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EFFECT OF FUSARIUM WILT DISEASE ON SEED YIELD OF ADVANCE LENTIL GENOTYPES

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Wilt caused by *Fusarium oxysporum* is considered as the most damaging soil disease of lentil. Current study was carried out to see the effect of Fusarium wilt disease on seed yield of advance lentil genotypes in wilt sick plot. Fourteen entries were tested in national yield uniform trial (NUYT), 11 in adaptation yield trial (AYT), 15 in advance line yield trial-I (ALYT-I), 12 in advance line yield trial-II (ALYT-II) and 25 in preliminary yield trial (PYT) along with standard check. Mean seed yields of 891.04, 1281.78, 1153.81, 1080.04 and 789.45 kg ha^{-1} were observed in NUYT, AYT, ALYT-I, ALYT-II and PYT, respectively. The average disease intensity in various trials was more than 30%. Disease severity was less than 10% in nine genotypes. This was also confirmed by high negative values of their losses over check. Out of these, the genotypes, 03501, NL 96625, NL 66184, NL 66106 and NL 31742/03 produced highest seed yield of 2945 kg ha^{-1}, 2667 kg ha^{-1}, 2490 kg ha^{-1}, 2390 kg ha^{-1} and 2691 kg ha^{-1} respectively. The higher yield may be attributed to inbuilt resistance against such a drastic disease. Overall, seed yield and disease incidence were negatively correlated in all yield trials. The genotypes under severe wilt attack produced no seed yield. It is clear from this study that resistance/tolerance is available in lentil that can be selected based on high yield potential along with minimum yield losses for further breeding.
Keywords: *Lens culinaris*, fusarium wilt, disease severity, yield

INTRODUCTION

Lentil (*Lens culinaris* Medikus), is the second major Rabi pulse crop in Pakistan after chickpea and contains about 25% protein (Zia *et al*., 2011). Being a leguminous crop, lentil restores the fertility of soil through biological nitrogen fixation and increases seed yield from 23-32% and straw yield up to 16% (Webb and Hawtin, 1981; Muscolo *et al*., 2014). World production of lentil primarily comes from India (36%), Canada (17%) and Turkey (15%). Other neighboring countries like Nepal (14%), Bangladesh (3%) and Iran (3%) have also quite higher share by production compared to Pakistan (7.25 thousand tons). In Pakistan, during 2003-04, the area under lentil crop was 35.1 thousand hectares yet decreased by 20.7% during 2004-05 and 26.0% during 2005-06 (Anonymous, 2009). There was a slight increase (8.54%) during 2006-07 but it was not stable. In 2007-08, again there was a decrease in area up to 20.9%. Similar trends of decrease were also observed in overall production of the country. Lentil production decreased up to 33.6% during 2006-07 as compared to the previous years. This declining lentil production is attributed to various agronomic, environmental and pathological factors. Regarding pathological factors, lentil wilt, rust, Ascochyta blight, collar rot and root rot are important diseases that affect the production of lentil in Pakistan (Chaudhry *et al*., 2008). Among fungal diseases wilt caused by *Fusarium oxysporum* F. sp. *Lentis,* is believed to be the most important constraints (Taylor *et al.*, 2007) and has been found to cause 50 percent yield losses under field conditions in India (Ilyas, 1999).

Fusarium wilt caused by several races of *F. oxysporum* is considered the most damaging soil born disease of lentil worldwide (Khare, 1981; Tosi and Cappelli, 2001). This disease may cause 5-10% yield losses but some times severe damage may result complete crop failure under favorable conditions for disease development (Chaudhary and Amarjit, 2002; Anonymous, 2009), especially in a warm spring and dry and hot summer (Agrawal *et al*., 1993). The damage also depends upon the crop stage being affected and severity of the pathogen (Taylor *et al*., 2007). The disease occurs both at seedling and flowering stages. In early sown crops wilting may occur in November but the disease ceases during the cool months of December and January. In February it starts to reappear and maximum incidence of disease occurs in March (Bashir and Malik, 1988). Under favorable conditions susceptible genotypes showed 100 % yield losses in Pakistan (Chaudhry *et al*., 2008). It is very difficult to control wilt through the use of chemicals or cultural practices. Breeding for host resistance is the most effective, efficient and environment friendly method (Akhtar *et al*., 2010, 2011, 2012). Most of the commercial varieties in field have been rendered susceptible to Fusarium wilt in Pakistan and research is in progress to screen resistant/tolerant genotypes (Chaudhry *et al*., 2008). Fusarium wilt of lentil is a serious disease inflicting heavy losses every year however, a literature survey revealed the scarcity of information's regarding its occurrence in Pakistan. Moreover, losses assessment due to Fusarium wilt in lentil has not yet been carried in Pakistan (Ilyas, 1999). So, present study will be helpful to understand the losses due to this disease and also to manage the disease to avoid future losses.

