of varieties and at different densities might, therefore, be expected to offer interesting information about the relationship of the two types and about competitive mechanism in general. Accordingly, two experiments, one in the field and the second in the green house were laid out during 1962 and 1963.

MATERIALS AND METHODS

Experiment 1.

The first experiment included four varieties (two linseed: Redwing and Valuta; two flax: Stormont Gossamer and Wiera) grown in five proportions and three densities in triplicate. The details of the combinations were as follows: Stormont Gossamer (Flax)+Redwing (Linseed); Wiera (Flax)+Redwing (Linseed); Stormont Gossamer (Flax)+Valuta (Linseed); Wiera (Flax)+Valuta (Linseed).

Flax and Linseed varieties were sown in the proportions of 0 and 100, 25 and 75, 50 and 50, 75 and 25 and 100 and 0 per cent respectively. The number of seeds of Flax and Linseed for these proportion sown were 0 and 36, 9 and 27, 18 and 18, 27 and 9 and 36 and 0 respectively.

The density of the seeds was kept at 40, 80 and 180 lbs. per acre which gave 1.41, 1.00 and 0.81 inches space from plant to plant. The experiment was sown in the field from 16-5-1962 to 19-5-1962 by means of hexagonal grids of different sizes, all accommodating 36 plants. The positions of the seeds of respective varieties in different proportions were laid out at random on the grids, using Fisher and Yates random tables.

Measurement

At maturity the entire grid plot plants population was harvested, and where it was a mixed plot the plants were separated into linseed and Flax components. Data with respect to final height, shoot number, capsule number and seed number per capsule were determined on an individual plant basis. Seed index was also calculated.

Information for dry weight and seed number per unit area was also calculated. The value per plot D_2 and D_3 (80 lbs and 120 lbs seed per acre) were multiplied by 2.00 and 3.05 to adjust these to the same plot size as D_1

(40 lbs seed per acre). From this, values per unit area (61.2 sq. cms. of size of the D_1 plot) were obtained.

Experiment 2

The experiment was carried out jointly with Professor John L. Harper and had 6 varieties (three linseed: Redwing, Valuta and Maroc; and three flax: Stormont Gossamer, Wiera and SV-0-226), sown either pure or in 50/50 mixture with two densities and two replications. This arrangement is a mechanical analogy of a Genetic diallel. Densities were made by sowing two plants and ten plants per pot. It was sown in a heated green house at Treborth on 17-12-1962. The high density was sown in a hexagon pattern. The mixture was sown at the following pattern:

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   X   O   X
 O  X   O    X
   O  X   X
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Measurement

At maturity data for seed number per pot and per plant were obtained from all the plants at low density and from the central two at high density.

RESULTS

Experiment 1

Due to the complex nature of the results obtained from this experiment, a simple analysis of variance in order to establish the level of significance between various varieties, combinations, proportions and densities was not possible, because all values are inter-related. But to understand the effect of competition under different conditions of this experiment, the entire data were examined in four ways, which are described in sequence.

a. **Actual Values**

These are the values for dry weight and seed number of each component in the mixture together with their totals, calculated on per unit area basis. The actual data are plotted in Fig. I and 2 respectively.

Dry Weight

A reference to Fig. I indicates that there is a profound general effect of density. Density affects both components of the mixture as well as the pure stand. Secondly, the yield of the two components in mixture is not related to their yields in pure stand. The yields of the mixtures lie on average above a line joining the two pure stand values (Fig. 1). Thirdly, the inter-relation of the components of the mixtures indicate a tendency for one component to do better than the other due to interference between them. But this inter-relationship is altered markedly by the change in the varietal combinations and densities. For example, in the case of Valuta+Stormont Gossamer at 50 per cent mixture in D_1 linseed (Valuta) gives higher dry weight. This position is maintained in D_2, but in D_3 linseed (Valuta) yield less than the Flax (Stormont Gossamer). However, when Valuta is in combination with Wiera this situation is even altered in D_2.

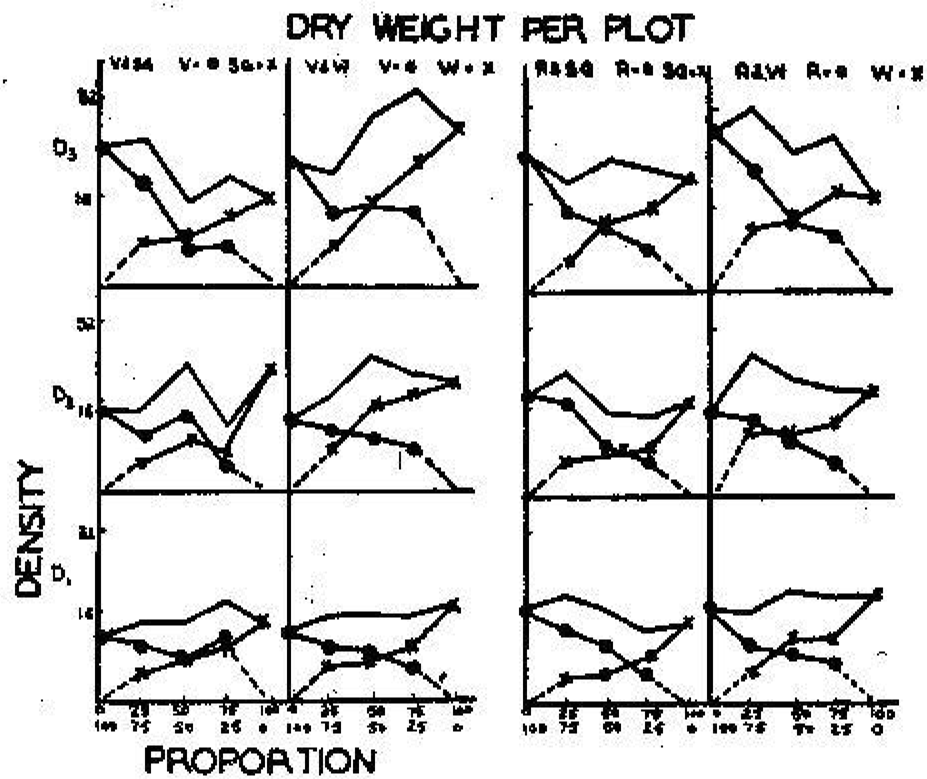

Fig. 1.—Dry weight per plot (gm.) for four varieties, two linseed (Redwing and Valuta) and two flax (Stormont Gossamer and Wiera) grown at three densities in five proportions. The data are taken from Experiment I. The top line in each graph (without symbols) represents the total production for each mixture.

