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Effect of selection response of segregating population for water use efficiency in inter-varietal rice (*Oryza sativa* L.) crosses suitable for moisture deficit aerobic planting

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ABSTRACT

Genetic parameters were studied in a set of five parental lines and ten F_2 populations in rice (Oryza sativa L.) under aerobic conditions during dry season 2013-14. The selected F_2 plants were forwarded to generate F_3 families during subsequent dry season. For all the characters in F_2 populations observed, the magnitude of PCV was higher than the GCV indicating lower environmental influence on those characters. Genetic advance and heritability indicated high genetic advance as percent mean coupled with high heritability suggesting that there is a pre-ponderance of additive gene action for the traits, plant height, number of tillers, number of panicles, 100-grain weight, leaf width, panicle exsretion and grain yield plant $^{-1}$. Correlation analysis revealed that grain yield exhibited significantly positive correlation with most traits observed so also path analysis revealed positive direct effect on most plant growth and yield contributing traits. Characters such as days to flowering, grain width, panicle exsertion and plant height had negative direct effect on grain yield. The intergeneration correlation and regression coefficient between F_2 and F_3 generations of crosses IR-64 × MAS-26 and IR-64 × IM-114 were significant for days to 50% flowering, days of maturity, plant height, productive tiller per plant, 100- grain weight, panicle length and grain yield. However, cross IR-64 × OYC-183 was significant for all the traits except productive tiller per clump showed non-significant correlation. The higher water use efficiency (WUE) was exhibited for cross IR64 × MAS-26 (5.60 %) while cross OYC-183 × Karimundhaga had the least (2.35%) WUE. The study revealed that there were several segregants performing well under aerobic condition and selection based on genetic parameters was effective in identifying superior genotypes in F_2 and F_3.

Key words: *Rice (Oryza sativa L.), drought, genetic variability, heritability, genetic advance, inter generation correlation and regression, water use efficiency*

Variation is the basis of plant breeding. Thus, the success of any improvement programme will largely depend on the magnitude and range of variability in the available genetic stocks (Tiwari 2015).Rice (*Oryza sativa* L.) is life and the prince among cereals as this unique grain helps to sustain two thirds of the world's population (Kahaniand Hittalmani 2015).It accounts for around 23 per cent of the global calorie intake and 16 per cent of per capita protein (Li *et al.* 2011; Bernier *et al.* 2008). India ranks first in area (44mha) and second in production (102 mt) among the rice producing countries in the world (Ministry of Agriculture, New Delhi, 2015). However, India ranks 9th in terms of productivity. In India, West Bengal stands first in production (14.60mt) followed by Uttar Pradesh (14.02mt) and Andhra Pradesh (12.89mt) (Listz 2015).

Breeding efforts specifically towards upland environments has also led to the development of aerobic rice which is higher yielding than traditional upland varieties and combines input responsiveness with improved lodging resistance and harvest index (Atlin *et al.* 2006). Traditional lowland rice with continuous flooding in Asia has relatively high water inputs. Because of increasing water scarcity, there is a need to develop alternative systems that require less water. Aerobic rice promises substantial water savings by minimizing seepage and percolation and greatly reducing evaporation. Experimentally growing the high-yielding lowland rice varieties under aerobic conditions has shown great potential to save water, but with severe yield penalty (Bouman *et al.* 2002). Water is essential for rice cultivation and its supply in adequate quantity is one of the most important factors in rice production (Akinbile *et al.* 2011; Mondonedo 2008). In Asia and other parts of the world, rice crop suffers either from too little water (drought) or too much (flooding or submergence). Most studies on constraints to high rice yield shows that water is the main factor for yield gaps and yield variability from experiment stations to farm (Papadimetriou 2001).Irrigated agriculture is the dominant use of water, accounting for about 70% of global, 44% of developing countries and in Middle East and North African, this percentage reaches up to 90% water consumption (Water footprint of Italy, 2014). Assessing the scope for gains in water productivity requires an understanding of basic biological and hydrological crop-water relations. How much more water will be needed for agriculture in the future is governed, to a large extent, by links between water, food and changes in diets (Rosegrant *et al.* 2002). The amount of water required for field crops and its relation to yield dominates the equation on the need for additional water for food. Exploring ways to produce more rice with less water is essential for food security. To feed over nine billion people by 2050, agricultural systems will rely on transformational technologies. For rational use of scarce resources, 'knowledge' as a production factor will play a decisive role (Awan *et al.* (2015). Water-saving rice production systems, such as aerobic rice culture, system of rice intensification (SRI), ground-cover rice production system (GCRPS), raised beds and alternate wetting and drying (AWD), can drastically cut down the unproductive water outflows and increase water-use efficiency (WUE). However, these technologies can sometimes lead to some yield penalty, if the existing lowland varieties are used (Farooq *et al.* 2009).Moreover before launching any breeding programme, a breeder should have a thorough knowledge on nature and magnitude of genetic variability, heritability, genetic advance and character association in a crop species. Genetic variability for agronomic traits is the key component of breeding programs for broadening the gene pool of rice and would require reliable estimates of heritability in order to plan an efficient breeding program (Akinwale *et al.* 2011). Information on association of characters, direct and indirect effects contributed by each character towards yield will be an added advantage in aiding the selection process. Ullah *et al.* (2011) noted that grain yield was positively and significantly associated with panicle length and grains per panicle. Hairmansis *et al.* (2010) recorded a positive and significant association of grain yield with filled grains per panicle, spikelets per panicle and spikelet fertility.

