Journal of Spices and Aromatic Crops
Vol. 12 (2) : 120-126 (2003)

Indian Society for Spices

Inheritance of powdery mildew resistance and growth habit in fenugreek (*Trigonella foenum-graecum* L.)

R S Raje, D L Singhania & D Singh

Department of Plant Breeding and Genetics
SKN College of Agriculture
Jobner-303 329, Rajasthan, India

Received 10 September 2002; Revised 21 June 2003; Accepted 30 December 2003

Abstract

Inheritance of resistance to powdery mildew was studied by evaluating parents, F_1 and F_2 generations of cross UM-305 x UM-117 along with susceptible check varieties over the years for powdery mildew reaction. The F_3 and F_4 families of the cross were also evaluated along with the F_1, parents and the check varieties for powdery mildew reaction to confirm the results. X^2 test was applied to test the fitness of assumed ratio. The inheritance pattern suggested resistance to powdery mildew was monogenic recessive. Results indicated that gene for powdery mildew resistance and gene for determinate growth habit assort independent of each other.

Key words: disease resistance, growth habit, inheritance, powdery mildew, *Trigonella foenm-graecum*

Introduction

Powdery mildew of fenugreek (*Trigonella foenum-graecum* L.) is caused by *Erysiphe polygoni* DC. This disease results in heavy loss to the crop. The existing high yielding varieties are not having the built-in resistance and thus there is a need to breed a resistant variety. Knowledge of genetic control of resistance is a prerequisite in any resistance breeding programme. In fenugreek, so far there has been only a single report about the inheritance of powdery mildew resistance (Raje *et al.* 2002). However, there are few reports of screening fenugreek germplasm lines for resistance to powdery mildew (Saxena *et al.* 1984; Mehta *et al.* 1994). Thus, in the present investigation an attempt has been made to determine the inheritance pattern of resistance to powdery mildew. In fenugreek, Raje *et al.* (2001) reported that a marker trait i.e. determinate growth habit is under the control of a single recessive gene and indeterminate growth habit under its dominant allele. Thus, it was thought important to verify the linkage between the gene for this marker trait and the gene for resistance to powdery mildew in order to know about the possibility of indirect selection for powdery mildew resistance. Therefore, in the present investigation an attempt has been made to determine the inheritance of powdery mildew resistance and to test the possibility of linkage between the gene for powdery mildew resistance and the gene for growth habit.

Materials and methods

The experimental material was obtained from A.I.C.R.P. on Spices, Department of Plant Breeding and Genetics, which consisted of two parents (UM-305 and UM-117), F_1, F_2, F_3 and F_4 generations of the cross (UM-305 x UM-117) and the check varieties (RMt-1 and local check).

The parent UM-305 is having determinate growth habit and is resistant to powdery mildew (Anonymous 2000). The other parent UM-117 is having indeterminate growth habit and is susceptible to powdery mildew (Anonymous 1995; 1996; 1997; 1998). Local check and RMt-1, which are susceptible to powdery mildew (Anonymous 1995; 1996; 1997; 1998) were grown as check varieties. The year-wise details of the experimental materials have been presented in Table 1. The experimental material was tested against powdery mildew during the *rabi* seasons in the years 1997-98, 1998-99, 1999-2000 and 2000-2001 under natural conditions. The susceptible check varieties also served as spreader rows and as a source of secondary infection.

The individual plants of parents, check varieties, F_1, F_2, F_3 and F_4 generations were evaluated for their reaction to powdery mildew and classified as either powdery mildew susceptible or powdery mildew resistant plants (based on 100% disease development). The plants in the resistant and susceptible categories were tagged individually for counting and were harvested individually for further advancement.

The cross UM-305 x UM-117 was attempted during *rabi* 1996-97. F_1 seeds of the cross produced each year during *rabi* 1997-98, 1998-99 and 1999-2000 were used in subsequent experiments.

Experiment I (rabi, 1997-98): In this experiment F_1, parents and the check varieties (RMt-1 & local check) were grown in 2 m long single row plots and disease reaction to powdery mildew of individual plants was noted when the disease appeared in full expression (100%) on susceptible checks. The growth habit in F_1 generation was also noted.