Seed Number

A study of Fig. 2 reveals that density again has very conspicuous effects on yield. It affects both mixtures as well as pure stands. The situation regarding the relationship between the yield of mixtures and that of the appropriate pure stands is exactly the same as it was in dry weight, mixtures often giving more yield than could be expected. Further, it can be observed that the inter-relationship between the components of mixture is again altered with changes in combinations and density.

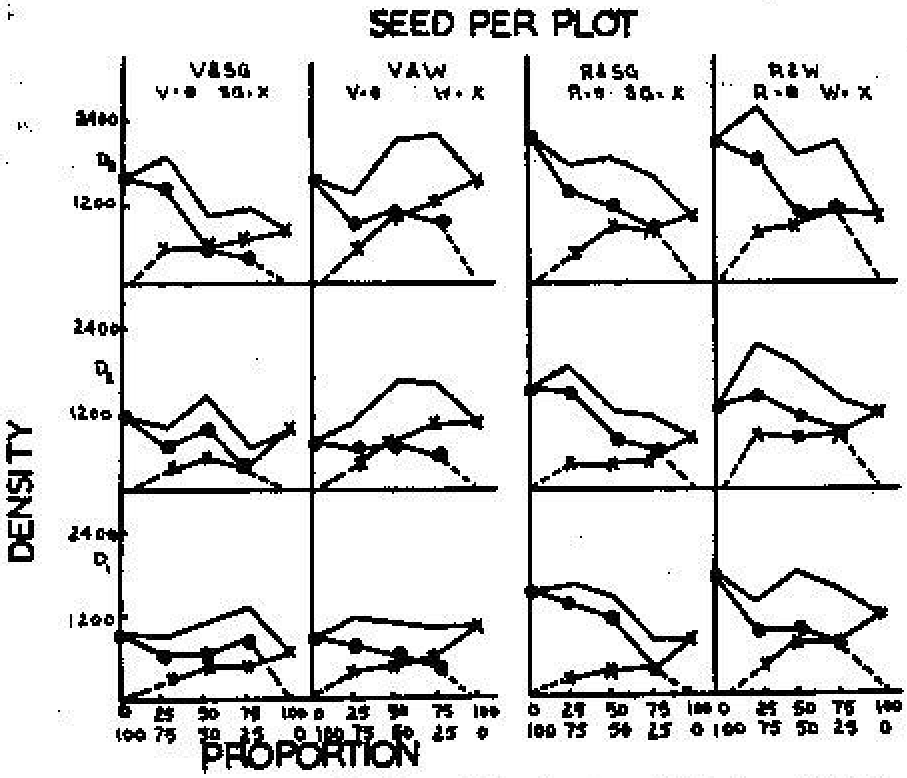

Fig. 2.—Seed number per plot for four varieties, two linseed (Redwing and Valuta) and two flax (Stormont Gossamer and Wiera) grown under three densities and in five proportions. (Experiment I). The top line in each graph (without symbols) represents the total production for each mixture.

b. **Ratio diagrams:**

As has been shown in Fig. 1 and 2, under all combinations, proportions and densities tried, mixed populations nearly always show better performance than would be expected from the values of the pure stands. This phenomenon can be investigated further by means of ratio diagrams of the relative reproductive ability following de wit (1960). In these log of O_1/O_2 is plotted against log z_1/z_2, where O_1 and O_2 are the yields of the species in mixture and Z_1 and Z_2 are the proportion of seed sown in a mixed population. In this investigation this nomenclature has been changed for clarity to O_F/O_L and Z_F/Z_L where F and L signify flax and linseed respectively. From the above relationship values of dry weight and seed number for all combinations, proportions and densities were calculated and are plotted in Fig. 3.

In a ratio diagram, if there is a simple relationship between the two components of a mixture no matter what is sown, what is harvested is directly related to what is sown. If the components are sown at several different proportions the points of O_1/O_2 against Z_1/Z_2 should lie on a straight line of 45° slope. If, however, the components do better than expected when sown at low frequency in mixture, the points will lie on a line of slope less than 45°. This type of performance in other words means that the components are not in direct competitions and not crowding for the same space in the sense of de Wit (1960).

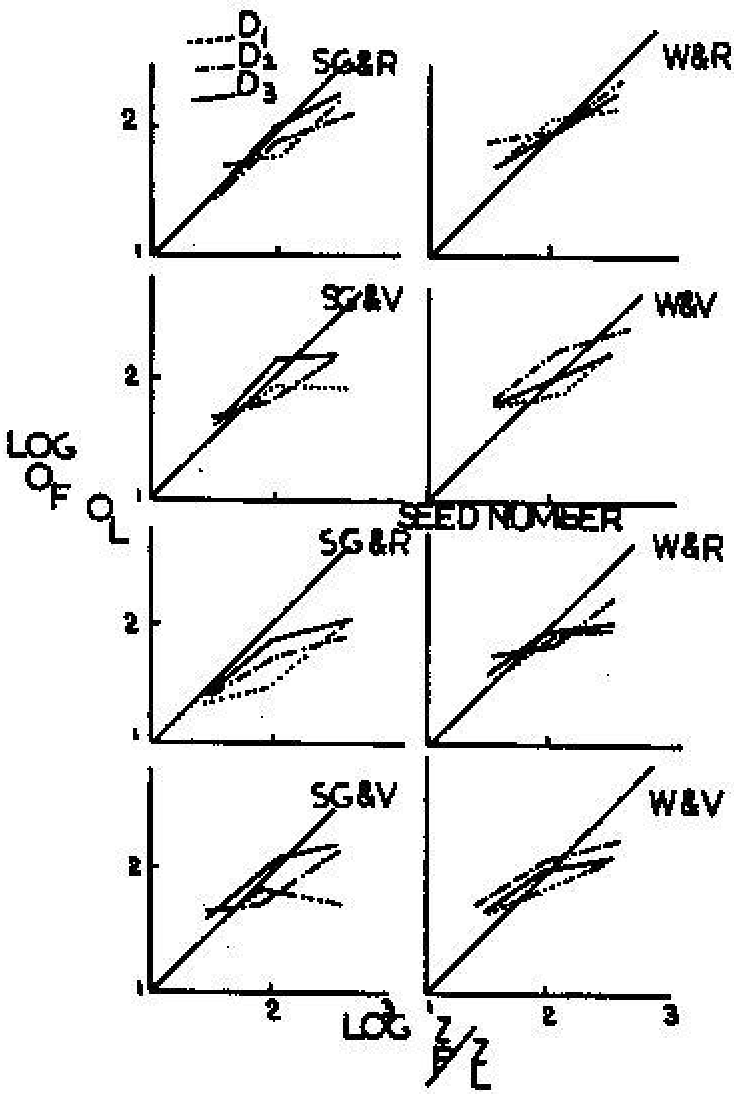

Fig. 3.--Ratio diagrams for dry weight and seed number for four varieties, two linseed (Redwing and Valuta) and two flax (Stormont Gossamer and Wiera) grown under three densities and in three proportions. (Experiment I)

In the case of dry weight (Fig. 3a). It is seen that under all varietal combinations these values do not lie on a straight line at a slope of 45°, which indicates that the components do not crowd for the same space. But the position of the line is clearly affected by density and variety combinations.

