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Ephemeral rice breeding: Viable approach for upland water stress tolerance

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Abstract

Two experiments were undertaken simultaneously (early generation evaluation and advanced generation evaluation respectively) at SGCARS, Jagdalpur, IGKV, Raipur, Chhattisgarh, to indentify and analyze ephemeral genotypes for suitability in rainfed upland rice production ecology. In early generation testing, mean plot flowering was recorded to be 72 DAS, plant height 83cm, panicles per square meter 212 and grain yield to be 2330kg/ha. Regional check Vandana and CRR-676-1 flowered earliest by 68 DAS followed by CRR-627-35-1-5 (69 DAS) and CRR-507-11-B-1 and CRR-605-23-1. The CRR-433-2-1-1 flowered latest by 83 DAS and as per hypothesis;yield was considerably reduced since plant could not develop optimum source-sink balance and carbon accumulation in seeds eventually. Regarding, crop yield five genotypes placed above the local check, namely CRR-597-5-1 (29.47%), the national check i.e. Anjali (21.05%), CRR-676-1 (15.79%), CRR-433-2-1-1 (10.53%) and the regional check i.e. Vandana (7.92%). Among advanced material, interestingly, the highest yielder genotype flowered earliest (69 DAS) that suggests the accomplishment of crop growth and physio-biochemical development while utilizing of soil and environmental reserve appropriately. On overall mean yield was 2349kg/ha, whereas genotype CRR-616-B-2-54-1 derived ranked 1st with 2718 kg/ha yield, 69 days of flowering duration and short bold grains. The bimodal experiment concludes that short life cycle and rapid *veg-repo* shift is critical for survival in rainfed rice growing regions and those genotypes which maintain the physiological buffer at the shift will be able to sustain genetic yield potential.

Keywords: Upland rice, drought escape, source sink balance, *veg-repo* shift, ephemerism.

Introduction

Rice (*Oryza sativa* L.) is predominant global food crops and feeds nearly 3 billion people's daily (Singh *et al*., 2015) [26];nevertheless its cultivation munches through more than 50% of the total irrigation water used for agriculture (Lingaraja *et al*., 2015) [18]. Therefore saving irrigation water without much compromising with grain yield in rice cultivation is global agenda of present decade. Furthermore, More than 80% of the Asian regions are drought prone and therefore development of rice cultivars suitable for semi-irrigated cultivation is indispensable (Zainudin *et al*., 2014) [31]. In contrast with other crops, rice is particularly more sensitive to water stress especially at critical growth stages such as panicle initiation, anthesis and grain filling (Yang *et al*., 2008; Akram *et al*., 2013) [28, 1] which terms for trait based breeding approach to progress rice yields under water limited conditions (Reynolds *et al*., 2010) [24]. Water stress becomes more complex when associates with upland ecology where one hand rainfed cultivation and poor water holding topography on the other has emerged as new challenge for crop breeders and geneticist (Kumar *et al*., 2015a) [16]. Rainfed upland ecosystem is characterized by moisture stress due to erratic rainfall distribution and frequent drought incidence at critical crop growth stages. Good seedling and vegetative vigour, short growth duration, weed competitiveness; tolerance to drought and other biotic stresses are the main objectives to improve the productivity of this harsh ecology (Kumar *et al*., 2015b) [17]. Water stress responses in rice expressed by leaves, shoot and roots depending upon on the timing of this stress (early, vegetative, intermittent or terminal), crop growth stage (vegetative or reproductive), severity level (mild or severe), edaphic properties and the target environment (Mukamuhiwara, 2015) [23]. Terminal or reproductive drought is the most injurious to grain yield (Xangsayasane *et al*., 2014) [30] whereas plants may recover from early and vegetative drought later in the growing season. Therefore, drought escape mechanism is key for upland research where monsoon switches of by second fortnight of September hence, crop must attain grain yield level prior soil moisture begins to exhaust. Looking for this complex upland scenario experiment was frames to identify and analyze ephemeral genotypes for suitability in plateau agriculture.