Experiment II (rabi, 1998-99): The parents, F_1, F_2 of the cross were grown with the check varieties in RBD with two replications in single row plots of 4 m length with row to row distance of 30 cm and plant to plant distance of 10 cm. All the individual plants were classified as resistant and susceptible following the procedure mentioned earlier. Each plant in F_2 generation was also classified as having determinate or indeterminate growth habit. Chi-square test was applied to test the goodness of fit for assumed segregation ratio. F_2 plants were harvested separately to collect the seed of F_3 families.

Experiment III (rabi, 1999-2000): Thirty F_3 families of each cross were evaluated during this season. For this, only a part of the total seed of each F_3 family was used for evaluation. The remaining seed of these F_3 families was kept for evaluation during *rabi* 2000-2001 (experiment IV). Thus, in experiment III, 30 F_3 families of cross, parents, F_1 and F_2 of the cross and the check varieties were evaluated in RBD with three replications in single row plot of 3 m length. Since powdery mildew incidence was not observed during this year, only observation on growth habit was noted.

As the total number of F_2 plants was less in the experiment II and also due to absence of powdery mildew incidence in the experiment III, it was thought that F_3 and F_4 families of the cross should be further evaluated in *rabi* 2000-2001 to confirm the results. Thus, 11 F_3 families were selected out of 30 F_3 families of the cross (UM-305 x UM-117) which were evaluated during experiment III. These 11 F_3 families were selected on the basis of reaction to powdery mildew of their progenitor F_2 plants in experiment II. Out of them, the seven selected F_3 families were progeny of seven susceptible F_2 plants while the other four selected F_3 families were progeny of four resistant F_2 plants harvested individually during *rabi*, 1998-99. The remaining seed of these F_3 families (kept in 1998-99) was used in the experiment IV during *rabi*, 2000-2001. F_4 families were derived from the F_3 families evaluated during the experiment III. From each of the eleven F_3 families (grown during *rabi*, 1999-2000) 15 plants were randomly selected and harvested separately to get 15 F_4 families. One F_4 family out of the 15 F_4 families derived from each of the F_3 family was chosen for further evaluation. Thus, 11 F_4 families were chosen for further evaluation during *rabi*, 2000-2001.

Experiment IV (rabi, 2000-2001): In this experiment parents (UM-305 x UM-117), F_1, 11 F_3 fami-

Table 1. Experimental details

Experiment	Season and year	Sowing date	Experimental material
I	*Rabi*, 1997-98	16.11.1997	Parents (UM-305 and UM-117), F_1 (UM-305 x UM-117) and check varieties (RMt-1 and Local check)
II	*Rabi*, 1998-99	15.11.1998	Parents (UM-305 and UM-117), F_1 and F_2 of cross (UM-305 x UM-117), check varieties (RMt-1 and Local check)
III	*Rabi*, 1999-2000	23.11.1999	Parents (UM-305 and UM-117), F_1 and F_2 of the cross (UM-305 x UM-117), 30 F_3 families of the cross (UM-305 x UM-117) and the check varieties (RMt-1 and Local check)
IV	*Rabi*, 2000-2001	25.12.2000	Parents (UM-305 and UM-117), F_1 (UM-305 x UM-117), 11 F_3 families (remnant seeds of 1998-99) (7 F_3 families derived from 7 susceptible F_2 plants and 4 F_3 families derived from 4 resistant F_2 plants of 1998-99, respectively), 11 F_4 progeny families (derived from 11 F_3 families evaluated in 1999-2000) and check varieties (RMt-1 and Local check)

lies and their 11 F_4 progeny families and check varieties were evaluated in RBD with two replications in single row plot of 2 m length. The row to row distance was 30 cm. This experiment was sown one month late in order to ensure the incidence of powdery mildew. Observation on reaction to powdery mildew of individual plant was recorded. Growth habit of individual plant was also recorded.

In all the four experiments recommended package of practices was followed but no disease control measure was followed.