MATERIALS AND METHODS

Seed yield losses due to wilt disease were assessed under natural field condition in different yield trials viz., national uniform yield trial (NUYT) with 14 entries, adaptation yield trial (AYT) with 11 entries, advance line yield trial-I (ALYT-I) with 15 entries, advance line yield trial-II (ALYT-II) with 12 entries and preliminary yield trial (PYT) with 25 entries. These trials were conducted on wilt sick piece of land at NIAB, Faisalabad during the year 2008-09. Material of national trial was provided by the national coordinator, Pulses Program, NARC, Islamabad. Genotypes included in different yield trials along with their genetic makeup are listed in Table 1. Each trial was planted separately in a randomized complete block design (RCBD) with 3 replicates. Four rows of 4 meter length of each genotype (plot size 4.8 m^2) were sown keeping inter and intra row spacing of 30 and 10 cm, respectively. Standard agronomic practices like application of fertilizer, irrigation and manual hoeing were followed. Plant population was counted 2 weeks after sowing when there were no disease symptoms. Based on visual observation in respect of disease symptoms, total number of wilt infected plants was noted when crop approached near physiological maturity. Seed yield of each genotype on plot basis was recorded from normal plants not affected by wilt. Association of wilt pathogen (*F. oxysporium*) with the wilted plants was confirmed by isolating the *F. oxysporium* from randomly selected plants of each entry on gram meal agar medium.

Percent disease intensity was worked out from the exact count of normal and wilted plants following Shah (2009). Losses in seed yield were estimated as under:

$$\text{Seed yield losses (kg ha}^{-1}\text{)} = \frac{\text{Seed yield of normal plants (kg ha}^{-1}\text{)} \times \text{N. of wilted plants}}{\text{Number of normal plants}}$$

Percent yield losses over standard check were determined as percent difference in disease intensity of a genotype from the standard check. Mean and standard deviation were calculated following Steel *et al*. (1997). Correlation of disease intensity with seed yield was also estimated to understand their relationship following Steel *et al*. (1997).

RESULTS AND DISCUSSION

Seed yield was highest in NUYT (2945 kg ha^{-1}). More than 30% disease intensity was noted in all yield trials; and was maximum in ALYT-II (55.73%). Overall, the average disease intensity in all the trials was less as compared to the check. The genotypes 03501 (NUYT), NL 96625 (AYT), NL 66184 (AYT), NL 66106 (ALYT-II) and NL 31742/03 (PYT) produced maximum seed yield of 2945, 2667, 2490, 2390 and 2691 kg ha^{-1}, respectively. Disease severity was less than 10% in nine genotypes, viz. 03501, AZRC-08-1, NARC 08-4 (in NUYT), NL 96625, NL 66184 (in AYT), NL 66106, NL 2103, NL 0214 (in ALYT-II) and NL 31742/03 (in PYT). This was also indicated by high negative values of their losses over the check. Out of these, the genotypes 03501, NL 96625, NL 31742/03, NL 66184 and NL 66106 had high yield potential in the present disease scenario.

In NUYT, seed yield ranged from 52 to 2945 kg ha^{-1} (Table 1). Genotypes, 03501 produced maximum seed yield (2945 kg ha^{-1}) followed by NARC 08-3 (2178 kg ha^{-1}) which was greater than the standard check (151 kg ha^{-1}). The highest seed yield of these genotypes may be due to the less attack of wilt disease. The minimum seed yield of 52 kg ha^{-1} was produced by NARC 06-1, which was due to heavy attack of disease (70.97%) on this genotype. Mean seed yield of NUYT was 891.04 kg ha^{-1}. Disease intensity ranged from 3.82 to 81.46% and seed yield losses observed were from 30.82 to 497.16 kg ha^{-1}. Disease intensity had negative and significant correlation with seed yield ($r = -0.75$) which is an indication of how much this disease is a threat to lentil crop. Negative correlation of viral disease infection with yield has also been observed by Anjum *et al*. (2005a). It may be concluded that wilt susceptible genotypes will definitely produce less yield as compared to the ones less susceptible to such a drastic disease. Percent losses over check showed negative trend which indicates that all genotypes in this trial had less disease incidence compared to the check (Table 1). Only one genotype NARC 06-1 showed a positive trend indicating that this genotype had more incidence of disease than the check.