Yield component breeding to increase grain yield would be most effective, if the components involved are highly heritable and genetically independent or positively correlated with grain yield (Khalid *et al.* 2012). However, it is very difficult to judge whether observed variability is highly heritable or not. Moreover, knowledge of heritability is essential for selection based improvement as it indicates the extent of transmissibility of a character into future generations (Sabesan *et al.* 2009).Akinwale *et al.* (2011) estimated broad sense heritability of 95.1% for days to flowering, 72.4% for plant height, 72.1% for grain yield, 59.4% for panicles plant^{-1}, 53.6% for panicle length and 19.2% for tillers per plant. Sadeghi (2011) also reported broad sense heritability estimates of 98.9% for days to maturity, 93.15% for panicle length, 70.2% for productive tillers, 69.2% for plant height and 68.1% for grain yield. The process of breeding is mainly influenced by the nature and magnitude of interaction of genotypes with the environment in plant characters. Hence, it is necessary to partition the observed variation into heritable and non-heritable components and to have the understanding of the parameters such as coefficient of variation, heritability and genetic advance. The main advantage of path coefficient analysis is that it helps to partition correlation coefficient into direct and indirect effects on dependable character and it also gives the idea of selecting suitable traits to improve yield under water limited conditions. Grain yield has been influenced by high direct positive effects of productive tillers, days to flowering (Sadeghi 2011), panicles per plant (Akinwale *et al.* 2011), plant height and days to flowering (Kole *et al.* 2008). Since yield is inherited in a complex way and is influenced by the environment, path coefficient analysis will be an added advantage to the breeder in crop improvement programme. The present investigation was therefore, undertaken to assess the magnitude of variability and to understand the heritable component of variation for yield and yield components in aerobic conditions.It is essential to estimate the various types of gene action for the selection of appropriate breeding procedure to improve the quantitative and qualitative characters (Banumathy *et al.* 2003; Sathya and Jebaraj 2013). Keeping in view, the genetic studies in aerobic rice were undertaken to compute the heritability, coefficients of variability, genetic advance and water use efficiencyin F_2 segregating populations of the 10 crosses for 14 characters, and also the response of selection for yield and its component characters through mean, percentage of population mean and through parent progeny correlation and regression method in between F_2 and F_3 generations.

MATERIAL AND METHODS

Ten F_2 populations were generated using half diallel mating design of rice by crossing five parental genotypes viz., IR-64, MAS-26, OYC-183, IM-114 and Karimundhga. Staggered sowing of the selected parental genotypes were done to achieve synchronization in the flowering for effective crossing programme to generate F_1. The seedlings were raised during dry season 2013-14 following all the recommended agronomic practices for aerobic cultivation (Gandhi *et al.* 2012). At panicle emergence and flowering stage, the florets of female parents were hand emasculated early in the morning, before 7 AM and later the pollen was collected from male parent and dusted on to the stigma within 11 AM. The seeds set on female plants were harvested, around 25-27 days after crossing event. Ten crosses were effected in a pair wise combination during dry season 2013-14, at K block, UAS, Bangalore.

Evaluation of F_2 generation population

The F_2 seeds of all the 10 crosses of rice were directly sown in the field under moisture scarce aerobic situation during dry season 2013-14 with single seeds per hill at spacing of 25 × 25 cm. On an average of 300 population size for each cross was maintained along with two rows parental lines. Mean values were utilized for statistical analysis and the characters observed for eliciting the information were: days to flowering, days to flowering and maturity, days to maturity, plant height (cm), number of tillers plant, number of Panicles plant^{-1}, productive tillers plant^{-1}, mother panicle weight (g), 100grain weight (g), panicle length (cm), panicle exsertion (±cm), leaf length (cm), leaf width (cm), grain length (mm), grain breadth (mm), straw weight (g) and grain yield plant^{-1} (g). The field experiment was raised under aerobic conditions by providing 12 surface irrigations during the cropping period with 56 mm of water in each irrigation. A total of 680 mm of water was provided. The package of practices for raising rice crop under aerobic conditions was followed (Hittalmani 2007; Gandhi *et al.* 2012).

