Indian Journal of Agricultural Sciences **92** (11): 1321–1325, November 2022/Article
https://doi.org/10.56093/ijas.v92i11.122493

Genetic variability studies in rice (*Oryza sativa*) genotypes of Assam for ratooning ability and perennation

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Received: 23 March 2022; Accepted: 16 September 2022

ABSTRACT

An experiment was conducted at the research farm of Assam Agricultural University, Jorhat, Assam during 2020–22 to assess the genetic variability among 50 rice (*Oryza sativa* L.) genotypes with respect to ratooning ability and perennation. Out of 50 genotypes, only 30 genotypes showed different degree of ratoon production and ratoon yield. All the genotypes showing better ratooning ability mainly belonged to photo-insensitive group and only few were slightly photosensitive. True perenniation as expressed by formation of rhizome (*O. longistaminata*) was not observed in any of the genotypes. However, stolen formation as in *O. rufipogon* was observed only in 1 genotype Terabali. ANOVA result suggested the presence of statistically significant variability among all the genotypes in both main and ratoon crop. Genotypes, viz. Binadhan-11, Sayjihari and IR-64 were found to be best performing for all the desirable ratoon crop traits. High heritability coupled with high genetic advance was estimated for all the ratoon crop traits except for days to ratoon maturity indicating the involvement of additive gene action in the expression of the traits.

Keywords: Genetic variability, Heritability, Ratooning ability, Rhizome

Rice (*Oryza sativa* L.) is a staple food for about 3.5 billion people around the globe. In India, rice production is 117.94 million tonnes (NRRI, 2019-20). However, we need to produce additional 1.5-2 million tonnes of rice every year to meet the target of 130 million tonnes by 2025 for which several factors has to be considered. Rice production is primarily based on annuals, but the annual rice crop is not necessarily the best choice for all agricultural situations. Practices like *jhum* or shifting cultivation, contribute heavily to soil erosion and rapid depletion of soil fertility. Such erosion costs farmers and the society in terms of lost nutrients, extended labour, siltation and degradation of water resources. In such situations, perennial grain crop could provide effective solution.

Perennial rice lives and remains productive for 2 or more years. Some wild species of rice like *O. longistaminata, O. rhizomatis* and *O. rufipogon* shows perennial characteristics as these species have energy storage structures like rhizomes and stolons. Perenniality in rice is often manifested as the ratooning ability. Chen *et al.* (2018) and Wang *et al.* (2020) have defined rice ratooning as green and resource efficient rice production technology where second crop of rice is obtained from the main crop plants as the re-growth from the stubble left after the harvest of main crop. Ratooning crop can generate additional rice yield with very less agricultural inputs (Shen *et al.* 2021). Perenniation in *O. sativa* is by growth of axillary buds on older tillers (i.e. tillering), whereas *O. rufipogon* can additionally propagate from stolons and *O. longistaminata* produces many long rhizomes that are the primary source of new shoots. It was estimated that ratoon rice yield is roughly 40–50% of the main crop yield and can lead to 50–70% reduction in labour and water input (Munda *et al.* 2009). However, rice ratooning for large-scale commercial farming has not been accepted, probably because of lack of cultivars with good ratooning ability and information about management practices. The present research was therefore aimed at evaluation and screening of Assam rice germplasm for ratooning ability and associated characters along with perenniality conferring traits like presence of rhizome or stolons.

