Pak. J. Bot., 51(1): 73-80, 2019. DOI: 10.30848/PJB2019-1(28)

CORRELATION AND PATH ANALYSIS OF MORPHOLOGICAL PARAMETERS CONTRIBUTING TO YIELD IN RICE (*ORYZA SATIVA*) UNDER DROUGHT STRESS

MUHAMMAD ASIM BHUTTA[1], SANA MUNIR[1], MUHAMMAD KAMRAN QURESHI[1*], AHMAD NAEEM SHAHZAD[2], KASHIF ASLAM[3], HAMID MANZOOR[3] AND GHULAM SHABIR[3]

[1]*Department of Plant Breeding & Genetics, Faculty of Agricultural Sciences & Technology, Bahauddin Zakariya University, Multan*
[2]*Department of Agronomy, Faculty of Agricultural Sciences & Technology, Bahauddin Zakariya University, Multan*
[3]*Institute of Molecular Biology & Biotechnology, Bahauddin Zakariya University, Multan*
[*]*Corresponding author's email: m.k.qureshi81@gmail.com*

Abstract

Current experiment is conducted to study correlation and path analysis among morphological traits and their contribution towards yield under normal and drought stress using twenty diverse rice genotypes at Department of Plant Breeding and Genetics, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan. Genotypes were significantly varied (p<0.01-0.05) in yield and yield related traits. In addition, growth (Plant height, r^2 = 0.17**) and yield attributes such as panicle length (0.49**), grains/ panicle (0.69**), grain weight/ panicle (0.99**), tillers/ plant (0.14) and 1000-grain weight (0.11*) were positively correlated in all genotypes under normal or drought stress conditions. Among genotypes, highest plant height was observed in Basmati-140 (43.13cm) comparatively to lowest was found in Sufaida 20 (26.27cm) under drought condition. Plant height was significantly reduced under drought stress than control condition in Munji 78B-1 from 64.71cm to 35.30cm, respectively. Drought drastically affected the yield/plant in different genotypes. Under drought stress, Harandi-379, Munji-78B-1 and Basmati-242 performed well for yield/plant with values of 7.54g, 7.69g and 9.28g, respectively. Grain weight/panicle showed highest positive effect (0.914 and 0.788) on yield/ plant and followed by spikelet fertility (0.022 and 0.056) under both drought and normal conditions, respectively. Results suggest that grain weight/panicle, 1000 seed weight and plant height can be used as selection indices for drought resistance.

Key words: Correlation, Path analysis, Morphological traits, Yield, *Oryza sativa*, Drought stress.

Introduction

Rice, a cereal crop, ranks second among staple food crops in Pakistan. It is mainly grown for its grain containing about 80% starch, 7% protein and 12% water (Hossain *et al.,* 2015). In addition to minerals such as copper, iron, calcium, magnesium, manganese and zinc, the rice grain contains niacin, riboflavin and thiamine (Oko *et al.,* 2012). In international market, Pakistani rice is considered best on account of its aroma and good cooking quality. Basmati and coarse type shared 40% and 60% of total rice production, respectively in Pakistan. Rice shared 0.6% and 3.1% to cost added in gross domestic product and value addition in agriculture, respectively (Anon., 2016).

About 42 stresses, both biotic and abiotic, affect the rice yield (Sarkar *et al.,* 2006). Drought is a worldwide problem that affects the grain production and quality (Lafitte *et al.,* 2002). Global climate changes manipulate the frequency and extent of hydrological fluctuations, causing floods and drought (Easterling *et al.,* 2007). Drought refers to a condition in which deficiency of rainfall occurs for such a longer period that causes moisture depletion in soil and ultimately decreases in leaf water potential of plant (Kramer, 1980). Many breeders define drought as "a sufficient decrease in water availability in soil that can cause yield reduction" (Fukai & Cooper, 1995; Comas *et al.,* 2013).

Drought drastically affects grain quality and overall yield production by affecting its physiology, morphology, anatomy and biochemistry (Lima *et al.,* 2015). Membrane structure, photosynthesis and pigments contents are affected by drought (Benjamin & Nielsen, 2006).

Rice may suffer from water stress either at vegetative or at reproductive stage. During vegetative stage, decrease in plant height, biomass and number of tillers are affected and leaf rolling occurs in rice (Ji *et al.,* 2012). Under water stress, phytohormones like ethylene are released by plant that inhibit leaf and root growth at initial phase (Basu *et al.,* 2016) and stress occurring before flowering reduces plant yield. At reproductive stage, drought affects grain development and spikelet infertility results in unfilled grains (Kamoshita *et al.,* 2004; Botwright *et al.,* 2008). Drought is responsible for leaf shrinkage and it affects tillering capacity and photosynthesis in plants (Kramer & Boyer, 1995). During grain filling stage, water stress causes early senescence in plant which reduces its filling period (Plaut *et al.,* 2004) leading to yield reduction (Qureshi *et al.,* 2018).

Developmental stage, specie type and drought severity influence the level of susceptibility in crop plant (Demirevska *et al.,* 2009). Small root system and less cuticular wax make rice susceptible to drought (Hirasawa, 1999).

Hence it is necessary to develop tolerant rice varieties which grow well and give better yield even under drought stress (Pantuwan *et al.,* 2002). Several morphological traits, which are controlled by multiple genes, are genetically correlated with yield. Therefore, genotypic and phenotypic correlation estimates can provide facts to the breeders about type of association among yield and yield contributing traits. Path analysis provides data about influencation of each yield contributing trait to yield directly and indirectly under water stress and also permits the breeders to rank the genetic characteristics according to their participation.