In AYT, seed yield ranged from 574 to 2667 kg ha^{-1} (Table 1). Maximum seed yield was produced by NL 96625 (2667 kg ha^{-1}) and NL 66184 (2940 kg ha^{-1}) compared to the check (522 kg ha^{-1}). Disease intensity for NL 96625 and NL 66184 was observed to be 9.30 and 5.41%, respectively, which revealed that the genotypes less affected by wilt, produced greater yield with those which were severely affected. Our results suggest that the potential of these genotypes may be exploited in lentil breeding for incorporating resistance against wilt disease into high yielding adapted, but susceptible varieties; or can be released as commercial varieties after testing their performance in NUYT. Genotype NL 96475B produced minimum seed yield (574 kg ha^{-}1) which may be due to the severe attack of wilt disease (89.37%). Such a high intensity of Fusarium wilt disease is more than the range of intensity of a viral disease of lentil (6-61%) reported by Anjum *et al*. (2005b). Overall seed yield losses ranged from 273.49 to 4825.91 kg

Table 1. Percent intensity of Fusarium wilt disease, seed yield of normal plants and yield losses in different yield trials.

Sr. No.	Genotypes	Trial/Origin	Disease intensity (DI %)	Seed yield (Kg ha^{-1})	Yield losses (Kg ha^{-1})	% Losses over check	Correlation of yield with DI%
1	00518	LNUYT§/AARI	47.10	432	385.00	-27	-0.75*
2	1512	//	11.64	1311	172.64	-82	
3	1505	//	81.46	113	497.16	26	
4	03501	//	7.52	2945	239.47	-88	
5	DL 10	//	50.43	139	141.04	-22	
6	AZRC 08-1	LNUYT/AZRC	3.82	775	30.82	-94	
7	NL 96475 A	LNUYT/NIAB	13.90	912	147.22	-78	
8	NL 96475 B	//	17.28	675	141.00	-73	
9	NARC 08-1	LNUYT/NARC	39.60	498	326.56	-39	
10	NARC 08-2	//	57.45	332	447.84	-11	
11	NARC 08-3	//	15.02	2178	384.96	-77	
12	NARC 08-4	//	8.91	1961	191.78	-86	
13	NARC 06-1	//	70.97	52	127.47	10	
	NIAB Masoor 2006	Standard Check	64.57	151	275.76		
	Mean ± SD		**34.98± 26.82**	**891.04± 892.69**	**250.62± 138.69**	**-49± 41**	
14	NL-96	AYT§/NIAB	32.39	1052	504.06	-52	-0.90*
15	NL 96475A	//	64.59	611	1114.50	-4	
16	NL 96617	//	52.77	1048	1170.37	-22	
17	NL 96625	//	9.30	2667	273.49	-86	
18	NL 96635	//	21.47	1902	519.85	-68	
19	NL 96639	//	56.98	844	1117.98	-16	
20	NL 66184	//	5.41	2490	142.26	-92	
21	NL 96475B	//	89.37	574	4825.91	32	
22	NL 9864	//	45.06	1161	952.68	-33	
23	NL 9916	//	22.06	1230	348.08	-67	
	NIAB Masoor 2006	Standard Check	67.58	522	1088.65		
	Mean ± SD		**42.45± 26.60**	**1281.78± 748.68**	**1096.17± 1294.88**	**-41± 39**	
24	NL-9857	ALYT-I§/NIAB	27.21	1212	453.18	-65	-0.89*
25	NL 9864	//	22.70	1699	498.71	-71	
26	NL 96680	//	42.31	739	541.86	-46	
27	NL 9727	//	29.89	1323	563.90	-62	
28	NL 03-38-1	//	23.37	1301	396.98	-70	
29	NL 03-5	//	21.02	1664	442.85	-73	
30	NL 03-54	//	28.31	930	367.08	-64	
31	NL 03-82	//	25.47	1096	374.30	-68	
32	NL 03-90	//	21.94	1136	319.29	-72	
33	NL 9877	//	29.97	1069	457.56	-62	
34	NL 96102	//	30.87	1154	515.18	-61	
35	NL 9877	//	34.28	999	521.01	-56	
36	NL 9848	//	33.79	1214	619.74	-57	
37	NL 2136	//	13.53	1664	260.45	-83	
	NIAB Masoor 2006	Standard Check	78.57	107	391.51		
	Mean ± SD		**30.88± 14.83**	**1153.81± 398.98**	**448.24± 97.77**	**-65± 09**	
38	NL-66106	ALYT-II§/NIAB	9.04	2390	237.56	-89	-0.88*
39	NL 66172	//	11.95	1164	158.01	-85	
40	NL 2048	//	98.39	-	-	22	
41	NL 2052	//	98.04	-	-	22	
42	NL 2003	//	98.69	-	-	22	
43	NL 2004	//	56.54	40	52.35	-30	
44	NL 2005	//	97.92	-	-	21	
45	NL 2007	//	96.97	-	-	20	
46	NL 2103	//	3.55	1795	66.04	-96	
47	NL 0195	//	11.11	950	118.74	-86	
48	NL 0214	//	5.95	1165	73.69	-93	
	NIAB Masoor 2006	Standard Check	80.60	56	231.80		
	Mean ± SD		**55.73± 43.53**	**1080.04± 855.17**	**134.03± 77.48**	**-34± 56**	

