

Genetic Variability, Correlation and Path Analysis in Rice under Optimum and Stress Irrigation Regimes

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Abstract

In order to estimate genetic variability and relationships among some agronomic traits of rice an experiment were conducted with 30 varieties of rice under two irrigation regimes. There were significant differences among the varieties for all traits. Broad-sense heritability varied from 0.05 for brown grain width to 0.99 for plant height and number of spikelet for panicle under optimum irrigation and from 0.1 for brown grain width to 0.99 for plant height. Evaluation of phenotypic and genotypic coefficient of variations (CV) showed that the lowest and highest phenotypic CV under optimum irrigation regime was observed to panicle fertility percentage and paddy yield and genotypic CV was related to brown grain width and plant height, respectively, while under drought stress condition, days to 50% flowering had the lowest phenotypic and genotypic CV and paddy yield and plant height had the highest phenotypic and genotypic CV. Furthermore, the lowest and highest expected genetic advance using selection intensity of 10% ($i=1.75$) were evaluated for brown grain width and plant height under optimum irrigation regime, respectively. Path analysis for paddy yield indicated that the number of spikelet per panicle and flag leaf length had positive direct effects and days to complete maturity and plant height had negative direct effects on paddy yield under optimum irrigation condition, while flag leaf width and number of filled grains per panicle had positive direct effects and days to 50% flowering had negative direct effect on paddy yield under drought stress condition.

Keywords: correlation coefficients, drought stress, genetic advance, paddy yield, path analysis, rice

Introduction

The periods of water shortage in soil or air often were happened during the life cycle of plants, even outside the drought and semi-drought regions. Plant responses to water deficit are complex including compromise changes or harmful effects. Drought conditions or water deficit stress in dry agroecosystems have a severe effect on rice production and they cause a meaningful decrease on its yield. As a result, increase of resistance to drought stress especially in rice, that is the main agricultural crops in Asia, is necessary (Singh, 2003; Widawsky and O'Toole, 1990).

In many Asian countries, rice production would be decreased due to drought stress. Plant breeding and introducing drought resistant varieties as well as improve of drought resistance mechanisms will be useful to solve this problem. In the present research it has been tried to prove that the yield of the number of rice cultivars is higher than the other cultivars under water stress. Plant varieties with high yield are generally dwarf and have high harvest index and in comparison with the other cultivars but if drought occurs during the late stages of growth, these cultivars will escape from drought stress and they will usually go flowering later than other cultivars. During the late season drought stress, some of the cultivars compared to others, are not able to maintain green leaves and increase their dry matter. So, the suitable cultivars for drought condi-

tions have high yield potential and high harvest index. Drought resistance cultivars escape from severe drought stress, occurred at the end of the rain season, by early flowering mechanism (Jearakongman *et al.*, 1995). Among agronomic practices, planting date is very important to escape from drought stress at flowering stage (Garrity and O'Toole, 1994).

During the late drought stress, the capacity of assimilate transmission into seeds increases and this is a useful physiological phenomenon under drought stress conditions. It has been reported that, during drought stress, enough dry matter stores in the vegetative organs and also there are some variations among cultivars regarding dry matter accumulation under drought stress conditions and non-stress conditions. Exertion of drought stress at vegetative stage leads to increase of dry matter accumulation in sinks called remobilization. The amount of accumulated dry matter in green leaves is different from one cultivar to another cultivar. In addition, the amounts of assimilate transferring from stems and leaves to filling grains will increase parallel with drought stress, on the other hand, drought stress is effective on stabilizing of yield in those cultivars which have late leaf senescence during the period of grain filling (Kumar *et al.*, 2006).

Drought stress during vegetative growth, flowering and terminal period of rice cultivation, can interrupt flo-

ret initiation (which cause spikelet sterility) and grain filling, respectively (Botwright Acuna *et al.*, 2008). On the other hand, it has been proposed that grain filling is closely linked to the whole-plant senescence process (Yang and Zhang, 2006). In some under-saturated soil moisture conditions, dry matter production and grain yield decreased significantly (Jun *et al.*, 2000).

Materials and methods

The experiment was carried out under optimum irrigation regime and drought stress conditions in a research farm located in Faculty of Agricultural Sciences, University of Guilan, Guilan, Iran during 2007 (49°36'E longitude, 37°16'N latitude and 7 m altitude). The yearly average precipitation was 298 mm also the mean annual temperature was 18.8°C. The site of study belonged to the semi-Mediterranean region based on Iran Meteorological Organization divisions, with warm summer and mild winter. Although the average annual rainfall in this area is the extremely high, but distribution of rainfall is not generally coincided with rice growing stages, especially reproductive stages (from April to September). To run this experiment, 30 rice cultivars were provided from Rice Research Institute, Rasht, Guilan, Iran. The seeds were germinated and then were transplanted into the main land. Studied cultivars included 13 native varieties from Iran ('Binam', 'Champabodar', 'Hasansaraei', 'Domzard', 'Domsorkh', 'Domsephid', 'Domsiah', 'Deylamani', 'Salari', 'Sadri', 'Anbarboob', 'Gharib' and 'Hashemi'), 7 Iranian improved cultivars ('Bejar', 'Khazar', 'Dorfak', 'Sephidroud', 'Kadous', 'Neda' and 'Nemat'), 7 bred cultivars from IRRI ('IR24', 'IR28', 'IR30', 'IR36', 'IR50', 'IR60', 'IR64') and 3 upland cultivars from Brazil ('Araguaya'), United state ('New Bonnet') and India ('Vandana'). This experiment was performed under two different conditions (normal and drought stress). The experimental design was Randomized Complete Blocks with three replications. The plots were apart each other about two meters. In each experimental unit, there were 5 rows with distance of 25 × 25 cm and distance of experimental transplant units from each other was 1 meter. After randomization of treatments, transplanting was performed as a single plant. All deep water irrigation operations were done until 20 days after transplanting, in the other word, until the full establishment of seedlings, and then drought stress was induced by irrigation with holding, while under normal conditions rice plants were irrigated completely until 10 days before harvesting. A deep drain at the depth of 40 cm and width 30 cm, was created to help the exit of extra water from plots in order to prevent influence of water into drought stressed plots. To improve plant growth nitrogen fertilizer from urea source was applied in the amount of 150 kg per hectare; two-thirds part of urea was used during transplantation and one-third part during tillering stage. Moreover, phosphorus fertilizer from ammonium phosphate source was used in the amount of 100 kg per hectare during transplantation.