Materials and Methods

Twenty rice genotypes (Basmati 122, Harandi 379, Hansraj 62, Sonfine 43, Begmi 51A, Toga 286A, Mushkan 312-2, Basmati 242, Basmati 140, Basmati 376, Basmati 388, Begumi, Munji 78B-1, RB2, Sufaida 20, Jhona 109, Dagar 303, Begumi 302, Kala Bunda 50, Jhona 86) were used. The experiment was conducted in greenhouse at Department of Plant Breeding and Genetics, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan (2014). Rice seeds were sown in plastic pots having length and width of 60.96 cm and 27.94 cm, respectively. Three plants were maintained in pots after germination. Three pots per replication or fifteen plants per replication were used for data collection of genotypes. Two water regimes were used: irrigated (control) and water stress condition using completely randomized design (CRD) with three (3) replications. Foliar application of fertilizer (N.P.K.) was applied at tillering and panicle initiation stage. Three consecutive drought spells (consecutively one after another of one week duration) were imposed on 4 weeks of old plants. The stressed plants were irrigated at leaf rolling to prevent plants from complete drying. At the time of maturity data was collected for traits like plant height (cm), tillers/ plant, flag leaf area (cm^2), grains/ panicle, panicle length (cm), spikelet fertility, grains weight/ panicle (g), thousand grain weight (g), yield/ plant (gm). The analysis of variance was performed for all traits as described by Steel and Torrie, (1980), to ascertain differences among twenty genotypes under both normal condition and drought stress. Genotypic correlations and phenotypic correlations between various characters were estimated according to Kown and Torrie (1964). Significance of phenotypic environmental correlation was estimated using t-test given by Steel and Torrie (1980). The path analysis using Dewey and Lu (1959) method was performed by SPSS Amos 20 for measuring direct and indirect effects of yield components.

Results and Discussion

Analysis of variance among all characters under normal and drought conditions was performed and results are given in Table 1. Highly significant differences (α=0.01) were observed among all parameters and genotypes except tillers/ plant which was significant (α=0.05) under normal condition (0.19*) and drought condition (0.02*). Hence, these significant differences among genotypes depicted high genetic diversity in studied genotypes, based on estimated traits.

Plant height (cm): Plant height showed highly significant values under normal (168.97**) and drought stress (54.72**) as shown in Table 1. Mean performance of twenty rice genotypes for yield and yield associated characters under normal and stress conditions (Table 2). Plant height significantly highest in Munji 78B-1 (64.71cm) followed by Hansraj 62 (61.2cm) and lowest in Begumi (35.13cm) under normal conditions while under stress highest plant height was given by Basmati 140 (43.13 cm) and lowest by Sufaida 20 (26.26 cm). Genotypes which showed good performance under both conditions are Toga 286A, Basmati 140 and Basmati 376. About 7-45 % plant height reduces under drought stress (Table 2). Correlation analysis depicted that plant height was significantly positive to yield/plant under drought (0.17*) and normal (0.67**) conditions at genotypic level (Table 3) favors the findings of Panja *et al.*, (2017). It was significantly positive to grain weight/panicle, 1000 grain weight, yield/plant and spikelet fertility under drought stress at both genotypic and phenotypic level (Tables 3 and 4), respectively. Plant height had non-significant positive direct effect (0.032) under normal (Fig. 1) but negative direct effect under stress conditions on yield (-.076) (Fig. 2) as proposed by Nayak *et al.*, (2001), Madhavilatha, (2002) and Babu *et al.*, (2012).

Table 1. Mean squares and their significance from analysis of variance, separately under normal and drought conditions.

Characters	Control			Stress		
	Genotypes	Reps	Error	Genotypes	Reps	Error
PH	168.97**	20.35^{ns}	6.91	54.72**	3.11^{ns}	6.38
PL	2.20**	0.47^{ns}	0.18	2.25**	0.20^{ns}	0.16
NOG	932.97**	48.85^{ns}	31.48	632.87**	53.80^{ns}	90.52
NTP	0.19*	0.19^{ns}	0.09	0.02*	0.03^{ns}	0.01
GWP	1.11**	0.52^{ns}	0.23	1.04**	0.76^{ns}	0.18
YP	13.63**	8.19^{ns}	5.19	6.70**	3.26^{ns}	1.27
SF	373.74**	177.17*	38.61	1345.13**	44.50^{ns}	16.56
FLA	88.96**	10.33^{ns}	16.06	847.80**	1.66^{ns}	5.86
GW	61.83**	6.92^{ns}	12.47	115.63**	7.85^{ns}	5.28

* = Significant at $p<0.05$, ** = Highly significant at $p<0.01$, ns = Non-significant, PH = Plant height, PL = Panicle length, NOG = Number of grains/ panicle, NTP = Number of tillers/ plant, GWP = Grain weight/ panicle, YP = Yield/ plant, SF = Spikelet fertility, FLA = Flag leaf area, GW = 1000 grain weight.

Table 2. Mean performances of twenty rice genotypes for yield related traits under control (C) and drought stress (S).

