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NATURAL CROSS-POLLINATION IN LINSEED

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Introduction. Linseed is cultivated entirely as an oil-seed crop in India, unlike Europe and America, where it is grown mainly for fibre. Next to Argentine, India is the largest linseed producing and exporting country. The area under linseed in India is about 34,000,00 acres, most of it being in the Central Provinces and Berar (9,70,000), United Provinces (8,60,000) and Bihar and Orissa (5,90,000)*. During 1934—35 the yield of linseed was estimated to be about 400 thousand tons. Next to these provinces come Bengal and Bombay which each grow over 100,000 acres annually.

Although Bombay Presidency is not a large producer of linseed, locally the crop is important. Most of the area is concentrated in the Karnatak and the Deccan, the important linseed growing districts in these two tracts being Bijapur and Nasik respectively. Gujrat and Konkan grow hardly any linseed.

In the Presidency, linseed is cultivated as a cold-season crop, like wheat, on deep black soils. It is sown in the beginning of October and harvested in February. In Bijapur, linseed is a row crop in rabi jowar or wheat; in the Nasik district it is grown as a main crop and sometimes sown around the wheat fields.

Since linseed is an important secondary crop in the Nasik district, it was decided to undertake its genetic improvement at the Cereal Breeding Station which is situated in the centre of the district. In order to handle the crop properly, one of the first requirements was to obtain evidence on the extent of vicinism under local conditions, so that proper methods of maintaining purity of the experimental material and eventually of pure strains could be adopted. The results of our observations are briefly reported in this Paper.

Review of Literature. As linseed (flax) is an important crop in many countries, considerable information is available on the magnitude of vicinism in this crop plant under various climes. The extent of natural crossing varies in different localities. The consensus of opinion is that protection of plants is necessary to ensure purity of a strain. A brief review of observations made in various countries is given below.

India:— Howard et al (1910) were the first to publish evidence of natural crossing in linseed. They observed hybrid plants in European

* These two provinces are now separate. The Director of Agriculture, Bihar, estimates 550,300 acres in 1936—37 under linseed in Bihar. (personal communication).

fibre-yielding types grown at Pusa but did not state the extent of contamination. In a further publication (1919) these authors present more definite evidence. During the years 1916, 1917 and 1918 they found 6, 1 and nil cases of segregation out of 340, 233 and 232 bagged plants respectively. This gives 1·8, 0·43 and 0 per cent of contamination during the three years. On the basis of total plants, 805, the natural crossing is 0·87 per cent.

In the Central Provinces, Graham and Roy (1924) observed 9 cases of segregation out of 212 line-cultures in three years or a little over 4 per cent of crossing.

Europe:— In 1911 Tammes observed natural crossing in Holland and concluded that plants should be protected to maintain purity. Bateson (1916) and Eyre and Smith (1916) in England found flax to be mostly autogamous. The latter detected natural hybridization in *L. humile* also. Fruwirth (1922) also mentions possibility of spontaneous contamination of flax in Germany. Davin and Searle (1925) also mention cases of intercrossing in Ireland and advocate protection of plants. In the publication, "Plant Breeding in the Soviet Union" issued by the Imperial Bureau of plant Genetics, Cambridge, England, (1933), it is stated that flax is subject to cross-pollination to the extent of 40 per cent in Russia. In this connexion it is interesting to note that Eyre and Smith (1916) state that in some countries flax is considered unstable and give as an example that in certain parts of Central Russia it is considered that besides changes in habit, the colour of the flower also changes.

U. S. America:— In the United States, Bolley (1927) mentions that he has observed no morphological variations in flax varieties although grown side by side for a number of years in North Dakota. He, however, does not present any figures. In a reply to Bolley (1927) Robinson (1928) states that under Michigan conditions vicinism in flax varies from zero to 3 per cent. Very recently Robinson (1937) has presented extensive figures on natural pollination in flax under Michigan and Oregan conditions. He found blue-flowered varieties were contaminated more than white-blossom varieties. In Michigan 5 to 6 per cent of crossing was found as against 1 to 2 per cent in Oregon. Robinson considers that spacing has some influence on the extent of crossing, but the figures he has given are somewhat erratic. The most systematic investigation is reported by Henry and Tu (1928) from St. Paul, Minnesota. They found 1·25 to 1·71 per cent vicinism in rows 1 foot apart. The percentage in crossing decreases from 1·26 at 1 foot to 0·33 per cent at 5 feet spacing. These workers found thrips the main pollinating agents.

Material and Methods. The investigation reported in this paper was conducted at the Cereal Breeding Station, Kundewadi, taluka Niphad, district Nasik.

In 1933 a number of bulk samples were collected for sowing in the *rabi* season. In the same season a large number of bulk samples were also

received from the Economic Botanist, as he had no facilities for growing them at Poona. The material was grown for him and selection supplied to him by us to carry on the work from the next season at Poona. The material for the study of natural crossing was obtained mostly from these samples.

