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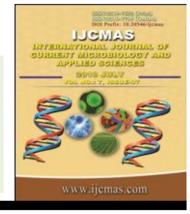

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Studies on Correlation and Path Analysis for Spot Blotch Disease Resistance and Yield Parameters in F_2 Segregating Population of Durum Wheat (*Triticum durum* L.)

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The experiment was conducted to examine the nature of association among seed yield, its component traits and spot blotch resistance traits in F_2 population of the cross Bijaga yellow x NIDW-295. Simple correlation analysis revealed that the significant positive correlation of spot blotch resistance traits such as disease severity (%) and AUDPC showed that highly significant and negative association with number of tillers per plant, spike length, number of spikelets per spike, number of grain per spike, thousand grain weight and seed yield per plant implies that indirect selection for these traits helps in development of spot blotch resistant genotypes. From the path coefficient analysis based on correlations, it was observed that the maximum direct positive effect on seed yield per plant was exhibited by thousand grain weight followed by number of tillers per plant, number of grains per spike and spike length whereas spot blotch severity (%) and AUDPC showed direct negative effects on seed yield and its component characters. Thus, these characters plays significant role in the formation of selection criteria to enhance the resistance to spot blotch in bread wheat. Present investigation suggests that selection in F_2 population of Bijaga yellow x NIDW-295 will be effective in selecting superior plants for yield parameters and spot blotch resistance in evolving high yielding disease resistant genotype in *durum* wheat.

Introduction

Wheat (*Triticum aestivum* L.) is the staple food for a large part of the world population. In India the crop ranks second in terms of total production next to rice. It plays an important role in ensuring food security in this densely occupied region of the world. India accounts for 13 per cent of the total global wheat production. The demand for wheat will grow faster than any other major crop as it is estimated that around 1,050 mt. of wheat will be required globally forever growing population by 2020 (Kronstad, 1998), while Indian demand will be between 105 to 109 million tonnes (Shoran *et al.*, 2005).

The wheat production and productivity in India are continuously challenged by various wheat diseases. Among all the diseases, spot blotch of wheat is considered as one of the most important disease in environments which are characterized by high temperature (coolest month greater than 17°C) and high humidity. However, it is also gradually instigating serious concerns among places with irrigated, low rainfall and temperate growing conditions. Globally, an estimated 25 million hectares of wheat cultivated land is affected by spot blotch disease (van Ginkel and Rajaram, 1998). Due to drastic changes in climatic conditions in the last two or three decades, spot blotch has emerged as a major threat to wheat production in India. Spot blotch is affecting nearly 9 million ha of the warm North-Eastern Plain Zone where millions of resource-poor farmers grow wheat after rice (Joshi *et al.*, 2004). The disease is gradually extending towards the North-West, the major wheat growing areas in the country (Chand *et al.*, 2003).

The average yield losses due to spot blotch disease for susceptible cultivars in farmer fields are reported to vary from 15.5 to 19.6 per cent (Dubin and van Ginkel, 1991; Saari, 1998) to up to 100 per cent under severe infection conditions (Mehta 1998; Srivasta *et al.*, 1971). The spot blotch disease is gaining much importance in Karnataka state of India because of the occurrence of severe outbreak every year (Kulkarni, 1985) where majority of area under tetraploid wheat cultivation characterized by dry and irrigated weather conditions. Generally, tetraploid wheat is endowed with natural resistance leaf and black stem rusts but are highly susceptible to spot blotch. The studies on genetic understanding and association of spot blotch resistance in tetraploid wheats are limited and not well documented so far.

The ultimate aim of any plant breeding programme is to improve the desirable trait of agronomic and economic importance. Grain yield is a complex trait and highly influenced by many genetic factors and environmental fluctuations. It is caused by multiplicative interactions of the different factors, therefore, selection for these factors may be helpful in controlling/managing the disease and on the other hand, several yield contributing traits are also influenced by the spot blotch disease. These component characters are inter-linked and in this inter-linked complex genetic system, selection practiced for one individual character might subsequently bring about a simultaneous change in other. Thus, the correlation and path coefficients analysis was carried out among yield, yield contributing and spot blotch disease resistant traits in F_2 segregating population of cross Bijaga Yellow x NIDW-295 to understand the association between component characters and their relative contribution to spot blotch resistance which is essential to bring a rational improvement for spot blotch resistance in durum wheat.