Genotypes	PH			PL			NOG			NTP			GWP		
	C	S	R%	C	S	R%	C	S	R%	C	S	R%	C	S	R%
Basmati 122	59.5	34.4	42.2	16.8	12.1	28.2	141.7	95.1	32.9	3.1	2.4	21.8	6.4	2.8	56.4
Harandi 379	52.0	35.0	32.7	16.0	11.9	25.8	127.3	92.1	27.6	3.5	2.4	32.0	4.1	3.2	23.4
Hansraj 62	61.2	30.4	50.3	13.3	11.8	11.1	131.1	112.4	14.2	3.2	2.5	22.8	3.9	1.9	52.2
Sonfine 43	45.4	33.2	26.9	14.5	10.5	27.5	160.6	99.0	38.4	2.9	2.4	18.1	4.2	2.1	49.4
Begmi 51A	44.1	36.7	16.8	15.6	10.5	32.5	142.3	111.0	22.0	3.0	2.6	13.3	3.7	1.7	53.5
Toga 286A	48.0	40.4	15.8	15.5	10.4	33.0	112.1	79.6	29.0	2.9	2.5	15.7	4.0	1.2	69.7
Mushkan 312-2	47.2	37.5	20.4	15.6	10.9	30.1	124.8	94.7	24.1	3.2	2.5	20.9	5.4	1.5	72.3
Basmati 242	46.5	30.5	34.4	15.3	11.5	24.9	129.3	121.8	5.8	3.4	2.5	25.6	3.9	3.5	9.8
Basmati 140	53.9	43.1	19.9	15.8	11.3	28.3	130.5	119.0	8.8	3.4	2.4	29.4	4.9	2.6	47.2
Basmati 376	44.1	43.1	2.5	16.1	9.9	38.6	124.6	106.0	14.9	3.4	2.3	31.5	4.5	2.3	49.0
Basmati 388	44.9	38.5	14.2	15.9	13.3	16.3	130.5	103.8	20.5	3.5	2.5	28.8	4.5	2.2	51.8
Begumi	35.1	32.7	7.0	16.7	12.7	24.0	133.7	116.2	13.1	3.0	2.6	13.3	4.5	2.6	42.2
Munji 78B-1	64.7	35.3	45.5	16.5	11.9	27.8	133.2	107.7	19.1	3.3	2.6	21.9	5.1	2.9	42.2
RB2	50.3	32.9	34.5	16.5	10.9	33.6	122.5	110.7	9.6	3.3	2.5	24.5	4.5	2.6	42.3
Sufaida 20	50.0	26.3	47.5	16.5	11.1	33.0	129.8	81.3	37.3	3.2	2.5	20.9	4.7	1.8	61.2
Jhona 109	55.0	32.3	41.2	16.5	11.2	32.0	128.5	103.7	19.3	3.3	2.6	20.5	4.7	2.5	47.5
Dagar 303	51.8	30.5	41.2	16.5	11.3	31.8	126.9	72.7	42.7	3.2	2.5	21.9	4.6	1.7	63.7
Begumi 302	52.3	32.4	38.0	16.5	10.1	39.0	128.4	64.7	49.6	3.2	2.5	21.9	4.7	1.7	64.0
Kala Bunda 50	53.0	34.2	35.5	16.5	10.9	34.1	127.9	91.0	28.9	3.3	2.6	20.0	4.7	2.2	53.2
Jhona 86	52.4	34.6	33.9	16.5	10.5	36.6	127.8	93.3	27.0	3.2	2.7	16.7	4.7	1.9	58.7

R% = Reduction percentage; PH= Plant height; PL = Panicle length (cm); NOG = Number of grains/panicle; NTP = Number of tillers/plant, GWP = Grain weight/ panicle (g)

Table 2. (Cont'd.).

Genotypes	SF			FLA			GW			YP		
	C	S	R%	C	S	R%	C	S	R%	C	S	R%
Basmati 122	61.2	39.3	35.8	24.7	18.2	26.2	21.0	17.6	16.4	19.5	6.6	66.0
Harandi 379	71.3	53.6	24.8	22.9	15.6	31.6	20.5	9.4	53.9	14.5	7.5	48.2
Hansraj 62	93.3	69.0	26.1	10.8	7.7	28.2	13.8	9.4	31.8	12.6	4.7	62.6
Sonfine 43	69.3	55.3	20.1	11.8	8.7	25.7	19.1	13.7	28.4	12.5	5.1	59.2
Begmi 51A	76.1	82.6	-8.6	22.4	22.3	0.2	17.5	12.5	28.2	11.1	4.4	59.5
Toga 286A	72.4	61.7	14.7	30.1	20.0	33.2	20.4	8.8	56.5	11.7	3.08	73.8
Mushkan 312-2	75.5	65.8	12.9	23.8	9.4	60.5	14.9	15.3	-2.4	17.1	3.7	78.1
Basmati 242	93.2	67.6	27.4	22.5	9.2	58.8	15.5	11.1	28.3	13.3	9.2	30.4
Basmati 140	84.5	70.4	16.6	22.3	19.0	14.5	17.4	15.8	9.2	17.0	6.2	63.2
Basmati 376	73.8	56.6	23.3	16.8	18.5	-10.2	13.1	10.5	20.1	15.3	5.4	64.4
Basmati 388	84.6	46.0	45.6	15.6	8.6	44.8	16.5	13.9	16.0	15.7	5.2	66.6
Begumi	76.6	60.9	20.4	12.5	10.1	18.8	13.0	11.2	13.6	13.5	6.7	49.8
Munji 78B-1	80.9	49.5	38.8	19.3	10.8	43.5	10.2	7.3	28.5	17.1	7.6	55.1
RB2	89.9	48.6	45.9	17.8	12.1	32.0	11.8	9.7	17.3	14.6	6.1	57.8
Sufaida 20	82.5	51.6	37.4	16.5	6.5	60.6	11.7	10.2	12.2	15.0	4.5	69.8
Jhona 109	84.5	47.8	43.4	17.9	11.7	34.4	11.2	9.0	20.0	15.6	6.3	59.1
Dagar 303	85.6	8.2	90.4	17.4	51.0	-193.1	11.6	18.4	-58.7	15.0	4.3	71.3
Begumi 302	84.2	10.8	87.1	17.3	47.4	-175.0	11.5	10.0	12.6	15.2	4.2	72.2
Kala Bunda 50	84.8	19.8	76.6	17.5	44.6	-155.1	11.4	10.4	8.7	15.3	5.6	63.1
Jhona 86	84.9	11.8	86.1	17.4	63.4	-264.5	11.5	9.4	17.8	15.2	5.1	66.1

R% = Reduction percentage; SF = Spikelet fertility; FLA = Flag leaf area (cm^2), GW = 1000 grain (g); YP = Yield/plant (g)

Table 3. Genotypic correlations under normal (lower diagonal) and drought (upper diagonal) conditions in rice.