MATERIALS AND METHODS

An experiment was conducted at research farm of Assam Agricultural University, Jorhat, Assam during February 2020 to February 2022. A total 50 cultivars of photosensitive and photo-insensitive groups from RARS Diphu, RARS Lakhimpur, RARS Karimganj and ICAR-IARI were collected and tested. Genotypes were planted

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using a randomized complete block design (RCBD) with 3 replications. Harvesting was done after 95% panicle ripening by cutting at a height of 10 cm from the soil surface as suggested by Petroudi *et al.* (2011). One day after harvest, the land was irrigated up to 3 cm of ponded water level (for *sali* genotypes). After recession of ponded water, Urea @50 kg/ha, Single super phosphate (SSP) 30 kg/ha and Muriate of potash (MOP) 25 kg/ha was applied to boost the growth of the ratoon crop. Five plants from each treatment were randomly chosen for evaluation. The variability present in population was calculated by using simple measures like range, mean, standard error, phenotypic and genotypic variance and coefficient of variation. For all the characters, genetic parameters were estimated using ANOVA. Genotypic variances (σ_g^2), phenotypic variances (σ_P^2) and error variance (σ_e^2) were calculated for each character as per the formula suggested by Burton and Devane (1953). Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were represented in terms of standard deviation as percentage of the grand mean. Heritability in broad sense was calculated using the formula given by Singh and Choudhary (1979). The expected genetic advance was calculated by formula suggested by Allard (1999).

RESULTS AND DISCUSSION

Analysis of variance: The ANOVA in main crop exhibited significant differences for all the observed traits elucidating the presence of genetic variation among the genotypes for all the observed morphological traits in main crop. The significant variation among genotypes was probably due to inclusion of rice genotypes belonging to various groups based on ecological differentiation (upland, lowland and deep water rice varieties), season of growing (*Ahu* and *Sali* varieties), species (*O. sativa* and wild species *O. longistaminata* and *O.rufipogon*). For all the analysis in ratoon crop, out of 50 genotypes only 30 genotypes were considered which produced ratoon yield or productive ratoon tillers. Therefore, ANOVA was worked out in the ratoon crop for 30 genotypes for 11 morphological traits. However, the trait "origin of ratoon" was measured as two sub characters, viz. nodal tillers (tillers originated from stubble) and basal tillers (tillers originated from underground nodes) for the convenience in understanding the analysis. Genotypes in ratoon crop exhibited significant variation for number of ratoon tillers, number of productive ratoon tillers, ratoon plant height (cm), days to ratoon maturity, ratoon spikelet fertility (%), ratoon yield per plant (g), days to ratoon emergence, number of nodal tillers and number of basal.

Mean performance of morphological traits in the main crop: Photo-insensitive genotypes (mainly *Ahu* rice varieties) were found better mean performing for several main crop traits like tiller diameter, tiller wall thickness, tiller weight and greenness of leaves at maturity which contribute to better ratooning ability. These characters contribute to ratooning ability was also elucidated by Ichii *et al.* (1983) and Vergara *et al.* (1988). Varieties belonging to *bao* group exhibited greater plant height as they possessed higher internode elongation ability. Wild rice species *O. longistaminata* and *O. rufiogon* exhibited least number of tillers, number of effective tillers and number of fertile grains hence the grain yield per plant was also less for these species. After screening 50 genotypes, Terabali was the only cultivated variety which was found to have stolon and for rest of the cultivated genotypes none of the two perenniality structures (rhizome/stolon) was observed.

Mean performance of morphological traits in ratoon crop: Most of the ratooning yields producing varieties were *Ahu* season varieties (February to July). Some varieties belonging to *bao* group had the ability of ratoon regeneration but, none of these varieties could produce productive ratoon tillers. *Sali* varieties (photo-sensitive genotypes) had less ratoon yield per plant as compared to photo-insensitive genotypes (*Ahu* varieties). This observation was in favour the result presented by Ahmed and Das (1988) who suggested that ratoon crop from *sali* varieties is not possible because of prevailing drought and cold conditions at the time of main crop harvesting.

