REPRODUCTIVE CHARACTERS IN LINSEED AS AFFECTED BY DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS, AND pH

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ABSTRACT

The influence of varying levels of nitrogen, phosphorus, and pH on the reproductive characters of flax (*Linum usitatissimum*) grown in sand cultures was investigated. The fertility of the plants was calculated by taking total ovule number and seeds produced into consideration. The results indicate that heavy application of nitrogen, and to a lesser extent phosphorus, enhanced the formation of flower buds but curtailed the development of flowers and fruits. Fertility level was reduced accordingly.

Optimum hydrogen ion concentration for bud, flower, and fruit formation occurred at pH 6. Fertility level was not significantly affected by the pH range. The influence of pH seems to be related to the uptake of nitrogen.

INTRODUCTION

Application of inorganic fertilizers is the usual practice for obtaining higher yields in crop plants. Increased nitrogen application has been observed by several workers to result in an increase in the number of reproductive parts (3, 6, 8). Crowther (1) observed an increase in the number of flowers and fruits per plant with the heavy application of nitrogen, while Das (2) observed an increase in the length of panicle in barley at a higher concentration of phosphorus supply. However, Kraus and Kraybill (5) noticed that heavy application of nitrogen to tomato plants resulted in reduction of fruiting. Shazkin and Zavadskaya (9) reported the formation of sterile pollen grains in crop plants when accompanied by an increased supply of this element. Recently Kinebuchi *et al.* (4) and Tanaka *et al.* (11) have also observed that increase in the sterility of rice accompanied the heavy application of nitrogen.

In the present study, an attempt was made to find the effect of nitrogen and phosphorus in relation to pH on the reproductive characters in linseed.

MATERIALS AND METHODS

Seeds of linseed (*Linum usitatissimum* var. type 1) were obtained from the Economic Botanist, U.P. Government, and sown in pots filled with washed sand. Taking Shive's solution (7) as a standard, three levels of nitrogen and of phosphorus were used:

NITROGEN		PHOSPHORUS	
Normal (N)	11 p.p.m.	Normal (P)	37.2 p.p.m.
3 Normal (3N)	33 p.p.m.	1/3 Normal (P/3)	12.4 p.p.m.
9 Normal (9N)	99 p.p.m.	1/9 Normal (P/9)	4.1 p.p.m.

Five pH levels were maintained in the experiment: 5, 6, 7, 8, and 9.

The concentrations of nitrogen and phosphorus used were decided on the basis of studies carried out by the authors in 1959–60. All possible combinations of nitrogen and phosphorus were used at the five pH levels. There were five replications for each treatment. The nutrient solutions were renewed at

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weekly intervals after leaching out the old solution, and the requisite amount of sulphuric acid or sodium hydroxide was added to adjust the pH in a particular pot to the desired level. Nitrogen was supplied as ammonium nitrate, and phosphorus as sodium dihydrogen phosphate (monobasic).

Observations on flower buds, flowers, fruits, and seeds were recorded and the results were analyzed statistically.

Calculation of Fertility

In *Linum usitatissimum*, there are 10 ovules per flower bud on the axile placenta. Fertility was measured by considering the total number of ovules and the seeds produced per plant. This may be expressed as follows:

$$\text{Fertility of plant} = (\text{seeds per plant} \times 10)/\text{total buds per plant.}$$

RESULTS

It is evident from Table 1 that the influence of nitrogen on all reproductive characters studied was highly significant. In addition, the effect of pH proved to be significant individually as well as in interaction with nitrogen for most of the characters. However, phosphorus had a highly significant effect on flower bud production, seed formation, and fertility. The triple interaction of nitrogen, phosphorus, and pH was highly significant for the development of buds, flowers, and seeds. However, it did not influence the fertility level significantly.

The influence of the variants and interactions are discussed below in relation to each character.

Flower Buds (Table 2)

The number of flower buds increased significantly with an increase of nitrogen supply. In the 3N treatment, buds were 2.73 times as great in number as in the N treatment, while with maximum application of nitrogen (9N), formation of buds was 5.07 times as great as in the N treatment. Amongst the various levels of phosphorus, there was no significant difference between P/3 and P treatments. These treatments, however, produced more buds than P/9. In relation to pH, the maximum number of buds was observed at pH 6 and it decreased both at higher and lower pH levels. The adverse effect of pH was more severe towards the alkaline range.