Evaluation of F_3 families

F_3 families were raised during the dry season 2014. From among the 10 crosses that were evaluated in F_2, threehighest yieldingcrosses were selected and forwarded to generate F_3 families. The crosses selected were IR-64 × MAS-26, IR-64 × OYC-183 and IR-64 × IM-114. Three hundred plants in each F_3 family were evaluated for traits days 50% flowering, days to maturity, plant height, productive tiller per plant, 100grain weight, panicle length and grain yield. Progeny mean, range and percentage of population mean for selected individual for each population were estimated. Mean values were used to estimate the parent offspring correlation and regression between F_2 and F_3 generation.

Statistical analysis

The observations recorded in respect of all the above quantitative traits were subjected to following standard statistical analysis: Descriptive statistics Sunderaraj *et al.* (1972), mean, range, standard error, variance, skewness and kurtosis as per Snedecor and Cochran (1974). The mean values of quantitative traits were used to estimate coefficients of skewness and kurtosis using 'SPSS' software program.Genetic variability parameters, coefficients of variation estimated as in Burton and De Vane (1953). Phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance (GA) were estimated using procedure of Johnson *et al*. (1955).

Water use efficiency or crop water productivity (WUE)

The term 'efficiency or productivity' refers to output/input ratio. If the ratio is more, the system is said to be more efficient or productive. Likewise, irrigation efficiency refers to the ratio of how much water utilized to how much water applied (Singh *et al.* 2014). The water use efficiency of parents and all the doubled haploid lines were estimated by taking grain yield per liters of water consumed.

$$WUE\ (\%) = \frac{\text{Grain yield plant}^{-1}\text{(g)}}{\text{Total water consumed (lts)}} \times 100$$

RESULTS AND DISCUSSION

The genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance as per cent of mean (GAM) were estimated for 14 characters and the results were presented in Table 1. The magnitude of PCV was higher than the GCV indicating less environmental influence on those characters. Heritability estimates (above 60%) along with genetic advance (above 20%) would be helpful in predicting gain under selection than heritability estimates alone (Nirmaladevi *et al.* 2015). All the traits exhibited high broad sense heritability except for grain length. Since many of the traits comprised of low to high genetic advance as percent mean coupld with high heritability suggesting that progress can be made through selection as it suggests the preponderance of additive gene action (Panse 1957). In the present study, traits such as high estimates of heritability and genetic advance were obtained for plant height, number of tillers, number of panicles, 100-grain weight, leaf width, panicle exsretion and grain yield plant^{-1}. Thus selection for these traits is likely to accumulate more additive genes leading to further improvement of their performance and these traits may be used as selection criteria in upland rice breeding program. Similar findings were also reported by Kishore *et al*. (2008) for plant height; Sabesan *et al.* (2009) for 100-grain weight; Chakraborty and Chaturvedi (2014) for number of panicles and grain yield; Kumar and Senapati (2013) and Chaturvedi *et al.* (2011)for yield per plant. While the lowest genetic advance as percent mean coupled with high heritability was observed for the traits days to flowering, days to maturity, grain width and panicle length which were indicative of non-additive gene action in their inheritance. Therefore, heterosis breeding could be used to improve these traits. The high heritability is being exhibited due to favorable influence of environment rather than genotype and selection for such traits may not be rewarding (Kumar *et al.* 2013).

Table 1. Genetic variability, heritability, genetic advance and genetic advance percent mean for F_2 population

Characters	PCV	GCV	h^2	GA	GA % MEAN
DF	5.05	5.02	98.08	9.78	10.26
DFM	10.42	10.25	96.29	8.11	20.78
DM	6.01	5.95	97.72	16.35	12.14
PHT	15.04	14.92	98.17	21.14	30.50
NT	26.06	25.32	94.19	9.89	50.69
NP	28.41	27.80	95.48	9.78	56.04
100GW	31.27	31.27	99.97	20.56	64.40
GL	12.82	10.04	13.99	0.04	3.90
GW	3.16	2.78	66.91	0.44	4.97
LW	21.53	21.52	99.94	12.60	44.32
PL	10.72	10.52	95.57	4.43	21.28
PE	17.20	19.51	68.98	1.20	62.31
SW	29.89	10.65	35.78	0.14	5.58
GYLD	33.11	32.59	96.14	16.81	66.10

DF=Days to flowering, DFM=Days to flowering and maturity,DM=Days to maturity, NT=Number of tillers Plant^{-1} PHT=Plant Height, GW=hundred grain weight, NP=Number of panicles, GW=Grain width, GL=Grain length, LW=Leaf width, PL=Panicle length, PE=Panicle excretion,SW=Straw weight, GYLD=Grain yield plant^{-1}