Characters	PH	PL	NOG	NTP	GWP	YP	SF	FLA	GW
PH	-	-0.16	0.19	-0.68**	-0.1	0.17*	0.3	-0.02	0.1
PL	-0.33**	-	0.51**	0.15	0.50**	0.49**	0.16*	-0.43**	0.1
NOG	-0.01*	0.27**	-	-0.06	0.69**	0.69**	0.75**	-0.68**	-0.36**
NTP	0.39**	-0.11*	-0.23*	-	0.04	0.14	-0.41**	0.37**	-0.1
GWP	0.38*	0.57**	-0.28*	-0.05	-	0.99**	0.19	-0.37*	-0.23*
YP	0.67**	0.41**	-0.37**	0.24*	0.98*	-	0.17*	-0.32	-0.25*
SF	0.26*	-0.34**	-0.07	0.36**	-0.26*	0.04	-	-0.80*	-0.34*
FLA	0.26*	0.22*	0.06	0.10**	0.28	0.29	-0.22**	-	-0.33*
GW	0.04*	0.09*	0.16*	-0.03	0.04*	0.11*	0.1	0.29	-

* = Significant at $p<0.05$, ** = Highly significant at $p<0.01$, ns = Non-significant; PH = Plant height, PL = Panicle length, NOG = Number of grains/ panicle, NTP = Number of tillers/ plant, GWP = Grain weight/panicle, YP = yield/plant, SF = Spikelet fertility, FLA = Flag leaf area, GW = 1000 grain weight

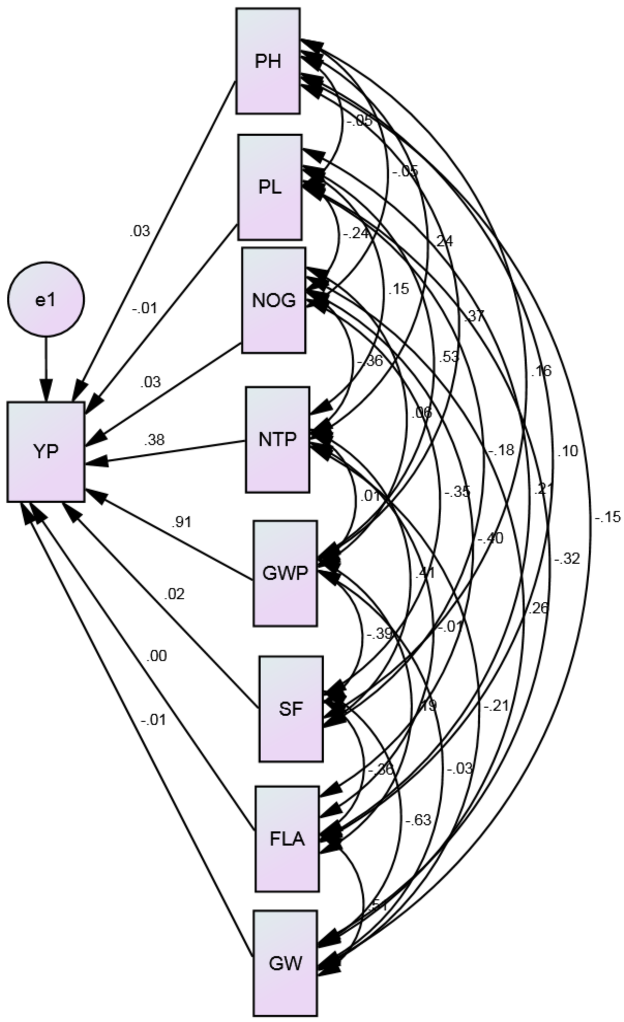

Fig. 1. Path diagram for yield/plant under normal conditions
GW = 1000 grain weight, FLA = flag leaf area, SF = spikelet fertility, GWP = grain weight/ panicle, NTP = number of tillers/ plant, NOG = number of grains/ panicle, PL = Panicle length, PH = Plant height, YP = yield/ plant

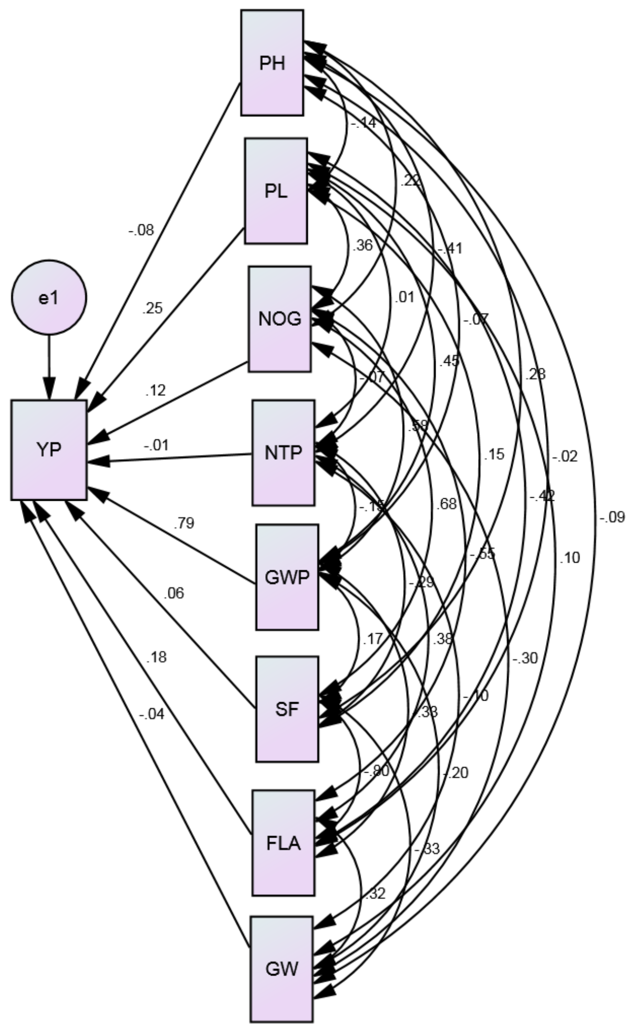

Fig. 2. Path diagram for yield/plant under drought stress
GW = 1000 grain weight, FLA = flag leaf area, SF = spikelet fertility, GWP = grain weight/ panicle, NTP = number of tillers/ plant, NOG = number of grains/ panicle, PL = Panicle length, PH = Plant height, YP = yield/ plant

Number of tillers/plant: Analysis of variance showed significant values for number of tillers/plant under normal (0.19*) and stress condition (0.02*) (Table 1). Tillers/plant showed highest number in Harandi 379 (3.53) and lowest in both Toga 286A (2.93) and Sonfine (2.93) genotypes under normal conditions while under stress maximum number of tillers/plant was shown by Jhona 86 (2.70) and minimum by Basmati 376 (2.33). Jhona 86 and Basmati 140 genotypes showed good performance under both conditions. Near, 13-32% reduction in tillers/plant occurs under drought stress (Table 2). Correlation analysis showed that tillers/plant was significantly positive to yield/plant under drought stress at both genotypic and phenotypic level (0.24**) and (0.57**), respectively but negative correlation with 1000 seed weight (Tables 3 and 4). Reddy *et al.,* (1995; 1997) also find the positive correlation of tillers/plant with yield/plant but negative correlation with thousand seed weight. Tillers/plant had positive and direct effect (.380) on yield under normal conditions (Table 5). While, it had negative direct effect on yield/plant (-.011) under stress conditions and favors the findings of Babu *et al.,* (2012) but had positive indirect effect via spikelet fertility (Table 6).