The fifteen traits were evaluated under both optimum and drought irrigation regimes, included plant height (cm), panicle length (cm), number of panicles/plant, flag leaf length (cm), flag leaf width (cm), brown grain length (mm), brown grain width (mm), days to 50% flowering, number of days to complete maturity, number of filled grains/panicle, number of spikelet/panicle, panicle fertility percentage, 1000-grain weight (g), paddy yield (kg ha⁻¹) and chlorophyll index (SPAD reading). Chlorophyll index was measured 76 days after transplanting. At first, data obtained from each irrigation regime were separately used to analysis of variance, then to assess the relationship among studied traits, genotypic and phenotypic correlation coefficients were determined. In order to demonstrate the importance of each trait, phenotypic correlation coefficients between paddy yield and other traits were separated to direct (path coefficient) and indirect affects using Dewey and Lu method (Dewey and Lu, 1959). Phenotypic and genotypic coefficients of variations (CV) for each trait were estimated by equations 1 and 2:

$$1) CV = \frac{\sqrt{V_G}}{\mu} \times 100$$

$$2) CV = \frac{\sqrt{V_P}}{\mu} \times 100$$

Broad-sense heritability was calculated by equation 3 and genetic advance percentage was calculated by applying a selection intensity of 10 percentages (i=1.75).

$$3) H_b = \frac{V_G}{V_P}$$

All statistical analyses were carried out of using SAS Ver. 9.1 and SPSS Ver. 15 software.

Results and discussion

The results of analysis of variance showed that there were significant differences among varieties considering all studied traits under optimum irrigation regime and drought stress conditions (p < 0.01, Tab. 1). Thus these significant differences among varieties showed high genetic diversity in studied populations, based on evaluated traits. Tab. 2 shows that the average of studied cultivars under both optimum irrigation regime and drought stress conditions calculated by HSD (Honestly Significant Difference or Tukey's test) and LSD (Least Significant Difference) at 5% probability level. Estimation of paddy yield showed that, the best paddy yield was obtained from 'Nemat' cultivar under both optimum irrigation regime (7430.4 kg ha⁻¹) and drought stress conditions (5126.6 kg ha⁻¹), By contrast, the lowest paddy yield was achieved from 'Domsephid' cultivar under above mentioned conditions 2094.8 and 1565.9 kg ha⁻¹, respectively (Tab. 2). Also

Tab. 1. Analysis of variance of studied traits in 30 rice cultivars under two irrigation regimes optimum irrigation (O) and drought stress(S)

		Mean of squares (MS)																	
		Plant height		Panicle length		Panicle number/ plant		Flag leaf length		Flag leaf width		Brown grain length		Brown grain width		Days to 50% flowering		Days to complete maturity	
S.O.V	d _f	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
Block	2	0.11 ^{ns}	0.96 ^{ns}	0.74 ^{ns}	0.63 ^{ns}	0.58 ^{ns}	1.51 ^{ns}	12.34 [*]	4.65 ^{ns}	0.01 ^{ns}	0.34 ^{**}	0.0007 ^{ns}	0.02 ^{ns}	0.02 ^{ns}	0.0003 ^{ns}	1.63 ^{ns}	3.24 ^{ns}	7.24 ^{ns}	15.01 ^{ns}
Genotype	29	3030.41 ^{**}	3094.49 ^{**}	15.62 ^{**}	33.008 ^{**}	79.36 ^{**}	50.55 ^{**}	49.08 ^{**}	49.23 ^{**}	0.26 ^{**}	0.18 ^{**}	1.21 ^{**}	1.33 ^{**}	0.02 ^{**}	0.003 ^{**}	51.56 ^{**}	40.36 ^{**}	113.52 ^{**}	75.5 ^{**}
Error	58	1.49	1.5	0.56	0.3	1.12	0.73	3.09	3.5	0.02	0.03	0.002	0.01	0.01	0.0004	1.95	5.92	11.95	14.22
CV (%)		1.98	1.33	2.37	1.94	4.89	5.16	4.94	6.11	9.62	11.23	0.7	1.61	6.39	1.25	1.6	2.92	3.15	3.61

ns: non-significant * and **: significant at 5% and 1% probability levels, respectively

Tab. 1. Analysis of variance of studied traits in 30 rice cultivars under two irrigation regimes optimum irrigation (O) and drought stress(S)-Continuous

		Mean of squares (MS)											
		Number of filled grains/panicle		Number of spikelet per panicle		Panicle fertility percentage		1000-grain weight		Paddy yield		Chlorophyll index	
S.O.V	d _f	O	S	O	S	O	S	O	S	O	S	O	S
Block	2	16/87 [*]	6/21 ^{ns}	19.3 [*]	1.47 ^{ns}	0.14 ^{ns}	1.65 ^{ns}	20.6 ^{6**}	35.6 ^{**}	1656063.4 ^{ns}	459119.4 ^{ns}	6.61 ^{ns}	92.05 ^{**}
Genotype	29	1271/38 ^{**}	1136/56 ^{**}	1475.65 ^{**}	1115.73 ^{**}	16.66 ^{**}	51.29 ^{**}	16.8 ^{7**}	21.85 ^{**}	4048717.1 ^{**}	2035926.49 ^{**}	21.1 ^{**}	18.52 ^{**}
Error	58	5/38	3/03	4.92	2.05	1.82	1.95	3.01	4.98	874308.8	250918.88	4.47	8.19
CV (%)		1/43	1/5	1.26	0.97	1.45	1.78	5.55	7.4	19.36	16.7	5.46	7.82

ns: non-significant * and **: significant at 5% and 1% probability levels, respectively