The degree of correlation between the traits is a key factor especially in complex and economic trait such as yield. The results of correlation analysis reveals that grain yield exhibits significantly positive correlation with plant height, leaf width, straw weight, number of tillers plant^{-1}, panicle length, number of panicles and panicle excretion (Table 2). These findings suggest that rice yield can be improved by using these traits as selection criteria in succeeding generations (Akhtar *et al.* 2011). It also indicated that grain yield can be increased whenever there is an increase in characters that showed positive and significant association with grain yield. Hence, these characters can be considered as criteria for selection for higher yield as these were mutually and directly associated with yield (Babu *et al.* 2012). However, traits such as days to flowering, days to maturity, grain width and grain length exhibited significant negative correlation on grain yield plant^{-1}.

Correlation is partitioned into direct and indirect effects through path coefficient analysis. Characters namely days to flowering and maturity (0.71), number of panicles (0.38), number of tillers plant^{-1}(0.53), hundred grain weight (0.54), leaf width (0.36), grain length (0.14) and straw weight (0.73) incurred positive direct effect on grain yield. Similar findings were also reported by Prasad *et al.* (2001), Zahid *et al.* (2006) and Yadav *et al* (2011). Days to flowering and maturity had a nullifying effect on grain yield through number of tillers (-0.26), number of panicles (-0.20), leaf width (-0.16) and straw weight (-0.19). As the significant

Table 2. Phenotypic correlations among traits in F_2 generations.

Char-acters	DF	DFM	DM	PHT	NT	NP	GW	GL	GW	LW	PL	PE	SW	GYLD
DF	1													
DFM	0.84**	1												
DM	0.98**	0.93**	1											
PHT	-0.69**	-0.57**	-0.68**	1										
NT	-0.65**	-0.49**	-0.62**	0.72**	1									
NP	-0.63**	-0.52**	-0.63**	0.77**	0.99**	1								
100 GW	0.21**	0.08	0.20**	0.28**	0.13**	0.18**	1							
GL	0.17**	-0.09	0.03	0.18**	-0.24**	-0.13**	0.15**	1						
GW	0.10*	0.21**	0.20**	-0.05	-0.12**	-0.18**	0.49**	-0.57**	1					
LW	-0.54**	-0.45**	-0.53**	0.11**	0.33**	0.32**	-0.64**	-0.24**	-0.51**	1				
PL	-0.55**	-0.52**	-0.59**	0.41**	0.42**	0.38**	-0.40**	0.18**	-0.40**	0.51**	1			
PE	0.07	0.31**	0.16**	0.32**	0.48**	0.51**	0.07	-0.30**	-0.03	0.17**	-0.16**	1		
SW	-0.49**	-0.26**	-0.44**	0.42**	0.81**	0.78**	-0.29**	-0.53**	-0.14**	0.51**	0.27**	0.67**	1	
GYLD	-0.25**	-0.09	-0.22**	0.25**	0.83**	0.79**	0.02	-0.35**	-0.24**	0.36**	0.24**	0.56**	0.78**	1

*significant @ p=0.01, **significant @ p=0.05

DF=Days to flowering, PHT=Plant Height, GW=Grain width, LW=Leaf width, SW=Straw weight, DFM=Days to flowering and maturity, NT=Number of tillers $Plant^{-1}$, GL=Grain length, PL=Panicle length, GYLD=Grain yield $plant^{-1}$, DM=Days to maturity, NP=Number of panicles, GW=hundred grain weight, PE=Panicle excretion

positive correlation between yield and other traits is mainly due to its direct effect, which reveals the true relationship between them, direct selection of these traits will be rewarding for yield improvement. Characters such as days to flowering (-0.14), grain width (-0.17), panicle exertion (-0.50) and plant height (-0.48) had negative direct effect on grain yield. The lower residual effect indicated that different characters other than the characters considered in this study influence the grain yield considerably (Table 3). The highest water use efficiency was reported for cross IR-64 × MAS-26 (5.60%) while cross OYC-183× Karimundhaga was the least (2.35%) WUE under aerobic condition. The parents were exhibited 5.15 %, 5.01%, 2.79%, 4.47% and 2.33% WUE with the mean value of 3.64 % (Table 4). Liu Cuihong (2011) reported that the yield and water use efficiency of rice under paper mulching improve 6.82% and 10.91% respectively than without paper mulching. Wang Bin (2011) showed that the rice theory and quadrat yields slightly decrease under CI1 (controlled irrigation measure without storing rainfall), while increase 6.3% and 10.6% under CI2 (controlled irrigation measure of storing rainfall). Awan *et al*. (2015) stated that aerobic rice is a viable eco-efficient option to improve water productivity in regions like India and Pakistan where

