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Genetics of rust resistance in lentil (*Lens culinaris* Medik.)

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Abstract

Inheritance of rust resistance in lentil was studied based on analysis of 23 crosses involving 8 resistant and 10 susceptible genotypes. The crosses were made in three possible combinations, viz., resistant × susceptible, resistant × resistant and susceptible × susceptible types. The F_2 segregation analysis of 14 out of 15 crosses involving resistant × susceptible parents revealed that resistance was governed by a single dominant gene. The F_2 analysis of the cross Lens 4076 × DPL 21, revealed that resistance in the variety DPL 21 was under monogenic recessive control. Analysis of three crosses involving only resistant parents indicated that genotype Precoz has a dominant gene for resistance at different locus to that of Pant L 4. The crosses among susceptible parents revealed susceptibility as noncomplementative. The gene symbol Urf_1 has been proposed for rust resistance in the genotypes Precoz and Lens 4603 and urf_2 in the varieties Pant L 4 and Lens 4147. The gene symbol $urf_3 urf_3$ has been proposed in variety DPL 21, where resistance was conferred by monogenic recessive gene.

Key words : Lentil, inheritance, rust resistance, gene symbols.

Introduction

Lentil (*Lens culinaris* Medik.) is one of the oldest known protein rich global food legume originated in the Fertile Crescent of the Near East. Its ability to thrive well on relatively poor soils under adverse agroclimatic conditions has ensured its survival as a crop species to the present day. Relatively easier digestibility and high protein content coupled with unique aroma of its culinary preparations impart a special position to lentil to human diet worldover.

The Indian subcontinent is the largest lentil producing region in the world, but the production of lentil has remained static for past several years. One of the major constraint responsible for the poor productivity has been the lack of rust resistant varieties. The lentil rust caused by the fungus *Uromyces fabae* (Pers) de Bary, is the most serious disease of lentil. It can cause upto 70-100% yield losses under epidemic situations [1, 2]. Since effective chemical control of this disease has not been found, development of resistant varieties is the most reliable and assured way to control the disease. However, lack of precise information regarding mode of inheritance and allelism about rust resistance in lentil has hampered the development of resistant varieties, as the precise knowledge is essential in deciding the breeding method, identification of gene(s) for resistance to develop varieties with broader genetic base for resistance. This necessitated the present investigation to work out the genetics of rust resistance in lentil.

Materials and methods

Eighteen lentil genotypes were selected from the germplasm collection maintained in the Division of Genetics, IARI, New Delhi (Table 1). These involved eight resistant (DPL 21, DPL 59, E 153, Lens 4147, Lens 4603, Precoz, P 42127 and Pant L 4) and ten susceptible parents (JLS 1, Lens 830, Lens 4076, Lens 4149, LC 68-1-3-2-2-1, LC 187-4-13, LG 362, P 22127, P 42129, PKVL 1). 23 cross combinations were made during *rabi* 1997-98 at the Research Farm of IARI, New Delhi. These included three different types of combinations viz., resistant × susceptible (15), resistant × resistant (3) and susceptible × susceptible (5) types. The F_1 seeds were sown during summer 1998 at Off-season Summer Nursery, Directorate of Wheat Research, Dalang Maidan, Lahaul and Spiti, Himachal Pradesh. During *rabi* 1998-99, the F_1 and F_2 generations along with parents were grown at HPKVV Regional Station, Dhaula Kuan, Himachal Pradesh, which is a hot spot for lentil rust.

With a view to avoid interplant competition and to facilitate proper screening of each plant for rust reaction, the F_2 plants were raised keeping 50 cm row-to-row and 20 cm plant-to-plant spacing, along with a single row of each of the parent and its F_1. Infector row was planted after every 20^{th} row to ensure adequate disease inoculum.