For seed number the examination of Fig. 3b indicates exactly the same situation and the components do not appear to crowd for the same space.

c. Relative and individual crowding Co-efficients:

Having established that the components do not compete or crowd for the same space, the next logical step would be to look further at their relationship and to develop a measure of their individual performance and competitive ability in a mixture. This can effectively be done by assessing the performance of a pure stand expressed on a per plant basis. This value which can be termed the individual crowding coefficient is given by $K = O_1/Z_1/M_1/Zm_1$, where O_1 is the yield per plot of one component in mixture and Z_1 is the number of seeds sown in that plot of the same component in mixture and M_1 is the yield of the same component in pure stand and Zm_1 is the number of seeds sown of the same component in pure stand. If for any mxture the individual crowding coefficient of the two components are combined together, in effect a comparison is obtained of the relative effect of mixing K on the two components. This can be written as below:

$$\frac{K_1}{K_2} = \frac{O_1/Z_1/M_1/Zm_1}{O_2/Z_2/M_2/Zm_2} \qquad (2)$$

This in fact gives the relative crowding co-efficient which has already been derived by de-Wit (1960), who has written it as below:

$$K_{12} = \frac{O_1}{Z_1} / \frac{O_2}{Z_2} / \frac{M_1}{M_2} \qquad (3)$$

In equation (2) $Zm_1 = Zm_2$ since these are the numbers of seed sown in pure stand, and are equal. Equations (2) and (3) are therefore the same. In the table (1 & 2) F has been substituted for I to denote flax and L for 2 to denote linseed.

Using the above equations, K_{FL}, K_F & K for dry weight and seed number were calculated and are given in Table I.

A reference to table I reveals that the relative crowding co-efficient is changed with changes in density and proportion. As the density shifts from D_1 to D_3 the relative performance of flax in mixture consistently improves. The effect of proportion also is very conspicuous. In all varietal combinations and densities, as the proportion varies the value for K_{FL} changes, being high when flax is low and *vice-versa*. This means that the component which is in small proportion in a mixture gives a relatively better performance in comparison with the other.

TABLE 1. *Relative and Individual Crowding Coefficients for Dry Weight*

Combination	Proportion		D_1			D_2			D_3		
	F*	L*	K_{FL}**	K_F**	K_L**	K_{FL}	K_F	K_L	K_{FL}	K_F	K_L
SG/R	9	27	1.59	1.71	1.07	1.19	1.44	1.21	1.29	1.01	0.79
	18	18	0.69	0.87	1.26	0.88	0.83	0.94	1.33	1.24	0.93
	27	9	0.58	0.73	1.26	0.50	0.66	1.34	0.77	0.95	1.23
W/R	9	27	1.47	1.15	0.78	2.08	2.56	1.23	2.62	2.66	1.01
	18	18	1.12	1.15	1.03	1.86	1.19	1.38	1.78	1.52	0.85
	27	9	0.47	0.81	1.71	0.56	0.93	1.65	0.97	1.39	1.43
SG/V	9	27	0.94	1.11	1.18	0.90	0.83	0.92	1.77	1.82	1.03
	18	18	0.68	0.93	1.37	0.42	0.79	1.88	2.17	1.08	0.50
	27	9	0.22	0.75	3.39	0.32	0.40	1.24	0.88	1.03	1.18
W/V	9	27	1.12	1.20	1.07	1.26	1.38	1.10	1.35	1.03	0.76
	18	18	0.53	0.75	1.43	1.01	1.52	1.51	0.81	1.11	1.37
	27	9	0.37	0.70	1.68	0.52	1.19	2.29	0.42	1.03	2.46

*F and L indicate Flax and Linseed respectively.

**K_{FL} incident relative crowding coefficient of flx and linseed, whereas K_F and K_L indicate individual crowding coefficient for flax and linseed variety.

An examination of the values for K_F and K_L includes what is occurring. Whenever a component is in low frequency in a mixture it has usually a high individual crowding co-efficient (more than one), while when in high frequency its individual crowding co-efficient is much less (usually less than one).

In the case of K_{FL} values for seed number and examination of Table 2 indicates exactly the same trend as was shown for dry weight. K_{FL} increases with increase in density, indicating the relative superiority of flax in comparison with linseed at high densities. The same effect of proportion is also shown.

K_{FL} declines with increase in proportion of flax in mixture, again indicating that the components in smaller proportion in a mixture always have relatively better performance. The individual crowding co-efficients bear this out.

TABLE 2. *Relative and Individual Crowding Coefficient for Seed Number*

Combination	Proportion		D_1			D_2			D_3		
	F*	L*	K_{FL}**	K_F**	K_L**	K_{FL}	K_F	K_L	K_{FL}	K_F	K_L
SG/R	9	27	1.27	1.51	1.18	1.53	1.96	1.29	1.91	1.60	0.84
	18	18	0.64	0.92	1.44	0.98	1.02	1.04	1.55	1.67	1.07
	27	9	0.61	0.65	1.07	0.53	0.83	1.57	0.68	1.04	1.55
W/R	9	27	1.59	1.19	0.75	1.84	2.80	1.52	2.56	3.00	1.17
	18	18	1.19	1.33	1.12	0.75	1.37	1.82	1.84	1.76	0.95
	27	9	0.49	0.85	1.75	0.56	0.98	1.75	0.73	1.43	1.96
SG/V	9	27	1.62	1.49	0.92	1.56	1.26	0.80	2.23	2.62	1.17
	18	18	0.95	1.37	1.44	0.66	1.10	1.68	2.29	1.35	0.59
	27	9	0.24	0.91	3.74	0.52	0.53	1.01	1.05	1.14	1.08
W/V	9	27	1.27	1.54	1.22	1.25	1.54	1.24	1.47	1.17	0.79
	18	18	0.61	0.89	1.44	0.85	1.69	1.99	0.93	1.33	1.43
	27	9	0.37	0.77	2.09	0.39	1.28	3.26	0.43	1.07	2.52

*F and L indicate Flax and Linseed respectively.