Tab. 2. Mean of 30 rice varieties for measured traits under two irrigation regimes, optimum irrigation (O) and drought stress (S)

Variety	PH		PL		PanN		FLL		FLW		BGL		BGW		DF		DM		NFG		NSP		PFP		100-GW		PY		CI		
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	
'Binam'	162.5	153.6	33.74	30.76	19.46	18.63	39.77	29.3	1.69	1.52	6.94	6.89	1.71	1.67	88.33	81.66	107.66	112.33	159	100.33	169.33	153.33	93.89	80.65	32.58	28.17	5662.81	2730.36	35.26	35.8	
'Champabodar'	173.66	172.25	35.25	33.53	20.36	18.41	36.95	33.22	2.69	2.18	6.06	6.03	1.91	1.83	81.66	86.66	115.33	102.33	191.33	107.66	197.66	167.33	96.8	77.68	34.66	33.38	4271.69	3360.14	34.4	36.9	
'Hasansaraei'	171.9	169.25	27.76	25.63	14.93	13.9	43.35	41.92	1.38	1.25	6.4	6.07	1.63	1.52	94.66	90.66	122	97	145.33	112.33	154.66	134.66	93.96	77.72	34.05	27.20	3210.79	2053.41	35.26	34.6	
'Domzard'	152.13	149.33	30.14	27.08	17.86	16.86	35.65	31.87	1.49	1.66	6.95	6.67	1.66	1.52	83	79	109	102	150	102	158.66	136.66	94.54	78.05	30.88	29.55	4232.25	3351.6	35.56	34.43	
'Domsorkh'	149.53	139.38	29.37	30.94	17.26	11.53	34.68	25.5	1.46	1.21	7.49	7.46	1.71	1.63	92.66	86	118	103.66	150.66	107.33	159	123.66	94.76	76.84	29.95	27.47	4023.91	2109.66	36.16	35.26	
'Domsaphid'	174.16	171.7	32.2	30.4	14.63	12.8	42.64	36.41	1.22	1.12	7.15	6.96	1.62	1.33	95.33	91.33	122	111.33	127.66	111.33	140.33	121.66	90.97	75.61	25.54	23.97	2094.78	1565.89	36.46	32.33	
'Domsiah'	136.98	132.08	28.34	25.66	18.66	13.8	30.24	28.78	1.34	1.38	7.9	7.45	1.67	1.64	88.66	85.66	111.66	97	144.66	102.33	154.66	163	93.52	74.45	26.05	30.15	3222.08	2517.74	36.5	43.9	
'Deylamani'	108	158.48	32.24	24.76	26.06	14.3	38.44	25.3	1.5	1.14	7.43	6.95	1.67	1.63	84	82.33	108.33	102	149.33	102	158.66	129.33	94.12	75.77	31.34	27.42	4285.98	1929.22	36.86	35.4	
'Salari'	152.63	147.47	28.84	26.8	16.26	13.73	34.76	27.62	1.42	1.34	7.62	7.44	1.74	1.57	93	88.33	107	98	129.66	98	142	140.66	91.31	74.4	29.57	29.85	3873.96	2297.46	37.36	34.23	
'Sadri'	147.06	139.18	30.49	25.13	17.23	15.06	34.01	26.36	1.41	1.26	7.62	7.34	1.72	1.71	90	84	103	101.33	143	101.33	143	154.33	128.66	92.66	77.2	28.78	30.58	3826.56	2147.36	37.5	35.76
'Anbarboo'	160.4	148.12	33.81	27.13	16.96	13.6	32.34	27.63	1.32	1.34	6.34	6.22	1.75	1.72	88.33	85.66	113	109.66	130.33	109.66	140	138.33	93.09	76.14	28.26	26.64	3468.06	2367.75	37.63	35.7	
'Gharib'	152	146.89	32.72	28.03	14.86	12.63	39.61	30.16	1.58	1.59	6.33	6.21	1.88	1.84	84.33	82.66	105	102	147.66	102	158.66	145.66	93.06	80.09	31.51	33.84	4928.65	3265.29	37.7	40.23	
'Hashemi'	138.03	132.23	31.6	28.1	22.3	16.53	35.1	30.08	1.48	1.49	8.15	8.00	1.74	1.66	81.33	79	104	102.66	144.66	99	153	144.66	94.55	80.18	30.006	32.43	4062.66	2700.36	37.8	39.06	
'Bejar'	116.28	100.96	33.31	32.94	22.42	21.86	29.94	28.48	1.59	1.7	7.54	7.45	1.84	1.76	83.33	80.66	101	104	187	96.66	198.33	162	94.3	80.45	31.95	35.08	5050.56	3810.45	38.13	36.2	
'Khazar'	117.18	114.88	31.87	25.53	14.03	11.53	32.76	26.58	1.84	1.78	7.82	7.29	1.67	1.49	91.66	80.66	113.33	106.33	170.66	106.33	190.33	131	89.67	73.28	32.23	26.55	5215.27	3726.55	38.16	33.13	