Materials and Methods

Two experiments were undertaken simultaneously with 14 and 9 genotypes (early generation testing and advanced generation testing respectively) under rainfed conditions at

Upland Rice Breeding Block of S. G. College of Agriculture and Research Station, Jagdalpur, IGKV, Raipur, Chhattisgarh. An upland ecology simulation model was created by choosing experimental plot where no water accumulates and cent percent rainfed treatment was given during entire life cycle of crop. Trench was made in periphery of experimental plot to avoid water accumulation. For statistical analysis software Window State Version 9.1 was used.

Early generation Evaluation: The test material was obtained from Directorate of Rice Research, Hyderabad, under All Indian Coordinated Rice Improvement Programme (Table 01) by the trial designation Initial Varietal Trial: Vary Early. Bireplicated sowing was completed by onset of monsoon by direct seeding in agronomically standardized geometry of 10sq M plot.

Advanced generation material: Under the AICRIP programme, in ICAR-SAU collaboration the experimental material was received from DRR, Hyderabad. Being advanced generation objects, the number of genotypes was lesser (Table 02). Trireplicated trial was laid out in second fortnight of June in DSR (Direct seeded rice) mode in gross plot size 15sqM and net plot size 13sqM.

Results and Discussion

Early generation evaluation

The experiment laid perfectly on the hypothesis that ephemeral genotypes are viable option for monsoon based rice breeding since optimum yield was obtained and crop growth cycle was completed within available rainy days. *Veg-repo* shift i.e. physiological shift from vegetative growth to reproductive development; is critical for rainfed survival as discussed by previous workers (Kumar *et al*., 2015a) [16]. The experimental mean of plot flowering was 72 DAS, plant height 83 cm, panicles per square meter 212 and grain yield to be 2330 kg/ha. Regional check Vandana and CRR-676-1 flowered earliest by 68 DAS followed by CRR-627-35-1-5 (69 DAS) and CRR-507-11-B-1 and CRR-605-23-1. The CRR-433-2-1-1 flowered latest by 83 DAS and, owing to post reproductive stress, yield was considerably reduced. Similarly CRR-676-2 bloomed by 80 DAS and plant could not developed optimum source-sink balance hence carbon accumulation in seeds consequently. Crop stature, the canopy length to accommodate sun energy in terms of chemical energy, affected less by rainfed treatment because of determinate growth advantage. CRR-433-2-1-1 exhibited maximum height (94 cm) followed by CRR-507-11-B-1 (91 cm) however, considerable difference appeared among these when crop yield is taken into account (Table 03) despite having statistically similar (70 and 71 DAS) blooming span. The minimum plant height was recorded for genotype CRR-627-35-1-5 (73 cm) and local check (74 cm) and again significant variation persist regarding grain yield. Water stress results in several physiological alterations in plants *viz.,* reduction in PAR (Photosynthetically Active Radiation), photosynthetic rate, transpiration rate, stomatal conductance, pigment degradation and relative water content (RWC) (Akram *et al*., 2013) [1] resulting in decreased water use efficiency (WUE) and growth reduction prior to plant senescence (Cattivelli *et al*., 2012; Tuna *et al*., 2010) [7, 29]. Therefore, if genotype produces sufficient canopy and blooms monsoon friendly, is expected to accumulate sufficient assimilate and eventually good crop (Kumar *et al*., 2015a) [16].

