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Evaluation of genetic potential of land races and improved varieties for drought tolerance in rice (*Oryza sativa* L.)

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Abstract

Genetic potentialities of 13 parents (including eight land races and five high yielding varieties) and their 40 hybrids of rice (*Oryza sativa* L.) was assessed through combining ability studies on 17 yield and drought tolerant traits. Chandaikar, Norungan and Nootripathu among lines and Co 47, ASD 18 and PMK 3 among testers were identified as potential parents based on *per se* performance and *gca* effects for maximum number of characters and crosses involving these parents would result in identification of superior segregants with favourable genes for most of the drought tolerant and yield traits. Three cross combinations *viz.*, Nootripathu / PMK 3, Chandaikar / ASD 18 and Nootripathu / ASD 18 were recommended for recombination breeding based on significant *gca* effects of parents and non significant *sca* effects of hybrids in order to get desirable segregants in early segregating generation for drought tolerance and yield attributes.

Key words: Rice, genetic potentiality, drought tolerant traits, combining ability

Introduction

Rice (*Oryza sativa* L.) is the staple food for nearly 65% of the population in India. India has the largest area under rice in the world and ranks second in rice production. Of the 44 m ha of total rice area, 45% is irrigated, 33% is rainfed lowland and 15 per cent is rainfed upland [1]. In India, as elsewhere, drought causes widespread crop failures leading to acute shortage of food and fodder that adversely affects human and livestock population. Drought situation is becoming precarious year after year due to inadequate precipitation and less water efficient irrigation methods in rice farms. Combining ability studies helps in the selection of suitable parents for incorporation in the hybridization programme, besides elucidating the nature and magnitude of gene action involved in the inheritance of a character. Such informations are required to design efficient breeding programme for rapid crop improvement. Dhillion [2] opined that the combining ability of parents gives useful information on the choice of parents in terms of expected performance of their hybrids and progenies. The *gca* effect is considered as intrinsic genetic value of the parent for a trait, which is due to additive gene effects and it is fixable [3]. Drought is a major constraint to the increased productivity of rice in rainfed regions. Hence, the development of high yielding drought tolerant rice cultivars will considerably improve rainfed rice production. In order to design an efficient breeding programme to develop varieties with virtues of drought tolerance and yielding ability, it is necessary to identify potential parents that combine well for both yield and drought tolerant traits. Hence, an attempt was made to study the combining ability of 13 parents and 40 hybrids under drought stress for yield and drought tolerant traits through line × tester analysis.

Materials and methods

Eight drought tolerant local land races *viz.*, Kallurundaikar (Kal), Kulliyadichan (Kul), Vellaichitraikar (Vel), Chandaikar (Cha), Mattaikar (Mat), Norungan (Nor), Nootripathu (Noo) and Varappukudanchan (Var) (lines) were crossed with five high yielding widely adapted rice varieties testers *viz.*, Co 47, ADT 45, ASD 18, IR 64 and PMK 3 during *rabi*, 2003 in a line × tester mating design. The F_1 hybrids of the resultant 40 crosses along with parents were sown in raised nursery bed on 15.05.2004 and transplanted to mainfield in a randomized block design replicated twice with a spacing of 20 × 15cm on 10.06.2004 under drought stress (moisture stress was induced by withholding irrigation for a period of 15 days during tillering stage starting on 60 days after sowing and the crop was irrigated after the stress period upto maturity). Single seedling per hill was transplanted for each hybrid in two rows of three metre length.

Recording observations: In each replication, 10 plants were randomly selected per genotype for recording observations on 17 yield and drought tolerant traits *viz.*, days to 50% flowering (DFF), days to 70% relative water content (RWC), leaf rolling (LR), leaf drying (LD), canopy temperature (CT), chlorophyll stability index (CSI), drought recovery rate (DRR), plant height (HT), productive tillers plant^{-1} (TN), grains panicle^{-1} (GN), 100 grains weight (TW), spikelet sterility (SS), root length (RL), root dry weight (RDW), root:shoot ratio (R:S), harvest index (HI) and grain yield plant^{-1} (GYP). The drought tolerant attributes were recorded as following procedure:

Days to 70% relative water content (RWC): Stress was induced during tillering stage on 60 days after sowing. Observations were recorded repeatedly every day till RWC reaches 70%. Leaf sampling was done at afternoon (1 pm). In each selected plant days to relative water content was recorded as follows: A sample of 0.5g of fresh, healthy and unblemished leaf material excluding the apex and collar regions was collected from each of the selected plants in each genotype when they are 60 days old. After taking the fresh weight (FW), the samples were placed in petridishes containing distilled water and kept it for 24 hours to obtain full turgidity. After 24 hours, the samples were removed from distilled water, blotted dry and turgid weight (TW) was recorded. The turgid leaf samples were kept in hot air oven at 60°C overnight and oven dry weight (DW) was determined. The relative water content was calculated using the formula suggested by Weatherley [4].

$$\text{Relative water content} = \frac{FW - DW}{TW - DW} \times 100$$

Leaf rolling and leaf drying: Leaf rolling and leaf drying were recorded when the selected plant attain days to 70% RWC. It is scored on an scale of 0 to 9 according to Standard Evaluation System for Rice. Scoring was taken at afternoon.

Canopy temperature: Canopy temperature was measured by using Infrared Thermometer. Measurement was taken at afternoon (1 pm) and expressed in degree celsius (°C).

Chlorophyll stability index: Chlorophyll stability index was estimated by Spectrophotometric method as suggested by Koloyereas [5] from the third leaf of the selected plants at 70% RWC.

Drought recovery rate: Moisture stress was induced by withholding irrigation for a period of 15 days during tillering stage starting on 60 days after sowing and the crop was irrigated after the stress period upto maturity Drought recovery rate was recorded after the stress period (10 days after irrigation), according to Standard Evaluation System for Rice (SESR).

Root length: At the time of harvest, selected plants (10 plants per replication) were uprooted by giving a deep dig near the base after watering and the maximum root length of the longest root was recorded in centimetre.

Root dry weight: Roots of the selected plants at the time of harvest were cut from the stem, dried moisture free in a hot air oven at 80°C for 48 hours (till attaining constant weight), weighed and recorded in grams.

Root:Shoot ratio: The root weight of selected plants was recorded as mentioned above. The shoot weight was recorded separately after drying the shoot portion including grains in hot air oven at 80°C for 48 hours till reaching constant weight. Root : Shoot ratio was worked out as follows,

$$\text{Root : Shoot ratio} = \frac{\text{Root dry weight (g)}}{\text{Shoot dry weight (g)}}$$

The mean data of these traits were used for combining ability analysis following Kempthorne [6].

Results and discussion

The analysis of variance for combining ability (line × tester mating design) revealed significant differences among the hybrids, lines, testers and line × tester interaction for all the characters studied.

Evaluation of parents: In the choice of parents, high mean value was the main criterion among the breeders. The parents with high mean performance would result in good performing offsprings [7]. Further, the parents with high *gca* effects are desirable for obtaining useful segregants in early generations [8]. Hence, the potentiality of parents to produce better offsprings with reservoir of superior genes was evaluated based on *per se* performance and *gca* effects (Table 1).

Parents and hybrids that had low days to 50% flowering, leaf rolling score, leaf drying score, canopy temperature, drought recovery rate and spikelet sterility and short stature (plant height) and, while for other traits, parents and hybrids that had more days to attain 70% relative water content, chlorophyll stability index, productive tillers plant^{-1}, grains panicle^{-1}, 100 grains weight, root length, root dry weight, root:shoot ratio, harvest index and grain yield plant^{-1} were desirable under moisture stress

Among the lines, Chandaikar recorded significantly favourable mean value for days to 50% flowering, days to 70% relative water content, leaf rolling, leaf drying, canopy temperature, chlorophyll stability index, drought recovery rate, 100 grains weight, spikelet sterility, root length, root dry weight and grain yield plant^{-1}. The lines Norungan and Nootripathu also registered significantly superior mean performance for ten traits each. Among the testers, PMK 3 had significantly superior mean performance for five drought tolerant (leaf drying, canopy temperature, chlorophyll stability index, drought recovery rate and root dry weight) and

Table 1. General combining ability effects and mean of parents for various trait under moisture stress in rice