The seed of various samples was dibbled at a distance of 4 inches in rows 18 inches apart. In each hole two to three seeds were sown and after a month the crop was thinned to one plant per hill. Thus a uniform stand was obtained for purposes of selection of outstanding plants for further breeding.

Experimental Data. 1933—34. During the course of the examination of various crops of linseed during the season of 1933—34 a number of plants with pale-blue or white flowers were observed among the mass of blue-flowered plants which constitute the predominating type. There were 33 such off-types of plants. These plants were allowed to set seed openly and at the end of the season each of the plants was harvested separately to determine the extent of natural crossing next season.

As the pale-blue or white flower colour is recessive to full blue, any contamination in such plants would show up in their progeny by the appearance of blue-flowered plants.

1934 - 35. During the season a progeny line from each of the 33 pale-blue and white-flowered plants was raised. The season, however, proved to be so abnormal that hardly any plants were left in the field. In the seedling stage there was a very severe attack by insects and a further reducion of the population resulted by injury from frost in mid-January, 1935. Out of the 33 lines 24 were completely wiped out. Even in the remaining lines, there were only very few survivals in each. In view of this, it was decided to discard the material and to grow again the remaining seed of the 1933—34 plants. There were, however, some blue-flowered plants among the surviving families and it was decided to harvest them individually with a view to ascertain whether or not they were natural hybrids or mere mechanical mixtures. Altogether only 13 such plants were available.

1935 - 36. Seed of only 23 pale-blue and white-flowered plants out of the original 33 was available for growing during the season. All the available seed of each plant was used and the crop was not thinned. The crop grew well and from the beginning up to the end of flowering, it was examined for off types of plants. In table I are given the number of blue-flowered plants that occurred in each progeny line, together with other necessary information.

It will thus be seen that the amount of contamination varies from 0 to 6·75 per cent. On the basis of the total plants the incidence is 3·08 per cent. In three of the families Nasik IV-2, Belapur 1-1 and Bijapur 1-3, showing no infection, there were some blue-flowered plants in 1934—35. Thus, a very large proportion of the individual plants gets contaminated under field conditions.

Table I

Extent of natural crossing in various families of linseed grown at the Cereal Breeding Station, Kundewadi, Niphad during the season 1935-36.

S. No.	Culture No.	Flower colour of the parental plant of the culture	Total No. of plants	No. of plants with blue flower	Percentage of natural crossing	Remarks.
1	K. L. 2	Pale-blue	121	0	0·00	
2	Nasik I-2	Pale-blue	57	2	3·50	
3	Nasik I-3	White	51	1	1·96	
4	Nasik I-4	White	75	3	4·00	
5	Nasik I-5	Pale-blue	69	2	2·89	
6	Nasik II-1	Pale-blue	56	0	0·00	
7	Nasik II-2	White	55	0	0·00	
8	Nasik II-3	White	64	1	1·56	
9	Nasik III-1	White	62	4	6·45	
0	Nasik IV-1	White	89	4	4·49	
1	Nasik IV-2	White	77	0	0·00	2 Blue-flowered plants in 1934—35
2	Nasik IV-3	Pale-blue	60	2	3·33	
3	Malegaon I-1	White	76	4	5·26	
4	Malegaon I-152	White	74	5	6·75	
5	Malegaon II-1	White	99	5	5·05	
6	Malegaon II-3	White	46	0	0·00	
7	Belapur I-1	Pale-blue	30	0	0·00	2 Blue-flowered plants in 1934—35
8	Sholapur I-1	White	35	2	5·71	
9	Bijapur I-1	White	83	2	2·41	
0	Bijapur I-3	Pale-blue	73	0	0·00	1 Blue-flowered plant in 1934—35
1	Bijapur I-4	White	104	7	6·73	
2	Belgaum II-2	White	24	1	4·16	
3	Belgaum II-3	White	45	2	4·44	
	Total.		1525	47	3·08 Average.	

The behaviour of the blue-flowered plants isolated in 1934—35. It as been stated above that the crop from pale-blue and white-flowered lants in 1934—35 was a failure, and that from the surviving lines 13 lue-flowered plants were obtained. These were presumed to be due to oss-pollination. In order to test this, they were grown in 1935—36. All e seed of each plant was sown and no thinning was done. Due to crowd-g, some plants remained stunted and produced no flowers. The behaviour f each plant is indicated in table II.

It will be observed that all of the 13 plants segregate in blue and ale-blue or white-flowered plants indicating that all were hybrids, being the esult of fortuitous crossing. Except Nasik IV-1-1, all show monogenic egregation, indicating that pale-blue and white colours are recessive to lue. In the exceptional case the white-flowered plants are in excess. The cause or causes of this are not traceable.

Agents of cross-pollination. Under Niphad conditions blooming takes place between 9 a. m. and 11 a. m. During this period bees and various types of butterflies are busy collecting nectar from the linseed flowers.

Undoubtedly these creatures affect cross-pollination by carrying pollen on the underside of their bodies. Howard *et al* (1919) observed bees visiting linseed flowers. Eyre and Smith (1916) and Fruwirth (1922) mention insects visiting the crop in bloom. Henry and Tu (1928) observed thrips in and around flax flowers and consider these as pollinaters.