'Dorfak'	102.4	102.7	33.86	30.86	21.86	15	30.41	30.31	1.6	1.54	8.25	8.13	1.65	1.75	81.33	83.66	104.66	104.66	184.66	104.66	195.66	135.66	94.37	84.52	32.04	32.53	5142.08	2847.92	38.26	39.53	
'Sephidroud'	98.23	89.62	34.1	34.3	29.56	24.2	35.52	35.24	1.95	1.91	7.56	7.35	1.79	1.76	87.66	77.33	107	102	200.66	102	213.66	171	93.95	76.81	31.28	30.41	6386.95	4830.47	38.36	38.26	
'Kadous'	101.54	94.3	35	33.73	29.13	18.63	36.35	33.9	1.68	1.8	8.35	7.77	1.76	1.72	86.33	81.66	107.66	103	169	103	189	165	93.89	76.97	32.87	32.6	5845.28	3702.09	38.4	41.13	
'Neda'	97.3	94.53	33.39	26.92	24.96	18.4	36.02	31.55	1.67	1.68	8.00	7.59	1.85	1.71	88.66	86	109.33	104.33	184	104.33	201.33	152.66	91.39	82.31	32.31	33.91	5632.91	3424.02	38.7	37.36	
'Nemat'	103.78	98.34	35.86	35.2	31.16	28.2	41.92	37.4	2.4	1.9	8.76	8.67	1.72	1.69	89.33	80	111	95.33	209.33	104	221.66	211.33	94.43	91.48	35.6	35.08	7430.37	5126.62	39	37.56	
'IR24'	75.76	76.26	31.92	30.26	26.4	18.83	29.32	27.22	1.49	1.36	7.06	6.79	1.75	1.69	93	83	122	115.66	161	116.66	179.33	148.33	89.77	82.7	31.4	31.11	4421.9	2415.61	39.16	33.6	
'IR28'	75.83	74.8	31.97	28.7	26.23	17.03	39.42	34.77	1.76	1.7	7.77	6.13	1.74	1.66	90	80	102.33	98	166.66	98	186.66	147.66	89.29	81.03	34.32	29.19	6150.01	3958.002	39.8	42.93	
'IR30'	87.57	87.04	31.53	25.2	27.5	15.13	38.87	29.1	1.71	1.42	7.72	6.04	1.63	1.65	85	82.33	107.33	107.33	172.33	100	193.33	130	89.14	76.41	33.98	27.11	6040.71	2588.27	39.93	39.36	
'IR36'	90.7	83.9	30.53	29.16	23.53	15.66	28.94	28.82	1.5	1.52	6.79	6.77	1.71	1.57	80	75.66	103	99.66	153.33	99.66	167.33	125	91.63	76.8	30.76	28.59	4158.12	282952	40.46	36.33	
'IR50'	103.23	79.66	31.91	27.76	25.66	23.5	37.98	29.44	1.68	1.56	7.51	7.44	1.99	1.66	85	84	105.33	107.66	161.66	102.66	181.66	169.66	89.005	75.64	33.69	31.15	5931.87	3179.72	41.5	34.76	
'IR60'	76.26	78.57	30.53	28.96	25.56	17.96	33.06	22.68	1.64	1.31	6.98	6.94	1.74	1.72	86	84.66	108	104.66	156.33	104.66	166.66	148.66	93.8	81.16	28.8	30.43	5370.1	2295.87	42.4	38.8	
'IR64'	92.63	84.83	31.8	27.9	28.76	22.5	33.59	32.37	1.66	1.64	7.32	7.28	1.74	1.7	88	80.66	109.66	107.66	173.33	107.66	200.33	162	86.51	79.62	31.9	30.36	5499.23	3367.76	42.9	33.83	
'Araguaya'	115.71	119.63	27.35	22.3	16.26	12.3	32.64	32.39	1.61	1.66	7.11	7.08	1.72	1.71	86.33	87	120.66	116.66	162	115.66	172.33	125	93.98	77.61	30.87	29.71	5155.76	3396.52	43.2	36.36	
'New Bonnet'	115.08	91.96	30.53	23.44	22.06	12.86	40.8	31.96	1.81	1.4	7.21	7.14	1.67	1.63	89.33	80	107.66	96	176	103.66	191	158.33	92.18	67.6	28.66	29.34	6266.21	2562.82	44.03	37.33	
'Vandana'	134.22	119.82	27.63	25.6	17.63	14.23	32.58	32.5	1.76	1.68	6.96	6.2	1.77	1.66	83.66	82	103.66	101.33	145.33	101.33	159.33	154.66	91.21	80.38	31.23	30.98	4016.59	3475.91	44.3	36.76	
HSD _{0.05}	3.93	3.95	2.41	1.78	3.41	2.76	5.66	6.02	0.51	0.56	0.16	0.36	0.35	0.06	4.5	7.83	11.13	12.14	7.46	5.61	7.14	4.61	4.34	4.49	5.59	7.18	3009.9	1612.5	6.8	9.21	
LSD _{0.05}	1.99	2.007	1.22	0.9	1.73	1.4	2.87	3.06	0.25	0.28	0.08	0.18	0.18	0.03	2.28	3.97	5.65	6.16	3.79	2.84	3.62	2.34	2.2	2.28	2.83	3.65	1528.2	818.7	3.45	4.67	