Results and discussion

Disease reaction of the parents, check varieties, F_1s and F_2s have been presented in Table 2 and Table 3. In the experiment I the plants of UM-305 showed resistant reaction whereas plants of UM-117 showed susceptible reaction. All the F_1s showed susceptible reaction. There was heavy incidence of powdery mildew as evident from the occurrence of the disease in check varieties. Thus, in experiment I reaction of parents and F_1s indicated that susceptibility was a dominant character and resistance was the recessive character. Similar findings for powdery mildew resistance have been reported in pea (Narsinghani 1979; Singh *et al.* 1983; Janila *et al.* 2001).

In experiment II the plants of parents, F_1s and F_2s were evaluated along with check varieties for powdery mildew reaction (Tables 2 & 3). Again, the parent UM-305 showed resistance whereas, UM-117 showed susceptible reaction. The F_1s showed susceptible reaction, which again indicated that resistance was recessive and susceptibility was dominant. F_2 plants showed segregation for susceptible and resistance reaction (Table 3). In F_2 generation, there were in total 41 susceptible and 12 resistant plants. This observed ratio of 41 susceptible : 12 resistant plants showed good fit to a 3:1

Table 2. Reaction of parental strains, F_1 and checks to powdery mildew

Genotype	Experiment-I (*Rabi*, 1997-98)	Experiment-II (*Rabi*, 1998-99)	Experiment-III (*Rabi*, 1999-2000)	Experiment-IV (*Rabi*, 2000-2001)
Parents				
UM-305	R	R	Disease did not occur	R
UM-117	S	S	Disease did not occur	S
Checks				
RMt-1	S	S	Disease did not occur	S
Local check	S	S	Disease did not occur	S
F_1				
UM-305x UM-117	S	S	Disease did not occur	S

R : Resistant; S : Susceptible

Table 3. F_2 segregation ratio for reaction to powdery mildew and growth habit in fenugreek (experiment II, *Rabi*, 1998-99)

Cross	Segregation ratio for reaction to powdery mildew	X^2 (3:1)	Segregation ratio for growth habit	X^2 (3:1)	Segregation ratio for reaction to powdery mildew & growth habit				X^2 (9:3:3:1)
					Susceptible & indeterminate	Susceptible & determinate	Resistant & indeterminate	Resistant & determinate	
UM-305 x UM-117	41 S : 12R	0.0565	39 Indeterminate: 14 Determinate	0.0063	29	12	10	2	0.4675

R : Resistant; S : Susceptible

monohybrid ratio. The calculated value of X^2 was non-significant which indicated that the data fit to a monohybrid ratio of 3 susceptible : 1 resistant. Thus, on the basis of resistant reaction of the parent UM-305, susceptible reaction of the parent UM-117, susceptible reaction of F_1s and a perfect fit to a 3 susceptible : 1 resistant ratio in F_2 (Tables 2 & 3) it can be concluded that resistance to powdery mildew in UM-305 is governed by a single recessive gene and the susceptibility in UM-117 by its dominant allele. The gene symbols *pmr* and *Pmr* are assigned for resistance and susceptibility to powdery mildew, respectively. Similar findings of monogenic control of powdery mildew resistance have been reported in peas (Narsinghani 1979; Sokhi *et al.* 1979; Singh *et al.* 1983; Janila *et al.* 2001).

In the experiment III there was no powdery mildew incidence hence, the investigation was carried out in the experiment IV.