Table 3. Genotypic direct (diagonal) and indirect effects of different quantitative traits in F_2 generation

Characters	DF	DFM	DM	PHT	NT	NP	GW	GL	GW	LW	PL	PE	SW	'r' values
DF	-0.14	0.59	0.04	0.33	-0.34	-0.24	0.11	0.02	-0.02	-0.20	-0.03	-0.03	-0.36	-0.25**
DFM	-0.12	0.71	0.04	0.28	-0.26	-0.20	0.04	-0.01	-0.04	-0.16	-0.03	-0.15	-0.19	-0.09
DM	-0.14	0.66	0.05	0.33	-0.33	-0.24	0.11	0.00	-0.03	-0.19	-0.03	-0.08	-0.32	-0.22**
PHT	0.10	-0.40	-0.03	-0.48	0.38	0.30	0.15	0.03	0.01	0.04	0.02	-0.16	0.31	0.25**
NT	0.09	-0.35	-0.03	-0.35	0.53	0.38	0.07	-0.03	0.02	0.12	0.02	-0.24	0.59	0.83**
NP	0.09	-0.37	-0.03	-0.37	0.52	0.38	0.10	-0.02	0.03	0.12	0.02	-0.25	0.57	0.79**
100 GW	-0.03	0.06	0.01	-0.14	0.07	0.07	0.54	0.02	-0.08	-0.23	-0.02	-0.03	-0.21	0.02
GL	-0.02	-0.06	0.00	-0.09	-0.13	-0.05	0.08	0.14	0.10	-0.09	0.01	0.15	-0.39	-0.35**
GW	-0.01	0.15	0.01	0.02	-0.06	-0.07	0.27	-0.08	-0.17	-0.18	-0.02	0.01	-0.10	-0.24**
LW	0.08	-0.32	-0.02	-0.05	0.17	0.12	-0.35	-0.03	0.09	0.36	0.03	-0.08	0.37	0.36**
PL	0.08	-0.37	-0.03	-0.20	0.22	0.15	-0.22	0.03	0.07	0.18	0.05	0.08	0.20	0.24**
PE	-0.01	0.22	0.01	-0.15	0.25	0.20	0.04	-0.04	0.01	0.06	-0.01	-0.50	0.49	0.56**
SW	0.07	-0.18	-0.02	-0.20	0.43	0.30	-0.16	-0.07	0.02	0.18	0.01	-0.33	0.73	0.78**

DF=Days to flowering, PHT=Plant height, GW=Grain width, LW=Leaf width, SW=Straw weight, DFM=Days to flowering and maturity, NT=Number of tillers $plant^{-1}$, GL=Grain length, PL=Panicle length, GYLD=Grain yield $plant^{-1}$, DM=Days to maturity, NP=Number of panicles, GW=hundred grain weight, PE=Panicle exsretion

Table 4. Water Use Efficiency of parental crosses and F_2 progenies

Genotypes	M-WUE %	Min-R WUE %	Max-R WUE %	IOT IR64	DOT IR64	IOT MAS 26	DOT MAS 26	IOT OYC 183	DOT OYC 183	IOT IM 114	DOT IM 114	IOT Karimundhga	DOT Karimundhga
IR64 × MAS26	5.60	2.94	6.91	0.45	-	0.59	-	-	-	-	-	-	-
IR64 × OYC183	2.98	0.88	5.88	-	2.17	-	-	0.19	-	-	-	-	-
IR64 × IM114	5.00	1.76	6.91	-	0.15	-	-	-	-	0.53	-	-	-
IR64 × Karimundhga	2.90	0.88	4.41	-	2.25	-	-	-	-	-	-	0.57	-
MAS26 × OYC183	2.79	1.02	5.58	-	-	-	2.22	0.11	-	-	-	-	-
MAS26 × IM114	4.63	1.47	6.47	-	-	-	0.38	-	-	0.16	-	-	-
MAS26 × Karimundhaga	2.70	0.73	4.11	-	-	-	2.31	-	-	-	-	0.37	-
OYC183 × IM114	3.52	0.77	4.85	-	-	-	-	0.73	-	-	0.95		-
OYC183 × Karimundhaga	2.35	0.66	2.94	-	-	-	-	-	0.44	-	-	0.02	-
IM114 × Karimundagha	2.49	1.07	3.67	-	-	-	-	-	-	-	1.98	0.16	-
IR-64	5.15	-	-	0.14	-	-	-	2.36	-	0.68	-	2.82	-
MAS-26	5.01	-	-	-	0.14	-	-	2.22	-	0.54	-	2.68	-
OYC-183	2.79	-	-	-	2.36	-	2.22	-	-	-	1.68	0.46	-
IM-114	4.47	-	-	-	0.68	-	0.54	1.68	-	-	-	2.14	-
Karimundhga	2.33	-	-	-	2.82	-	2.68	-	0.46	-	2.14	-	-