PH=Plant height (cm); PL=Panicule length (cm); PanN=Panicule number/plant; FLL=Flag leaf length(cm);FLW= Flag leaf width (cm); BGL= Brown grain length (mm); BGW= Brown grain width (mm); DF= Days to 50% flowering; DM= Days to complete maturity; NFG= Number of filled grains per panicle; NSP=Number of spikelet/panicle; PFP=Panicule fertility percentage;1000-GW= 1000-grain weight; PY=Paddy yield (kg/ha¹); CI= Chlorophyll index; * Honestly Signification Different (Tukey's test) at 5% probability level; ^b Least Significant Different at 5% probability level

the result indicated that effect of year was not significant on evaluated traits, nonetheless the optimal and high yield components have made 'Nemat' cultivar as a high paddy yield during two experimental years. The 'Nemat' cultivar showed high phenotypic value under both irrigation regimes in respect of many important aspects of agronomic traits or related traits to yield. In case of panicle length, panicles number per plant, brown grain length, number of filled grains per panicle, number of spikelet per panicle, 1000-grains weight and paddy yield under both irrigation regimes and also panicle fertility percentage under drought stress conditions (most traits in path analysis were determined as the most important traits affecting on paddy yield) 'Nemat' cultivars was superior cultivar compared with other studied cultivars, so it can be considered as one of the most important cultivars. The obtained results from genotype variation coefficient demonstrated that, plant height (25.55 percent), panicle number per plant (23.58 percent) and paddy yield (21.30 percent) had maximum amount and browning grain width (1.81 percent) had the lowest amount (Tab. 3). Also under drought stress conditions plant height (27.14 percent), paddy yield (25.73 percent) and panicle number per plant (24.46 percent) had maximum amount. Furthermore, number of days to 50% flowering (4.07 percent) and number of day to complete maturity (4.33 percent) had the lowest amount of coefficient of genotype variation (Tab. 4).

The high variation in plant height and paddy yield especially under drought stress conditions gives promising news about applying these traits in accordance with the goals of breeding program. Evaluation of genetic advance on plant height, panicles number per plant and paddy yield showed that under both optimum irrigation regime and drought stress conditions these traits had the maximum increase (Tab. 3 and Tab. 4). Similar to variation coefficient, when variability in the studied population is high, an effective selection would be possible for breeding of most traits, so that high amount of genetic advance would be confirmed. At the first stage, it has been used the simple selection method to improve these traits and then increase favorite genes sharing with addition effects on the population and after that it has been used full capacity of gene with this kind of effect, thus it has been possible to use the other effects of genes such as dominance and super dominance and presumably heterosis phenomenon. Two traits including brown grain width (0.57) and panicle fertility percentage (3.43) under optimum irrigation condition, and chlorophyll index (4.82) under stress conditions had the lowest average of genetic advance percentage (Tab. 3 and Tab. 4). Upon broad-sense heritability calculating for traits, all of the traits except for brown grain width (0.05) (Tab. 3) in optimum irrigation condition and all traits except brown grain width (0.1) and chlorophyll index (0.29) under drought stress conditions had broad-sense heritability more than 50% (Tab. 4). Mixing genotype cross effect \times environment due to survey of experiment

in one year could be one of the important reasons being traits high heritability in both experimental environments. The obtained results from broad-sense heritability of traits demonstrate that, plant height, number of spikelet per panicle and number of filled grains per panicle were affected by optimum irrigation regime and drought stress conditions. Brown grain width had broad-sense heritability (0.05) under optimum irrigation regime that shows the full impact of environment and crops conditions on this trait. In addition, under drought stress conditions brown grain width had broad-sense heritability (0.1) that shows it had the same environment and genetic effects on this trait. Kumar *et al.* (2007) expressed that, the heritability of rice under drought stress is lower than the optimal irrigation. Ekanayake *et al.* (1985) believed that, avoiding drought stress in rice is dependent on tensile resistance of rice root system and concluded that, the root tensile resistance will have low heritability (39%-47%). Increasing the root tensile resistance and then drought resistance in order for the selection on base of line average will be better than individual selection. Phenotypic and genotypic correlation coefficients of studied traits under both optimum irrigation regime and drought conditions are presented in Tab. 5 and 6, respectively. Phenotypic correlations in terms of optimum irrigation regime showed that, there was significant correlation among paddy yield with plant height, panicle number per plant, flag leaf width, number of filled grains per panicle, number of spikelet per panicle and 1000-grain weight ($p < 0.01$), panicle length, brown grain length a day to complete maturity and chlorophyll index ($p < 0.05$) (Tab. 5). All characteristics, except for plant height and number of days to complete maturity had positive correlation with final yield and these results were consistent with findings of Mehetre *et al.* (1994) and Lanceras *et al.* (2004). Significant and positive correlation between yield and other traits showed that each factor leads to changes in these traits will change correlation coefficients. It has been reported that, there is positive and significant correlation between panicle length and yield (Abd El Samie and Hasan, 1994; Bapo and Soundarapandian, 1992; Choudhury and Das, 1998; Padmavathi *et al.*, 1996). Phenotypic correlations under drought stress conditions showed that, paddy yield had significant and positive correlation with plant height, panicle length, number of panicles per plant, flag leaf width, days to 50% flowering, number of filled grains per panicle, number of spikelet per panicle, 1000-grain weight ($p < 0.01$), flag leaf length, brown grain width, panicle fertility percentage and chlorophyll index ($p < 0.05$) while correlation between paddy yield and plant height or paddy yield and days to 50% flowering were negative (Tab. 5). Garrity and O'Toole (1994) have been reported that, there is positive correlation between panicle fertility percentage and paddy yield under water stress conditions. In addition, Lafitte *et al.* (2006) showed that, there is a negative and significant correlation between plant heights and final yield under

Tab. 3. Estimation of statistical and genetic parameters of studied traits under optimum irrigation regime