Genotypes	DFF	RWC	LR	LD	CT	CSI	DRR	HT	TN	GN	TW	SS	RL	RDW	R:S	HI	GYP
Lines																	
Kal	0.5	–0.4	–1.4*	–0.9*	–1.5*	–2.9*	–0.2	0.6*	–1.2*	–3.3*	–0.1*	1.5*	–0.8*	–0.2*	0.001	–0.02*	0.9*
	(83.5*)	(13.5*)	(2.8*)	(3.2)	(33.5)	(51.5*)	(3.7)	(106.9)	(9.0)	(75.2)	(2.7*)	(17.6*)	(23.4*)	(2.14*)	(0.1)	(0.3)	(10.4)
Kul	0.7*	–0.6*	–0.9*	–1.8*	0.7*	–3.2*	0.1	8.5*	–0.1	–11.5*	–0.04	3.4*	–2.0*	–0.4*	–0.01*	–0.04*	–1.3*
	(85.5*)	(10.5)	(3.4)	(3.4)	(33.0*)	(27.9)	(4.4)	(134.0)	(9.3)	(71.9)	(2.3)	(19.7*)	(21.3)	(1.87)	(0.1)	(0.3)	(9.6)
Vel	0.2	–1.2*	1.0*	–0.2*	2.0*	–3.4*	0.6*	7.1*	0.3	–11.7*	–0.02	2.3*	–1.3*	–0.3*	–0.004*	–0.1*	–2.1*
	(86.0)	(9.5)	(3.0*)	(2.7*)	(33.0*)	(45.4*)	(3.6)	(106.1)	(7.8)	(72.8)	(2.3)	(18.6*)	(22.7*)	(1.97*)	(0.1)	(0.3)	(9.7)
Cha	0.6	0.8*	–0.5*	–0.1	–0.8*	7.2*	–0.6*	–5.6*	1.0*	19.3*	–0.01	–1.3*	0.4	0.3*	0.02*	0.03*	0.8*
	(83.0*)	(13.5*)	(2.4*)	(1.2*)	(32.3*)	(56.6*)	(2.7*)	(102.1)	(9.9)	(78.9)	(2.5*)	(17.2*)	(23.3*)	(2.72*)	(0.1)	(0.4)	(12.4*)
Mat	5.6*	–3.6*	3.7*	3.6*	1.9*	–13.7*	1.7*	6.9*	–1.6*	–27.8*	–0.2*	3.9*	–1.9*	–0.4*	–0.03*	–0.1*	–2.9*
	(84.0*)	(6.5)	(6.4)	(6.4)	(36.5)	(33.0)	(5.7)	(111.7)	(7.9)	(78.5)	(2.5*)	(18.5*)	(22.6*)	(1.76)	(0.1)	(0.3)	(9.9)
Nor	–2.9*	2.3*	0.1	0.6*	–1.2*	5.3*	–0.4*	–3.9*	1.5*	13.4*	0.3*	–3.8*	2.2*	0.2*	0.01*	0.1*	2.4*
	(85.0*)	(14.5*)	(2.8*)	(1.2*)	(32.8*)	(55.5*)	(3.2)	(115.2)	(10.9)	(77.6)	(2.5*)	(16.6*)	(24.5*)	(2.2*)	(0.1)	(0.4)	(10.6)
Noo	–3.4*	2.6*	–1.6*	–0.8*	–2.4*	9.7*	–1.3*	–5.9*	1.1*	16.6*	0.1*	–5.4*	2.3*	0.7*	0.02*	0.1*	2.5*
	(83.0*)	(14.5*)	(1.4*)	(1.2*)	(32.5*)	(53.9*)	(2.5*)	(102.9)	(10.8)	(78.7)	(2.4)	(14.5*)	(23.5*)	(2.3*)	(0.1)	(0.4)	(10.9)
Var	–1.1*	0.2	–0.4*	–0.4*	1.3*	1.2*	0.2	–7.7*	–0.9*	4.9*	–0.1*	0.7*	1.0*	0.1*	–0.003*	0.01	–0.4
	(84.0*)	(12.5*)	(3.5)	(2.4*)	(33.5)	(49.1*)	(3.9)	(113.0)	(8.9)	(77.4)	(2.8*)	(17.4*)	(21.2)	(1.9*)	(0.1)	(0.4)	(10.7)
S.E.	**0.3**	**0.2**	**0.1**	**0.1**	**0.2**	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**	**0.1**	**0.001**	**0.01**	**0.3**
Testers																	
Co 47	–0.7*	0.9*	–1.1*	–0.6*	–1.6*	1.4*	–0.4*	–0.9*	1.1*	10.9*	0.01	–0.3	1.2*	0.2*	0.01*	0.02*	1.9*
	(88.0)	(8.5)	(4.0)	(3.6)	(34.5)	(43.4)	(3.6)	(70.1*)	(12.0*)	(98.4*)	(1.7)	(27.5)	(17.7)	(1.3)	(0.1)	(0.4)	(10.6)
ADT 45	1.5*	–2.6*	1.3*	0.5*	1.5*	–8.5*	0.9*	2.4*	–1.4*	–13.5*	–0.1*	1.3*	–1.3*	–0.3*	–0.01*	–0.02*	–1.8*
	(91.5)	(5.5)	(6.7)	(5.6)	(36.0)	(25.4)	(5.8)	(71.1*)	(9.9)	(77.3)	(1.8)	(33.3)	(18.5)	(0.9)	(0.1)	(0.5*)	(7.7)
ASD 18	–2.5*	2.1*	–1.3*	–0.7*	–1.2*	8.7*	–0.8*	–7.8*	1.9*	21.2*	0.3*	–4.3*	1.5*	0.5*	0.01*	0.1*	2.1*
	(91.0)	(8.5)	(3.6)	(6.0)	(33.0*)	(42.3)	(3.7)	(70.9*)	(11.1*)	(130.2*)	(2.8*)	(25.9)	(16.6)	(2.1*)	(0.1)	(0.5*)	(13.8*)
IR 64	3.0*	–1.5*	1.7*	1.1*	1.2*	–6.9*	0.5*	3.5*	–1.6*	–23.9*	–0.3*	8.2*	–2.7*	–0.5*	–0.01*	–0.1*	–2.0*
	(92.0)	(6.5)	(5.8)	(4.4)	(35.0)	(32.6)	(5.3)	(64.1*)	(9.3)	(106.5*)	(2.1)	(30.4)	(15.3)	(1.1)	(0.1)	(0.3)	(6.5)
PMK 3	–1.3*	1.2*	–0.6*	–0.2*	0.1	5.4*	–0.3	2.9*	0.002	5.4*	0.1*	–5.0*	1.2*	0.1*	0.01*	0.03*	–0.2
	(89.0)	(9.5)	(3.7)	(2.7*)	(32.5*)	(45.6*)	(3.1*)	(98.9)	(11.1*)	(129.5*)	(2.4)	(23.3)	(19.7)	(2.2*)	(0.1)	(0.4*)	(15.1*)
S.E.	**0.3**	**0.2**	**0.1**	**0.1**	**0.2**	**0.2**	**0.1**	**0.2**	**0.2**	**0.1**	**0.02**	**0.3**	**0.2**	**0.04**	**0.001**	**0.01**	**0.20**

