A NOTE ON THE INVESTIGATIONS ON BREEDING RUST-RESISTANT LINSEEDS AT THE INDIAN AGRICULTURAL RESEARCH INSTITUTE

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INTRODUCTION

LINSEED (*Linum usitatissimum* L.) is an important oilseed crop of India, the oil, which is a drying oil, being used for manufacturing paints and varnishes, oilcloth, linoleum, and other products. The residue, the oilcake, is a good cattle feed and can also be used as a manure. The straw produces fibre which, although short and coarse, can be converted into twine, strings, canvas, etc. The latest investigations show that linseed fibre can be easily mixed with jute to the extent of 50 per cent for making bags and other articles[1]. The crop therefore has a wide range of uses.

Linseed stands fourth amongst the Indian oilseeds both as regards the acreage and seed production. The Madhya Pradesh, the Uttar Pradesh, Bihar and Hyderabad (Deccan) are important linseed-growing areas and constitute between them about 90 per cent of the total area under this crop, the Madhya Pradesh topping the list.

According to the Agricultural Statistics (U.S.D.A. 1945-47) Argentina stands first both as regards area under linseed and its production followed by U.S.A. and India.

The United Kingdom is a large buyer of Indian linseed. France and Italy are other important importers of Indian linseed. In the world trade in this commodity Argentina is the only serious competitor to India. In the U.S.A. the area under this crop is increasing and in Australia linseed has been introduced in recent years and its cultivation is steadily increasing. In Europe, excepting in Russia, cultivation of linseed is practically negligible.

PREVIOUS WORK

The linseed crop has been very exhaustively dealt with by the Botany Division of the Indian Agricultural Research Institute, New Delhi and valuable results both in the field of pure genetics and breeding have been achieved.

The work on this crop was started in 1915 and from a collection of large number of seed samples obtained from commercial firms and Government Agricultural Departments in India, 123 elementary types have been isolated and botanically classified and described[4]. Of these, N.P. (New Pusa) 12 and 121 and 124 which arose as a mutation from N.P. 12, were selected for distribution for general cultivation, being heavy yielding and most suitable for growing on the alluvial soils of the Uttar Pradesh, Bihar, Bengal and Assam and are very popular.

These types, although heavy yielding possess small seeds with low oil content. With a view to improve their seed size and oil content a further step was taken in 1924 when suitable types of Northern India were crossed with Peninsular types which possess bold seed with high oil content[5]. As a result of this breeding work a large number of strains combining high yield, bold seededness and high oil content were evolved. Of these, N.P. hydbrids 10, 21, 55 and 68 were found to be the best and have been released for general cultivation.

Breeding for rust resistance

Of all diseases of linseed in India the rust disease is perhaps the most important from the point of view of the damage it causes to the crop. According to the late Dr. K. C. Mehta of Agra College four physiological races of this fungus disease (*Melampsora lini*) have so far been observed in India. The rust, which derives its name from the resemblance of the colour of its spores to that of rust on iron, is prevalent in most of the linseed-growing tracts of India and does considerable damage to the crop, reducing both the seed yield and oil content. When it occurs in an epidemic form, as it usually does, the income from the crop is hardly sufficient to meet the cost of harvesting and threshing it.

The investigation on breeding for rust resistance in this crop was taken up in 1933 and is still in progress. It had been observed at Pusa (Bihar) that none of the N.P. types, which form an all-India collection, is resistant to rust. In the year 1930-31 some seed samples of linseed varieties were obtained from Australia, some of which were observed to be immune from rust. The strains immune to rust had bold seeds of brown colour and were unfortunately very late in maturity for our conditions in India and were therefore unsuitable for direct cultivation. They were, therefore, used as parents in crossing with suitable N.P. varieties, some of which are under distribution, with a view to combine rust resistance, early maturity and other economically important characters, such as high yield, high oil content, white seededness, etc.

The work on breeding for rust resistance was commenced in 1933-34 at Pusa (Bihar) by crossing some of the foreign varieties referred to above after their purity had been tested and their immunity to the rust disease confirmed, with some of the outstanding N.P. varieties. The difference in the flowering time of the N.P. and foreign varieties being great the former had to be grown about two weeks later and the latter about two weeks earlier than the normal sowing time, so that both the types of parents may be in flower at the same time so as to ensure sufficient flowers for crossing purposes.

