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Breeding for *Fusarium* wilt resistance in safflower

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Abstract
Safflower wilt caused by *Fusarium oxysporum* f.sp. *carthami* is one of the major diseases responsible for a substantial loss in yield of the crop. The pathogen being mainly soil-borne is quite difficult to manage using the conventional methods and so the development of resistant varieties seems to be the only option. During 2006-07 winter season a screening program for wilt resistance with BC_4F_6 progenies was undertaken.

The results indicated that Nira (susceptible check) and HUS-305 (resistant check) recorded on an average 92% and 22% wilting respectively. None of the entries were immune or resistant to wilt. Six entries viz. WR-11-4-6, WR-8-24-12, WR-8-19-10, WR-4-6-5, WR-5-20-10 and WR-8-17-9 were moderately resistant, 31 entries were moderately susceptible and 15 were susceptible to wilt. The check varieties Bhima, A-1 and Nira were highly susceptible, while HUS-305 and Manjira were moderately susceptible and CO-1 moderately resistant in both the trials. The highest seed yield was recorded by the entry WR-11-6-14 (1854 kg/ha) which was on par with 20 other entries in trial-I for seed yield. In trial-II maximum seed yield was recorded by the entry WR-8-24-4 (2015 kg/ha) which was on par with 10 other entries for seed yield.

Introduction
Safflower (*Carthamus tinctorius* L.) is known to be infected by 57 pathogens including 40 fungi, two bacteria, 14 viruses and one mycoplasma (Patil *et al*. 1993). Amongst the fungal diseases *Fusarium* wilt caused by *Fusarium oxysporum* Schlecht f.sp. *carthami* is one of the most notorious (Klisiewicz and Houston 1962). The infected plants show symptoms such as wilting, leaf yellowing and head blight (Weiss 1983). The disease can cause severe damage and yield reductions (Smith 1996). The wilt disease is economically the most important disease of safflower in India. The repeated use of wilt-susceptible traditional varieties is a major factor causing increased wilt incidence in this crop (Sastry *et al.* 1993). The use of environmentally sound methods, such as breeding has become increasingly important in this new era of environmental awareness (Mundel and Huang 2003). The present investigation deals with breeding for fusarial wilt resistance in safflower while maintaining its yield level.

Material and Methods
Material for the present investigation has originated from a breeding programme for wilt resistance in safflower initiated at NARI in the year 1996-97. The parental lines for the wilt resistance programme comprised of widely adapted high-yielding but wilt-susceptible safflower cultivar Nira, the wilt-resistant genotypes 237550 and C 2614-4-1-7 and moderately wilt-resistant cultivar HUS-305. Inheritance of wilt resistance in safflower, studied in the ongoing programme revealed the role of inhibitory gene action in expression of *F. oxysporum* resistance and suggested the backcross method of breeding as is usually practised for the transfer of a dominant gene-controlled trait (Singh *et al*. 2001). Therefore, continuous backcrossing of a cross between susceptible X resistant genotypes with the recurrent parent (wilt-susceptible cultivar) up to BC_4 was done to transfer the wilt resistance to it. Each backcross F_1 generation was raised under wilt-sick plot conditions in order to screen them for wilt resistance and subsequently the wilt-resistant F_1 plants were crossed with the recurrent parents. The backcrosses were subjected to generation advancement under wilt-sick plot conditions in the years that followed. During the course of generation advancement, about 1000-1200 plants in BC_4 F_2 and 300-400 plants in F_3, F_4 and F_5 generations of each cross entry were raised. Segregating populations were handled by resorting to individual plant as well as bulk population

selection methods. The poor yielders irrespective of their level of resistance to Fusarium were discarded.