Table 1. Analysis of variance of the effect of nitrogen + phosphorus + pH on the reproductive characters in linseed

Source of variance	D.F.	Mean squares				
		Flower buds	Flowers	Fruits	Seeds	Fertility
N	2	38381**	5605.3 **	83.2**	657.5**	10656.7**
P	2	837**	21.7	2.6	453.9**	592.9**
pH	4	1159**	439.81**	17.1**	197.7**	32.8
N + P	4	441**	23.6	4.8	203.2**	149.7**
N + pH	8	1168**	331.5 **	11.3*	158.0**	207.0
P + pH	8	134	65.0 **	1.8	6.2	74.5
N + P + pH	16	309**	32.4 **	1.2	53.7**	117.0
Error	180	104	17.3	5.6	12.2	64.4
Total	224					

*Significant at $P = 0.05$. **Significant at $P = 0.01$.

Table 2. Influence of nitrogen + phosphorus + pH on the number of flower buds in linseed

Treatments	pH levels 5	6	7	8	9	Mean for N + P	Mean for N
N + P/9	8.28	21.44	10.08	10.12	10.22	12.03	
N + P/3	10.68	9.52	9.50	9.14	9.56	9.68	11.06
N + P	10.68	12.76	10.90	13.08	9.92	11.47	
Mean for N + pH	9.88	14.57	10.16	10.78	9.90		
3N + P/9	31.58	29.90	27.64	30.08	25.68	28.97	
3N + P/3	41.42	34.34	31.64	27.82	37.12	34.47	31.84
3N + P	33.30	36.88	32.34	28.36	29.56	32.09	
Mean for 3N + pH	35.43	33.71	30.54	28.75	30.79		
9N + P/9	55.62	56.78	57.18	42.62	33.14	49.07	
9N + P/3	60.46	80.48	61.48	43.78	40.86	57.41	56.24
9N + P	62.10	95.35	58.52	52.08	43.16	62.24	
Mean for 9N + pH	59.39	77.54	59.06	46.16	39.05		
Mean for pH	34.9	41.94	33.25	28.56	26.58		
Mean for P	P/9 28.75	P/3 33.85	P 34.76				

NOTE: L.S.D. at 5% for nitrogen = 3.25; phosphorus = 3.25; pH = 4.27; nitrogen + pH = 7.27; nitrogen + phosphorus = 4.50; nitrogen + phosphorus + pH = 12.73.

The combined effect of nitrogen and phosphorus was significant at higher concentration levels of nitrogen. Apparently a similar effect was observed for the interaction of nitrogen and pH, and the treatment of 9N + pH 6 produced the maximum number of buds. The triple interaction of nitrogen, phosphorus, and pH was highly significant and the treatment 9N + P + pH 6 was judged the best treatment for bud formation.

Flowers (Table 3)

The number of flowers per plant also increased with the heavy application of nitrogen. The increase of flowers per plant was 2.51 and 3.30 times with 3N and 9N treatments respectively when compared with normal treatment. This enhancement was less than the bud production at the same treatment levels. Flower production was maximum at pH 6 and was reduced by acidic conditions as well as alkaline conditions. At pH 9, the flower number was only 62.6% of that at pH 6. The interaction of nitrogen and pH was highly significant. At the lowest level of nitrogen, significantly more flowers developed in the alkaline range but at the 3N level the combination 3N + pH 7 was the best. Furthermore, at the highest concentration of nitrogen, the treatment 9N + pH 6 produced the maximum number of flowers. Therefore, influence of pH on flower formation changed in relation to nitrogen concentration. The triple combination, 9N + P + pH 6, proved to be the best treatment for flower development also, though it was not significantly superior to 9N + P/3 + pH 6 treatment.

Table 3. Influence of nitrogen + phosphorus + pH on the number of flowers in linseed

Treatments	pH levels					Mean for N
	5	6	7	8	9	
N + P/9	4.24	8.82	8.54	8.12	7.90	
N + P/3	3.92	6.34	7.22	7.72	7.26	7.23
N + P	4.28	7.86	8.28	10.84	7.18	
Mean for N + pH	4.15	7.67	8.01	8.89	7.45	
3N + P/9	17.18	15.46	19.22	17.22	15.30	
3N + P/3	19.62	19.82	20.24	17.72	20.66	18.17
3N + P	17.68	23.04	20.32	16.52	14.52	
Mean for 3N + pH	18.16	19.44	19.92	16.49	16.83	
9N + P/9	20.68	31.62	29.98	19.72	17.76	
9N + P/3	27.00	37.88	21.90	14.68	16.36	24.30
9N + P	27.18	40.76	21.26	21.52	14.22	
Mean for 9N + pH	24.95	37.42	24.38	18.64	16.11	
Mean for pH	15.75	21.51	17.44	14.67	13.46	

NOTE: L.S.D. at 5% for nitrogen = 1.33; pH = 1.72; nitrogen + pH = 2.97; nitrogen + phosphorus + pH = 5.15.