The F_1, F_2 and subsequent generations were grown in the following years. In the F_1, immunity to rust was found to be dominant and in F_2 the ratio of immune to susceptible plants was 3 : 1 in one cross and 15 : 1 in another. In the other crosses the F_2 phenotypes did not conform to any of the known genetical ratios. Dominance of immunity and 3 : 1 and 15 : 1 F_2 ratios observed in two crosses are in agreement with the results obtained by Henry[3]. Although dominance of immunity over susceptibility has been confirmed by later work, the observations on F_2 cannot be relied upon as the breeding work was carried under conditions of natural infection in the field as facilities for testing the resistance to rust by artificial infection were not available until 1942-43.

Selection of plants was made from F_2 onwards on the basis of rust resistance (as observed in the field under conditions of natural infection), early maturity, high yield, medium to bold seed size, white colour of seeds, etc. The results of the inheritance studies and correlation studies conducted previously[2,5] were heplful in making selections.

After the transfer of the Indian Agricultural Research Institute from Pusa (Bihar) to New Delhi in 1936 breeding work was also transferred to New Delhi. However, as conditions at Delhi are not favourable for the occurrence of rust incidence, the place being dry, duplicate sowings of selections were made both at Pusa and Karnal (Punjab). The sowings at Pusa were discontinued after the 1938-39 season, but those at Karnal are still being continued as Karnal is within easy reach of Delhi and from the point of view of rust incidence is as good as Pusa.

On the basis of observations recorded on rust infection at Pusa and Karnal, and on agronomical and other characters at New Delhi selection work was continued from year to year until 1942-43, when for the first time in the course of this breeding

work facilities were available for testing the selections for their rust resistance under conditions of artificial infection. The results of observations on rust resistance of these selections under conditions of natural infection at Pusa, Karnal and New Delhi for the years when the incidence of rust was heavy are given in the following Table :

Place	Year	No. of cultures grown	Percentage of cultures showing immunity or susceptibility			
			Immune	Slightly infected	Moderately infected	Heavily infected
Pusa ...	1938–39	150	78·0	19·0	2	1
Karnal ...	1939–40	160	97·0	3·0	...	...
,, ...	1943–44	130	98·5	1·5	...	...
,, ...	1945–46	110	99·0	1·0	...	...
,, ...	1946–47	105	97·0	3·0	...	...
,, ...	1947–48	100	84·0	16·0	...	...
,, ...	1948–49	101	96·0	4·0	...	...
New Delhi ...	1944–45	110	96·0	4·0	...	...
,, ,, ...	1946–47	168	97·6	2·4	...	...

In all these years the N.P. types used as parents and those under distribution have shown susceptibility to rust whereas the foreign types used as parents have remained free from infection.

Test under conditions of artificial infection

As mentioned earlier, facilities for testing the resistance of these selections under conditions of artificial infection were available for the first time in 1942-43, when Dr. R. Prasad, Assistant Mycologist, Division of Mycology, Indian Agricultural Research Institute, then working at the Wheat Rust Research Laboratory, Simla kindly tested 70 of these most promising selections for their rust-resistance in seedling stage. The seedlings were infected with inoculum of spore material obtained from the different linseed-growing tracts in India. This material, therefore, may be taken as representing all the four physiological races of the rust fungus so far observed in India by the late Dr. K. C. Mehta of Agra College. The results of these tests showed that out of 70 cultures tested, 7 were immune to rust, 41 resistant* and 24 were susceptible. According to these observations some of the cultures which were observed to be immune to rust both at Pusa and Karnal were susceptible to rust. Some of the discrepancies between the observations under natural and artificial conditions of infection may be due to the following facts :

1. All the four races of the fungus observed by Dr. Mehta and with which the tests were conducted at Simla may not be existing at Pusa and Karnal where these selections for rust resistance were made under conditions of natural infection.
2. Plants showing infection in certain cultures called susceptible by Dr. Prasad might have been rogues (off plants, etc.). As the tests were conducted in seedling stage, there was no means of verifying this fact. That this assumption is true is supported by the observation in the field tests that are being

* Although these did not develop any rust pustules, they, according to Dr. Prasad, exhibited some other symptoms which indicated that they were not immune to rust.

conducted in the Botany Division since 1947-48, that the plants showing infection in some cultures have proved to be actually off plants on flowering.