Panicles count, the sink strength, were in correspondence with flowering and vegetative stature i.e. genotype CRR-427-21-6-1 flowered in 71 DAS and with 86cm vegetative length produced 256 panicles. Similarly genotype CRR-597-5-1 attained 277 panicles within 71 DAS flowering span and 90cm average plant height. Parallel behavior was observed for most of the genotypes and perfect correlation persisted between these three major yield attributes. However prolonged vegetative phase, in some genotypes, reduced the panicle population because of insufficient developmental span for reproductive counterparts. Grain yield was ranged between 1750 kg/ha to 3075kg/ha with experimental mean 2330 kg/ha. Dramatic behavior appeared when yield was assessed in correlation with days to 50 percent flowering, canopy length and panicle count. CRR-597-5-1 flowered by 71 DAS and with 90cm canopy length and 277 panicles per unit area, produced maximum experimental yield (3075 kg/ha). Similarly, in CRR-676-1 and CRR-433-2-1-1, flowered by 68 and 71 DAS, vegetative length 86 and 91 cm had comparative lower panicle population (153) but, despite lesser number of reproductive units, produced significant higher plot yield under rainfed conditions (2750 kg/ha and 2625 kg/ha). This may pertain to strong sink strength that maintain the assimilation and translocation of photosynthates irrespective to panicle population. On the contrary in CRR-507-11-B-1 and CRR-127-35-1-5, took 70 and 69 DAS to accomplish 50 percent flowering, good panicles (253 and 213) count but even though ultimate grain yield was reduced (1988 kg/ha and 1925 kg/ha). This is because of undersized sink; the genotype doesn't have the capacity to bear bulky quantity of panicles and when due to agronomical and environmental causes it happens, sink size reduced. Additionally, excess plant population where by default large number of panicles are produced but do not attain significant size because of over crowd hindrances. Danteshwari, the local check (LC), found to be good standard to screen the test entries with 74 cms canopy length, 73 DAS to attain 50 percent plants flowering, 169 panicle count produced 2375 kg/ha experimental yield. Five genotypes placed above the Local check i.e. Danteshwari; namely CRR-597-5-1 (29.47%), Anjali; the national check, (21.05%) and CRR-676-1 (15.79%), CRR-433-2-1-1 (10.53%), and the regional check, Vandana (7.92%). However, genotype CRR-427-21-6-1 (2.61%) and CRR-605-23-1 (2.65%) was statistically similar.

Reports on variable water stress tolerance indicate its complex genetic nature and collective regulation of crop genetics and physiology by environmental factors (Kumar *et al*., 2015) [18]. Considering the tolerance and or resistance as capacity to sustain leaf area and growth under unmitigated water stress at vegetative stage, source of variation seems to be constitutive roots architecture that permits continuance of favorable plant water status (Liu *et al*., 2004; Sabar and Arif, 2014) [21, 25]. Further, in both constitutive and adaptive root systems, the mechanisms underlying genetic variability may be the involvement of signals sensitivity that affects root elongation and branching (Bao *et al.,* 2004; Ge *et al.,* 2004) [3, 10]. Water Stress between panicle initiation and pollen meiosis delays flowering due to an apparent delayed floral development (Kathiresan *et al.*, 2006) [12]. Water unavailability adversely affects starch deposition process in pollen grain which normally starts three days prior to anthesis resulting in reduced anther dehiscence (Liu *et al.*, 2006 and 2013) [20, 19]. Water stress at heading cause panicle desiccation and, therefore, genotype specific canopy temperature and water potential is vital to check panicle failure due to its ability to refill cavitated xylem vessels in shoots (Stiller *et al.*, 2003) [27]. Summarily, genotypes capable of maintaining leaf and shoot water potential under critical stage have an advantage under water stress but drought escape could still be a viable option to sustain significant grain yield.