Though there was an increase of flower formation with an increased supply of nitrogen, the percentage of flower buds opening into flowers decreased. At the highest concentration of nitrogen (9N), only 43.8% of the buds flowered while at the lowest concentration (N), the percentage was 68.9. A similar trend was observed with the phosphorus variation: maximum number of buds flowered at P/9 (59.5%) and minimum at P (54.6%). In relation to pH, the maximum number of buds opened into flowers at pH 7.

Table 4. Influence of nitrogen + phosphorus + pH on the number of fruits in linseed

Treatments	pH levels					Mean for N
	5	6	7	8	9	
N + P/9	4.02	5.38	5.12	5.04	5.92	
N + P/3	3.92	4.14	4.16	5.38	4.34	4.96
N + P	4.02	5.18	4.68	6.58	4.48	
Mean for N + pH	4.66	4.90	4.65	5.67	4.91	
3N + P/9	11.46	8.90	11.08	9.62	9.28	
3N + P/3	12.44	11.62	12.98	7.70	11.30	10.72
3N + P	11.80	14.54	11.38	9.02	7.72	
Mean for 3N + pH	11.90	11.67	11.81	8.78	9.43	
9N + P/9	11.52	20.56	14.28	10.08	9.08	
9N + P/3	12.56	19.32	7.48	3.02	7.36	10.72
9N + P	11.08	16.12	7.48	7.76	3.38	
Mean for 9N + pH	11.72	18.66	9.75	6.89	6.64	
Mean for pH	9.43	11.75	8.74	7.11	6.99	

NOTE: L.S.D. at 5% for nitrogen = 0.21; pH = 0.35; nitrogen + pH = 1.04.

Fruits (*Table 4*)

The number of fruits increased as nitrogen concentration increased, but to a small extent. Equal numbers of fruits developed per plant with the 3N and 9N treatments. Again pH 6 proved to be the best for the development of the reproductive parts, and the interaction of nitrogen and pH was significant. However, at the lowest level of nitrogen, this interaction did not influence fruit formation. The interaction of pH with 9N had a marked effect.

The percentage of fruits over buds and flowers decreased with the increase of nitrogen concentration. A similar trend was observed for phosphorus.

Seeds (*Table 5*)

The number of seeds increased with the increase of nitrogen application while it decreased with the increase of phosphorus concentration. Maximum seed production was observed at pH 6. Amongst the combinations of nitrogen and phosphorus, 9N + P/9 produced the maximum number of seeds. The 9N + P/3 and 9N + P treatments produced the minimum number of seeds. In the triple interaction these treatments were significantly better than several others at pH 6. However, the 9N + P/9 + pH 6 was the best triple combination with regard to seed production.

Fertility (*Table 6*)

The fertility of linseed decreased with the increase of nitrogen and phosphorus concentrations. The effect of pH individually on fertility was insignificant, though its interaction with nitrogen had a marked influence. At the N + pH 8 treatment, fertility was maximum. The triple interaction was also significant and the plants were most fertile at N + P/3 + pH 8.

Table 5. Influence of nitrogen + phosphorus + pH on the number of seeds in linseed

Treatments	pH levels					Mean for N + P	Mean for N
	5	6	7	8	9		
N + P/9	29.12	34.62	37.00	29.10	29.30	31.83	
N + P/3	29.62	27.48	27.28	32.62	24.82	28.36	29.77
N + P	26.36	29.96	31.12	37.64	20.58	29.13	
Mean for N + pH	28.36	30.69	31.80	33.12	24.90		
3N + P/9	59.12	40.82	55.88	48.76	44.88	49.89	
3N + P/3	49.32	49.38	49.02	39.42	47.98	46.98	45.96
3N + P	45.14	50.66	50.96	27.78	30.56	41.02	
Mean for 3N + pH	51.26	46.82	51.95	38.65	41.14		
9N + P/9	37.30	87.70	44.78	37.20	44.84	50.36	
9N + P/3	22.92	53.96	12.16	3.94	9.56	20.51	29.73
9N + P	25.02	37.04	7.58	7.82	14.18	18.33	
Mean for 9N + pH	28.41	59.57	21.57	16.32	22.86		
Mean for pH	36.01	45.69	35.09	29.63	29.36		
Mean for P	P/9	P/3	P				
	44.03	31.95	29.49				