Cont.....

Sr. No.	Genotypes	Trial/Origin	Disease intensity (DI %)	Seed yield (Kg ha^{-1})	Yield losses (Kg ha^{-1})	% Losses over check	Correlation of yield with DI%
49	NL 30211/03	PYT§/NIAB	30.43	812	272.35	-58	-0.83
50	NL 30212/03	//	44.87	461	258.75	-37	
51	NL 31742/03	//	6.84	2691	185.00	-90	
52	NL 38022/03	//	84.69	34	103.21	18	
53	NL 43532/03	//	80.93	19	45.49	13	
54	NL 43721/03	//	93.70	6	49.88	31	
55	NL 3852/03	//	31.04	700	240.32	-57	
56	NL 3853/03	//	29.43	827	266.45	-59	
57	NL 5212/03	//	24.76	1101	290.61	-65	
58	NL 5223/03	//	30.03	1073	354.21	-58	
59	NL 5225/03	//	25.28	753	203.39	-65	
60	NL 5232/03	//	21.51	1230	277.25	-70	
61	NL 5234/03	//	19.32	1102	221.22	-73	
62	NL 5235/03	//	24.71	1123	295.46	-66	
63	NL 5242/03	//	25.96	802	223.23	-64	
64	NL 5412/03	//	30.91	525	179.50	-57	
65	NL 5432/03	//	29.71	1255	409.04	-59	
66	NL 5463/03	//	27.41	833	246.96	-62	
67	NL 8221/03	//	27.27	872	256.85	-62	
68	NL 3835/03	//	27.78	954	287.28	-61	
69	NL 5421/03	//	26.67	1005	288.51	-63	
70	NL 8229/03	//	22.87	1144	276.19	-68	
71	NL 19011/03	//	63.22	246	258.57	-12	
72	NL 19012/03	//	96.72	4	56.10	35	
	NIAB Masoor 2006	Standard Check	71.69	163	413.25		
	Mean ± SD		**39.91± 25.50**	**789.45± 573.49**	**308.41± 110.32**	**-46± 35**	
	Grand Mean		**40.79**	**1039.22**	**447.49**	**-47**	**-0.80***

§LNUYT = lentil national uniform yield trial; AYT = adaptation yield trial; ALYT-1 = advance line yield trial-1; ALYT-2 = advance line yield trial-2; PYT = preliminary yield trial; * Significant at 0.05 probability level.

ha^{-1} with a mean value of 1096.17 kg ha^{-1} (Table 1). Maximum yield loss was observed in NL 96475B (4825.91 kg ha^{-1}). Out of ten genotypes, only one (NL 96475B) showed a positive trend in percent losses over check. This means that seed yield losses for this genotype were greater than those of check. Furthermore, intensity of wilt disease exhibited negative and significant correlation with seed yield (r = -0.90).