*Significant at 5 % level; Note: Values in parenthesis indicate the respective mean values

yield and yield contributing traits (productive tillers plant^{-1}, grains panicle^{-1} and harvest index). Likewise, ASD 18 and Co 47 recorded significantly high *per se* performance for six (plant height, productive tillers plant^{-1}, grains panicle^{-1}, 100 grains weight, harvest index and grain yield plant^{-1}) and three yield attributes (plant height, productive tillers plant^{-1}, grains panicle^{-1}) respectively.

High magnitude of *gca* effects was exhibited by the lines Nootripathu, Norungan and Chandaikar and by the testers ASD 18, Co 47 and PMK 3 for more number of traits. Among them, Nootripathu and ASD 18 expressed significant *gca* effects for all the traits. Norungan and Chandaikar, which also showed significant *gca* effects for all the traits, except leaf rolling and leaf drying for the former and days to 50% flowering, leaf drying, 100 grains weight and root length for the latter. Similarly, significant *gca* effects were recorded by Co 47 for all the traits, except 100 grains weight and spikelet sterility. PMK 3 also acted as good general combiner for seven drought tolerance and five yield component traits.

Considering both *per se* performance and *gca* effects, Nootripathu was adjudged as the best because of its superior performance for eight drought tolerance traits *viz.*, days to 70% relative water content, leaf rolling, leaf drying, canopy temperature, chlorophyll stability index, drought recovery rate, root length and root dry weight and two yield component traits *viz.*, days to 50% flowering and spikelet sterility. Norungan and Chandaikar could be selected as next superior performers for eight traits each. Among the testers, ASD 18 was adjudged as the best, since it showed high mean and *gca* values for eight traits *viz.*, canopy temperature, plant height, productive tillers plant^{-1}, grains panicle^{-1}, 100 grains weight, root dry weight, harvest index and grain yield plant^{-1} followed by PMK 3 and Co 47 for five and three traits respectively. Therefore, multiple crosses involving Chandaikar, Norungan, Nootripathu, Co 47, ASD 18 and PMK 3 would result in identification of superior segregants with favourable genes for most of the drought tolerant and yield traits.