**K_{FL} indicates relative crowding coefficient of flax and linseed, whereas K_F and K_L indicate individual crowding coefficient for flax and linseed variety.

d. **Morphological Characters:**

After studying the curious nature of the relationship of flax and linseed in mixture, some of the morphological character of the flax and linseed plants were examined to understand this relationship. The results for plant height, shoot number for plant, capsule number per plant, seed number per capsule and seed index are described in Tables 3-6.

The results on final height shown in Table 3 indicate that the effect of density is very clear, but there does not appear to be any differential response of varieties to either density or proportion.

TABLE 3. *Final Height (CM) of the Main Stem*

Combination	Proportion		D_1		D_2		D_3	
	Z_F	Z_L	Flax	Linseed	Flax	Linseed	Flax	Linseed
SG/R	0	36	..	73.6	..	67.3	..	69.0
	9	27	95.0	68.4	91.6	69.7	84.5	67.0
	18	18	96.2	70.4	83.5	64.6	87.4	62.0
	27	9	97.4	68.7	88.7	66.9	89.6	60.7
	36	0	97.5	..	87.4	...	87.7	..
W/R	0	36	..	70.6	..	71.9	...	67.4
	9	27	93.0	73.4	92.3	70.0	85.1	68.4
	18	18	94.2	74.4	85.3	68.6	88.4	69.4
	27	9	99.7	73.7	90.2	67.9	87.5	67.9
	36	0	96.7	..	85.8	..	76.5	..
SG/V	0	36	..	67.8	..	65.1	..	66.0
	9	27	95.5	69.9	87.1	61.8	88.7	65.7
	18	18	90.2	63.8	90.5	65.8	83.8	62.1
	27	9	98.9	65.1	88.8	64.1	89.2	60.5
	36	0	95.0	..	89.5	..	87.5	..
W/V	0	36	..	66.1	..	65.7	..	66.3
	9	27	88.7	70.6	80.7	63.6	81.8	61.9
	18	18	89.2	67.9	91.2	66.9	89.4	69.3
	27	9	96.7	69.2	88.8	65.3	87.6	67.7
	36	0	95.4	..	93.2	..	86.8	..

The results for shoot number given in Table 4 show that varieties give some indication of differential response to density, but apparently seems to be no effect of proportion.

Results for capsule number given in Table 5, however, reveal that proportion here has a very startling effect on this character. In both the types when a component is in low frequency in a mixture, its capsule production improves as compared to when it is in pure stand. This behaviour has already been seen in K & K_L values for dry weight and seed number (Table 1 & 2), where in both the cases K shifts with the change in proportion, and is always higher when the component is in low frequency in a mixture. The relative effect of density on both components is similar.

The results on seed number per capsule given in Table 6 indicate that there appears to be no differential response of both the components to density and proportion but there is a slight indication of the effect of density on both the components.

The final character of seed index (Fig. 4) does not directly contribute to the character of seed number, and only little to the character of total dry weight, and it can, therefore, be considered separately; the results are, however, peculiar and of interest. There appears to be a differential response to different proportions shown by both the components. Seed index is a fairly stable character in relation to change in density. The flax component of the mixtures maintain this situation, but in the case of the linseed components, there appears a profound and consistant effect of the proportion. With the exception of only a few cases the linseed component has a higher seed index when it is in a mixture as compared to when it is in a pure stand. Apart from this behaviour it changes with proportion.

At low frequencies seed index appears to be higher than at high frequencies. The effect of density seems to be negligible.

Experiment 2:

Data for seed number from this experiment were examined in two different ways: (*a*) actual values, (*b*) by the diallel analysis, and these are described in sequence.

(*a*) Actual Values:

In this case the actual values represent the seed number per pot in pure and in mixed stands. The average values of the reciprocal components (arrays in genetic sense) for both the densities are plotted in Fig. 5 a & b. In the case of mixture the black columns represent the actual yields observed and the blank ones represent the expected yields from a mixture on an additive basis.

TABLE 4. *Shoot Number Per Plant.*

Combination	Proportion F	Proportion L	D_1 Flax	D_1 Linseed	D_2 Flax	D_2 Linseed	D_3 Flax	D_3 Linseed
SG/R	0	36	..	1.1	..	1.0	..	1.0
	9	27	1.0	1.0	1.0	1.0	1.0	1.0
	18	18	1.0	1.0	1.0	1.3	1.0	1.0
	27	9	1.0	1.0	1.0	1.0	1.0	1.0
	36	0	1.0	..	1.0	..	1.0	..
W/R	0	36	..	1.3	..	1.0	..	1.0
	9	27	1.0	1.2	1.0	1.0	1.0	1.0
	18	18	1.0	1.5	1.0	1.0	1.0	1.0
	27	9	1.2	1.8	1.0	1.0	1.0	1.0
	36	0	1.0	..	1.0	..	1.0	..
SG/V	0	36	..	1.1	..	1.0	..	1.0
	9	27	1.0	1.1	1.0	1.0	1.0	1.0
	18	18	1.0	1.5	1.0	1.0	1.0	1.0
	27	9	1.0	1.8	1.0	1.0	1.0	1.0
	36	0	1.0	..	1.0	..	1.0	..
W/V	0	36	..	1.5	..	1.1	..	1.0
	9	27	1.0	1.4	1.0	1.1	1.0	1.0
	18	18	1.0	1.7	1.0	1.0	1.0	1.0
	27	9	1.0	1.2	1.0	1.0	1.0	1.0
	36	0	1.0	..	1.0	..	1.0	..

A reference to Fig. 5a indicates quite similar results as shown under experiment I. In some of the cases, the yield of the mixture is better than the pure stands. In the case of high density a study of Fig. 5b reveals the same information. Again, there are some indications of the better performance of mixtures as compared to pure stands.

After studying the better performance of mixtures as compared to pure stands, the individual performance of a plant in mixture as compared to its performance in a pure stand was studied. This in effect is equivalent to examining its crowding co-efficient. This information is plotted in Fig. 6a and b.