In the experiment IV there was heavy incidence of powdery mildew as evident from 100% disease development in the both the checks. This may be due to delayed sowing by one month. In Table 4, reaction of eleven F_3 families and their respective F_4 progeny families during *rabi*, 2000-2001 has been shown along with the reaction of parental F_2 plants (during experiment II i.e., in *rabi*, 1998-99) from which these F_3 and F_4 families were derived. Out of the total F_2 parental plants used for getting F_3 and F_4 families, seven F_2 plants had susceptible and four F_2 plants had resistant reaction in 1998-99 experiment (experiment II). Thus, if the resistant reaction is governed by a single recessive gene and susceptibility by its dominant allele as indicated by a perfect fit of F_2 data (in 1998-99 experiment) to a 3 susceptible : 1 resistant plants, the genotypes of these F_2 plants could be derived on the basis of segregation ratios in F_3 and F_4 families. Therefore, plant numbers 1-7 could have either SS (homozygous dominant for susceptible reaction) or Ss (heterozygous for susceptible reaction) genotype while the resistant F_2 plants must have ss (i.e. recessive homozygous) genotype (Table 4). To confirm these results the disease reaction of F_3 progeny families, F_4 progeny families along with those of parents, F_1s and check varieties were recorded in experiment IV (Table 4). The parent UM-305 showed resistance whereas, other parent UM-117 showed susceptible reaction. All the F_1s showed susceptible reaction, which again confirmed that susceptibility was dominant and resistance was recessive. The susceptible check varieties (RMt-1 and local check) showed susceptible reaction. Reaction of the two check varieties and the parental genotypes over the years (1997-98, 1998-99 and 2000-2001) indicated that race flora was same over the years. The reaction types of F_3 families and their respective F_4 families derived from different susceptible and resistant F_2 plants were analyzed with respect to reaction type of the F_2 plants in 1998-99. In the F_3 progeny of the F_2 plant No. 1 all the plants showed susceptible reaction, which indicated that the genotype of its progenitor F_2 plant was SS. This was again confirmed by the presence of all susceptible plants and by the absence of any resistant plant in the F_4 progeny. Thus plant No. 1 had genotype SS.

In the F_3 progeny of F_2 plant No. 2 there were 12 resistant and 43 susceptible plants while in F_4 progeny there were 11 resistant and 39 susceptible plants. The segregation pattern in F_3 & F_4 progenies was a perfect fit to a 3 susceptible

Table 4. Reaction of F_2 genotypes of cross UM-305 x UM-117 to powdery mildew and segregation ratios in their F_3 and F_4 progenies in fenugreek

F_2 genotype	Reaction of F_2 genotypes (1998-99) used to get F_3 families	Predicted genotypes of F_2 plant used to get F_3 families	F_3 segregation (2000-2001) Number of plants R	S	S : R	X^2	Predicted genotypes of F_3 plants used to get F_4 families	F_4 segregation (2000-2001) Number of plants R	S	S : R	X^2
1	S	SS	0	49	-	-	SS	0	48	-	-
2	S	Ss	12	43	3 : 1	0.1514	Ss	11	39	3 : 1	0.1066
3	S	Ss	16	54	3 : 1	0.0761	Ss	15	56	3 : 1	0.3802
4	S	Ss	15	38	3 : 1	0.1572	Ss	13	46	3 : 1	0.1412
5	S	Ss	10	39	3 : 1	0.3333	SS	0	44	-	-
6	S	Ss	9	37	3 : 1	0.4637	SS	0	53	-	-
7	S	Ss	11	41	3 : 1	0.2306	ss	56	0	-	-
8	R	ss	54	0	-	-	ss	48	0	-	-
9	R	ss	52	0	-	-	ss	49	0	-	-
10	R	ss	55	0	-	-	ss	56	0	-	-
11	R	ss	54	0	-	-	ss	69	0	-	-

R : Resistant; S : Susceptible

: 1 resistant ratio. This indicated that the F_2 plant must have been heterozygous i.e., Ss and also that the F_3 plant in 1999-2000 from which F_4 progeny family was derived was also heterozygous i.e. Ss. Similar results were obtained in the F_3 progeny family and F_4 progeny family of the F_2 plant No. 3 and 4, and the segregation ratios were perfect fit to 3 susceptible : 1 resistant ratio. Thus, the F_2 plant No. 2, 3 and 4 were having genotype Ss and the F_3 plants from which the F_4 progeny families were derived had the same heterozygous genotype i.e. Ss. Thus, on the basis of reaction of parents, F_1 and segregation ratios in F_3 and F_4 it can be concluded that the resistance is governed by a single recessive gene in UM-305 while susceptibility is governed by its dominant allele in UM-117.

The F_2 plant No. 5 and 6 (Table 2) had susceptible reaction in 1998-99. The F_3 progeny family of these two plants showed segregation for susceptible and resistant plants. The F_3 progeny family of F_2 plant No. 5 segregated into 39 susceptible : 10 resistant plants while the F_3 progeny family of plant No. 6 also segregated into 37 susceptible : 9 resistant plants. These ratios were tested by Chi-square test (Table 4), which indicated that these ratios were perfect fit to the 3 susceptible : 1 resistant ratio. This again confirmed that resistance is governed by a single recessive gene and susceptible reaction by its dominant allele. In the F_4 progeny families of these two F_3 families (derived from F_2 plants no 5 and 6) (Table 4) all the plants were susceptible which indicated that the F_3 plants used to derive F_4 progeny families were homozygous dominant (SS).