M-WUE-Mean water use efficiency, Min range WUE-Minimum water use efficiency, Max range WUE-Maximum water use Efficiency, IOT-Increase over than , DOT-Decrease over than IR-64

Table 5. Mean performance of selected plants in F_2 and F_3 generation for different characters in three crosses

Characters	F_2 Population (IR64 × MAS26)				F_3 Population (IR64 × MAS26)			
	Range	Mean	% of F_2 population		Range	mean	% of F_3 population	
Day to 50% flowering	90-99	94.52	96.27	103.68	85-96	91.96	93.51	103.30
Days to maturity	120-148	134.97	89.64	108.19	117-146	133.67	88.65	107.72
Plant height (cm)	48-78	61.36	81.48	123.85	50-70	58.79	88.45	117.36
No of productive panicles	7-27	18.5	137.83		15-26	19.65	132.31	
100- Grain weight	2.4-2.6	2.53	102.60		2.4-2.7	2.54	102.32	
Panicle length	14-23	20.54	107.10		17-24	21.17	106.28	
Grain Yield per plant	20-47	38.08	120.79		28-49	39.62	118.62	

Characters	F_2 Population (IR64 × OYC183)				F_3 Population (IR64 × OYC183)			
	Range	Mean	% of F_2 population		Range	mean	% of F_3 population	
Day to 50% flowering	90-101	97.17	92.62	102.91	88-99	94.94	93.74	103.22
Days to maturity	123-154	138.06	89.81	110.09	121-145	136.18	89.58	105.74
Plant height (cm)	40-87	66.05	62.07	130.20	50-80	63.17	80.73	125.05
No of productive panicles	4-16	11.13	134.77		8-17	13.09	129.87	
100 Grain weight	2.4-2.5	2.47	101.17		2.35-2.5	2.48	100.80	
Panicle length	11-25	19.11	130.82		12-25	20.2	118.81	
Grain Yield per plant	6-40	20.32	167.32		8-41	23.26	154.77	

Characters	F_2 Population (IR64 × IM114)				F_3 Population (IR64 × IM114)			
	Range	Mean	% of F_2 population		Range	mean	% of F_3 population	
Day to 50% flowering	88-102	95.07	93.08	105.18	87-100	94.78	92.31	103.39
Days to maturity	123-150	141.07	87.89	104.91	125-145	139.61	90.25	101.71
Plant height (cm)	45-77	62.2	75.56	123.79	50-70	60.57	82.54	112.26
No of productive panicles	7-31	18.2	148.35		11-32	20.17	138.82	
100- Grain weight	2.2-2.6	2.53	102.40		2.4-2.6	2.55	101.96	
Panicle length	14-26	21.03	116.50		16-25	22.15	108.35	
Grain Yield per plant	12-47	34.05	132.15		15-49	36.13	124.55	

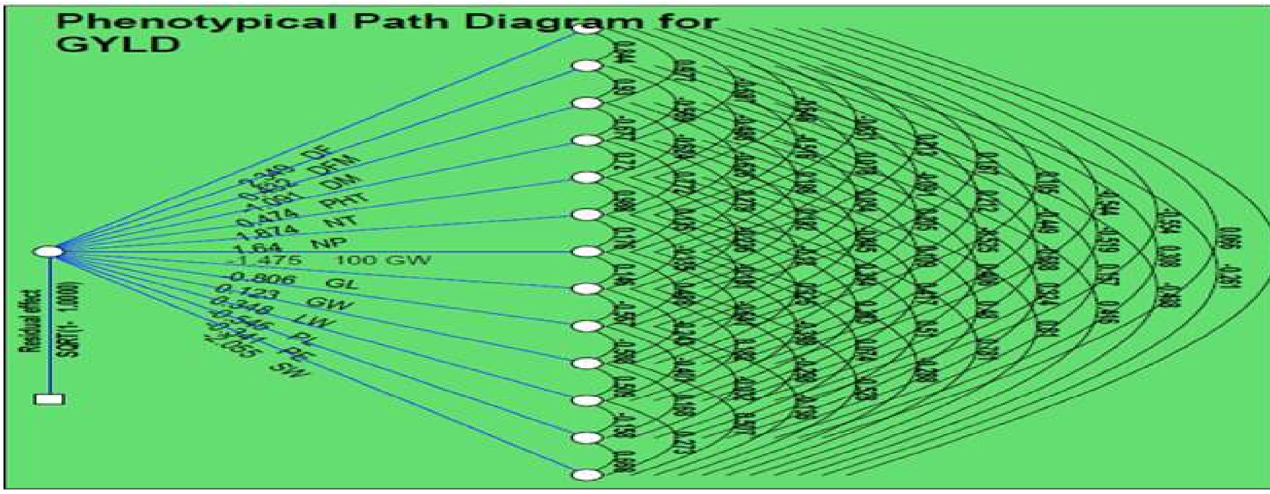

Fig. 1. Path diagram for F_2 population
DF=Days to flowering, PHT=Plant height, DFM=Days to flowering and maturity, NT=Number of tillers Plant $^{-1}$, DM=Days to maturity, NP=Number of panicles, GW=Grain width, LW=Leaf width, SW=Straw weight,