NOTE: L.S.D. at 5% for nitrogen = 3.52; phosphorus = 3.52; pH = 4.54; nitrogen + phosphorus = 6.11; nitrogen + pH = 7.89; nitrogen + phosphorus + pH = 13.83.

Table 6. Influence of nitrogen + phosphorus + pH on the fertility of linseed

Treatments	pH levels					Mean for N
	5	6	7	8	9	
N + P/9	35.9	20.2	36.5	28.7	29.3	
N + P/3	28.6	29.9	29.5	46.6	25.9	29.29
N + P	24.7	23.7	29.1	29.1	21.6	
Mean for N + pH	29.72	24.56	31.71	34.81	25.61	
3N + P/9	18.8	14.5	20.3	16.6	16.2	
3N + P/3	12.2	15.2	15.9	12.3	29.0	15.71
3N + P	14.4	13.9	15.8	10.1	10.5	
Mean for 3N + pH	15.14	14.57	17.35	12.97	18.59	
9N + P/9	7.5	15.1	7.8	6.9	15.3	
9N + P/3	3.7	7.2	1.9	1.1	2.3	5.51
9N + P	3.6	3.9	1.4	1.4	3.5	
Mean for 9N + pH	4.95	8.76	3.70	3.13	7.05	
Mean for pH	16.60	15.96	17.59	16.97	17.10	
Mean for P	P/9	P/3	P			
	19.31	17.42	13.78			

NOTE: L.S.D. at 5% for nitrogen = 2.56; phosphorus = 2.56; nitrogen + pH = 7.54; nitrogen + phosphorus + pH = 9.93.

DISCUSSION

The results lead to the conclusion that increasing concentrations of nitrogen and phosphorus produced a greater number of flowering parts but that fertility was reduced. The pH level had no significant effect on the fertility of linseed though it did affect the formation of buds, flowers, and fruits. Sinha (10) observed an increase in the percentage of seed-set in the spikes of barley grown in sand cultures, with increased supply of nitrogen. Changes in the concentration of phosphorus and the levels of pH had no significant effect on this crop. Similarly, Ranjan and Das (8), Hoshino *et al.* (3), and Langer (6) observed an increase in the number of reproductive parts with an increase of nitrogen.

In the present study, it has been noticed that in the plants fed with a high concentration of nitrogen, the percentage of bud opening and fruit formation was reduced. Therefore, it is obvious that some factor becomes limiting in this treatment, inhibiting both processes. It was observed that in the development of linseed plants, three phases can be distinguished, viz. (*i*) vegetative development, (*ii*) flowering, (*iii*) fruit maturation. These three phases were distinct in plants receiving a low concentration of nitrogen while less distinct in plants grown at a high concentration of nitrogen. In the plants growing under high nitrogen conditions, vegetative growth continued even when bud formation and flowering was at its maximum and similarly bud formation continued when fruit maturation had already set in during the beginning of summer. Since at this stage no vegetative growth takes place and leaf senescence has already started, the new buds do not get enough food supply to open into flowers and mature into fruits. This assumption is supported by the fact that

seeds produced under heavy application of nitrogen were lighter in weight than seeds obtained from plants receiving lesser amounts of nitrogen (10).

The influence of phosphorus is comparable to that of nitrogen. The highest concentration produces the maximum number of buds but results in the lowest fertility of plants. This also seems to be related to growth phases. However, the effect of phosphorus variation is not so marked as that of nitrogen.

The hydrogen ion concentration had a significant effect on the production of flower buds, flowers, and fruits. The maximum development of these parts was observed at pH 6. However, the interaction of nitrogen and pH produced high fertility in the alkaline range (Table 6), though the individual effect of high pH was adverse on the production of reproductive parts. This presumably is related to the absorption of nitrogen. Since at pH 6 absorption of nitrogen is highest in linseed (10) and decreases with the increase of pH, it can be argued that response of plants to pH is a reflection of nitrogen effect.

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