Flag leaf area (cm^2): Flag leaf area showed highly significant values under normal (88.96**) and stress conditions (847.80**) for analysis of variance (Table 1). Maximum flag leaf area was observed in Toga 286A (30.05 cm^2) and Jhona 86 (63.40 cm^2) and minimum flag leaf area was found in Hansraj 62 (10.79 cm^2) and (7.74 cm^2) under normal and drought stress, respectively. Toga 286A and Basmati 140 genotypes performed well under both conditions i.e. normal or stress. About, 0.22- 60% flag leaf area was reduced under stress (Table 2). Correlation analysis showed that flag leaf area was negatively correlated to yield/plant under drought stress at both genotypic and phenotypic level (-0.32) and (-0.24), respectively (Tables 3 and 4). Flag leaf area had positive and direct effect on yield/plant under normal conditions (.004) and drought condition (0.183) (Tables 5 and 6). Abarshahr *et al.,* (2011) also reported that flag leaf area had positive correlation and direct effect on plant yield. While, it had positive direct effect on yield/plant under stress conditions via spikelet fertility, panicle length and tillers/plant (Table 6).

Table 4. Phenotypic correlations under normal (lower diagonal) and drought (upper diagonal) conditions in rice.

Characters	PH	PL	NOG	NTP	GWP	YP	SF	FLA	GW
PH	-	-0.1	0.17	-0.30*	-0.04	0.09*	0.26	-0.01	0.06
PL	-0.27*	-	0.37**	0.07	0.37**	0.36**	0.15*	-0.39**	0.11*
NOG	0.02*	0.23*	-	-0.03	0.45**	0.45**	0.59**	-0.52**	-0.27*
NTP	0.2*	-0.02*	-0.09*	-	0.01	0.12	-0.22	0.22	-0.09*
GWP	0.22*	0.43**	-0.19	0.06	-	0.98**	0.13	-0.28*	-0.17*
YP	0.33*	0.32**	-0.18**	0.57**	0.79**	-	0.12	-0.24	-0.17
SF	0.26*	-0.26*	-0.05	0.2	-0.28*	-0.01	-	-0.78*	-0.29*
FLA	0.22*	0.09*	0.03	-0.04	0.13	0.02	-0.15	-	-0.31*
GW	0.08*	0.03*	0.08*	0.01	0.06*	0.18*	0.15*	0.12	-

* = Significant at $p<0.05$, ** = Highly significant at $p<0.01$, ns = Non-significant; PH = Plant height, PL = Panicle length, NOG = Number of grains/panicle, NTP = Number of tillers/plant, GWP = Grain weight/panicle, YP = Yield/plant, SF = Spikelet fertility, FLA = Flag leaf area, GW = 1000 grain weight

Table 5. Direct and Indirect effects of various characters to yield per plant under normal condition.

	GW	FLA	SF	GWP	NTP	NOG	PL	PH	YP
GW	**-0.009**	-0.652	-0.014	-0.43	-0.036	0.006	0.521	-0.116	-0.328
FLA	-0.006	**0.004**	0.072	0.004	-0.016	0.002	-0.002	-0.161	.062
SF	0.030	0.003	**0.022**	0.002	-0.170	0.001	-0.003	-0.540	-.020
GWP	0.187	0.179	0.147	**0.914**	-0.006	-0.045	-0.170	-0.078	.073
NTP	0.145	0.007	-0.043	-0.001	**0.380**	0.004	-0.002	0.001	.006
NOG	0.083	-0.039	0.024	-0.294	-0.016	**0.035**	0.056	-0.042	-.130
PL	-0.012	-0.010	-0.016	-0.077	0.033	0.234	**-0.008**	-0.013	.230
PH	0.067	0.140	-0.008	-0.072	0.120	0.150	-0.110	**0.032**	-.005

Residual effect = 0.59, Bold indicates values of direct effect; FLA = Flag leaf area, SF = Spikelet fertility, GWP = Grain weight/panicle, NTP = Number of tillers/plant, NOG = Number of grains/panicle, PL = Panicle length, PH = Plant height, YP = Yield/ plant, GW = 1000 grain weight

Table 6. Direct and Indirect effects of various characters to yield per plant under drought condition.

	GW	FLA	SF	GWP	NTP	NOG	PL	PH	YP
GW	**-0.038**	-0.439	0.005	0.396	-0.38	0.019	-0.004	0.024	0.196
FLA	0.067	**0.183**	-0.236	0.266	0.068	0.074	0.248	0.014	0.222
SF	-0.018	0.001	**0.056**	0.122	-0.261	-0.179	0.282	0.012	-0.268
GWP	0.053	0.266	0.068	**0.788**	0.001	-0.597	0.081	-0.047	0.009
NTP	0.003	0.018	0.289	0.035	**-0.011**	-0.213	0.071	0.142	-0.006
NOG	-0.326	-0.088	053	0.163	-0.015	**0.124**	0.222	-0.044	0.022
PL	-0.264	0.248	0.074	-0.083	0.012	-0.444	**0.252**	-0.007	-0.664
PH	0.108	-0.382	-0.492	-0.047	-0.001	0.080	-0.033	**-0.076**	0.112

Residual effect = 0.62, Bold indicates values of direct effect, FLA = Flag leaf area, SF = Spikelet fertility, GWP = Grain weight/panicle, NTP = Number of tillers/plant, NOG = Number of grains/panicle, PL = Panicle length, PH = Plant height, YP = yield/plant, GW = 1000 grain weight