A study of Fig. 6a and b reveals that in the case of low density (Fig. 6a), the performance of Redwing, Maroc and SVO 226 is very spectacular, no matter what is mixed, their yield in mixture on an individual plant basis goes up. But the other varieties do not behave in this way and give less yield in mixture as compared to their pure stands, while on the other hand Valuta and Wiera give exceptionally better performances in mixture as compared to their pure stands.

From a comparative study under both the densities it appears that there is a considerable tendency for varieties to give better yields in mixture than in pure stands. But this differs with different varieties and with different densities. With some exceptions linseed varieties give better performances under low density and flax varieties do well under high density.

(*b*) Diallel Analysis:

In this case data were analysed in a diallel fashion and the Vr/Wr graphs are plotted in Fig. 7a and b. The actual average values of the reciprocal components (arrays in genetics sense) for both densities are those given in Fig. 5a and b.

A reference to Fig. 7a and b reveals that in the case of low density (Fig. 7a) the regression line with unit slope cuts the *Wr* axis above the origin. In a genetic sense this situation would signify that the gene action is additive with partial dominance, and Wiera, Maroc and SVO 226 have the most dominant genes. But its interpretation in term of competition (Fig. 6a and b) appears to be that in most of the arrays, with few exceptions, there is a general trend that the yield of the mixture is greater than that of the mean of the pure stands of the two components, following deWit (1960). This means that the species do not behave in an additive fashion and hence do not crowd for the same space. It, therefore, appears that on the Vr/Wr graphs the occurrence of the degree of dominance in ecological terms means that the species do not act in an additive manner, hence partially or fully are not crowding for the same space. In the case of high density (Fig. 7b) the situation appears to be of a dominant relationship,

TABLE 5. *Capsule Number Per Plant.*

Combination	Proportion		D_1		D_2		D_3	
	F	L	Flax	Linseed	Flax	Linseed	Flax	Linseed
SG/R	0	36	..	5.2	..	2.6	..	2.6
	9	27	4.0	6.0	2.7	3.5	1.6	2.1
	18	18	2.3	7.1	1.3	2.9	1.7	2.6
	27	9	1.9	5.7	1.1	4.1	1.2	3.8
	36	00	2.5	..	1.6	...	1.1	...
W/R	0	36	..	5.9	...	2.1	...	2.6
	9	27	4.3	4.4	4.7	3.2	3.1	3.1
	18	18	4.8	6.4	2.4	3.9	1.8	2.2
	27	9	3.1	10.6	1.7	3.5	1.5	4.5
	36	00	3.6	..	1.7	...	1.1	...
SG/V	0	36	..	3.6	..	2.3	...	2.5
	9	27	3.2	3.7	2.0	2.6	2.4	2.8
	18	18	2.8	5.0	1.8	3.8	1.4	1.5
	27	9	1.9	12.1	0.9	2.5	0.9	2.4
	36	0	2.5	..	1.6	...	0.9	...
W/V	0	36	..	3.2	...	1.8	...	2.3
	9	27	4.9	4.2	2.6	2.0	1.9	2.0
	18	18	2.8	5.1	2.8	3.1	2.2	3.1
	27	9	2.3	6.9	2.1	4.8	1.7	5.4
	36	0	3.2	..	1.6	..	1.7	...

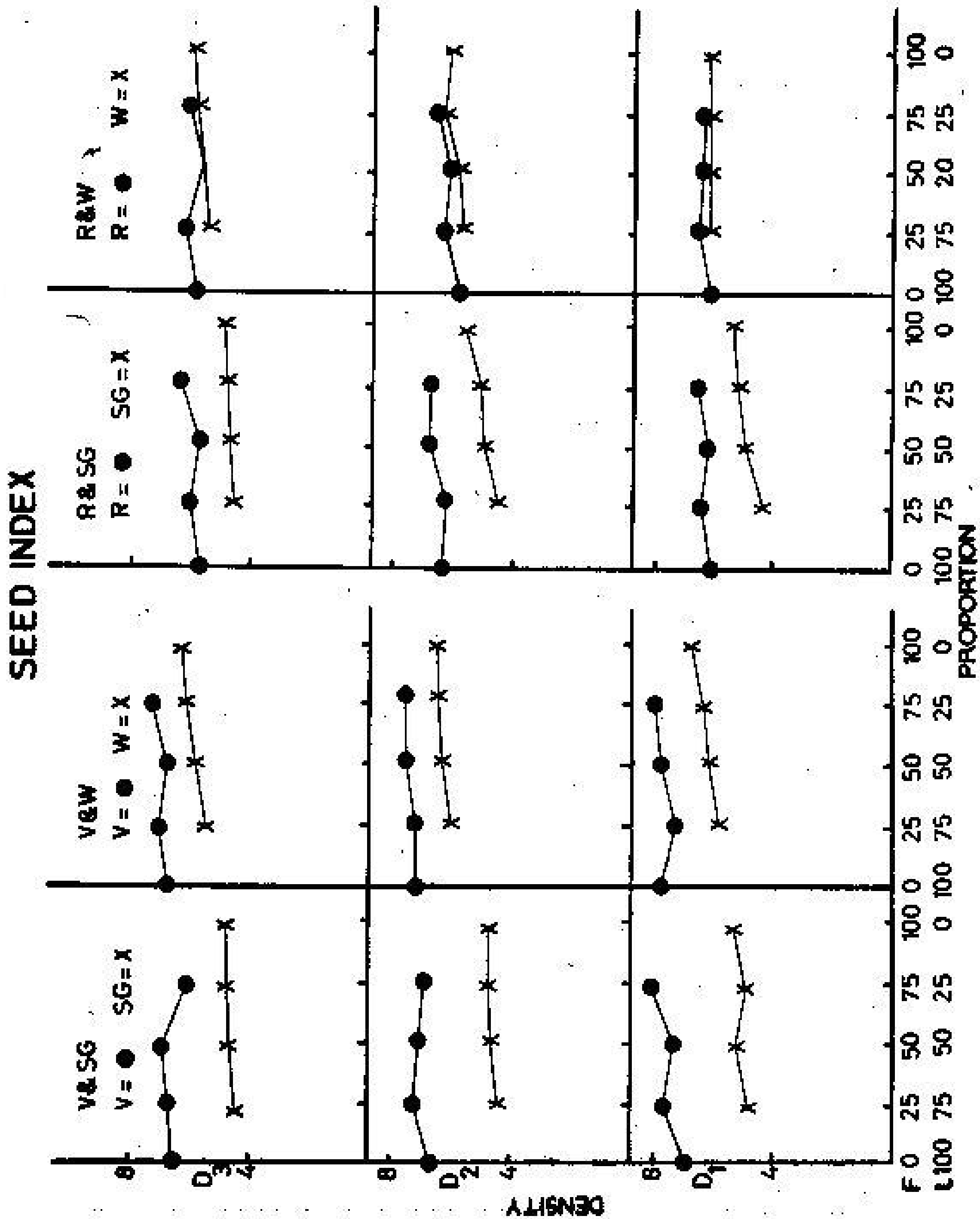

Fig. 4.—Seed index for four varieties, two linseed (Redwing and Valuta) and two flax (Stormont Gossamer and Wiera) grown under three densities and in five proportions. The data are taken from Experiment I.

as the regression line passes through the origin. But there appears to be some interaction as the line significantly deviates from u nit slope.