The material for the present paper comprised of 50 BC_4F_6 selections which were evaluated in two trials to reduce spatial variability. Each trial was laid out in a randomized block design with two replications under wilt-sick plot conditions during winter 2006-07 and consisted of 31 entries including wilt-susceptible and resistant checks Nira and HUS-305 respectively in addition to four widely adapted cultivars as checks. Each entry was sown in two rows of 5 m length with spacing of 45 cm between rows and 20 cm between hills with 4-5 seeds/hill. No thinning of the excess plants was performed, to maintain a high population density for each entry in the trial. The wilt-susceptible check Nira and resistant check HUS-305 were sown after every five test entries in each replication. The standard cultural practices were followed to raise a good crop. The observations on initial plant stand were recorded at 20 days after sowing and those on final plant stand at the time of harvesting. The difference between the initial and final plant populations of different entries was used to calculate the percentage disease intensity. The angular transformed values of disease intensity for each entry were computed and the same have also been furnished in the tables. The observations on seed yield were recorded by considering the whole plot for each entry.

Results and Discussion

The screening of BC_4F_6 entries of trial 1 as furnished in Table 1 revealed significant differences between the entries for percent disease intensity and seed yield indicating thereby, the variability among the entries for the two traits. The wilt-susceptible check Nira recorded the highest wilting of 92.4% among the entries screened, confirming the high and uniform infestation of *Fusarium* in the soil and effectiveness of screening the entries for resistance to *Fusarium*. The percent disease intensity among the entries screened ranged from 7.7 to 34.0%. All the test entries recorded significantly lower disease intensity as compared to the susceptible check Nira (92.4%). The comparison of the test entries against wilt-resistant check HUS-305 for percent disease intensity showed that 18 entries out of the 25 screened gave numerically higher resistance to wilt than HUS-305. The entry WR-11-4-6 recorded the maximum resistant reaction to *Fusarium* as it exhibited the lowest wilting of 7.7% which was followed by the entry WR-8-24-12 (8.3%) and WR-8-19-10 (9.2%). As far as seed yield is concerned, 12 entries recorded significantly higher seed yield than the highest yielding check CO-1. The entry WR-11-6-14 recorded the maximum seed yield of 1854 kg/ha, which was followed by the entries WR-5-20-10 (1837 kg/ha), WR-11-4-6 (1812 kg/ha) and WR-8-8-4 (1770 kg/ha). Considering both reaction to wilt and seed yield, entry WR-11-4-6 was found to be the most promising one since it recorded the maximum resistance to *Fusarium* (7.7% disease intensity) and gave seed yield at par with the highest yielding entry in the trial. This entry will be tested in multilocation yield evaluation trial for its suitability and adaptability for commercial production.

The results of BC4F6 entries in trial 2 as furnished in Table 2, also exhibited significant differences between entries for percent disease intensity and seed yield suggesting the existence of significant variation among the entries screened for the traits concerned. The wilt-susceptible check Nira exhibited the maximum percent disease intensity of 89%. The test entries gave a range of 9.6 to 37.8% for percent disease intensity. All the test entries evaluated showed significantly lower percent disease intensity as compared to the susceptible check Nira (89%). Nineteen entries of the 25 evaluated exhibited significantly lower percent disease intensity than the wilt-resistant check HUS-305. The entry WR-4-6-5 recorded the significantly highest resistance to *Fusarium* wilt, as it showed the minimum disease intensity of 9.6%, which was followed by the entries WR-5-20-10 (10.4%), WR-8-17-9 (10.7%) and WR-8-17-2 (11.9%).

With regard to seed yield, seven entries of the 25, gave significantly higher seed yield than the highest yielding check HUS-305. The significantly highest seed yield of 2015 kg/ha was given by the entry WR-8-24-4 which was followed by the entry WR-4-6-10 (2006 kg/ha). These two were found to be the most promising entries in the trial as they not only recorded the maximum seed yield but also exhibited reaction to wilt at par with the entry exhibiting the highest resistance to wilt. These two entries in addition to the entry WR-11-4-6 from trial 1 will be screened for their yielding ability and reaction to wilt in multilocation trials. The best among them will be released as a cultivar for commercial production. In addition, the wilt-resistant entries can also be utilized as sources of resistance to wilt in a breeding program for developing high yielding wilt-resistant cultivars in safflower. Similar reports regarding resistance to *Fusarium* wilt in safflower and developing wilt-resistant genotypes have been made earlier (Sastry and Chattopadhyay 2003, Singh *et al*. 2001, Singh *et al*. 2003).