Materials and Methods

The experimental material for the present study comprised of the F_2 population of cross involving spot blotch susceptible (Bijaga yellow) and resistant (NIDW-295) genotypes.

The present study was conducted in the experimental area of Agricultural Research Station (ARS), Arabhavi, University of Agricultural Sciences, Dharwad considered as hotspot for spot blotch screening located between 15^o 26' N latitude and 75^o 07' E longitude. The F_2 seeds of cross Bijaya yellow x NIDW 295 were space planted along with parents Bijaga yellow and NIDW-295. The susceptible checks *viz.*, Kiran, Bijaga Yellow and Amruth were also sown as an infector row to increase and uniform spread of disease in an experimental field. The F_2 seeds and checks were sown in a row length of one meter length with the help of a dibble, keeping plant to plant distance of 20cm and row to row distance of 10 cm during *Rabi* 2014-15. The recommended agronomic practices were followed during the crop growth period. Each individual F_2 plants were tagged to record the observation on spot blotch disease, yield and yield attributing traits.

Disease evaluation and disease assessment

The spore suspension was prepared from 15 days old culture of *Bipolaris sorokiniana* multiplied on sorghum seeds (Joshi *et al.*, 1969) and was inoculated at tillering stage, flag leaf stage and anthesis stages on Zodok scale (1974) crop growth stages during evening hours following the method of Chaurasia *et al.*, (1999). Plots were irrigated immediately after inoculation to maintain a high relative humidity for facilitating disease establishment and development in field. The five individual disease score was taken at weekly intervals using the double digit scale (00-99) developed as a modifications of Saari and Prescott's (1975) at three different growth stages (GS), *viz.*, GS 63 (beginning of anthesis to half complete), GS 69 (anthesis complete) and GS 77 (late milking). Percentage disease severity is estimated based on the following formula. (Sharma and Duveiller, 2007)

$$\% \text{ severity} = (D_1/9) \times (D_2/9) \times 100$$

The area under disease progress curve (AUDPC) based on disease severity over time was estimated using the following formula (Roelfs *et al.*, 1992).

$$AUDPC = \sum_{i=1}^{n} [\{(Y_i + Y_{(i+1)})/2\} \times (t_{(i+1)} - t_i)]$$

Where, Y_i = disease level at time t_i, $t_{(i+1)} - t_i$ = time (days) between two disease scores,
n = number of dates on which spot blotch was recorded.

Data was recorded on seed yield per plant and its attributing traits *viz.*, days to fifty percent flowering, days to maturity, number of tillers per plant, number of productive tillers per plant, plant height, peduncle length, awn length, spike length, number of spikelets per spike, number of grains per spike, thousand-grain weight and seed yield per plant.

Correlation coefficient analysis was done according to Robinson *et al.*, (1951) and the methodology proposed by Dewey and Lu (1959) was followed to carry out path analysis for grain yield and its components keeping grain yield as dependent variable and other parameters as independent variables.

$$\text{Phenotypic correlation (\%)} = r_{xy}(p) = \frac{Cov(XY)_p}{\sqrt{\sigma^2(X)_p \times \sigma^2(Y)_p}} \times 100$$

Where,

COV_{xy} - phenotypic covariances between x and y characters,
σ^2_x - phenotypic variances of x character and
σ^2_y - phenotypic variances of character y

Results and Discussion

Correlation studies among traits give an insight in to the relationship among traits, particularly, yield contributing traits which help in plant breeding during selection. An estimate of direct and indirect effects of different independent traits on a dependent trait, say yield, is provided by path coefficient analysis. Thus, it helps in determining the cause of association among traits. The path coefficient analysis helps in indirect selection for genetic improvement of yield because of its low heritability direct selection would not be very effective for yield improvement. Thus, information on association of yield attributes and spot blotch resistance and their direct and indirect on yield were analyzed in F_2 segregating population of cross Bijaga Yellow x NIDW-295.