3. It is possible that some of the cultures may be susceptible in seedling stage but resistant in adult stage.

In 1947-48 these selections were tested for the first time for their rust resistance in the Botany Division in the field, in the adult stage, and under laboratory conditions, both in the seedling and adult stage, in the Mycology Division. These tests were repeated in 1948-49. In the Botany Division the cultures were replicated twice along with their parents and the N.P. varieties under distribution. N.P. 21, which is very susceptible to rust, was used as control.

The inoculation of the strains in the field in the Botany Division was done by the Division of Mycology. The inoculum was obtained by the latter Division from the Wheat Rust Research Laboratory, Simla where the four physiological races of the rust fungus have been maintained, and multiplied it in that Division. In 1947-48 the inoculation of the strains in the field was commenced as soon as rust was observed in a susceptible type in the collection of the Botany Division. However, in the following year, the control was inoculated about two weeks before rust was observed. This was done in order to ensure sufficient infective material in the proximity of the strains to be tested even before they themselves were inoculated.

The strains to be inoculated were covered with a tent-like structure of thick cloth for about 24 hours and kept moist by spraying water over it (Plate I, Fig. 1). The inoculation was done late in the afternoon after keeping the strains under the moist cover for nearly 24 hours. Immediately before inoculation, the strains were moistened with a fine spray of water in order that the spores which were mixed with a certain amount of talc powder for even distribution, may well adhere to the leaves. The dusting was done with a hand rubber blower. After inoculation the covers were replaced and kept moist as before for another 24 hours.

The symptoms of infection usually appeared in about 10 days in the susceptible varieties. Those that were immune remained absolutely free from infection. Plate I, Fig. 2 shows two rows of N.P. 21, the control, in the centre foreground, which have been wiped out, with rows of rust-resistant strains on either side of them.

The results of the two years' tests, which are very similar, are given below. In both the years the foreign rust immune parents of these strains remained free from infection, while the rust susceptible N.P. parents and other N.P. varieties under distribution as also all the replications of N.P. 21, the control, were heavily infected and died without producing seeds and in some cases they did not even produce capsules.

Year	No. of cultures tested	Percentage of cultures showing immunity or susceptibility		
		Immune	Slightly infected	Moderately infected
1947-48	101	78·22	5·94	15·84
1948-49	101	77·23	5·94	16·83

Early maturity of the strains

Many of the rust-resistant strains are also much earlier in maturity than the rust-resistant foreign varieties used as parents in these investigations. This is clear from