	Min.	Max.	Range	Mean ± S _x	Coefficient of Variation (CV %)		Variance components			Heritability	Genetic advance (%) ^a
					Genotypic	Phenotypic	Environmental Variance	Genotypic Variance	Phenotypic Variance		
PH	72.83	174.16	101.33	124.35±31.78	25.55	25.57	1.49	1009.64	1011.14	0.99	44.68
PL	27.35	35.86	8.51	31.65±2.28	7.07	7.46	0.56	5.02	5.58	0.89	11.74
PanN	14.03	31.16	17.13	21.65±5.14	23.58	24.08	1.12	26.08	27.21	0.95	40.40
FLL	28.94	43.35	14.41	35.59±4.04	11.001	12.05	3.09	15.33	18.42	0.83	17.56
FLW	1.22	2.69	1.46	1.64±0.29	17.17	20.13	0.02	0.08	0.11	0.72	25.62
BGL	6.06	8.76	2.69	7.37±0.63	8.57	8.68	0.002	0.4	0.41	0.97	14.82
BGW	1.62	1.99	0.37	1.74±0.08	1.81	8.11	0.01	0.001	0.02	0.05	0.57
DF	80	95.33	15.33	87.33±4.14	4.65	4.92	1.95	16.54	18.49	0.89	7.70
DM	101	122	21	109.65±6.15	5.30	6.17	11.95	33.86	45.81	0.73	7.98
NFGc	127.66	209.33	81.66	161.55±20.58	12.71	12.79	5.38	422	427.38	0.98	22.11
NSP	140	221.66	81.66	174.66±22.17	12.67	12.73	4.92	490.24	495.17	0.99	22.07
PPF	86.51	96.8	10.28	92.52±2.28	2.32	2.74	1.82	4.61	6.44	0.71	3.43
1000-GW	25.54	35.6	10.05	31.23±2.37	6.88	8.84	3.01	4.62	7.64	0.6	9.36
PY	2094.78	7430.37	5335.59	4829.27±1161.71	21.30	28.78	874308.8	1058136	1932445	0.54	27.58
CI	34.4	44.3	9.9	38.7±2.65	6.08	8.17	4.47	5.55	10.02	0.55	7.92

PH=Plant height (cm); PL=Panicle length (cm); PanN=Panicle number/plant; FLL=Flag leaf length(cm);FLW= Flag leaf width (cm); BGL= Brown grain length (mm); BGW= Brown grain width (mm); DF= Days to 50% flowering; DM= Days to complete maturity; NFG= Number of filled grains per panicle; NSP=Number of spikelet/panicle; PPF=Panicle fertility percentage;1000-GW= 1000-grain weight; PY=Paddy yield (kg/ha¹);CI= Chlorophyll index; ^a Honestly Signification Different (Tukey's test) at 5% probability level; ^b Least Significant Different at 5% probability level; ^c Genetic advance with 10% selection intensity (i=1.75)

Tab. 4. Estimation of statistical and genetic parameters of studied traits under drought stress condition

	Min	Ma.	Range	Mean ± S _x	Coefficient of Variation (CV %)		Variance components			Heritability	Genetic advance (%) ^a
					Genotypic	Phenotypic	Environmental Variance	Genotypic Variance	Phenotypic Variance		
PH	71.8	172.25	100.44	118.3±32.11	27.14	27.16	1.5	1031	1032.51	0.99	47.46
PL	22.3	35.2	12.89	28.42±3.31	11.61	11.77	0.3	10.9	11.21	0.97	20.04
PanN	11.53	28.2	16.66	16.65±4.1	24.46	25.004	0.73	16.61	17.35	0.95	41.89
FLL	22.68	41.92	19.24	30.63±4.05	12.74	14.13	3.5	15.24	18.75	0.81	20.10
FLW	1.12	2.18	1.05	1.53±0.24	14.53	18.38	0.03	0.05	0.08	0.62	20.10
BGL	6.03	8.67	2.63	7.06±0.66	9.39	9.49	0.01	0.44	0.45	0.97	16.25
BGW	1.33	1.84	0.51	1.66±0.1	6.004	6.004	0.001	0.01	0.01	0.1	10.50
DF	75.66	91.33	15.66	83.07±3.66	4.07	5.02	5.92	11.48	17.4	0.65	5.79
DM	96.66	116.66	20	104.21±5.01	4.33	5.64	14.22	20.43	34.65	0.58	5.82
NFGc	92	193.33	101.33	115.85±19.46	16.77	16.84	3.03	377.84	380.88	0.99	29.24
NSP	121.66	211.33	89.66	147.52±19.28	13.06	13.09	2.05	371.23	373.28	0.99	22.79
PPF	67.6	91.48	23.87	78.32±4.13	5.17	5.47	1.95	16.45	18.4	0.89	8.56
1000-GW	23.97	35.08	11.11	30.16±2.69	7.85	10.79	4.98	5.62	10.61	0.52	10.01
PY	1565.89	5126.62	3560.73	2997.81±823.79	25.73	30.68	250918.88	595002.5	845921.4	0.7	37.76
CI	32.33	42.93	10.6	36.59±2.48	5.06	9.32	8.19	3.44	11.64	0.29	4.82

PH=Plant height (cm); PL=Panicle length (cm); PanN=Panicle number/plant; FLL=Flag leaf length(cm);FLW= Flag leaf width (cm); BGL= Brown grain length (mm); BGW= Brown grain width (mm); DF= Days to 50% flowering; DM= Days to complete maturity; NFG= Number of filled grains per panicle; NSP=Number of spikelet/panicle; PPF=Panicle fertility percentage;1000-GW= 1000-grain weight; PY=Paddy yield (kg/ha¹);CI= Chlorophyll index; ^a Honestly Signification Different (Tukey's test) at 5% probability level; ^b Least Significant Different at 5% probability level; ^c Genetic advance with 10% selection intensity (i=1.75)

drought stress conditions. The significant and positive correlation was observed between flag leaf width and paddy yield while under conditions of optimum irrigation regime, number of spikelet per panicle had significant and positive correlation with paddy yield that shows the importance of flag leaf at grain filling stage under water deficit stress. Genotype correlation under optimum irrigation

conditions showed that, there is a significant and positive correlation among paddy yield and panicle length, panicle number per plant, flag leaf width, brown grain length, the number of filled grain per panicle, number of spikelet per panicle, 1000-grain weight and chlorophyll index while paddy yield had significant and negative correlation with days to complete maturity and plant height (Tab. 6). Gen-

