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**Research Note**

# Inheritance of gene conferring resistance to wilt (*Fusarium oxysporum* f sp. lini) disease of linseed (*Linum usitatissimum* L.) in North West Himalayas

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**Abstract**
The genetics of resistance against wilt disease caused by *Fusarium oxysporum* f sp. lini in linseed was studied in $F_1$, $F_2$, $BC_1$ and $BC_2$ generations of two susceptible varieties T-397 and Chambal, crossed with two resistant varieties HimAlsi-1 and Nagarkot. On the basis of the segregating ratio obtained in $F_2$ and backcross generations of the two crosses, Nagarkot x Chambal and Nagarkot x T-397, the disease resistance was controlled by two recessive alleles with duplicate gene action in the variety Nagarkot. On contrary in the crosses HimAlsi-1 x T-397 and HimAlsi x Chambal-1, two dominant genes with complimentary gene action confirming wilt resistance in HimAlsi-1. These resistant genotypes may be used as donor for transferring resistance in good cultivars otherwise susceptible to wilt using suitable breeding programme.

**Keywords**
Linseed, wilt, inheritance, resistance

Linseed (*Linum usitatissimum* L.) is a multipurpose *rabi* oilseed crop, cultivated for oil and fibre, which belongs to the family Linaceae having 14 genera. The linseed production is affected by several infectious and non infectious diseases throughout the world. Wilt, Rust, Alternaria blight and Powdery mildew are major diseases associated with it. Out of these diseases, wilt is the most serious disease of linseed. Wilt attacks linseed plant at all stages of growth and the pathogen is *Fusarium oxysporum* Schl. f. lini (Bolley, 1901) Synder and Hansen (1940) (Syn. *f. lini* Bolley). Losses up to 80% have been reported under conditions favourable for wilt development. Since effective chemical control of this disease is not available, use of resistant cultivars have been suggested. To breed stable resistant cultivars against this disease it is imperative to know the genetics and gene responsible for resistance against this disease. A breeder engaged in crop improvement work is interested in incorporating disease resistance in commercial cultivated varieties. In most cases donors are available for high yields and quality traits while for the disease resistance it is often lacking. Therefore, the breeder has to look for the resistant gene(s) in the genotypes. The information on inheritance of the wilt resistance is also important to decide the breeding strategies in linseed crop. In view of growing importance of wilt, lack of resistance to it and scant availability of information an underlying genetic mechanism of resistance, studies were conducted on genetics of plant resistance in linseed to the pathogen, *Fusarium oxysporum.*

Two resistant linseed lines, namely Nagarkot and HimAlsi-1 were crossed with two susceptible varieties *viz.*, T-397 and Chambal to produce test materials for study of genetics of resistance and gene action of wilt disease in linseed during *Rabi* 2012-13. A part of $F_1$ seeds were planted along with parents in the Experimental Farm of Department of Crop Improvement of CSKHPKV Palampur (H.P.) during *Rabi* 2013-14 for generating $BC_1$ and $BC_2$ and also $F_2$ seeds. A field trial was conducted comprising of parents, four $F_{1s}$, back crosses ($BC_1$ and $BC_2$) and $F_2$s in Compact Family Block Design with three replications in wilt sick plot during *Rabi* 2014-15. Parents and $F_{1s}$ were grown in single row, back cross generations in two rows and $F_{2s}$ in four rows of 3 mt. length with 30 cm apart and 10 cm distance between seed to seed. Standard agronomic practices were followed.

Disease assessment: After complete germination the total number of plants in each row was counted for initial plant stand. Wilt incidence was observed frequently at 15 days interval in each variety. The final wilt incidence was calculated by deducting the number of plants survived from the initial plant stand and converted into per cent using the formula given as below;

$$\text{Per cent wilt incidence} = \frac{\text{No.of wilted plants}}{\text{Total no.of plants}} \times 100$$

The genotypes were placed in various categories of resistance and susceptibility on the basis of standard rating on 0-5 scale (Table.1) for *Fusarium* wilt as described by Sharma *et al.* (1972). For fitting genetic ratios, HR, R and MR plants were grouped together and considered as resistant and plants moderately susceptible, susceptible and highly susceptible were considered as susceptible. Simple $\chi^2$ test was applied to test the goodness of fit of different genetic ratios.

Wilt disease reaction to parents emphasized that the resistant parents *viz.*, HimAlsi-1 and Nagarkot expressed wilt reaction 0 to 10 per cent while susceptible genotypes *viz.*, Chambal and T-397 suffered heavily with 20 to 100 per cent infection. The wilt reaction in the $F_{1s}$ of the two crosses involving resistant parent Nagarkot with susceptible parents Chambal and T-397 (Nagarkot x Chambal and Nagarkot x T-397) showed susceptible reaction to the disease (Table.2). This clearly indicated dominance of susceptibility over resistance in both the crosses. $BC_1$ and $BC_2$ populations and segregation analysis in $F_2$ generation of these two crosses supported the above observation. In $BC_1$ generation, (Nagarkot x Chambal) x Nagarkot (55), (Nagarkot x T-397) x Nagarkot (48), all the plants were susceptible, whereas in $BC_2$ generation (Nagarkot x Chambal) x Chambal and (Nagarkot x T-397) x T-397 progenies were segregated in the ratio of 1 resistant: 3 susceptible plants. In $F_2$ generation segregation pattern of 1 resistant: 15 susceptible plants were observed in both the crosses. Thus on the basis of result obtained it may be concluded that resistance in the variety Nagarkot is controlled by two recessive genes with duplicate gene action. Goray *et al.* (1987) has also reported similar results in few other linseed strains.