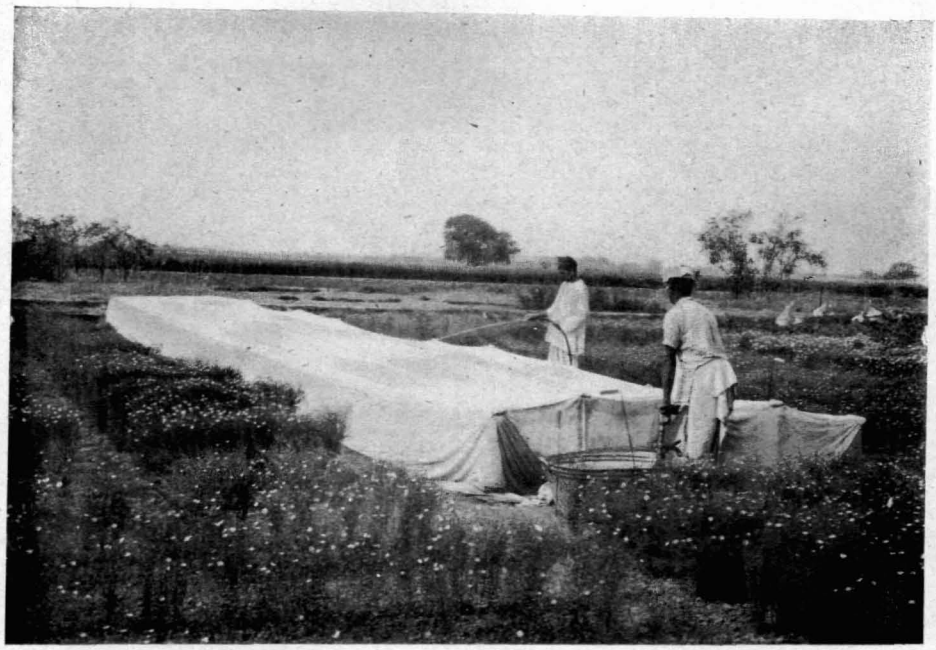

FIG. 1

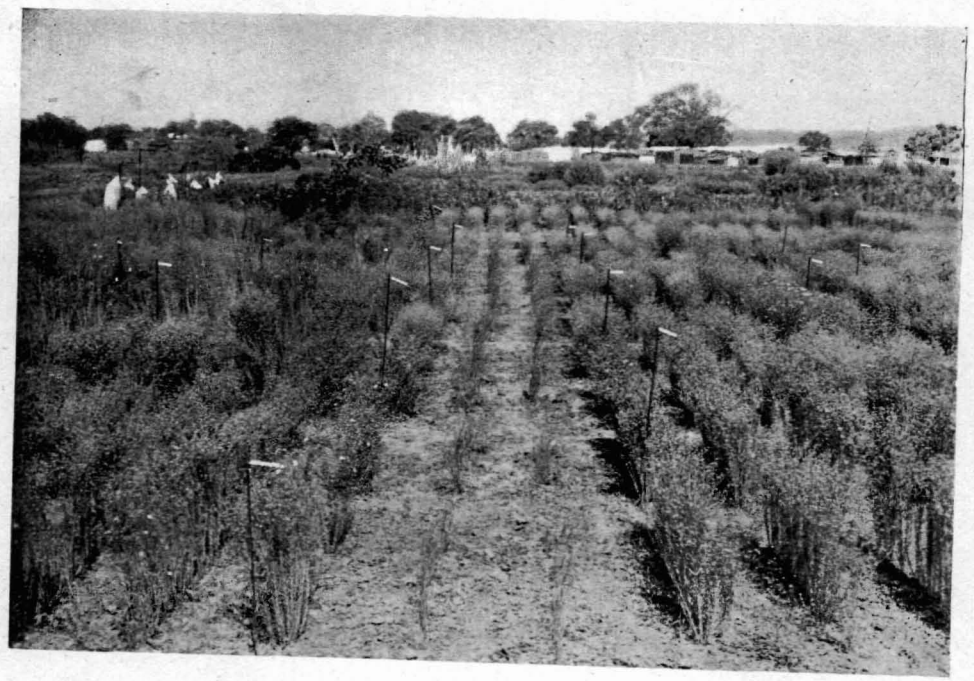

FIG. 2

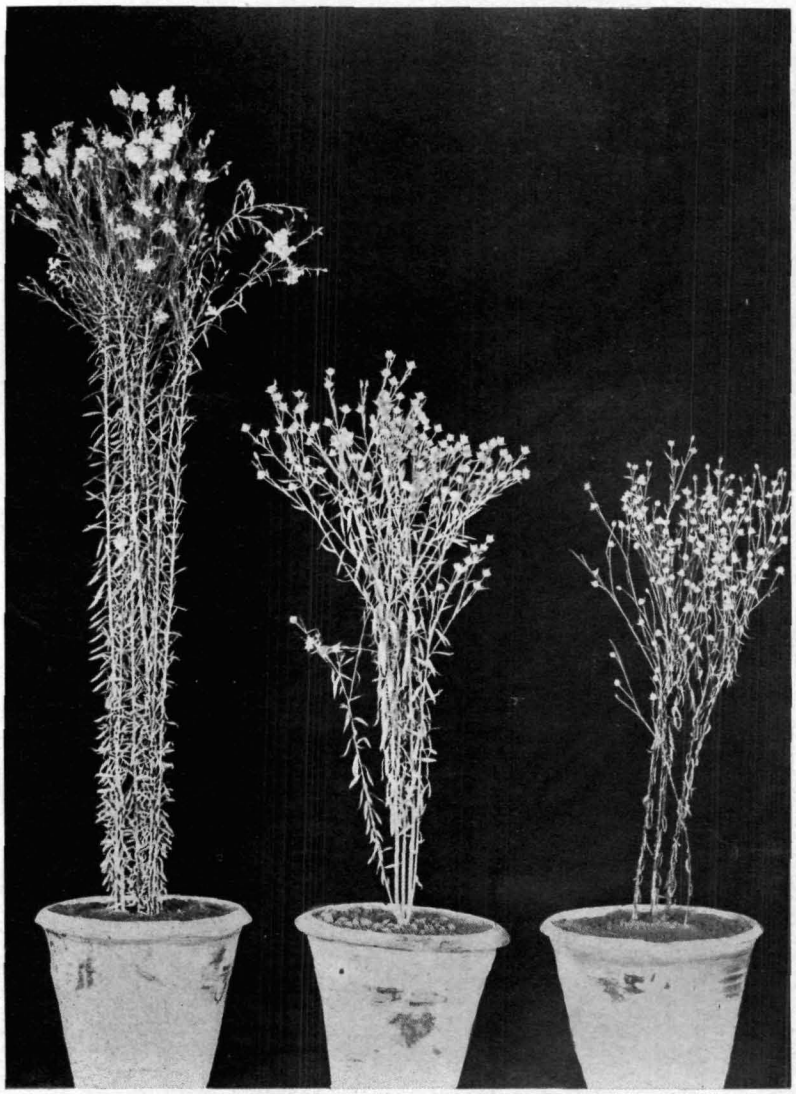

Plate II which shows the resistant parent (left) still in full bloom while the synthetic hybrid (centre) is ready for harvest and has clean healthy stalks. The stalks of the susceptible parent (right) are marked with black streaks which is the *teleuto* stage of the rust fungus.

Seed size and colour

Not only have disease resistance of the foreign varieties and early maturity of the N.P. types been combined in the hybrid strains but many of them also possess bold seeds that are light in colour. These are important characters that have been inherited from the one parent or the other. Bold seeded varieties fetch a higher price than the small seeded ones owing to the belief that they are high in oil content. The varieties with lighter coloured seeds also fetch a higher price than those with dark coloured seeds as the oil extracted from them is paler in colour.

Oil content

Next to yield and disease resistance, oil content is the most important character. The oil content determinations were done by the Division of Chemistry by the semi-micro method. These have been tabulated below :

Oil per cent		39·01–42·00	42·01–45·00	45·01–48·00	48·01–51·00	51·01–54·00
Number of rust Resistant cultures	...	12	48	31	8	2
Number of parents	...	6	2	1	...	...