The presence of stable and durable resistance to *Fusarium* wilt accompanied with high seed yield is a desirable strategy for sustainable safflower cultivation.

Table 1: Screening of BC_4F_6 selections for wilt resistance (Trial-I)

Sr. No.	Entries	Seed yield (Kg/ha)	Initial plant stand (000^s/ha)	Final plant stand (000^s/ha)	Percent disease intensity*
1.	WR-11-1-1	1496	302	247	18.9 (24.8)
2.	WR-8-8-4	1770	323	270	16.8 (23.9)
3.	WR-8-20-2	1530	307	236	23.4 (28.4)
4.	WR-11-4-6	1812	281	259	7.7 (15.4)
5.	WR-8-13-36	1129	282	231	15.5 (21.0)
6.	WR-11-7-14	1197	279	218	21.8 (27.8)
7.	WR-8-17-15	1442	307	267	13.1 (21.2)
8.	WR-4-19-1	1230	309	229	25.2 (29.9)
9.	WR-8-22-2	1363	291	231	20.3 (26.5)
10.	WR-4-23-4	1452	331	218	34.0 (34.9)
11.	WR-5-20-8	1207	288	207	28.8 (31.9)
12.	WR-8-19-3	1420	320	270	15.6 (23.3)
13.	WR-5-22-1	1417	318	260	18.1 (25.1)
14.	WR-4-13-7	1753	312	253	18.8 (25.7)
15.	WR-5-20-10	1837	262	209	20.3 (26.8)
16.	WR-11-1-5	1449	293	251	14.3 (21.9)
17.	WR-5-20-13	1543	283	250	11.3 (18.3)
18.	WR-8-19-10	1557	313	284	9.2 (17.6)
19.	WR-8-19-14	1388	304	257	15.3 (22.9)
20.	WR-11-1-2	1550	273	201	26.1 (30.3)
21.	WR-8-18-7	1630	299	251	16.0 (23.5)
22.	WR-11-6-14	1854	284	222	21.9 (27.9)
23.	WR-8-14-6	1744	319	280	12.7 (20.2)
24.	WR-8-24-12	1594	311	284	8.4 (16.3)
25.	WR-11-4-11	1520	293	251	14.3 (22.1)
26.	HUS-305	1121	248	193	21.6 (27.5)
27.	Manjira	1030	269	170	37.4 (37.4)
28.	CO-1	1153	266	234	11.7 (19.7)
29.	Nira	26	270	21	92.4 (74.3)
30.	Bhima	370	223	100	57.7 (49.4)
31.	A-1	144	210	63	70.0 (56.9)
	General Mean	1346	290	226	28.16
	CD at 0.05	496	63	64	14.28
	SEm ±	172	22	22	4.95
	C.V.%	18.04	10.61	13.89	24.86

* Figures in parentheses are angular transformed values

Table 2: Screening of BC_4F_6 selections for wilt resistance (Trial-II)