Table 6. Parent offspring correlation in F_2 and F_3 and regression of the crosses over segregating generation for different characters in cross IR64 × MAS26

Characters	Correlation coefficient F_2	Correlation coefficient F_3	Correlation coefficient between F_2 & F_3	Regression coefficient between F_2 & F_3
Days 50 % flowering	-0.10**	-0.10**	0.11**	0.09
Days of maturity	0.11**	0.11**	0.60**	0.64**
Plant Height	0.05	0.05	0.47**	0.45**
Productive tiller per plant	0.33**	0.13**	0.78**	0.52**
100-hGrain weight	-0.01	-0.05	0.85**	0.83**
Panicle length	-0.23**	-0.22**	0.45**	0.35**
Grain yield	-	-	0.51**	0.41**

* Significant @ p=0.05, ** Significant @ p=0.05

Table 6a. Parent offspring correlation in F_2 and F_3 and regression of the crosses over segregating generation for different characters in cross IR64 × OYC-183

Characters	Correlation coefficient F_2	Correlation coefficient F_3	Correlation coefficient between F_2 & F_3	Regression coefficient between F_2 & F_3
Days 50 % flowering	0.09	-0.002	0.45**	0.41**
Days of maturity	0.07	0.12**	0.78**	0.54**
Plant height	0.06	0.15**	0.43**	0.42**
Productive tiller per plant	0.67	0.07	0.09	0.09
100 grain weight	0.003	-0.0006	0.77**	0.68**
Panicle length	-0.06	0.005	0.60**	0.45**
Grain yield	-		0.58**	0.52**

*Significant @ p=0.05, **Significant @ p=0.05

water is getting scarcer than land. The developing technology will benefit from well-informed knowledge based entry points to fill the identified technological and attitudinal gaps.

The yield performance and other attributing characters of F_3 families raised from the selected F_2 populations on the basis of phenotypic performance of the crosses did not showed much encouraging results (Table 5). Out of 10 crosses, only three families could be isolated as promising families for F_3 generation. Thus, there was practically no relation between the yield of individual F_2 selection and the mean yield of corresponding F_3 families. Similar findings were also

Table 6b. Parent offspring correlation in F_2 and F_3 and regression of the crosses over segregating generation for different characters in cross IR-64 × IM-114

Characters	Correlation coefficient F_2	Correlation coefficient F_3	Correlation coefficient between F_2 & F_3	Regression coefficient between F_2 & F_3
Days 50 % flowering	-0.14**	-0.11**	0.74**	0.75**
Days of maturity	0.18**	0.09	0.85**	0.73**
Plant height	0.12**	0.23**	0.47**	0.38**
Productive tiller per plant	-0.0362	0.09	0.55**	0.54**
100 grain weight	-0.07	0.03	0.70**	0.58**
Panicle length	0.03	-0.04	0.42**	0.38**
Grain yield	-	-	0.66**	0.62**