Another F_2 plant No. 7 had susceptible reaction in 1998-99. The F_3 progeny family derived from this plant showed segregation for susceptible and resistant plants. The ratio of susceptible to resistant plants in this F_3 progeny was 41:11 which was good fit to 3:1 ratio with X^2 value of 0.2306, which was non-significant (Table 4). This again indicated that resistance was governed by a single recessive gene and susceptibility by its dominant allele. The segregation in this F_3 family indicated that the parental F_2 plant of this progeny i.e. F_2 plant No. 7 was heterozygous and had the genotype Ss.

Interestingly, the F_4 family derived from the F_2 plant No.7 had only resistant plants and there was not a single susceptible plant. This indicated that the F_4 family was derived from the recessive homozygous (ss) plant of F_3 progeny in the year 1999-2000. This again confirmed that the resistance is governed by single recessive gene.

The resistant F_2 plants that were used to derive F_3 and F_4 progeny families were the F_2 plant No. 8, 9, 10 and 11 (Table 4). All the F_3 progeny families derived from these F_2 plants did not show segregation for susceptibility and resistance. All the plants in these F_3 families were resistant. This indicated that all the four parental F_2 plants of these F_3 families i.e. F_2 plant No. 8, 9, 10 and 11 were recessive homozygous for the resistance gene. Moreover, the F_4 families derived from the resistant F_2 plant No. 8, 9, 10 and 11 had only resistant plants which indicated that these F_4 families were derived from the recessive homozygous F_3 plants of F_3 generation of the year 1999-2000. The recessive homozygous nature of the four F_2 plants and their F_3 and F_4 progeny plants alongwith the susceptible reaction type of the F_1 (Table 2 and 4) again confirmed that the resistance is governed by single recessive gene.

On the basis of reaction type of parents, F_1s, the segregation ratios in F_2 and segregation ratios in F_3 and F_4 families in the cross (UM-305 x UM-117) it can be concluded that resistance to powdery mildew in UM-305 is governed by a single recessive gene and the susceptible reaction type in UM-117 is governed by its dominant allele. Similar findings of monogenic recessive control of powdery mildew resistance were reported in garden peas (Narsinghani 1979; Sokhi *et al.* 1979; Singh *et al.* 1983; Janila *et al.* 2001). The high yielding resistant F_5 lines identified in the experiment IV will be useful in further breeding programme.

In the present investigation inheritance pattern of growth habit was also considered along with the inheritance pattern of powdery mildew resistance in order to verify the possibility of linkage between the genes governing these two characters. In fenugreek, indeterminate growth habit is under the control of single dominant gene and the determinate growth habit under its recessive allele (Raje *et al.* 2001). In experiment I and II all F_1s showed indeterminate growth habit, which indicated that indeterminate growth habit was dominant to determinate growth habit.