From a comparative study it appears that occurrence of the degree of dominance on the Vr/Wr graphs, in an ecological sense, gives a fair indication of the crowding nature of the components of a mixture. On the other hand, it is very difficult to explain the position of array point on the regression line in these terms. In low density, Redwing gives a better performance in mixture, while Stormont Gossamer gives poor performance in mixture, but on the Vr/Wr graphs they occupy the same most recessive position. Hence, at least in this experiment, no definite relationship with respect to array points on the line can be worked out.

DISCUSSION

Investigations of Sakai (1955), Roy (1960), Harper and McNaughton (1962), Cavers and Harper (1962) and others have shown the effect of competition stress on various phases of plant life and its possible biological interpretation. Harper (1961) suggests that the result of interference is the gain of one species at the expense of another. Sakai (1955) states that the performance or competitive ability under competition varies with the varieties or species and has some genetical basis. From the result described, it becomes clear that mixed cultures frequently give better performances than either of the pure stands.

This particular behaviour poses a peculiar problem in understanding the mechanism of competition in flax and linseed. The situation becomes most clear if the results are looked in term of interference. In Fig. 1 and 2, the yield curves of the separate components are in the same direction indicating that one component does not gain at the expense of another. This is borne out by values for individual and relative crowding co-efficients. When a component is in low frequency in a mixture, it has a high value for both relative and individual crowding co-efficients. In other words, this means that the component performs better when it is in low frequencies in a mixture than when it is in high frequencies.

The results of the second experiment tend to confirm these conclusions. In effect, the component reacts more to its own density than it does to that of the component with which it is mixed. Similar finding in a competition experiment on red clover, *Trifolium proteins* and Lucern, *Medicago sativa* have been reported by Black (1960). He concluded that a clover plant is most suppressed when clover numbers are high and lucern number are low, and exceeds the expected value where its own density is low and that of lucern is high. Precisely the same holds for lucern, which is most suppressed when

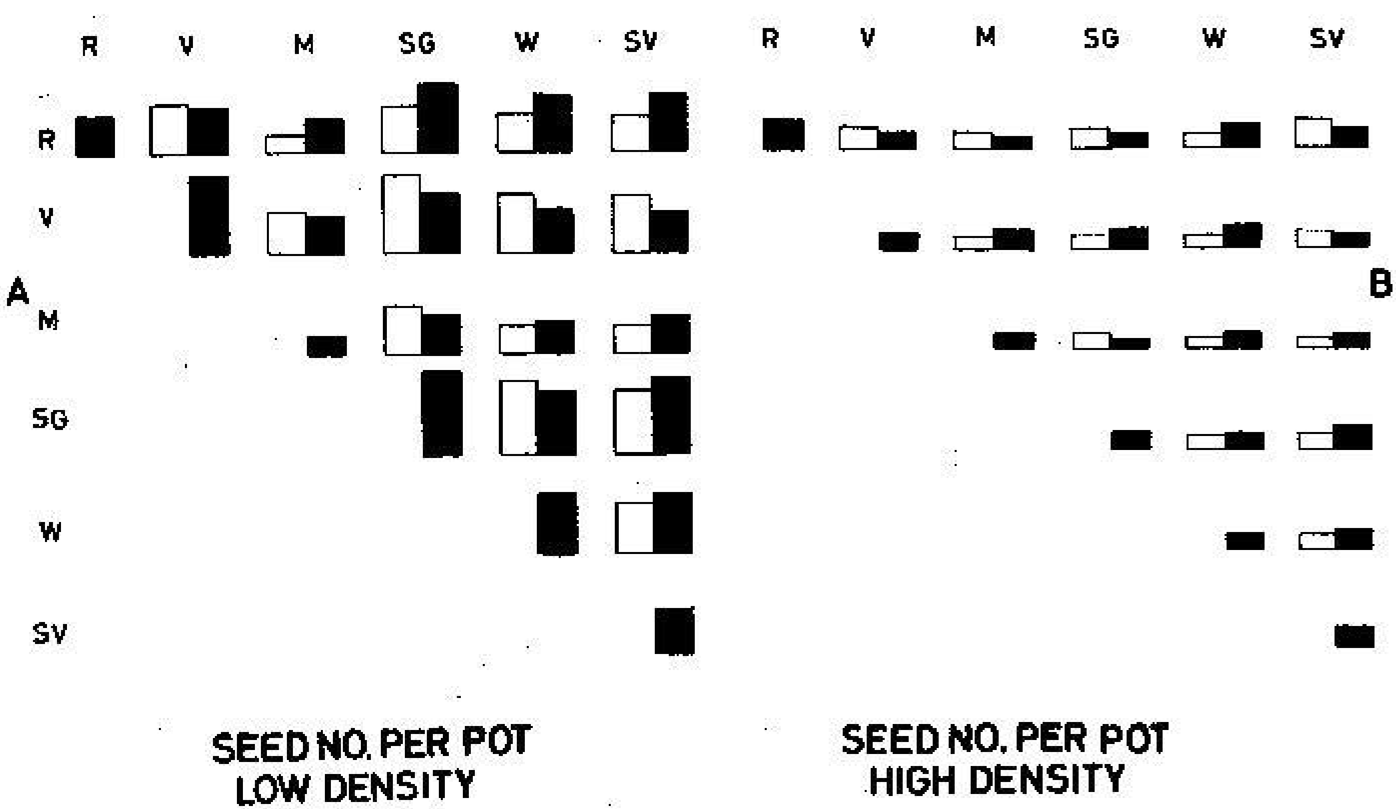

Fig. 5.—Seed number per pot of six varieties, three linseed (Redwing, Valuta and Maroc) and three flax (Stormont Gossamer, Wiera and SV O 226) grown under the two densities. The black columns represent the actual yields observed and the blank ones represent the expected yields (on an additive basis) from a mixture. The data are taken from Experiment II.