The correlation coefficients among different characters were worked out and are presented in (Table 1). The seed yield per plant showed positive significant phenotypic correlation with number of tillers per plant (0.4934), number of productive tillers per plant (0.4875), plant height (0.203), peduncle length (0.1403), spike length (0.2297), thousand grain weight (0.5368), number of seeds per spike (0.1833) and number of grains per spike (0.3131) and negative phenotypic association with days to 50 per cent flowering (-0.0072), days to maturity (-0.0492). The negative association of grain yield with days to 50 per cent flowering and days to maturity suggests that early flowering/heading and maturing genotypes would give higher grain yield. The positive correlation coefficients of grain yield with most of the traits implying that improving one or more of the traits could result in high grain yield for durum wheat. The highly significant association of seed yield per plant was observed in the present study (Table 1) as reported by Khodarahmpour *et al.*, (2011) and Olfati *et al.*, (2010). It suggests that these characters should be included in selection criterion for genetic improvement for wheat genotypes. Association analysis revealed that the spot blotch disease severity (%) has significant and negative correlation with all the important yield and yield attributes *viz.*, grain yield (-0.1453), thousand grain weight (-0.0745), spike length (-0.1385), number of spikelets per spike (-0.2349), number of grain per spike (-0.2213). number of tillers per plant (-0.1274) and number of productive tillers per plant (-0.1370). Simultaneously, disease severity (%) has shown negative correlation with days to 50 per cent heading (-0.0071) and positive correlation with traits such as days to maturity (0.0877). plant height (0.0277), peduncle length (0.0646) and awn length (0.0372). Area under disease progress curve (AUDPC) showed significant and negative association with the grain yield (-0.1602), thousand grain weight (-0.1139), spike length (-0.1557), number of spikelets per spike (-0.2438), number of grain per spike (-0.2213) and number of tillers per plant (-0.1062) while AUDPC exhibited a positive association with the traits like plant height (0.0261), peduncle length (0.0706), awn length(0.0360) and days to maturity (0.0697).

In the present investigation, it was observed that spot blotch resistance traits such as disease severity (%) and AUDPC exhibited significant and negative association with seed yield per plant and its attributing traits *viz.*, number of tillers per plant, spike length, number of spikelets per spike, number of grain per spike and thousand grain weight. These obtained results are in confirmation with the findings of Meena *et al.,* (2014), Singh *et al.*, (2015) and Singh *et al.*, (2016). These results indicated that spot blotch disease had significant affect on reduction of seed yield per plant and its component traits in wheat. Therefore, it could be concluded that the negative association of disease with important yield components as well as yield *per se* will have bearing on over all yield of the crop.

Table.1 Correlation among yield, yield attributes and spot blotch resistance in the F_2 (Bijaga Yellow x NIDW-295) population