Comparative mean performance of best ratooning genotypes: The comparison between mean performance of 10 best ratooning genotypes (based on ratoon yield) in main crop and ratoon crop was done for some selected traits (Table 1). Genotypes, viz. Binadhan 11, Sayjihari, IR 64, Baomurali, Jaya and IR 8 had more number of tillers in ratoon crop as compared to main crop. This result could be justified by the fact that in ratoon crop new tillers may originate from all the nodes present in the stubble or from the lower underground nodes as suggested by Vargara *et al.* (1988). The Number of productive tiller was also more for these genotypes in ratoon crop as compared to main crop. In contrast, genotypes, viz. DRR 44, Surojmukhi and Terabali had less number of tillers in ratoon crop as compared to the main crop tillers which was similar to the observation made by Maqsood *et al.* (2000). However, for all the 10 best ratooning genotypes, yield per tiller and yield per plant was found comparatively less in ratoon crop. This reduction in yield of ratoon crop was also recorded by Frageria *et al.* (1997) and Faruq *et al.* (2014). This reduction in yield of ratoon crop even after having more number of tillers and productive tillers was probably due to reduced spikelet fertility and panicle size (number of spikelet per panicle) in ratoon crop as compared to the main crop. Reduced spikelet fertility in ratoon crop was also observed by Chouhan *et al.* (1990). Such result indicated that not all the regenerated tillers had the ability to contribute towards ratoon grain yield. Another factor that might have limited the grain yield in ratoon crop is the relatively short maturity duration of the ratoon tillers (53-84 days as compared to 115-160 days in the main crop). The shorter maturity duration effectively cut down the photosynthetic efficiency and photosynthate conversion into sink might be affected. The recovery of yield from ratoon crop was highest for genotype Binadhan 11 (81.86%) which revealed that 81.86% of main crop yield can be realised from the ratoon crop of Binadhan 11.

Table 1 Comparative mean performance of 10 best ratooning genotypes and their yield recovery from ratoon crop

Genotype	Number of tillers		Productive tillers		Plant height (cm)		Yield/tiller (gm)		Yield/plant (gm)		Spikelet fertility (%)		Spikelets/ panicle		Yield recovery from Ratoon crop (%)
	MC	RC	MC	RC	MC	RC	MC	RC	MC	RC	MC	RC	MC	RC	
Binadhan 11	10.87	21.20	10.00	19.13	90.27	83.33	2.63	0.93	21.62	17.70	95.78	90.13	95.00	83.00	81.86
Sayjihari	12.07	18.53	9.93	17.47	81.40	82.29	2.28	0.78	17.95	13.57	95.86	93.44	106.00	84.00	75.61
IR 64	16.07	22.67	12.87	20.20	79.07	92.57	2.37	0.59	18.24	11.91	96.43	89.85	78.00	67.00	65.28
DRR 44	17.05	13.47	9.07	11.53	90.75	84.09	3.65	0.96	24.32	11.37	97.56	85.75	102.00	90.00	46.74
Jaya	13.33	15.20	11.33	13.75	86.83	71.80	2.62	0.70	22.90	10.13	95.48	58.59	113.00	43.00	44.24
Baralusai	9.60	9.60	7.40	5.53	98.90	100.20	3.00	1.61	21.54	9.43	96.57	84.03	103.00	81.00	43.76
Baomurali	8.33	11.07	8.27	8.95	142.27	127.34	4.56	1.02	26.22	9.42	95.89	62.73	190.00	93.00	35.92
Surojmukhi	15.73	10.73	14.46	8.20	117.93	85.37	2.74	1.23	27.40	8.92	95.75	61.02	121.00	79.00	32.54
IR 8	11.80	12.33	10.07	10.33	73.53	56.09	2.72	0.78	23.05	8.68	97.84	70.56	105.00	41.00	37.64
Terabali	12.53	6.00	11.87	5.33	116.80	97.26	3.15	1.41	23.48	8.37	93.26	80.82	127.00	72.00	35.63

MC, Main Crop; R.C, Ratoon crop.