TABLE 6. *Seed Number Per Capsule.*

Combination	Proportion		D_1		D_2		D_3	
	F	L	Flax	Linseed	Flax	Linseed	Flax	Linseed
SG/R	0	36	..	8.13	..	7.78	..	7.53
	9	27	8.02	8.30	7.87	7.65	8.97	7.82
	18	18	8.82	8.55	8.06	7.39	8.63	7.96
	27	9	8.69	7.86	8.42	8.02	7.52	7.89
	36	00	9.14	..	7.15	..	8.11	..
W/R	0	36	..	8.07	..	7.54	..	7.61
	9	27	9.08	8.27	8.88	7.93	8.67	7.22
	18	18	9.03	8.36	8.56	7.93	8.80	7.91
	27	9	8.89	7.97	8.95	8.27	8.71	..
	36	0	9.14	..	8.77	..	8.23	..
SG/V	0	36	..	6.88	..	6.49	..	6.04
	9	27	8.43	6.23	7.89	5.87	7.49	5.91
	18	18	8.81	7.28	7.99	6.66	6.80	5.61
	27	9	8.53	7.63	7.63	6.05	7.93	5.91
	36	00	7.57	..	7.55	..	7.01	..
W/V	0	36	..	7.18	..	5.41	..	6.13
	9	27	8.75	6.66	8.47	6.16	8.48	5.41
	18	18	8.49	6.65	8.92	6.32	8.71	6.19
	27	9	9.08	6.93	8.98	6.80	8.72	6.17
	36	00	8.61	..	8.93	..	8.46	..

Lucern numbers are high and clover numbers low, and which gains most when clover densities are high and its own are low.

From all this it can be seen that the components show a fair degree of independence, *i.e.*, each is affected more by itself than by the other. Since the two components co-operate to give the final yield, this is higher than if they interfered with each other. Such independence can be equated with the deWit concept of not crowding for the same space. In the diallel analysis the occurrence of dominance may be equated with the same thesis. Now the question arises what enables them to be independent? what is the difference in their biology? do they have the same growth pattern? do they crowd for the same space for light or not? De Wit (1960) from his experiment on *Anthoxantham odoratum* when grown in a mixture with *Phleum pretense* for a full season under outdoor conditions obtained a similar relationship to that found for flax and linseed. The reason suggested in this case was that in a full season out doors *Anthoxanthan odoratum* has its major growth period earlier than *Phleum pretense*. No experiments have been carried out to test this effect in linseed and flax crops. But from a qualitative observation it is seen that flax varieties as a group mature earlier than linseed types, and during their growth period at least for some time they do not crowd for the same space. This is sufficient to explain the results of the first experiment but in the second experiment the situation is more complex since some linseed varieties are as early as flax. Apart from this there might be some physiological and morphological factors playing a part in this type of relationship between flax and linseed.

Another feature of these investigations is the effect of competition stress on various developmental characters. It is seen that on final height of the main stem, shoot number and seed number per capsule, there appears to be no effect which can be due to mixing, but there is an effect of density. In the case of capsule number per plant the effects of competition is very clear and final out put of seeds appears to be the direct reflection of this character. In this case as the proportion of a component changes from high to low the capsule number per plant goes up. This trend is common in both the components. It is here that the first sign of independence of the components is shown. It is not shown at the earlier stage of shoot production. This allows the suggestion that the phase of independence occurs later than the stage of shoot production.

The curious results for seed index can be used to support this argument further. Changes in density appear to have no effect at all on this character in pure stand, although there may be violent changes in seed number. But in mixtures there is a profound effect due to changes in proportion of the components. This is very clear in linseed, but flax types show no such effect. The change that occurs is, that there is an increase in seed index of linseed