	DFF	DTM	NTP	NPTP	PH	PL	SL	AL	NSS	TGW	NGS	AUDPC	DS	SYP
DFF	1.0000													
DTM	-0.0795	1.0000												
NTP	-0.0217	-0.0232	1.0000											
NPTP	-0.0107	-0.0305	0.9415**	1.0000										
PH	0.0699	0.0513	0.2031**	0.2041**	1.0000									
PL	-0.0365	-0.1121*	0.0789	0.0898	0.4529**	1.0000								
SL	-0.0400	0.0024	0.1475**	0.1353*	0.2360**	0.2169**	1.0000							
AL	0.0269	-0.0293	0.0717	0.0546	0.1528**	0.0550	0.0955	1.0000						
NSS	-0.0134	-0.0241	0.2620**	0.2491**	0.1600**	-0.0973	0.3542**	0.0216	1.0000					
TGW	-0.0579	-0.0264	0.1802**	0.1980**	0.2094**	0.1460**	0.0977	0.0042	0.1158*	1.0000				
NGS	-0.0483	-0.0394	0.1914**	0.2002**	0.0503	0.0079	0.1214*	-0.0790	0.2851**	0.2033**	1.0000			
AUDPC	-0.0492	0.0697	-0.1062*	-0.0993	0.0261	0.0706	-0.1557**	0.0360	-0.2438**	-0.1139*	-0.2198**	1.0000		
DS	-0.0071	0.0877	-0.1274*	-0.1370*	0.0277	0.0646	-0.1385**	0.0372	-0.2349**	-0.0745	-0.2213**	0.8046**	1.0000	
SYP	-0.0072	-0.0492	0.4934**	0.4875**	0.203**	0.1403**	0.2297**	0.027	0.1833**	0.5368**	0.3131**	-0.1602**	-0.1453**	1.0000

Significant at * P<0.05, ** P<0.01, respectively.

DFF – Days to 50 per cent flowering
DM – Days to maturity
NTP – Number of tillers per plant
NPTP – Number of productive tillers/plant
PH – Plant height (cm)
PL – Peduncle length (cm)
SL – Spike lengths (cm)
AL – Awn length (cm)
NSS – Number of spikelet's per spike
TGW- Thousand grain weight (g)
NGS- Number of grains per spike
AUDPC- Area under disease progress curve
DS - Disease severity (%)
SYP - Seed yield per plant (g)

Table.2 Phenotypic path coefficients analysis of yield, yield attributing and spot blotch resistance characters in F_2 (Bijaga yellow x NIDW-295) population

	DFF	DTM	NTP	NPTP	PH	PL	SL	AL	NSS	TGW	NGS	AUDPC	DS	Correlation with Seed yield per plant (r)
DFF	0.0348	-0.0028	-0.0008	-0.0004	0.0024	-0.0013	-0.0014	0.0009	-0.0005	-0.0020	-0.0017	-0.0017	-0.0002	-0.0072
DTM	0.0017	-0.0209	0.0005	0.0006	-0.0011	0.0023	0.0000	0.0006	0.0005	0.0006	0.0008	-0.0015	-0.0018	-0.0492
NTP	-0.0071	-0.0076	0.3261	0.3070	0.0662	0.0257	0.0481	0.0234	0.0854	0.0588	0.0624	-0.0346	-0.0415	0.4934***
NPTP	-0.0007	-0.0019	0.0582	0.0618	0.0126	0.0056	0.0084	0.0034	0.0154	0.0122	0.0124	-0.0061	-0.0085	0.4875***
PH	0.0007	0.0005	0.0019	0.0020	0.0096	0.0043	0.0023	0.0015	0.0015	0.0020	0.0005	0.0002	0.0003	0.203***
PL	-0.0004	-0.0012	0.0008	0.0010	0.0048	0.0106	0.0023	0.0006	-0.0010	0.0015	0.0001	0.0007	0.0007	0.1403**
SL	-0.0054	0.0003	0.0198	0.0181	0.0316	0.0291	0.1340	0.0128	0.0475	0.0131	0.0163	-0.0209	-0.0186	0.2297***
AL	-0.0016	0.0017	-0.0042	-0.0032	-0.0089	-0.0032	-0.0056	-0.0583	-0.0013	-0.0002	0.0046	-0.0021	-0.0022	-0.027
NSS	0.0008	0.0015	-0.0161	-0.0153	-0.0098	0.0060	-0.0218	-0.0013	-0.0614	-0.0071	-0.0175	0.0150	0.0144	0.1833***
TGW	-0.0247	-0.0112	0.0767	0.0843	0.0892	0.0622	0.0416	0.0018	0.0493	0.4257	0.0866	-0.0485	-0.0317	0.5368***
NGS	-0.0069	-0.0056	0.0272	0.0284	0.0072	0.0011	0.0172	-0.0112	0.0405	0.0289	0.1421	-0.0312	-0.0314	0.3131***
AUDPC	0.0014	-0.0019	0.0029	0.0027	-0.0007	-0.0019	0.0043	-0.0010	0.0067	0.0031	0.0061	-0.0275	-0.0222	-0.1602**
DS	0.0000	-0.0002	0.0003	0.0004	-0.0001	-0.0002	0.0004	-0.0001	0.0006	0.0002	0.0006	-0.0021	-0.0026	-0.1453**