Genetic variability studies

Higher genetic variability among genotypes guarantees better chances of breeding desired form of crop varieties. The variability for a trait results from the cumulative effect of genetic and environmental components. Analysis of genetic variability is useful for effective and better selection. It enables breeder to estimate the heritable variability component from overall phenotypic variability. In the present research, genetic variability studies were carried out separately for the genotypes grown as the main crop and genotypes that produced ratoon tillers because some of the morphological traits under study were different in main crop and the ratoon crop.

Estimation of genetic parameter for main crop traits: The estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) ranged from 18.02 to 47.06 (Table 2). GCV and PCV values were recorded high for number of tillers, number of effective tillers, tiller weight, greenness of upper leaves (green seeker reading), plant height, number of filled grains, yield per tiller, yield per plant and harvest index, indicating small influence of environment and higher contribution of genetic component on the phenotypic expression of these traits. However, for the traits namely tiller diameter and tiller wall thickness, GCV was recorded moderate albeit, PCV was estimated high. This is probably due to relatively more influence of environment on the expression of these traits. Similar results were also reported by Prasad *et al.* (2001), Singh *et al.* (2011) and Babu *et al.* (2012).

The effectiveness of selection for improvement of the particular trait is best explained by the degree of heritability. Heritability estimate for a trait reveals the reliability of phenotypic value. However, heritability estimates coupled with genetic advance are more helpful in predicting the gain under selection than heritability estimates alone. Heritability is categorized as low (below 30%), medium (30-60%) and high (above 60%) as per Johanson *et al.* (1955).

The characters studied in the main crop exhibited medium to high heritability estimates ranging from 54.27-96.79% except for yield per plant. Low heritability for yield components was also reported by Rafi *et al.* (2014) although Dhanwani *et al.* (2013) and Yadav *et al.* (2017) have observed high heritability for yield per plant which was contradictory to the result obtained in the present investigation. Traits exhibiting high heritability indicated their simple inheritance pattern irrespective of number of genes governing those traits. Selection of plants based on relatively high heritable quantitative traits is easy and reliable. Thus, greater improvement could be expected for these characters.

Genetic advance as the per cent of mean was high for all the observed main crop traits, suggesting that these traits could be improved through selection. Higher heritability coupled with high genetic advance was estimated for all main crop traits except for yield per tiller where heritability was comparatively lower than other traits which indicated the complex inheritance of this trait due involvement of several genes for its expression. High heritability along with high genetic advance indicates that heritability is most likely due to additive gene effects and selection may be effective in early generations for these traits.

Estimation of genetic parameter for ratoon crop traits: The estimates of GCV and PCV were recorded high (Table 3) for number of ratoon tillers, number of productive ratoon tillers, number of lodging tillers, ratoon spikelet fertility, yield per ratoon tiller, yield per ratoon plant, number of basal tillers and number of nodal tillers. However, number of dwarf tillers exhibited moderate GCV and high PCV and ratoon plant height exhibited moderate GCV and PCV. For the traits showing high and comparable GCV and PCV, variations in phenotype were mainly due to high amount of genotypic variations for different characters and less of environmental variations, which suggests the major contribution of genetic variance and less effect of environmental variation towards total phenotypic variation. Thus, selection based on phenotype itself can be useful for enhancement of these traits. Heritability estimate is useful in revealing the heritable portion (genetic variations) of variation from total variability present in population for a character.

Genetic advance as the per cent of mean was high for all the ratoon crop traits except for days to ratoon maturity which exhibited low genetic advance. Higher heritability coupled with high genetic advance was estimated for number of ratoon tillers, number of productive ratoon tillers, number of lodging tillers, number of dwarf tillers, ratoon plant height (cm), ratoon spikelet fertility (%), ratoon yield per tiller (g),