Tab. 5. Phenotypic correlation coefficients between traits in 30 rice cultivars in two conditions, optimum irrigation (up) and drought stress (down)

Trait	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	-0.14	-0.71**	0.32	-0.17	-0.44'	-0.1	0.14	0.29	-0.51**	-0.61**	0.46**	-0.28	-0.66**	-0.63**
2	-0.12	1	0.5**	0.17	0.5**	0.22	0.32	-0.2	-0.18	0.57**	0.54**	0.15	-0.39'	0.45'	-0.26
3	-0.46**	0.63**	1	0.01	0.39'	0.46**	0.19	-0.24	-0.3	0.63**	0.67**	-0.18	0.43'	0.69**	0.32
4	0.1	0.21	0.25	1	0.21	-0.04	-0.08	0.32	0.16	0.03	0.03	0.03	0.27	0.18	0.2
5	-0.25	0.45'	0.52**	0.35	1	0.06	0.37'	-0.26	-0.07	0.77**	0.72**	0.19	0.63**	0.59**	0.07
6	-0.25	0.31	0.38'	-0.06	0.09	1	-0.15	0.04	-0.29	0.37'	0.39'	-0.1	0.12	0.43'	0.1
7	-0.26	0.28	0.35	-0.16	0.45'	0.04	1	-0.31	-0.28	0.25	0.25	-0.005	0.32	0.26	0.1
8	0.53**	-0.2	-0.39'	0.11	-0.41'	-0.17	-0.22	1	0.58**	-0.23	-0.18	-0.28	-0.22	-0.18	-0.16
9	0.15	-0.1	-0.18	0.2	-0.14	-0.14	-0.13	0.52**	1	-0.15	-0.17	0.07	-0.13	-0.37'	-0.24
10	-0.32	0.6**	0.83**	0.33	0.58**	0.41'	0.44'	-0.27	-0.14	1	0.97**	0.09	0.62**	0.78**	0.16
11	-0.33	0.53**	0.8**	0.32	0.6**	0.37'	0.43'	-0.28	-0.19	0.94**	1	-0.1	0.63**	0.81**	0.26
12	-0.21	0.5**	0.54**	0.18	0.3	0.28	0.35	-0.12	0.01	0.68**	0.41'	1	-0.04	-0.14	-0.49**
13	-0.3	0.41'	0.55**	0.07	0.58**	0.4'	0.71**	-0.26	-0.27	0.7**	0.65**	0.55**	1	0.61**	-0.004
14	-0.44'	0.45'	0.64**	0.37'	0.87**	0.26	0.38'	-0.55**	-0.23	0.69**	0.68**	0.42'	0.57**	1	0.42'
15	-0.38'	0.22	0.13	0.12	0.34	-0.01	0.55**	-0.35	-0.42'	0.26	0.22	0.29	0.42'	0.38'	1

1-Plant height; 2-Panicle length; 3-Number of panicles per plant; 4-Flag leaf length; 5-Flag leaf width; 6-Brown grain length; 7-Brown grain width; 8-Days to 50% flowering; 9-Days to maturity; 10- Number of filled grains per panicle; 11-Number of spikelet per panicle; 12-Panicle fertility percentage; 13-1000-Grain weight; 14-Paddy yield; 15-Chlorophyll index

Tab. 6. Genotypic correlation coefficients between traits in 30 rice cultivars under two irrigation regimes, optimum irrigation (up) and drought stress (down)

Trait	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	-0.14	-0.72**	0.33'	-0.18	-0.44'	0	0.15	0.31	-0.51**	-0.61**	0.5**	-0.31	-0.75**	-0.72**
2	-0.13	1	0.51**	0.18	0.55**	0.23	0	-0.22	-0.2	0.59**	0.56**	0.15	0.43'	0.5'	-0.3
3	0.47**	0.64**	1	0.03	0.43'	0.47**	0	-0.25	-0.32	0.64**	0.68**	-0.2	0.49**	0.79**	0.37'
4	0.11	0.23	0.27	1	0.23	-0.04	0	0.34'	10.18	0.04	0.03	0.06	0.32	0.2	-0.22
5	-0.28	0.5**	0.57**	0.41'	1	0.06	0	-0.29	-0.09	0.81**	0.76**	0.23	0.72**	0.67**	0.11
6	-0.26	0.32	0.39'	-0.07	0.07	1	0	0.05	-0.31	0.37'	0.39'	-0.11	0.14	0.49**	0.11
7	-0.28	0.3	0.37	-0.18	0.45**	0	1	0	0	0	0	0	0	0	0
8	0.58**	-0.22	-0.43'	0.13	-0.53**	-0.18	-0.27	1	0.64**	-0.24	-0.19	-0.3	-0.24	-0.23	-0.18
9	0.17	-0.11	-0.19	0.23	-0.19	-0.16	-0.15	0.62**	1	-0.17	-0.19	0.08	-0.13	-0.44'	-0.32
10	-0.33	0.61**	0.84**	0.35	0.64**	0.41'	0.46**	-0.29	-0.16	1	0.98**	0.09	0.7**	0.89**	0.17
11	-0.33	0.54**	0.81**	0.34	0.66**	0.38'	0.45**	-0.31	-0.21	0.95**	1	-0.11	0.7**	0.92**	0.3
12	-0.22	0.52**	0.56**	0.19	0.33	0.29	0.37'	-0.12	0.01	0.69**	0.43'	1	-0.02	-0.15	-0.62**
13	-0.35'	0.48**	0.62**	0.05	0.77**	0.46**	0.84**	-0.33	-0.33'	0.81**	0.75**	0.67**	1	0.78**	-0.01
14	-0.47**	0.49**	0.7**	0.41'	1.02**	0.29	0.42'	-0.65**	-0.31	0.75**	0.73**	0.47**	0.71**	1	0.55**
15	-0.52**	0.31	0.19	0.18	0.6**	-0.02	0.81**	-0.52**	-0.58**	0.35'	0.3	0.39'	0.66**	0.6**	1