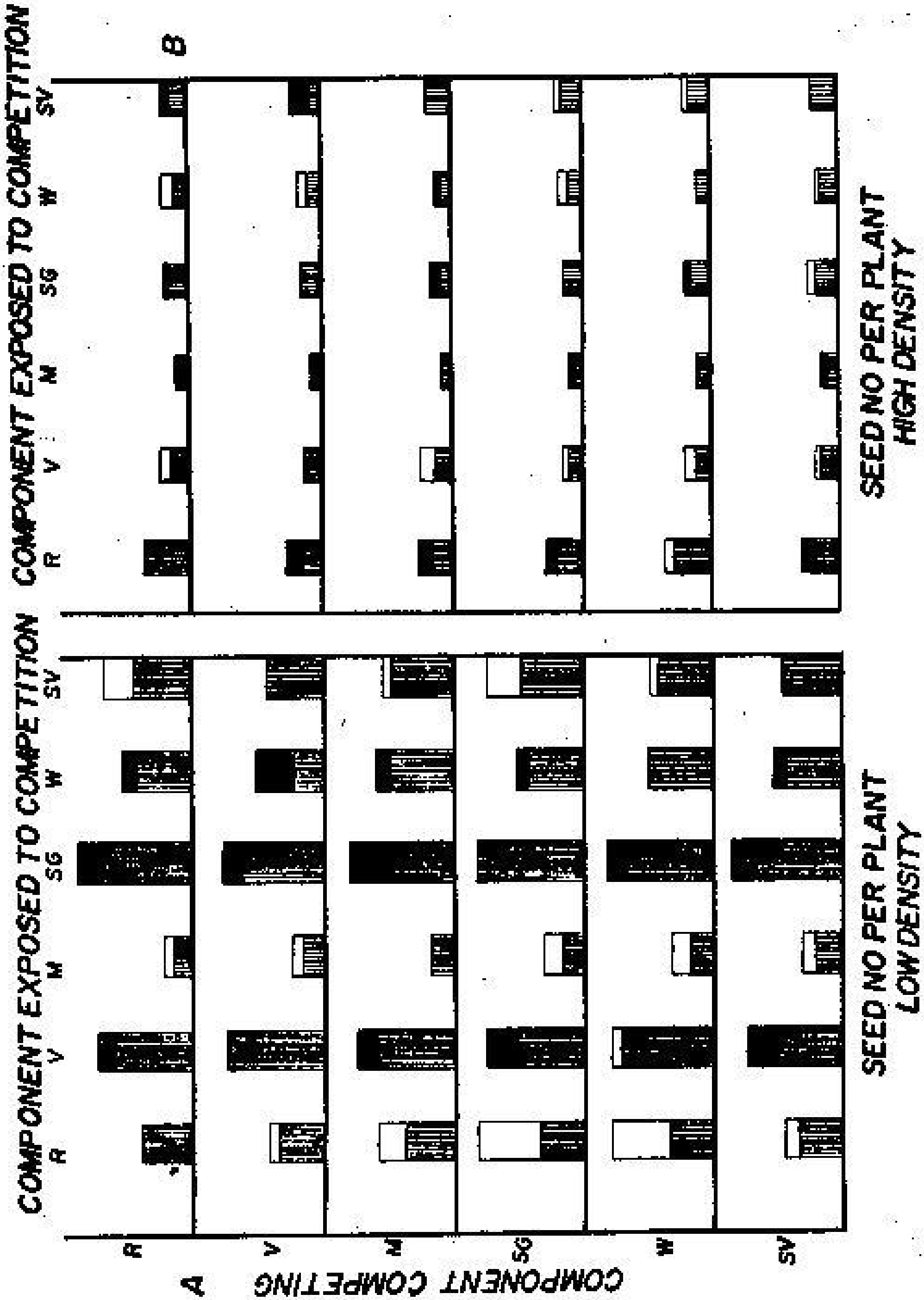

Fig. 6.—The performance of six varieties, three linseed (Redwing, Valuta and Maroc) and three flax (Stormont Gossamer, Wiera and SV O 226) (as measured by the number of seed produced per plant) when the varieties are exposed to interference at two densities. The blank columns represent the increase in yield when the variety is exposed to interference. The patched columns show the decrease in yield when the variety is exposed to interference. The data are taken from Experiment II.

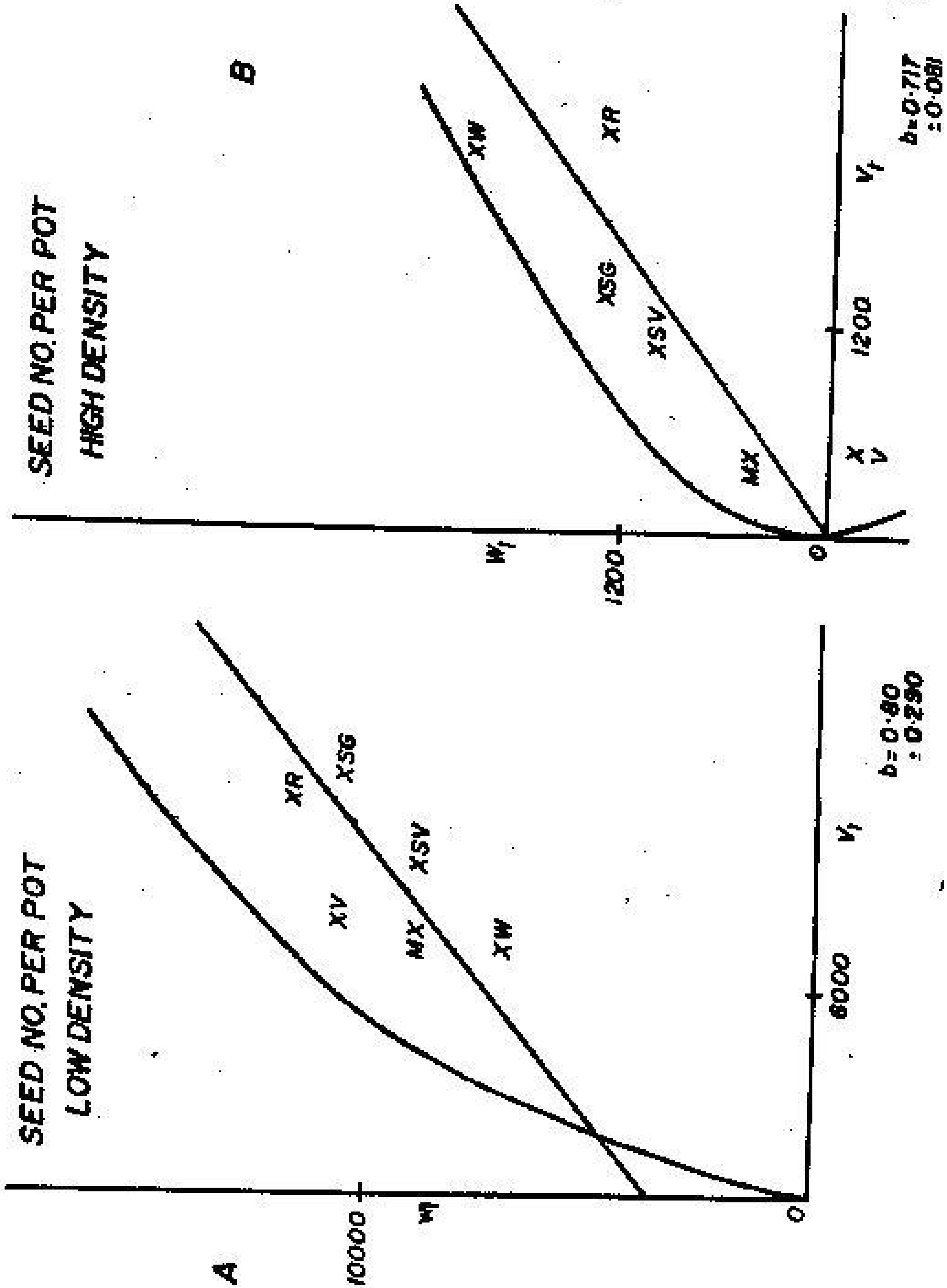

Fig. 7.—Vr/Wr graphs, A and B are seed numbers per pot at low and high densities respectively. The data are taken from Experiment II where six varieties, three linseed (Redwing, Valuta and Maroc) and three flax (Stormont Gossamer, Wiera and SV O 226) were used.

with the decrease of proportion in a mixture. The only possible reason for this type of behaviour would seem to be that in a mixture of flax and linseed the flax plant matures 2-3 weeks earlier, while linseed plants are still growing, so that they get the advantage of extra food and light which results in the increase of seed index. In the later stages of the development of a mixture the flax plant begins to mature and allows the linseed plant in the same mixture to utilize an increasing environment which becomes available. According to the particular stage of development of the linseed this may allow an increase in capsule number per plant and an increase of seed weight.

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