Grains/panicle: Grains/panicle showed highly significant values under normal (932.97**) and drought stress (632.87**) as shown in Table 1. Grains/panicle was found highest in Sonfine 43 (160.60) followed by Begmi 51A (142.33) and lowest in Toga 286A (112.07) under normal conditions while under stress highest grains/panicle was given by Basmati 242 (121.80) and lowest by Begumi 302 (64.73). Genotypes which showed good performance under both conditions are Basmati 242, Basmati 140 and RB2. About 6-50 % grains/panicle reduces under drought stress (Table 2). Correlation analysis showed that grains/panicle was significantly positive to yield/plant under drought (0.69**) and normal (0.45**) conditions at genotypic level (Table 3) and significantly positive to 1000 grain weight, grains weight/panicle yield/plant and panicle length under drought stress at both genotypic and phenotypic level (Tables 3 and 4), respectively. Earlier researches also reported significant and positive correlation among yield/plant and grains/panicle (Abarshahr *et al.,* 2011; Haider *et al.,* 2012). Path analysis showed that grains/panicle had positive direct effect (0.035) on yield under normal and drought stress (0.124) and followed the findings of Abarshahr *et al.,* (2011) (Tables 5 and 6).

Panicle length (cm): Analysis of variance showed significant values for panicle length under normal (2.20**) and stress condition (2.25**) (Table 1). Panicle length showed highest number in Basmati 122 (16.80 cm) and lowest in Hansraj 62 (13.27 cm) genotypes under normal conditions while under stress maximum number of panicle length was shown by Begumi (12.67cm) and minimum by Basmati 376 (9.87cm). Basmati 388 and Hansraj 62 genotypes showed good performance under both conditions. Nearly, 11-39 % reduction in panicle length occurs under drought stress (Table 2). Correlation analysis depicted that panicle length was significantly positive to yield/plant under drought stress at both genotypic and phenotypic level (0.49**) and (0.36**), respectively (Tables 3 and 4). Choudhury & Das, (1998) and Padmavathi *et al.,* (1996); Abarshahr *et al.,* (2011); Panja *et al.,* (2017) also supported these findings. Panicle length had negative direct effect (-.008) on yield under normal conditions (Table 5) favored by results of Haider *et al.,* (2012); Panja *et al.,* (2017) but positive direct effect under drought conditions (0.252) as shown in Table 6; also supported by Abarshahr *et al.,* (2011).

Spikelet fertility: Spikelet fertility showed highly significant values under normal (373.74**) and stress conditions (1345.13**) for analysis of variance (Table 1). Maximum spikelet fertility was observed in Hansraj 62 (93.33) and Begmi 51A (82.60) and minimum spikelet fertility was found in Basmati 122 (61.23) and Dagar 303 (8.20) under normal and drought stress, respectively. Begmi 51A, Toga 286A and Mushkan 312-2 genotypes performed well under both conditions i.e. normal or stress. About 12- 90% spikelet fertility was reduced under stress (Table 2). Correlation analysis showed that spikelet fertility was non-significantly correlated to yield/plant under drought stress at both genotypic and phenotypic level (0.04) and (-0.01), respectively (Tables 3 and 4). Findings of Lafitte *et al.,* (2007) and Abarshahr *et al.,* (2011) also support these results. Spikelet fertility had positive and direct effect on yield/plant under normal conditions (0.022) and drought condition (0.056) (Tables 5 and 6). It favors the findings of Panja *et al.,* (2017). While, it had positive indirect effect on yield/plant under stress conditions via panicle length and grain weight/panicle (Table 6).

Grain weight/panicle (g): Grains weight/panicle showed highly significant values under normal (1.11**) and drought stress (1.04**) as shown in Table 1. Grains weight /panicle was found highest in Basmati 122 (6.40g) followed by Mushkan 312-2 (5.41g) and lowest in Begmi 51A (3.40g) under normal conditions while under stress highest grains weight/panicle was given by Basmati 242 (3.51) and lowest by Toga 286A (1.22g). Genotypes which showed good performance under both conditions are Harandi 379 and Basmati 242. About 9-72 % grains weight /panicle reduces under drought stress as shown in Table 2. The reduced grain weight may be due to the reduction in assimilation and nitrogen availability to reproductive plant parts due to drought stress (Cornic, 2002; Sadras, 2007; Majeed *et al.*, 2011). Correlation analysis depicted that grains weight/panicle was significantly positive to yield/plant under drought (0.99**) and normal (0.98**) conditions at genotypic level (Table 3) and significantly positive to grains/panicle, 1000 grain weight and panicle length under drought stress at both genotypic and phenotypic level (Tables 3 and 4), respectively. Path analysis showed that grains weight/panicle had maximum positive direct effect (0.914) on yield under normal and drought stress (0.788) but indirect positive effect on yield via 1000 grain weight and flag leaf area under both conditions (Tables 5 and 6), respectively.

1000-grain weight (g): 1000-grain weight showed highly significant values under normal (61.83**) and drought stress (115.63**) as shown in Table 1. 1000-grain weight was found highest in Basmati 122 (21.08g) followed by Harandi 379 (20.59g) and lowest in Munji 78B-1 (10.28g) under normal conditions while under stress highest 1000-grain weight was given by Dagar 303 (18.43g) and lowest by Munji 78B-1 (7.35g). Genotypes which showed good performance under both conditions are Basmati 122 and Mushkan 312-2. About 9-56 % 1000-grain weight reduces under drought stress (Table 2). Correlation analysis showed that 1000-grain weight was significantly positive to yield/plant under normal (0.11*) and (0.18*) but negative under stress conditions (-0.25*) and (-0.17) at both genotypic and phenotypic level (Tables 3 and 4) and significantly positive to grain/panicle, grains weight/panicle yield/plant, plant height and panicle length under drought stress at both genotypic and phenotypic level (Tables 3 and 4), respectively. Kumar *et al.,* (2011) also found strong positive association between yield/plant and thousand grain weight. Path analysis showed that 1000-grain weight had indirect positive and negative effect on yield via panicle length under normal and stress, respectively (Tables 5 and 6). Path diagrams (Figs. 1 & 2) displayed that 1000 grain weight had negative direct effect on yield under both conditions which favors the findings of Babu *et al.,* (2012).