The disease started appearing in the 1^{st} week of February 1999, as yellowing white (muddy coloured)

Table 1. Details of the parents used in the crossing programme of lentil

Parental strain	Pedigree	Rust reaction
DPL 21	PL 406 × BDL 23	Resistant
DPL 59	K 75 × Precoz	Resistant
E 153	EC 157635	Resistant
Lens 4147	(L 3875 × P4) × PKVL 1	Resistant
Lens 4603	Precoz × L 3991	Resistant
Precoz	ILL 4605	Resistant
P 42127	ILL 4349 × ILL 4605	Resistant
Pant L 4	UPL 175 × (Pant L 184 × P 288)	Resistant
JS 1	Selection from local germplasm at JNKVV,Jabalpur	Susceptible
Lens 830	Selection from germplasm at IARI,New Delhi	Susceptible
Lens 4076	PL 234 × PL 639	Susceptible
Lens 4149	RAU 101 × PL 639	Susceptible
Lc 68-1-3-2-2-1	Precoz × L 3991	Susceptible
Lc 187-4-13	AUR 101 × PL 639	Susceptible
LG 362	LG 171 × PL 77-2	Susceptible
P 22127	Selection from local material at ICARDA,Syria	Susceptible
P 42129	ILL 5582 × ILL 707	Susceptible
PKVL 1	Selection from local germplasm at P.K. Vishwavidyalaya, Akola	Susceptible

pycnia and aecial cups developed on the lower surface of leaflets of the susceptible plants. By the first week of March 1999 all the aerial parts of the susceptible plants were covered with rust.

Natural epidemics of disease was exploited for screening for rust reaction. The plants were classified into two categories, i.e. resistant (R) or susceptible (S). Data were recorded on individual plant basis on all the plants in parents, F_1, and F_2 population. The presence/absence of disease symptom was taken as criteria for recording disease reaction. However, there was no ambiguity an identifying the resistant and susceptible plants.

The segregation for rust resistance was analyzed by χ^2 test to determine the goodness of fit of the observed segregation with the expected ratios. To test uniformity of the families so as to pool their data to provide an overall test for the expected segregation ratio, the formula of Mather [3] and Panse and Sukhatme [4] were used.

Results and discussion

Resistant × susceptible crosses

A set of 15 crosses were made in resistant × susceptible category. Out of 15 crosses, the F_1 of 14 crosses were found to be resistant (Table 2). This indicated the dominance of resistance over susceptibility. In F_2, the ratio of resistant (R) and susceptible (S) plants in these crosses showed goodness of fit to the expected segregation ratio of 3R:1S individually as well as on pooled data basis (Table 2) with fair probability for goodness of fit (χ^2 = 0.002-2.02; P = 0.1552-0.9643). The heterogeneity χ^2 for 3:1 ratio was also nonsignificant. This allowed the pooling of plants over 14 crosses that gave 2603 resistant and 856 susceptible plants which yielded a very low and nonsignificant pooled χ^2 (0.119; P = 0.7301). This indicated that rust resistance was under monogenic dominant control in the materials tested. This finding confirmed the earlier reports about monogenic dominant control of rust resistance in lentil

Table 2. Segregation for rust resistance in resistant × susceptible crosses of lentil

Cross	F_1 pheno type	No. of F_2 plants Total	R	S	Expe-cted ratio	χ^2	P
Precoz × PKVL 1	R	151	122	29	3.1	2.02	0.1552
Precoz × P 22127	R	155	113	42	3.1	0.36	0.5485
Precoz × Lens 830	R	184	140	44	3.1	0.11	0.735
Precoz × Lens 4076	R	210	163	47	4.1	0.77	0.1833
Pant L4 × Lens 830	R	192	152	40	3.1	1.77	0.1833
Pant L4 × PKVL 1	R	296	218	78	3.1	0.28	0.5967
E 153 × Lens 830	R	241	176	65	3.1	0.449	0.4839
P 42127 × PKVL 1	R	201	151	50	3.1	0.002	0.9643
JLS 1 × Precoz	R	111	86	25	3.1	0.36	0.5485
Lens 4076 × Lens 4603	R	298	214	84	3.1	1.61	0.2044
Lens 4076 × DPL 59	R	287	211	76	3.1	0.33	0.5656
Lens 4149 × Pant L4	R	134	99	35	3.1	0.09	0.7654
Lens 830 × E 153	R	645	493	152	3.1	0.70	0.4027
PKVL 1 × Precoz	R	354	265	89	3.1	0.004	0.9495
Total (14 d.f.)	-	-	-	-	-	8.897	-
Pooled over 14 crosses	-	3459	2603	856	3.1	0.110	0.7301
Heterogeneity (13.df.)	-					8.778	0.7894
Lens 4076 × DPL 21	S	343	44	259	3.1	0.048	0.8265

R = Resistant; S = Susceptible

[5, 7]. However, the F_1 of the cross L 4076 × DPL21 was found to be susceptible. The F_2 segregation based on 343 plants (Table 2) showed a good fit to the segregation ratio of 3S:1R, indicating that resistance in the variety DPL21 was conditioned by a single recessive gene. The monogenic recessive control of rust resistance is the first report in lentil. However, this needs further confirmation as the analysis is based on only one cross.