In the experiment II (*rabi*, 1998-99), F_2 generation showed segregation ratio of 3 indeterminate : 1 determinate which was a good fit to 3:1 monohybrid ratio (Table 3). On the basis of dominance of indeterminate growth habit in F_1 generation and a good fit to a 3 indeterminate : 1 determinate ratio in F_2 generation of both the crosses it was again concluded that indeterminate growth habit was under the control of single dominant gene and determinate growth habit by its recessive allele as earlier reported by Raje *et al.* (2001) based on the same genetic material used in the experiment II of present investigation. The gene symbols *Dgh* and *dgh* are assigned for indeterminate and determinate growth habit, respectively. Thus, both resistance to powdery mildew and determinate growth habit were under the control of single recessive gene. It was thought to verify whether the genes for resistance to powdery mildew and determinate growth habit are linked. For this, in the F_2 generation segregation for both the characters i.e. powdery mildew resistance and growth habit were considered simultaneously and the data was tested by Chi-square test for independent assortment. For this F_2 plants were classified into four categories i.e. susceptible with indeterminate growth habit, susceptible with determinate growth habit, resistant with indeterminate growth habit and resistant with determinate growth habit. The F_2 data has been presented in Table 3. Chi-square test was applied to test the goodness of fit to the classical dihybrid F_2 phenotypic ratio of 9:3:3:1. The observed 9 susceptible indeterminate : 3 susceptible determinate : 3 resistant indeterminate : 1 resistant determinate ratio was fitting at a very high level to a 9:3:3:1 dihybrid classical ratio. Thus, it was concluded that the gene for powdery mildew resistance and gene for determinate growth habit assort independently of each other and are not linked. Moreover, the F_3 progeny families of the F_2 plants having determinate growth habit bred true while the F_3 families derived from F_2 plants having indeterminate growth habit segregated for indeterminate and determinate growth habit or bred true. This again confirmed that the indeterminate growth habit was under the control of single dominant gene and determinate growth habit under its recessive allele. In the experiment IV (Table 4) out of 11 F_3 families, in three F_3 families i.e. family No. 2,6 and 8, all the plants had determinate growth habit. Moreover, all the three-progeny F_4 families derived from these three F_3 families were also having all the plants with determinate growth habit. This confirms that determinate growth habit was under the control of single recessive gene. On considering both the characters simultaneously it was observed that all the four categories of plants i.e. indeterminate susceptible, indeterminate resistant, determinate susceptible and determinate resistant were present in the F_3 and F_4 family plants. This confirmed again that these two characters assort independently of each other.

On the basis of present investigation it can be concluded that the resistance to powdery mildew in UM-305 is governed by single recessive gene and susceptible reaction to powdery mildew in UM-117 is governed by its dominant allele. It is also concluded that gene for resistance to powdery mildew and gene for determinate growth habit assort independent of each other and are not linked.

References

Anonymous 1995 Ninth Annual Report 1994-95. All India Co-ordinated Spices Improvement Project. Dept. of Plant Breeding and Genetics (R.A.U). Jobner.

Anonymous 1996 Tenth Annual Report 1995-96. All India Coordinated Spices Improvement Project. Dept. of Plant Breeding and Genetics (R.A.U), Jobner.

Anonymous 1997 Eleventh Annual Report 1996-97. All India Coordinated Spices Improvement Project. Dept. of Plant Breeding and Genetics (R.A.U), Jobner.

Anonymous 1998 Twelfth Annual Report 1997-98. All India Coordinated Spices Improvement Project, Dept. of Plant Breeding and Genetics (R.A.U), Jobner.

Anonymous 2000 Fourteenth Annual Report 1999-2000. All India Coordinated Spices Improvement Project, Dept. of Plant Breeding and Genetics (R.A.U), Jobner

Janila P, Sharma B & Mishra S K 2001 Inheritance of powdery mildew resistance in pea (*Pisum sativum* L.). Indian J. Genet. 61:129-131.

Mehta N, Thakral K K & Gandhi S K 1994 Varietal behaviour of fenugreek to powdery mildew and their differential response to fungicides. Plant Disease Research 9:112-115.

Narsinghani V G 1979 Inheritance of powdery mildew in peas (*Pisum sativum* L). Indian J. Hort. 36:471-2.

Raje R S, Singh D & Dashora S L 2001 Inheritance of growth habit and multipoddedness in fenugreek (*Ttrigonella foenum-graecum* L). Indian J. Genet. 61:183-184.

Raje R S, Singhania D L & Singh D 2002 Inheritance of powdery mildew resistance in fenugreek. Indian J. Genet. 62:175-176.

Saxena P, Ahmad S T & Shashi Chauhan 1984 Field screening of methi germplasm against powdery mildew. Indian J. Mycol. Pl. Pathol. 41:85-86.

Singh R B, Singh M N, Singh U P & Singh R M 1983 Inheritance of resistance to powdery mildew in pea and its use in breeding. Indian J. agric. Sci. 53:855-859.

Sokhi S S, Jhooty J S & Bains S S 1979 Resistance in pea against powdery mildew. Indian Phytopathol. 32 : 571-574.