Evaluation of hybrids for recombination breeding: The basic idea of hybridization is to combine favourable genes present in different parents into a single genotype. The genetic architecture of the progenies will be improved by the effective recombination of parents in a cross combination. Development of hybrids in rice without employing male sterility system is not possible. Instead, recombination breeding has been the major avenue for rice improvement over decades because of high magnitude of fixable additive gene action [9]. To get outstanding recombinants in segregating generations, the parents of the hybrids must be good general combiners for the characters to which improvement is sought [10]. In case of hybrids with significant *sca* effects, selection in early segregating generation is likely to fail as the *sca* effects mask the true performance of the selected plants. Specific combining ability is due to non additive gene action. Therefore, it will be useful to select only those hybrids showing parents with significant *gca* effects and non significant *sca* effects for recombination breeding, since it is likely to throw segregants with favourable genes derived from both the parents [11]. Therefore, significant *gca* effects of parents and non significant *sca* effects of hybrids for various trait was presented in Table 2.

The hybrids Nootripathu/PMK 3 was recommended for recombination breeding, since it exhibited non significant *sca* effect with significantly favourable *gca* effects for five drought tolerance traits *viz.*, days to 70% relative water content, leaf rolling, leaf drying, root length and root dry weight and three yield component traits *viz.*, days to 50% flowering, 100 grains weight and spikelet sterility. The next best hybrids *viz.*, Chandaikar / ASD 18 and Nootripathu / ASD 18 were suitable for recombination breeding for six traits each. The former satisfied the said criteria for three drought tolerance traits *viz.*, days to 70% relative water content, canopy temperature and root:shoot ratio and three yield component traits *viz.*, plant height, productive tillers plant^{-1} and harvest index, while the latter also for three drought tolerance traits *viz.*, chlorophyll stability index, drought recovery rate and root length and three yield component traits *viz.*, days to 50% flowering, spikelet sterility and harvest index.

Hence, the hybrids Nootripathu/PMK 3, Chandaikar /ASD 18 and Nootripathu/ASD 18 are suitable for recombination breeding to get desirable segregants in early segregating generations for drought tolerance and yield attributes.

Table 2. Significant *gca* and non significant *sca* effects of parents and hybrids respectively for various trait under moisture stress in rice

Parents/hybrids	Traits associated with significant *gca*/ non significant *sca* effects
Norungan	DFF, RWC, CT, CSI, DRR, HI, TN, GN, TW, SS, RL, R:S, HI, GYP
Nootripathu	DFF, RWC, LR, LD, CT, CSI, DRR, HT, TN, GN, TW, SS, RL, ROW, R:S, HI, GYP
Chandaikar	RWC, LR, CT, CSI, DRR, HT, TN, GN, SS, ROW, R:S, HI, GYP
Co 47	DFF, RWC, LR, LD, CT, CSI, DRR, HT, TN, GN, RL, ROW, R:S, HI, GYP
ASD 18	DFF, RWC, LR, LD, CT, CSI, DRR, HT, TN, GN, TW, SS, RL, ROW, R:S, HI, GYP
PMK 3	DFF, RWC, LR, LD, CSI, GN, TW, SS, RL, ROW, R:S, HI
Norungan/ASD 18	DFF (–0.4), DRR (–0.6), HI (0.03)
Norungan/Co 47	DFF (–0.7), R:S (–0.001)
Norungan/PMK 3	DFF (1.4)
Nootripathu/Co 47	DFF (–1.3), RWC (0.9), LD (–0.2), DRR (–0.6)
Nootripathu/ASD 18	DFF (0.5), CSI (1.1), DRR (–0.4), SS (0.8), RL (0.4), HI (–0.03)
Nootripathu/PMK 3	DFF (1.3), RWC (–0.3), LR (–0.2), LD (–0.2), TW (–0.03), SS (1.2), RL (0.3), RDW (–01l)
Chandaikar/ASD 18	RWC (0.5), CT (–0.04), HT (0.8), TN (0.3), R:S (0.002), HI (0.02)
Chandaikar/PMK 3	RWC (–0.6), CSI (1.1)
Varappukudanchan/Co 47	DFF (1.4), RL (–0.5)
Varappukudanchan/ASD 18	DFF (–1.3), RL (0.5), RDW (0.01)
Varappukudanchan/PMK 3	DFF (-1.0)
Kallurundaikar/Co 47	LD (–0.1), GYP (0.6)
Kallurundaikar/PMK 3	LD (0.004)
Kalliyadichan/PMK 3	LD (0.2)
Vellaichitraikar/ASD 18	LD (–0.2)

Note: Values in parenthesis indicate the *sca* effects

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