*Significant @ p=0.05, **Significant @ p=0.05

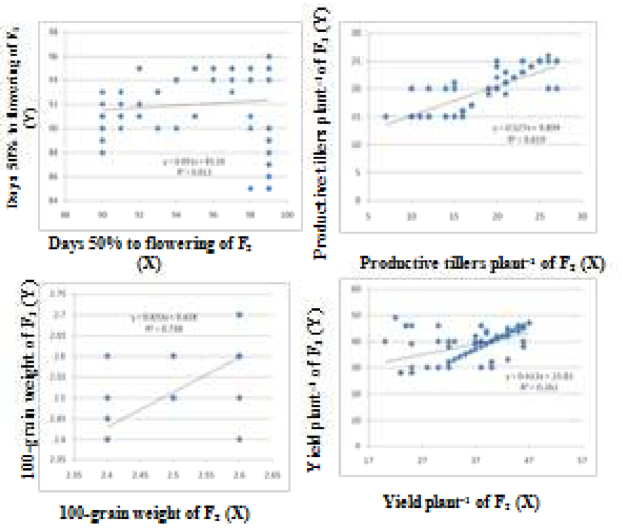

Fig. 2. Parent progeny relationship based on F_2, F_3 in cross IR-64 × MAS-26

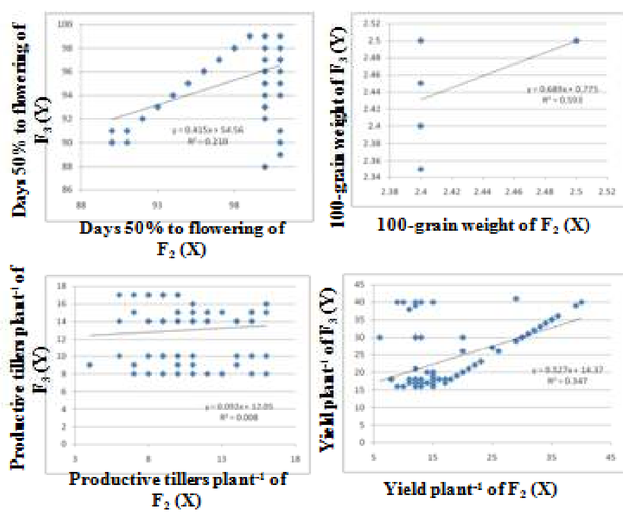

Fig. 3. Parent progeny relationship based on F_2, F_3 in cross IR-64 ×OYC-183

reported by Suwarto *et al.* (2015) and Borahb (2012). Thus selection based on phenotypic performance for yield in early generation is ineffective.

In respect of plant height, number of productive panicles, 100-grain weight, panicle length and grain yield per plant in F_3 generation showed high mean performance and lower percentage of population mean than in F_2 generation in crosses IR64 × MAS-26 and IR64 × IM-114 and except number of productive panicle trait in IR64 × OYC-183. Moreover, all the characters showed strong correlation and regression between F_2 and F_3 generation

The inter generation correlation and regression

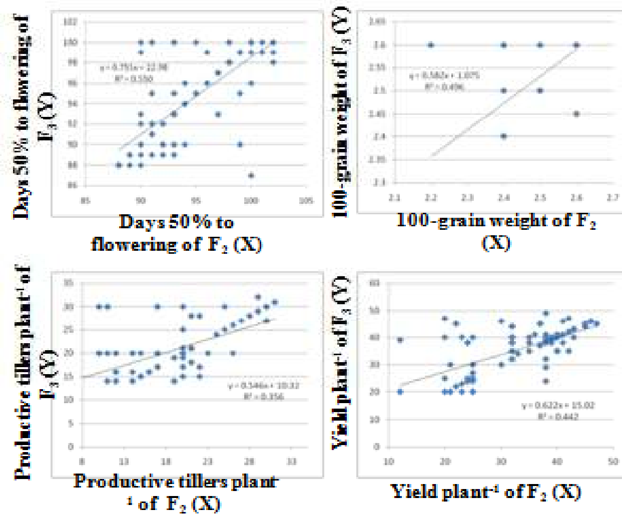

Fig. 4. Parent progeny relationship based on F_2, F_3 in cross IR-64 × IM-114

coefficient between F_2 and F_3 generation for crosses IR64 × MAS-26 and IR64 × IM-114 were significant for days 50 % flowering, days of maturity, plant height, productive tiller per plant, 100- grain weight, panicle length and grain yield. This indicated the effectiveness of selection for these characters. However, cross IR64 × OYC-183 were significant for all the traits except productive tiller per clump showed non-significant correlation between F_2 and F_3 generation. This indicates that selection for productive tiller per plant on the basis of phenotypic performance during early generation may not be advisable.

The inter generation correlation and regression for yield component characters are presented in Tables 6, 6a and 6b. The F_2 generation showed significant positive correlation and regression with F_3 generation for days 50 % flowering, days of maturity, plant height, productive tiller per plant, 100- grain weight, panicle length and grain yield in crosses IR64 × MAS-26, IR64 × IM-114 except productive tiller per plant trait in cross IR64 × OYC-183. The highest correlation in the cross IR64 × MAS-26 was observed in 100-grain weight (0.85) and lowest is days 50% flowering (0.11). The highest correlation in the cross IR64 × IM-114 was observed in days of maturity (0.78) and lowest is panicle length (0.42). The highest correlation in the cross IR-64 × OYC-183 was observed in days of maturity (0.78) followed by 100-grain weight (0.77) and lowest is productive tiller per plant (0.09). The results were in conformity with the findings of Suwarto *et al*. (2015)

and Borahb (2012). This indicated the effectiveness of selection for these characters. These results were also agreed with the mean performance of the F_2 selection and F_3 progeny mean performance. However, Productive tiller per clump in cross IR64 × OYC-183 showed non-significant correlation between F_2 and F_3 generation. This indicates that selection for productive tiller on the basis of phenotypic performance during early generation may not be advisable. (Figures 2, 3 and 4).

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