Yield/plant (g): Analysis of variance showed significant values for yield/plant under normal (13.63**) and stress condition (6.70**) (Table 1). Yield/plant showed highest number in Basmati 122 (19.59g) followed by Mushkan 312-2 (17.16g) and lowest in Begmi 51A (11.11g) genotypes under normal conditions while under stress maximum number of yield/plant was shown by Basmati 242 (9.28g) followed by Munji 78B-1 (7.69g) and lowest in Toga 286A (3.08g). Basmati 242 and Harandi 379 genotypes performed better in term of yield compared to other genotypes under drought stress. The possible reason might be that these genotypes might have deep root system and better stomatal conductance or they have the ability to maintain water status in the reproductive parts and these have better seed setting (Atlin *et al.,* 2006; Serraj *et al.,* 2011). About 30-78% reduction in yield/plant occurs under drought stress (Table 2). Yield reduction is due to the reason that sensitive cultivars have poor root system unable to absorb moisture from lower soil layers (Gowda *et al.,* 2011). Correlation analysis showed that yield/plant was significantly positive to plant height, panicle length, grains/panicle and grains weight/panicle under drought stress at both genotypic and phenotypic level (Tables 3 and 4). Earlier reports showed that 1000 grain weight, grains/panicle and spikelet fertility showed significant and positive correlation with plant yield (Haider *et al.,* 2012; Abarshahr *et al.,* 2011).Yield/plant is positively and directly affected by grain weight/panicle (0.914 and 0.788), spikelet fertility (0.022 and 0.056), grains/panicle (0.035 and 0.124) under normal and stress conditions (Tables 5 and 6). Mehetre *et al.,* (1994) and Panja *et al.,* (2017) have been reported that grain per panicle, panicle length and plant height are most effective and important traits for breeding of rice yield.

Conclusion

Drought stress had influence on yield and yield contributing traits in rice. BASMATI-242 and Harandi 379 showed high yield under drought stress along with tillers/plant, grain weight/panicle and grains/panicle, this suggested that the genotype possessed genes for the high expression of their respective genes i.e. tillers/plant, grain weight/panicle and grains/ panicle. Whereas, Basmati 122 and Mushkan 312-2 both genotypes performed well under normal conditions. The traits grains/panicle, spikelet fertility, plant height and grain weight/panicle were associated with plant yield and had either high direct or indirect effect and could be exploited for selection of desirable genotypes. Such genotypes can be exploited in the breeding program designed for evolving high yielding and drought tolerant rice cultivars.

Acknowledgements

The authors wish to thank National Agriculture Research Council, Islamabad for providing rice germplasm. This study is a part of M.Phil research.

References

Abarshahr, M., B. Rabiei and H.S. Lahigi. 2011. Genetic variability, correlation and path analysis in rice under optimum and stress irrigation regimes. *Not. Sci. Biol.*, 3: 134-142.

Anonymous. 2016. Pakistan Economic Survey. Ministry of Food and Agriculture, Division (Economic Wing) Government of Pakistan, Islamabad.

Atlin, G., H. Lafitte, D. Tao, M. Laza, M. Amante and B. Courtois. 2006. Developing rice cultivars for high-fertility upland systems in the Asian tropics. *Field Crops Res.,* 97: 43-52.

Babu, V.R., K. Shreya, K.S. Dangi, G. Usharani and A.S. Shankar. 2012. Correlation and path analysis studies in popular rice hybrids of India. *Int. J. Sci. Res.,* 2: 1-5.

Basu, S., V. Ramegowda, A. Kumar and A. Pereira. 2016. Plant adaptation to drought stress. *F1000 Res.,* 5 (*F1000 Faculty Rev*.): 1554.

Benjamin, J.G. and D.C. Nielsen. 2006. Water deficit effects on root distribution of soybean, field pea and chickpea. *Field Crops Res.,* 97: 248-53.

Botwright, A.T.L., H.R. Lafitte and L.J. Wade. 2008. Genotype and environment interactions for grain yield of upland rice backcross lines in diverse hydrological environments. *Field Crops Res.*, 108: 117-125.

Choudhury, P.K.D. and P.K. Das. 1998. Genetic variability, correlation and path coefficient analysis in deep water rice. *Ann. Agricult. Res.,* 2: 120-132.

Comas, L.H., S.R. Becker, V. M.V. Cruz, P.F. Byrne and D.A. Dierig. 2013. Root traits contributing to plant productivity under drought. *Front. Plant Sci.,* 4: 442.

Cornic, G. 2002. Drought stress inhibits photosynthesis by decreasing stomatal aperture: not by affecting ATP synthesis. *Trends Plant Sci.,* 5: 187-88.

Demirevska, K., D. Zasheva, R. Dimitrov, L. Simova-Stoilova, M. Stamenova and U. Feller. 2009. Drought stress effects on Rubisco in wheat: Changes in the Rubisco large subunit. *Acta Physiol. Plant.,* 31: 1129-38.

Dewey, R.D. and K.H. Lu. 1959. A correlation and Path coefficient analysis of components of crested wheat grass seed production. *Agron. J.,* 51: 515-18.

Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.F. Soussana, J. Schmidhuber and F.N. Tubiello. 2007. Food, fiber and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In: (Eds.): Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, C.E. Hanson. Cambridge University Press, Cambridge, UK, pp. 273-313.

Fukai, S. and M. Cooper. 1995. Development of drought-resistant cultivars using physio-morphological traits in rice. *Field Crops Res.,* 40: 67-86.

Gowda, V.R., A. Henry, A. Yamauchi, H. Shashidhar and R. Serraj. 2011. Root biology and genetic improvement for drought avoidance in rice. *Field Crops Res.,* 122: 1-13.

Haider, Z., A.S. Khan and S. Zia. 2012. Correlation and path coefficient analysis of yield components in rice (*Oryza sativa* L.) under simulated drought stress condition. *American-Eurasian J. Agric. & Environ. Sci.,* 12: 100-104.

Hirasawa, T. 1999. Physiological characterization of rice plant for tolerance of water deficit. In: (Eds.): Ito, O., J.C.O. Toole and B. Hardy. Genetic improvement of rice for water-limited environments. Los Banos, Philippines: IRRI, pp. 89-98.