From glasshouse experiments, it was supported that rust resistance in the variety Precoz is conditioned by duplicate dominant genes [7, 8]. Contrarily, in the present study after analyzing 1165 plants over five crosses, viz., JLS 1 × Precoz, Precoz × P 22127, Precoz × Lens 830, Precoz × Lens 4076, Precoz × PKLV 1 under field conditions, it was found that rust resistance in the variety Precoz is governed by a single dominant gene.

Differential rust reaction under field conditions and in artificial epiphytotic conditions have been reported earlier [9, 10]. This may be partly because of the presence of a large number of unidentified races of pathogen under natural conditions. This could also happen if resistance itself is not perfect and a few resistant segregants in F_2 generation show minor symptoms of infection and are classified as susceptible.

Resistant × resistant crosses

The three crosses, viz., Precoz × Pant L 4, Lens 4147 × Pant L4, and Precoz x Lens 4603 were made in resistant × resistant category (Table 3) to determine allelic relationship between genes for rust resistance carried by different parents. The F_1s of all the three crosses were resistant. Out of three crosses, the F_2 population of one cross, i.e. Precoz × Pant L4 in which 257 plants were analysed, segregated into a close fit to 15R:1S segregation ratio with nonsignificant χ^2 value (3.19; P = 0.074). It indicated that rust resistance in the variety Precoz is due to a gene which is different from the one carried by the Pant variety L4. However, in the cross Precoz X Lens 4603 no segregation was found in F_2 and all the plants were resistant, suggesting the presence of a common dominant gene for resistance in both the parents. This was further confirmed by the pedigree analysis of variety Lens 4603 where Precoz was one of the parents used to develop this variety. Same was the case with the cross Lens 4147 × Pant L4 which did not segregate in F_2 generation indicating involvement of the same dominant gene for resistance in both the varieties. These results indicated the presence of two different dominant genes conferring rust resistance in the material studied. Hence, to know the exact number of genes for rust resistance, it is necessary to analyse all possible resistant × resistant crosses in future studies.

Table 3. F_2 segregation for rust resistance in different resistant × resistant crosses of lentil

Cross	F_1 phenotype	No. of F_2 plants			Expected ratio	χ^2	P
		Total	R	S			
Precoz × Pant L 4	R	257	234	23	15:1	3.19	0.074
Lens 4147 × Pant L 4	R	271	271	0	-	-	-
Precoz × Lens 4603	R	235	235	0	-	-	-

R = Resistant; S = Susceptible

Susceptible × susceptible crosses

The crosses were also made among susceptible parents for complementation test (Table 4). The F_1s of all the five crosses made in this category were susceptible and none of them segregated in the F_2 generation. This gave clear evidence that susceptibility was non-complementative in nature in the material studied.

Table 4. F_2 Segregation for rust resistance in different susceptible × susceptible crosses of lentil

Cross	F_1 phenotype	No. of F_2 plants		
		Total	R	S
PKVL1 × Lens 4076	S	211	0	211
PKVL 1 × P 42129	S	235	0	235
Lc 187-4-13 × JLS 1	S	195	0	195
Lens 4076 × LG 362	S	209	0	209
Lc 68-1-3-2-2-1 × Lens 1-3-2-2-1	S	271	0	271

R = Resistant; S = Susceptible

Gene symbol for rust resistance

No gene symbol has so far been proposed till date for denoting rust resistance in lentil. The present investigation revealed that at least three different genes for rust resistance are present in the material studied. Two of them cause resistance in dominant state while the recessive allele of the third gene determines resistance. We denote the dominant genes by a common symbol *Urf* (as per latest system of proposing symbols for newly identified genes in a three letter word), where Urf_1 is for the dominant gene present in the varieties Precoz and Lens 4603 and Urf_2 for the gene present in the varieties Pant L4 and Lens 4147. The susceptible phenotype will appear only under homozygous recessive state i.e. $urf_1\ urf_1$ and $urf_2\ urf_2$. For the third gene which causes rust resistance in the variety DPL 21 under recessive condition, we propose the gene symbol $urf_3\ urf_3$. However, further confirmation is necessary for the existence of recessive gene for rust resistance.

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