Sr. No.	Entries	Seed yield (Kg/ha)	Initial plant stand (000^s/ha)	Final plant stand (000^s/ha)	Percent disease intensity*
1.	WR-8-17-2	1420	309	272	11.9 (20.2)
2.	WR-11-6-12	1590	311	250	18.8 (25.5)
3.	WR-8-24-4	2015	300	258	14.0 (22.0)
4.	WR-8-17-9	1742	319	284	10.7 (18.9)
5.	WR-11-1-4	1511	309	247	20.2 (26.6)
6.	WR-5-20-10	1214	290	259	10.4 (18.7)
7.	WR-5-2-10	1663	318	259	18.8 (25.3)
8.	WR-8-10-11	1566	347	283	18.1 (22.5)
9.	WR-8-22-11	1421	321	233	27.4 (31.5)
10.	WR-11-6-1	1349	321	257	20.1 (26.6)
11.	WR-5-3-12	1189	313	236	24.8 (29.3)
12.	WR-9-12-7	1376	319	273	14.5 (22.2)
13.	WR-4-19-7	1634	303	263	13.2 (21.3)
14.	WR-9-18-3	1578	293	230	21.3 (27.3)
15.	WR-4-6-10	2006	314	268	15.3 (22.7)
16.	WR-10-26-3	1469	311	233	25.0 (30.0)
17.	WR-5-22-12	1217	311	241	22.6 (28.3)
18.	WR-9-20-7	1598	286	210	26.5 (31.0)
19.	WR-5-2-15	1562	318	253	20.0 (26.4)
20.	WR-9-9-3	1583	317	198	37.8 (37.9)
21.	WR-5-2-9	1703	326	272	16.7 (23.7)
22.	WR-4-6-5	1330	322	291	9.6 (18.1)
23.	WR-4-19-14	1508	334	283	15.5 (23.1)
24.	WR-4-13-3	1770	269	210	21.5 (27.4)
25.	WR-5-20-11	1584	314	274	12.8 (20.8)
26.	HUS-305	1498	301	222	25.9 (30.6)
27.	Manjira	1201	244	179	27.0 (31.3)
28.	CO-1	1243	309	262	15.1 (24.8)
29.	Nira	97	296	32	89.0 (70.8)
30.	Bhima	642	263	92	65.2 (53.9)
31.	A-1	434	236	106	55.1 (47.9)
	General Mean	1416	305	233	28.6
	CD at 0.05	437	57	60	9.13
	SEm $\pm$	151	20	21	3.16
	C.V.%	15.18	9.16	12.52	15.65

* Figures in parentheses are angular transformed values

References

Klisiewicz, J. M. and Houston, B. R. 1962. *Fusarium* wilt of safflower. Plant Dis. Rep. 46 (10) : 748- 749.

Mundel, H. H. and Huang, H. C. 2003. Control of major diseases of safflower by breeding for resistance and using cultural practices. In: Advances in Plant Disease Management, Research Signpost, Trivandrum, Kerala, India. pp. 293-310.

Patil, M. B., Shinde, Y. M. and Attarde, K. A. 1993. Evaluation of safflower cultures for resistance to alternaria leaf spot (*Alternaria carthami*) and management strategies. Proc. Third International Safflower Conference, June 14-18, Beijing, China. pp. 269-278.

Sastry, R. K., Rego T. J. and Burford, J. R. 1993. Effects of cropping systems on wilt of safflower. P. Proc. Third International Safflower Conference, June 14-18, Beijing, China. pp. 636-645.

Sastry, R. K. and Chattopadhyay, C. 2003. Development of *Fusarium* wilt-resistant genotypes in safflower (*Carthamus tinctorius*). European Journal of Plant Pathology. 109: 147-151.

Singh V., Galande, M. K., Deshpande, M. B. and Nimbkar, N. 2001. Inheritance of wilt (*Fusarium oxysporum* f. sp. *carthami*) resistance in safflower. In: Bergman J. W., Mundel H. H., Flynn C. R., Jensen J. L., Grings E. E., Tanaka D. L., Riveland N. R., Johnson R. C. and Hill A. B. (eds.) Proc. Fifth International Safflower Conference, July 23-27, Williston, ND, and Sidney, MT, USA. pp. 127-131.

Singh, Vrijendra, Rathod, D. R., Deshpande, M. B., Deshmukh, S. R. and Nimbkar, N. 2003. Breeding for wilt resistance in safflower. ISOR National Seminar – Stress Management in Oilseed Crops. pp. 368-369.

Smith, J. R. 1996. Safflower. American Oil Chemists' Society Press, Champaign, IL USA, 606 p.

Weiss, E. A. 1983. Chapter 6. Safflower. In: Tropical Oilseed Crops. Tropical Agriculture Series, Longman, London and New York. p. 233-251.