Hossain, S., H.M.D. Maksudu and R.J. Jamilur. 2015. Genetic variability, correlation and path coefficient analysis of morphological traits in some extinct local Aman rice (*Oryza sativa* L.). *J. Rice Res.,* 3: 158.

Ji, K., Y. Wang, W. Sun, Q. Lou, H. Mei, S. Shen and H. Chen. 2012. Drought-responsive mechanisms in rice genotypes with contrasting drought tolerance during reproductive stage. *J. Plant Physiol.*, 169: 336-344.

Kamoshita, A., R. Rodriguez, A. Yamauchi and L. Wade. 2004. Genotypic variation in response of rainfed lowland to prolonged drought and rewatering. *Plant Prod. Sci.,* 7: 406-20.

Kown, S.H. and J.H. Torrie. 1964. Heritability and interrelationship among traits of two soyabean populations. *J. Crop Sci.,* 4: 196-98.

Kramer, P.J. 1980. Linking Research to Crop Production. Plenum Press, New York, 51-62.

Kramer, P.J. and J.S. Boyer. 1995. Water relations of plant and soil. San Diego, Academic Press, pp. 495.

Kumar, Y., B.N. Singh, O.P. Verma, S. Tripathi and D.K. Dwived. 2011. Correlation and path coefficient analysis in scented rice. *Environ. Ecol.,* 29: 1550-56.

Lafitte, H., G. Yongsheng, S. Yan and Z. Li. 2007. Whole plant responses, key processes and adaptation to drought stress: the case of rice. *J. Exp. Bot.,* 58: 169-75.

Lafitte, H.R., B. Courtois and G.N. Atlin. 2002. The International Rice Research Institute's experience in field screening for drought tolerance and implications for breeding. In: (Eds.): Saxena, N.P. and J.C. O'Toole. Field Screening for Drought Tolerance in Crop Plants with Emphasis on Rice: Proceedings of an International Workshop on Field Screening for Drought Tolerance in Rice, ICRISAT, Patancheru, India. ICRISAT and the Rockefeller Foundation, New York.

Lima, J.M., M. Nath, P. Dokku, K.V. Raman, K.P. Kulkarni, C. Vishwakarma, S.P. Sahoo, U.B. Mohapatra, S.V.A. Mithra, V. Chinnusamy, S. Robin, N. Sarla, M. Seshashayee, K. Singh, A.K. Singh, N.K. Singh, R.P. Sharma and T. Mohapatra. 2015. Physiological, anatomical and transcriptional alterations in a rice mutant leading to enhanced water stress tolerance. *AoB Plants,* 7: 23.

Madhavilatha, L. 2002. Studies on genetic divergence and isozyme analysis on rice *(Oryza sativa* L). M.Sc. (Ag.) Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.

Majeed, A., M. Salim, A. Bano, M. Asim and M. Hadees. 2011. Physiology and productivity of rice crop influenced by drought stress induced at different developmental stages. *Afr. J. Biotechnol.,* 10: 5121-36.

Mehetre, S.S., C.R. Mahajan, P.A. Patil, S.K. Land and P.M. Dhumal. 1994. Variability, heritability, correlation, path analysis and genetic divergence studies in upland rice. *IRRI Note,* 19: 8-10.

Nayak, A.R., D. Chaudhary and J.N. Reddy. 2001. Correlation and path analysis in scented rice *(Oryza sativa* L). *Indian J. Agric. Res.,* 35: 186-189.

Oko, A.O., B.E. Ubi, A.A. Efisue and N. Dambaba. 2012. Comparative analysis of the chemical nutrient composition of selected local and newly introduced rice varieties grown in Ebonyi State of Nigeria. *Int. J. Agric. For.,* 2: 16-23.

Padmavathi, N., M. Mahadevappa and O.U.K. Reddy.1996. Association of various yield components in rice (*Oryza sativa* L.). *Crop Res. Hisar.,* 12: 353-357.

Panja, S., H.S. Garg, K. Debnath, K.K. Sarkar, S. Mukherjee and C. Bhattacharya. 2017. Effect of water stress on different morphological traits of rice (*Oryza sativa* L.) genotypes in red & laterite zone of West Bengal. *IJABR,* 7: 419-425.

Pantuwan, G., S. Fukai, M. Cooper, S. Rajatasereekul and J.C.O. Toole. 2002. Yield response of rice *(Oryza Sativa* L.) genotypes to different types of drought under rainfed lowlands. *Field Crops Res.,* 73: 181-200.

Plaut, Z., B.J. Butow and C.S. Blumenthal. 2004. Transport of dry matter into developing wheat kernels and its contribution to grain yield under post-anthesis water deficit and elevated temperature. *Field Crops Res.,* 86: 185-98.

Qureshi, M.K., S. Munir, A.N. Shahzad, S. Rasul, W. Nouman and K. Aslam. 2018. Role of reactive oxygen species and contribution of new players in defense mechanism under drought stress in rice. *Int. J. Agric. Biol.,* 20: 1339-1352.

Reddy, J.N., R.N. De and A.V.S. Rao. 1997. Correlation and path analysis in low land rice under intermediate (0-50 cm) water depth. *Oryza,* 34: 187-90.

Reddy, N.Y.A., T.G. Prasad and U.M. Kumar. 1995. Genetic variation in yield, yield attributes and yield of rice. *Madras Agric. J.,* 82: 310-313.

Sadras, V.O. 2007. Evolutionary aspects of the trade-off between seed size and number in crops. *Field Crops Res.,* 100: 125-38.

Sarkar, R.K., J.N. Reddy, S.G. Sharma and M.I. Ab-delbagi. 2006. Physiological basis of submergence tolerance in rice and implication for crop improvement. *Curr. Sci.,* 9: 899-906.

Serraj, R., K.L. McNally, I. Slamet-Loedin, A. Kohli, S.M. Haefele, G. Atlin and A. Kumar. 2011. Drought resistance improvement in rice: an integrated genetic and resource management strategy. *Plant Prod. Sci.,* 14: 1-14.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics, 2nd ed. McGraw Hill, New York.

(Received for publication 11 October 2017)