Advanced Generation Evaluation

Being advanced generation materials, all the genotypes were promising and had noteworthy adaptive performance under rainfed experimental environment. The critical difference to access the statistical difference was 450 kg/ha and the only genotype Vandana were less than standard yield mark of upland rice. Genotype CR-616-B-2-54-1 flowered earliest with 69 DAS, showing suitability as ephemeral to escape post reproductive drought, followed by genotype Anjali and Vandana (70 DAS). CRR-523-2-2-1-1 (Kalinga III x Bhupen) (DRR 2014) [9], accomplished vegetative growth later (77 DAS) followed by CRR-451-15-B-A1 (76 DAS) but still can be considered promising for upland rice growing regions. Similar to early generation materials, the average plant height was short, 81 cm, picturing comparative suitability to selective environment. As previously discussed, the lower plant height in early maturing entries may pertain to short vegetative span (55-65 days) within which it has to complete vegetative growth and development i.e. *Veg-repo* shift. The local check Purnima exhibited successful execution of this hypothesis with short stature (64 cms) without significant alteration in grain yield. Plant height was ranged between 64-90 cms, which may be relevant to deeper root penetrance, genotypic fitness and protoplast buffer to restricted water availability. The experimental location mean yield ranged from 1974 kg/ha (Vandana) to 2718 kg/ha (CRR-616-B-2-54-1). Interestingly, the highest yielder genotype flowered earliest (69 DAS) that suggests the accomplishment of crop growth while utilizing of soil and environmental reserve appropriately. The information on location means, flowering duration, plant height, panicles/sq.m. and quality traits are given in Table 04. On overall mean yield under drought was 2349 kg/ha, whereas entry CRR-616-B-2-54-1 derived from the cross Vandana/Apo, ranked 1st with 2718 kg/ha yield, 69 days of flowering duration and short bold grains. It recorded 23.27 and 19.96% higher yield than the national and local check respectively. Earlier research reviews suggest that responses to environmental variation, predominantly water accessibility, can alter plants' reproductive strategies (Gonzalez *et al*, 2014) [11] in several ways. Primarily plants may change the number of viable gametes formed, which translates into the number of panicles produced, viable ovules per panicle, or viable pollen per flower. All of these can be sensitive to variation in precipitation (Kawashima *et al*., 2011) [13]. Second, alteration in environmental conditions can modify physiological, biochemical and molecular synchrony within plant or population (Campbell *et al*., 2013; 2014) [6, 5]. In field crop, the phenology of anthesis is sensitive to variation in soil moisture (Kumar *et al*., 2014) [15], air temperature (Cicchino *et al*., 2010) [8], latitude (Liu *et al*., 2013) [19] and earliness or delay in flower opening reduces the yield.

Table 1: Composition of entries for Early Generation Evaluation

S No	Designation	Cross Combination	Grain Type
1.	CRR 427-21-6-1	Vandana/WAB 56-50	Short Bold
2.	CRR 433-2-1-1	IRAT 112/Ananda	Long Bold
3.	CRR 507-11-B-1	Vandana/IR47701-6-B-1	Long Bold
4.	Vandana	*Regional Check (Eastern Zone)*	
5.	CRR 552-72-1-1	Vandana/Kalinga III	Long Slender
6.	CRR 597-5-1	Anjali/RR166-645	Long Bold
7.	CRR 605-23-1	RR-166-645/IR62608-213	Long Bold
8.	CRJ 1101-1	Birsadhan 101/Basmati 370	Medium Slender
9.	Anjali	*National Check*	
10.	CRR 627-35-1-5	Br Gora/Kalinga III/Vandana/RR166-645	Long Slender
11.	CRR 676-2	Vandana 2/Way Rarem	Long Bold
12.	CRR 677-1	Vandana 3/Way Rarem	Long Bold
13.	CRR 676-1	Vandana 2/Way Rarem	NA
14.	Danteshwari	*Local Check*	

Table 2: Composition of Entries for Advanced Generation Evaluation

S No	Designation	Cross Combination	Grain Type
01.	CR 616-B-2-54-1	Vandana/Apo	Short Bold
02.	CRR 451-1-B-2-1	Vandana/IR 64	Long Slender
03.	CRR 617-B-47-3	Vandana/UPLR17	Long Slender
04.	Anjali	*National Check*	
05.	Danteshwari	*Local Check*	
06.	CRR 523-2-2-1-1	Kalinga III/Bhupen	Long Slender
07.	CRR 427-21-2	Vandana/ WAB 56-60	Long Slender
08.	CRR 451-15-B-A1	Vandana/IR 64	Long Slender
09.	Vandana	*Regional Check (Eastern Zone)*	