In the $F_1$ and $BC_1$ generations of other two crosses, HimAlsi-1 x Chambal and HimAlsi-1 x T-397 the plants were resistant to wilt. These findings indicated the dominance of the resistance over susceptibility. However, in $BC_2$ and $F_2$ generations, the plant progenies segregated in different ratio. The $F_2$ and $BC_2$ generations of the crosses HimAlsi-1 x Chambal and HimAlsi-1 x T-397 segregated in to 9:7 and 1:3 ratio, respectively. This segregation ratio indicated the presence of the two dominant genes with complimentary gene action which control wilt resistance in variety, HimAlsi-1. Earlier Jeswani and Upadhyaya (1970) have also reported that inheritance of wilt resistance is based on single or double pair of dominant genes. However Tisdale (1971) reported multiple factor control of this character. Knowles and Hauston (1953), Goray *et al.* (1987), Goray *et al.* (1988) and Agrawal *et al.* (1991) recorded similar dihybrid ratio and confirmed that wilt resistance was due to the action of two complementary genes. The recessive alleles in Nagarkot and different genes in HimAlsi-1 identified in the present study may serve as new source of resistance to wilt in the linseed for breeding cultivars.

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Table.1: Disease scale for linseed wilts (*Fusarium oxysporum* f sp. lini)

| Scale | Percent Mortality | Disease reaction |
|---|---|---|
| 0 | 0 | Highly resistant (HR) |
| 1 | Up to 5 | Resistant (R) |
| 2 | 5 – 15 | Moderately resistant (MR) |
| 3 | 15 – 30 | Moderately susceptible (MS) |
| 4 | 30 – 50 | Susceptible (S) |
| 5 | Above 50 | Highly susceptible (HS) |

Table.2. Segregation for wilt resistance in $F_2$, $BC_1$ and $BC_2$ generations of four cross combinations.

| S. no. | Generations | Total no. of plants | No. of observed plants | | Ratio tested | No. of expected plants | | Observed $\chi^2$ value | P value |
|---|---|---|---|---|---|---|---|---|---|
| | | | Resistant | Susceptible | | Resistant | susceptible | | |
| A. | Nagarkot x Chambal | | | | | | | | |
| 1. | $P_1$ | 178 | 178 | 0 | - | | | - | |
| 2. | $P_2$ | 182 | 0 | 182 | - | | | - | |
| 3. | $F_1$ | 50 | 0 | 50 | - | | | - | |
| 4. | $BC_1$ | 55 | 0 | 55 | - | | | - | |
| 5. | $BC_2$ | 54 | 14 | 40 | 1:3 | 13.50 | 40.50 | 0.025 | 0.874 |
| 6. | $F_2$ | 198 | 14 | 184 | 1:15 | 12.38 | 185.62 | 0.227 | 0.634 |
| B. | Nagarkot x T-397 | | | | | | | | |
| 1. | $P_1$ | 180 | 180 | 0 | - | | | - | |
| 2. | $P_2$ | 190 | 0 | 190 | - | | | - | |
| 3. | $F_1$ | 51 | 0 | 51 | - | | | - | |
| 4. | $BC_1$ | 48 | 0 | 48 | - | | | - | |
| 5. | $BC_2$ | 47 | 12 | 35 | 1:3 | 11.75 | 35.25 | 0.007 | 0.933 |
| 6. | $F_2$ | 218 | 13 | 205 | 1:15 | 13.63 | 204.37 | 0.031 | 0.860 |
| C. | HimAlsi-1 x Chambal | | | | | | | | |
| 1. | $P_1$ | 152 | 152 | 0 | - | | | - | |
| 2. | $P_2$ | 165 | 0 | 165 | - | | | - | |
| 3. | $F_1$ | 58 | 58 | 0 | - | | | - | |
| 4. | $BC_1$ | 44 | 44 | 0 | - | | | - | |
| 5. | $BC_2$ | 43 | 11 | 32 | 1:3 | 10.75 | 32.25 | 0.008 | 0.929 |
| 6. | $F_2$ | 235 | 134 | 101 | 9:7 | 132.19 | 102.81 | 0.057 | 0.811 |
| D. | HimAlsi-1 x T-397 | | | | | | | | |
| 1. | $P_1$ | 150 | 150 | 0 | - | | | - | |
| 2. | $P_2$ | 162 | 0 | 162 | - | | | - | |
| 3. | $F_1$ | 48 | 48 | 0 | - | | | - | |
| 4. | $BC_1$ | 42 | 42 | 0 | - | | | - | |
| 5. | $BC_2$ | 40 | 12 | 28 | 1:3 | 10 | 30 | 0.233 | 0.629 |
| 6. | $F_2$ | 203 | 116 | 87 | 9:7 | 114.19 | 88.81 | 0.067 | 0.796 |