The oil content of the cultures varied from 39·67 to 53·50 per cent and nearly 50 per cent of them fall under 42.01-45·00 per cent group. On the other hand, all the foreign and two N.P. parents come under 39·01-42.00 per cent group, two N.P. varieties come under 42·01-45·00 per cent group, and only one parent comes under 45·01-48·00 per cent group. Considering 42 per cent and below as low oil content, 42·01-45·00 per cent as medium and 45·01-48·00 per cent as high and above 48 per cent as very high, it is seen that only 12 out of 101 strains analysed have low oil content, 48 have medium oil content and the rest, i.e. 41 have high or very high oil content. Of the parents, N.P. 11 has the highest oil content, viz. 46·5 per cent and 25 strains have a higher oil content than it. These are cases of transgressive segregation.

Field performance tests

The field performance tests were commenced in the important linseed-growing tracts of India in 1941. To commence with only six most outstanding strains were released for preliminary trials. Since 1947, however, 35 out of the 101 strains, including the six referred to above, which have been selected on the basis of rust resistance, high yield, high oil content, early maturity, etc. are being tested against N.P. 21, a type highly susceptible to rust, and the best local variety. The available reports of the first set of trials with the six strains show that these strains proved rust resistant in all the places where they were tried whereas the local varieties showed rust infection. In Madhya Pradesh one of the strains besides being rust resistant was also observed to be resistant to the insect pest, *Dasyneura lini*.