In ALYT-I, seed yield ranged from 739 to 1699 kg ha^{-1}. A minimum seed yield of 739 kg ha^{-1} was observed for NL 96680 with 42.31% disease intensity and maximum seed yield was noted for NL 9864 (1699 kg ha^{-1}) and NL 2136 (1664 kg ha^{-1}) which were greater than the check (107 kg ha^{-1}). The intensity of disease ranged from 13.53 to 42.31% with a mean value of 30.88%. The maximum disease intensity of 42.31% was observed in the genotype NL 96680. Yield losses ranged from 260.45 to 619.74 kg ha^{-1} (Table 1). Disease intensity showed consistency in the incidence of wilt disease on genotypes included in this trial. A consistent trend was also observed for seed yield which is because of same sequence of disease intensity among the genotypes included in this trial. This phenomenon was not observed in other trials. Minimum yield losses (260.45 kg ha^{-1}) were observed in the genotype NL 2136. Seed yield was found maximum for the genotype NL 9864 (1699 kg ha^{-1}) indicating its high yield potential. However, percent disease intensity was 22.70%. This genotype may be selected from this trial as high yielding line with moderate yield losses. Correlation between disease intensity and seed yield was negative and significant (r = -0.89). All fourteen genotypes exhibited negative values for percent yield losses over check ranging from -46% to -83% with a trial mean of -65%. This indicates that these genotypes may produce highest yield potential in wilt affected soil.

In ALYT-II, seed yield ranged from 40 to 2390 kg ha^{-1} (Table 1) with maximum produced by genotype, NL 66106 (2390 kg ha^{-1}) followed by NL 2103 (1795 kg ha^{-1}) which was greater than check NIAB Masoor 2006 (56 kg ha^{-1}). The superiority in yield of these two genotypes is both due to their genetic yield potential and less disease incidence (9.04% and 3.55%, respectively). Minimum seed yield of 40 kg ha^{-1} was produced by NL 2004 with 56.54% disease intensity. In this trial, mutant genotypes i.e. NL 2048, NL 2052, NL 2003, NL 2005 and NL 2007 produced no seed yield due to the severe attack of wilt (more than 95%). Disease intensity ranged from 3.55% to 98.69% with a mean value of 53.73%. Seed yield losses ranged from 52.35 to 237.56 kg ha^{-1} (Table 1) with a mean value of 134.03 kg ha^{-1}. It can be concluded that in this trial different genotypes behave differently to wilt disease, even some genotypes produced no yield at all as mentioned earlier due to the heavy attack of disease. This is also evident from positive values of their percent losses over check (Table 1). Strong negative and significant correlation of wilt disease with seed yield (r = -0.88) was also observed (Table 1). Anjum *et al*. (2005a) reported negative and significant correlation of seed yield with pod dehiscence and viral diseases. It is, therefore, suggested that breeding for inbuilt resistance against Fusarium wilt must be attempted for improving the sustainable yield potential of lentil genotypes.

Among twenty four genotypes evaluated in PYT, the genotype NL 31742/03 produced maximum yield (2691 kg ha^{-1}) which was greater than standard check (163 Kg ha^{-1}) with minimum disease intensity of 6.84%. Seed yield in this trial ranged from 4 to 2691 kg ha^{-1}. Minimum yield of 4 kg ha^{-1} was produced by NL 19012/03 that was due to severe attack of wilt (96.72%). As evident from our results, genotypes with low disease intensity produce higher yield as compared to those, more prone to wilt. Disease intensity ranged from 6.84% to 96.72% with a mean value of 39.91%. Seed yield losses ranged from 45.49 to 409.04 kg ha^{-1} (Table 1) with a mean value of 308.41 kg ha^{-1}. Out of twenty four genotypes, viz; NL 38022/03, NL 43532/03, NL 43721/03 and NL 19012/03 had positive values for their percent losses over check, indicating their susceptible behavior. Correlation of wilt disease with seed yield was also of high magnitude, negative and significant (r = -0.83) (Table 1).

Wilt disease, if appears once anywhere, makes soil wilt sick and causes considerable losses in succeeding cropping seasons. Present results indicated that seed yield and disease incidence was found negatively correlated with each other. The genotypes under severe attack of wilt produced no yield. Such relationship may be useful in lentil breeding to assess the yield potential of lentil genotypes on wilt sick lands. The high yielding genotypes with less disease intensity have inbuilt genotypic resistance against fusarium wilt which may be exploited as source of resistance in lentil breeding program for the development of wilt resistant varieties. Our results are in line with the findings of Eujayl *et al*. (1998), Stoilova and Chavdarov (2006) Chaudhary *et al*. (2008), and Shah (2009) who reported the resistance of lentil genotypes against Fusarium wilt.

From the above discussion, it can be concluded that out of 72 genotypes evaluated in different yield trials grown in wilt sick pieces of land, the genotypes NL 96625, NL 66184, NL 66106 and NL 31742/03 produced maximum seed yield (more than 2300 kg ha^{-1}) in the presence of wilt disease, so these can be used in future breeding programme of lentil as a resistance/tolerance source and may be released as commercial varieties after checking their performance in lentil growing regions of the Punjab province.

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