R square = 0.7112, Residual effect = 0.3942

X_1 – Days to 50 *per cent* flowering
X_2 – Days to maturity
X_3 – Number of tillers/plant
X_4 – Number of productive tillers/plant
X_5 – Plant height (cm)
X_6 – Peduncle length (cm)
X_7 – Spike lengths (cm)
X_8 – Awn length (cm)
X_9 – Number of spikelet's per spike
X_{10} -1000 grain weight
X_{11}- Number of grains per spike
X_{12}- AUDPC
X_{13}- Disease severity (%)
X_{14}- Correlation with seed yield per plant (r)

It reflects that the negative selection for disease severity and AUDPC will result in to less damage to crop and consequently to improved yield. The same result was reported by Malik. (2008). The disease severity and AUDPC have highly significant positive correlation between them. However, disease severity (%) and AUDPC had shown significant negative correlation with seed yield and its attributing traits. Thus, indirect selection of lines/genotypes high tillers per plant, higher seed yield per plant, thousand grain weights, of will be an effective selection strategy to enhance the yield with increased level of resistance to spot blotch.

Association of various plant traits with the trait of major and economic importance like seed yield is the consequence of their direct and indirect effects. Therefore, it becomes imperative to partition such associations into measures of direct and indirect effects of component traits through path coefficient analysis. Path co-efficient analysis aims at partitioning the correlation coefficient into direct and indirect effect which probes the cause and effect relationship (Table 2). Path analysis showed that the maximum direct positive effect on seed yield per plant was exhibited by thousand grain weight (0.4257) followed by number of tillers per plant (0.3261), number of grains per spike (0.1421) and spike length (0.1340).

The direct negative effect on seed yield per plant was exerted by days to maturity, awn length, number of spikelets per spike, AUDPC and disease severity (%). The spot blotch resistance traits such as disease severity (%) and AUDPC were also had indirect negative effects on seed yield via other characters like days to maturity, plant height, peduncle length and awn length coupled with high significant and negative correlation with the seed yield per plant. A relatively low or moderate value of residual effect (0.3942) was estimated in path coefficient analysis. This was in compliance with the earlier reports from Nagireddy and Jyothula (2009) and Singh *et al.,* (2012). Therefore, the characters which show negative direct effect may play significant role in the formation of selection criteria for breeding the resistant genotypes. Thus, direct selection for these traits in order to achieve yield improvement will be fruitful.

In conclusion, the negative correlation of spot blotch resistance traits such as disease severity (%) and AUDPC with seed yield per plant was mainly due to its direct negative effect on seed yield indicated that the negative effect of spot blotch disease on seed yield per plant. The disease severity (%) and AUDPC showed indirect negative effects on seed yield via other characters like number of tillers per plant, productive tillers per plant, spike length, thousand-grain weight, number of spikelets per spike and number of grains per spike. Since resistance is the main aim, it is therefore, interesting to note that characters showing negative and direct association with disease severity may be quite useful for the formation of selection criteria for breeding of spot blotch resistant varieties, but characters showing positive and direct effect with spot blotch severity (%) and AUDPC are yield contributing traits. It is therefore, suggested that by sacrificing such important yield components the breeder has to put more emphasis on other yield contributing characters in such a way so that yield is not sacrificed for resistance. Therefore, the characters which show negative direct effect and highly significant negative association with spot blotch resistance may play major important role in the formation of indirect selection criteria for breeding the spot blotch resistant genotypes.

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