Table II.

Behaviour of 13 blue-flowered plants isolated in 1934-35 from the surviving progenies of nine pale-blue and white-flowered plants.

S. No.	Culture No.	Total plants	No of blue-flowered plants.	No. of pale-blue flowered plants.	No. of white-flowered plants.	No. of plants which did not flower.
1	Naik I—2—1	60	43	12	0	5
2	Nasik IV—1—1	90	29	0	49	12
3	Nasik IV—2—1	88	66	0	14	8
4	Nasik IV—2—2	95	62	0	24	9
5	Nasik IV—3—1	86	51	22	0	13
6	Malegaon I—1	61	45	0	12	4
7	Malegaon II—1	94	72	0	15	7
8	Malegaon II—2	52	35	0	16	1
9	Belapur I—1	99	68	26	0	5
10	Belapur I—2	50	25	12	0	13
11	Bijapur I—2—1	56	30	16	0	10
12	Bijapur I—2—2	37	10	11	0	16
13	Bijapur I—3—1	87	64	12	0	11

Discussion. From the foregoing experimental evidence it is clear that under Niphad conditions vicinism in linseed is sufficiently extensive to warrant protection of plants. A large proportion of the plants, chosen to study the amount of fortuitous crossing, was affected ; the infection ranging from zero to as high as 6·75 per cent. The average amount of natural hybridization was slightly over 3 per cent.

The review of the observations of other workers also shows more or less similar situations. Bolley (1927) is the only exception. He, however, does not present any facts, but makes a definite statement that he has observed no morphological variations in flax varieties grown side by side for a number of years in North Dakota. The reflections and the general attitude of Bolley (1927) appear to be so widely divergent from the generally accepted conceptions of modern genetics that one is not constrained to accept wholly his conclusions.

The amount of vicinism varies under different climates, and Robinson (1937) has presented definite evidence that it is more in Michigan than in Oregon, U. S. America. The amount of contamination in the Central Provinces, India, (Graham and Roy, 1924), is almost similar to our results, whereas under Bihar conditions it appears to be lower, (Howard *et al*, 1910, 1919). Thus, in Peninsular India natural-hybridization in linseed appears to be more than in the Gangetic alluvial tract.

Besides regional influences, varietal differences may also affect the amount of natural-pollination. Robinson (1937) mentions that blue-flowered plants are more affected than white. He does not ascribe any definite cause for such differential behaviour, but it is very probable that insects are attracted more by blue colour than by white.

The mode of pollination in linseed is such as to ensure self-fertilization very largely, but the long range of flowering period of about a month exposes every plant to the danger of cross-pollination by insects. Protection of plants, therefore becomes a necessity to maintain genetic purity. For plant breeding purposes it would be necessary to protect individual plants. For this purpose muslin bags stretched over galvanised rings of suitable diameter have proved to be more convenient and efficient than butter-paper bags which present a number of undesirable features, the most serious being very low seed-setting in them.

For the production of seed for multiplication of an improved strain it would be necessary to adopt larger scale methods. Muslin cages of convenient size and suitably constructed would cover a number of plants. By employing a few of such cages it would be easy to produce a fairly large initial stock of pure seed. The further multiplication of such seed will have to be done at an isolated place, preferably under controlled conditions, since raising of a crop from the selfed-seed on or around the breeding plot is fraught with the danger of contamination as a collection of various varieties would most likely be grown on the experimental site. The seed of the M_2 (second multiplication) generation may be supplied to the Propaganda Staff for further multiplication on Government Farms or to the I class Registered-seed-growers. Under such conditions the crop should be roqued at the time of blooming or before, if possible. Such operations can be greatly facilitated if the improved variety differs conspicuously in some morphological character, such as flower-colour, from the local variety.

Henry and Tu (1928) advocate growing of linseed varieties or strains at a distance of 5 feet, the intervening space being grown under a tall crop, like oats, as a barrage. This may work well where thrips are the pollinating agents, as found by these workers; but it is extremely doubtful if this plan would be feasible where insects such as bees play a prominent part.

Summary

1. Under Niphad conditions, vicinism in linseed varied from zero to 6·75 per cent in pale-blue and white-flowered plants. The average was slightly over 3 per cent.

2. In Peninsular India there appears to be more natural-pollination than in the Gangetic alluvial area.

3. The amount of contamination is sufficiently large to make it obligatory to protect the plants. For this purpose muslin bags are better than paper bags to cover individual plants.

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* Original not seen.

What is good Farming ? Good farming demands the recognition of three basic principles : Judicious economy in time, in labour, and in money. The farmer who can direct these successfully will eventually win through. Good farming makes management in every branch of farm production return a profit, and it also leaves a farm at the end of fifty years in a state of productivity as high as, if not higher than, at the beginning—W. Waston, General President, Agricultural Bureau of New South Wales. (*Queensland Agricultural Journal*, Vol. XLVIII, October 1937).