Table 2 Genetic variability studies in main crop

Trait	Range		GCV	PCV	Heritability %	GA	GA as % of mean	Mean	SE(d)
	Min	Max							
NT	6.13	23.33	25.68	28.74	79.82	6.18	47.25	13.09	1.38
NET	6.13	19.20	21.83	25.40	73.85	4.43	38.64	11.45	1.21
TD	0.43	1.00	19.06	20.79	84.04	0.27	35.99	0.74	0.05
TWT	0.92	2.21	18.03	22.43	64.57	0.43	29.84	1.44	0.16
TW	3.66	19.73	36.77	38.47	91.38	7.01	72.41	9.68	0.89
PH	62.40	201.40	29.84	30.33	96.79	71.66	60.47	118.52	5.26
GS	0.21	0.67	28.22	29.65	90.59	0.26	55.32	0.46	0.03
YPT	0.53	5.76	33.54	37.45	80.25	1.59	61.90	2.57	0.35
YPP	8.40	36.23	23.70	32.17	54.27	7.48	35.96	20.79	3.69
NFG	47.85	252.21	30.43	32.84	85.90	65.64	58.10	112.97	11.37
HI	5.91	55.75	44.13	47.06	87.93	26.90	85.25	31.56	4.21

NT, Number of tillers; NET, Number of effective tillers; TD, Tiller diameter(cm); TWT, Tiller wall thickness (mm); TW, Tiller weight (g); PH, Plant height (cm); GS, Green seeker reading/Leaf greenness at maturity; YPT, Yield per tiller(g); YPP, Yield per plant(g); NFG, Number of filled grains; HI, Harvest index (%).

Table 3 Genetic variability studies in ratoon crop

Trait	Range		GCV	PCV	Heritibility (%)	GA as % of mean	Mean	SE(d)
	Min	Max						
NRT	6.00	22.66	36.44	38.35	90.31	71.34	10.83	1.05
NPRT	3.75	20.20	47.59	49.90	90.96	93.50	8.49	1.04
NLT	0.00	1.93	26.57	30.58	75.46	47.54	1.28	0.15
NDT	0.00	1.75	19.56	20.64	89.79	38.18	1.12	0.06
RPH	40.40	127.34	18.73	19.15	95.62	37.73	85.82	2.80
DRM	54.00	84.30	10.82	15.69	47.58	15.38	64.15	5.95
RSF	35.34	93.44	25.84	26.92	92.13	51.10	65.24	4.02
RYPT	0.51	1.61	26.84	31.63	72.03	46.94	0.87	0.11
RYPP	2.42	17.70	44.05	46.48	89.80	85.99	7.32	0.88
DRO	4.00	13.00	24.44	24.92	96.17	49.37	5.94	0.23
NT	4.70	15.95	36.70	38.72	89.85	71.68	10.83	1.09
BT	0.00	11.41	30.02	31.78	84.56	64.29	2.38	0.41

NRT, Number of ratoon tillers; NPRT, Number of productive ratoon tillers; NLT, Number of lodging tillers; NDT, Number of dwarf tillers; RPH, Ratoon plant height (cm); DRM, Days to ratoon maturity; RSF, Ratoon spikelet fertility (%); RYPT, Ratoon yield per tiller (g); RYPP, Ratoon yield per plant (g); DRO, Days to ratoon origin/emergence; NT, Number of nodal tillers; BT, Number of basal tillers.

ratoon yield per plant (g), days to ratoon origin/emergence, number of nodal tillers and number of basal. Therefore, these traits can be used for direct selection of ratoon yield.

The present research work provides useful information about the genetic variability in both main and ratoon crop for the observed traits. Assam rice genotypes have sufficient variability for ratooning ability. Varieties Binadhan 11, Sayjihari, IR 64 and DRR 44 are best in terms of ratooning ability and ratoon yield per plant. Hence, these genotypes are recommended when ratoon crop of rice is to be taken. These genotypes may be further used in crop improvement programme for enhancing ratooning ability. Among all the 50 genotypes screened, Terabali was the only cultivated variety which had perenniality structure in form of stolon. Thus, Terabali may be used as parent in breeding programme for introgressing stolon formation ability.

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