Regarding relative yields of these strains, the report from Madhya Pradesh says that when the incidence of rust is very heavy these strains give better yields than the local varieties. In Kangra (Punjab), two of these rust-resistant strains outyielded the local variety by about 50 to 100 per cent5.

As regards the field performance tests of the 35 rust-resistant strains, reports from three provinces, Madhya Pradesh, Bengal and East Punjab only are so far available. The Madhya Pradesh results are rather discouraging as the local variety E.B. 3, used as control, outyielded all the 35 strains although it was affected by rust and all the 35 strains were free from rust infection. There were two replications but in one replication four of the 35 strains gave higher yield than the control and two yielded as much as the control. The reason for this poor performance of these strains seems to be the fact that the growing season in Madhya Pradesh is short and that the rust-resistant cultures are relatively late maturing and the control is somewhat early in maturity. Moreover, the sowings were done very late, i.e., nearly four to six weeks later than the normal sowing time for this State.

According to the report of trials in Bengal, all the 35 strains were free from rust, whereas N.P. 21 and the local control, the best Murshidabad type, were infected with rust. On the basis of yield of 100 plants 9 out of the 35 strains gave higher yield than the mean yield of the local from 18 replications. Again as in Madhya Pradesh, the sowings were done late, nearly four to six weeks later than the normal sowing time. The local variety used as control is relatively early maturing and did not perhaps suffer as much as the rust-resistant strains from this handicap. Had the sowings been done in time there is every reason to expect that many more rust-resistant strains would have done better than the control.

According to the report of trials in the Punjab (I), N.P. 21 was heavily attacked by rust and the "Jullundur Local" was slightly attacked, whereas all the 35 strains were free from rust infection. As regards relative yields, the yield trials were split up into three groups, two of yellow seeded strains and one of brown seeded strains. Amongst the brown seeded strains N.P. 21 which is brown seeded gave the lowest yield, very much less than any other yellow or brown seeded strain or "Jullundur Local" in any of the three groups of trials. All the rust-resistant cultures in this group outyielded "Jullundur Local". In the first group of yellow seeded strains, 12 strains out of 13 and in the second group, 5 out of 13 strains outyielded the control and one equalled it.

The results of these trials, although of a preliminary nature, indicate that some one or the other of these 35 strians would prove suitable for cultivation in the different linseed growing tracts. The trials will be repeated in these States. Steps have been taken already to conduct trials in all the other important linseed-growing States.

In the meantime breeding investigations are being continued. Special attention is being paid to breed early maturing varieties suitable for tracts having a short growing period. Oil content determinations will be repeated and quality of oil (Iodine Number) determined.

Limited quantities of seeds of these strains will be available for trials.

REFERENCES

1. Anonymous (1950). Linseed fibre to meet raw jute shortage. *Jute Bulletin*, **12** : 607.
2. Deshpande, R. B. and Malik, A. K. (1937). Studies in Indian oilseed. VI. Some Correlations between oil-content and other characters in the Pusa linseed hybrids. *Indian J. Agric. Sci.*, **7** : 841-848.
3. Henry, A. W. (1930). Inheritance of immunity from Flax Rust. Phytopath., **20** : 707-721.
4. Howard, G. L. C. and Khan, A. R. (1924). Studies in Indian oilseeds. II. Linseed. Dept. Agric, India (Bot. Ser.)., **12** : 135-183.

5. John, C. M. (1948). Report on research on oilseeds in India.

6. Shaw, F. J. F., Khan, A. R. and Alam, M. (1931). Studies in Indian oilseeds. V. The inheritance of characters in Indian linseed. *Indian J. Agric. Sci.*, 1 : 1-57.

EXPLANATION OF PLATES

PLATE I.

Fig. 1. Showing how linseed cultures are kept under humid condition 24 hours before and after inoculation with the rust organism.

Fig. 2. Showing two rows of N.P. 21, the control, wiped out by rust (centre) and rust-resistant cultures on either side.

PLATE II.

Left—Exotic parent which is immune to rust but very late in maturity.

Right—N.P. 11 parent which is early in maturity, high in oil content, but highly susceptible to rust.

Centre—Strain obtained by crossing the two parents showing early maturity and immunity from rust.