1-Plant height; 2-Panicle length; 3-Number of panicles per plant; 4-Flag leaf length; 5-Flag leaf width; 6-Brown grain length; 7-Brown grain width; 8-Days to 50% flowering; 9-Days to maturity; 10- Number of filled grains per panicle; 11-Number of spikelet per panicle; 12-Panicle fertility percentage; 13-1000-Grain weight; 14-Paddy yield; 15-Chlorophyll index

otype correlation under drought stress conditions showed that paddy yield had significant and positive correlation with panicle length, panicles number per plant, flag leaf width, number of filled grains per panicle, number of spikelet per panicle, panicle fertility percentage, 1000-grain weight and chlorophyll index but it had significant and negative correlation with plant height and number of days to 50% flowering (Tab. 6). Path analysis results under optimum irrigation regime condition showed that, num-

ber of spikelet per panicles had the most direct positive and direct effect (0.55) on paddy yield. Indirect effect of these traits had 0.27 approximately; therefore due to days to complete maturity (0.04), flag leaf length (0.01) and plant height (0.22) were effective on paddy yield (Tab. 7). The days to complete maturity had a negative direct effect (-0.22) on yield after spikelet number per panicle and indirect effect of this trait was approximately -0.14 and through respectively number of spikelet per panicle (-0.09), flag

Tab. 7. Path analysis for paddy yield of 30 studied rice varieties under optimum irrigation regime. The bold values are direct effects (path coefficients)

Traits	Number of spikelet per panicle	Days to complete maturity	Flag leaf length (cm)	Plant height (cm)	Total indirect effects	Correlation with Paddy yield
Number of spikelet per panicle	0.55	0.04	0.01	0.22	0.27	0.82 ^{**}
Days to complete maturity	-0.09	-0.22	0.05	-0.10	-0.14	-0.36 [*]
Flag leaf length (cm)	0.02	-0.04	0.317	-0.12	-0.14	0.17
Plant height	-0.33	-0.06	0.10	-0.36	-0.29	-0.65 ^{**}
$R^2=0.827$						

* and **: significant at 5% and 1% probability levels, respectively

Tab. 8. Path analysis for paddy yield of 30 studied rice varieties under drought stress condition. The bold values are direct effects (path coefficients)

Traits	Flag leaf width (cm)	Number of filled grains per panicle	Days to 50% flowering	Total indirect effects	Correlation with Paddy yield
Flag leaf width (cm)	0.63	0.16	0.09	0.25	0.88 ^{**}
Number of filled grains per panicle	0.36	0.27	0.06	0.42	0.69 [*]
Days to 50% flowering	-0.26	-0.07	-0.22	-0.33	-0.55 ^{**}
$R^2=0.861$					

* and **: significant at 5% and 1% probability levels, respectively.

leaf length (0.05) and plant height (-0.1) on paddy yield. Flag leaf length had a positive and direct effect (0.317) on paddy yield and its indirect effects were through traits including number of spikelet per panicle, days to complete maturity and plant height, 0.02, -0.04 and -0.12, respectively, on paddy yield. Last trait into the path analysis model was plant height with a direct effect (-0.36) on paddy yield and negative indirect effect on paddy yield was through both the number of spikelet per panicle -0.33, days to complete maturity -0.06 and flag leaf length 0.1. The number of spikelets per panicle were the most important trait effective on paddy yield and it may be suitable for selective and breeding. Determination of the most important selection scale for breeding of paddy yield is different, but in most of researches yield components have been reported, as an important criterion. In many researches panicle number per plant (Paul and Nanda, 1994; Yadav and Bhushan, 2001) and also number of spikelet per panicle (Yolanda and Das, 1995; Zheng *et al.*, 2003) have been reported as effective traits with the highest direct effect on grain yield to improve of grain yield breeding. Basavaraja *et al.* (1997) studied 10 traits related to yield components on F_2 cultivars and they concluded that, panicles number per plant have the highest positive direct effect on grain yield. In similar studies of Padmavathi *et al.* (1996) performing of path analysis on 23 rice cultivars showed that, indirect selection based on panicle number per plant and panicle length can be useful tool for increasing grain yield. Under drought stress conditions flag leaf width had the highest positive and direct effect on paddy yield (0.62). Indirect effects of flag leaf width on yield were due to number of filled grains per panicle (0.16) and days to 50% flowering (0.09) and total 0.25. After this trait, number of

filled grain per panicle (0.27) and days to 50% flowering (-0.22) had the highest direct effect on yield, respectively (Tab. 8). Number of filled grains per panicle had a direct and positive effect (0.27) and also a positive and indirect effect was observed via flag leaf width and days to 50% flowering on yield that is 0.36 and 0.06 respectively. Days to 50% flowering had negative and direct effect (-0.22) and negative indirect effects via flag leaf width and number of filled grains per panicle were -0.26 and -0.07, respectively. Similarly path coefficients was observed so that the largest direct effect showed a significant difference between the direct effects and other traits were belonging to flag leaf width. In addition, number of filled grains per panicle and days to 50% flowering had significant and indirect effect on paddy yield through the flag leaf width. So it seems that, the flag leaf width was the most important influencing trait on paddy yield and it will be studied as good selection criteria in order to yield breeding programs. Mehetre *et al.* (1994) have been reported that, number of filled grain per panicle, plant height and panicle length are the most important and effective traits on yield for breeding of upland rice.

Conclusions

The results of this research showed that indirect selections for increasing the number of spikelet per panicle and flag leaf length and decreasing plant height and days to complete maturity under optimum irrigation, and for increasing flag leaf width and number of filled grains per panicle and reducing days to 50% flowering can be suitable to improve paddy yield of rice in breeding programs.

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