Table 3: Ancillary Traits Data of Initial Generation Evaluation

Genotypes	Plant Height			Days to 50% Flowering			Panicles/Sqm			Grain Yield(kg/plot)			Grain Yield (Kg/ha)
	R1	R2	Mean	R1	R2	Mean	R1	R2	Mean	R1	R2	Mean	
CRR 427-21-6-1	85	87	86	69	72	71	245	266	256	1.80	1.90	1.85	2313
CRR 433-2-1-1	90	97	94	70	72	71	170	230	200	2.00	2.20	2.10	2625
CRR 507-11-B-1	93	88	91	70	69	70	235	271	253	1.60	1.50	1.55	1938
Vandana	80	86	83	69	66	68	162	186	174	1.80	2.30	2.05	2563
CRR 552-72-1-1	82	75	79	70	70	70	210	264	237	1.80	1.50	1.65	2063
CRR 597-5-1	84	96	90	69	72	71	241	313	277	2.17	2.75	2.46	3075
CRR 605-23-1	85	93	89	70	69	70	220	255	238	1.70	2.20	1.95	2438
CRJ 1101-1	86	73	80	75	75	75	251	283	267	1.90	1.50	1.70	2125
Anjali	74	90	82	72	70	71	165	185	175	2.40	2.20	2.30	2875
CRR 627-35-1-5	73	72	73	69	68	69	195	230	213	1.48	1.60	1.54	1925
CRR 676-2	76	85	81	79	80	80	157	191	174	1.50	1.30	1.40	1750
CRR 677-1	87	80	84	85	80	83	135	180	158	1.40	1.50	1.45	1813
CRR 676-1	89	82	86	70	66	68	145	160	153	2.10	2.30	2.20	2750
Danteshwari	71	77	74	70	75	73	154	183	169	1.60	2.20	1.90	2375

Table 4: Ancillary Traits Data of Advanced Generation Evaluation

Genotypes	Plant Height				Days to 50% Flowering				Panicle/Sq M				Yield (kg/plot)				Yield (kg/ha)
	R 1	R 2	R 3	Mean	R 1	R 2	R3	Mean	R 1	R 2	R 3	Mean	R 1	R 2	R 3	Mean	
CR 616-B-2-54-1	91	83	87	87	69	70	68	69	234	230	305	256	3.90	3.25	3.45	3.53	2718
CRR 451-1-B-2-1	86	90	95	90	75	73	72	73	225	246	251	241	2.90	3.20	3.30	3.13	2410
CRR 617-B-47-3	88	83	85	85	73	74	71	73	223	187	335	248	3.50	3.20	3.40	3.37	2590
Anjali	84	70	77	77	70	70	71	70	199	247	245	230	2.50	3.00	3.10	2.87	2205
Danteshwari	60	65	68	64	74	72	73	73	180	175	196	184	3.50	3.20	2.60	3.10	2385
CRR 523-2-2-1-1	74	84	79	79	79	75	77	77	266	236	222	241	2.45	2.30	3.10	2.62	2013
CRR 427-21-2	78	88	86	84	73	75	71	73	255	254	265	258	3.40	3.30	3.00	3.23	2487
CRR 451-15-B-A1	80	87	84	84	76	78	75	76	235	259	185	226	3.10	3.30	2.80	3.07	2359
Vandana	75	82	79	79	70	71	68	70	186	172	160	173	2.20	2.60	2.90	2.57	1974

Conclusion
The sound effects of various kinds of abiotic stress more particularly water stress on physiology of grain development are different, but always negative, i.e. always results in yield decline. The ephemeral genotypes adopt drought escape mechanism and completes life cycle in accordance to existing monsoon hence, plant resists late seasonal water stress. In present experiment, genotype CRR-616-B-2-54-1 and CRR-616-B-47-3 (early generation material) and Vandana and CRR-597-5-1 (advanced generation material) are found to mature by 100-110 DAS without significant yield curtail. The study concludes, breeding for specific ecosystem (upland rice) necessitate for developmental synchrony with prevailing microenvironment since the genotypic yield potential realization is, however, dependent not only on the stress sensitivity of the reproductive and grain-filling stages but on overall plant growth and development.

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