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RESEARCH ARTICLE

Variability in seed germination and dormancy of Indian weedy rice

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ABSTRACT

Seed dormancy is an adoptive trait of weedy rice to persist in rice production system. Weedy races and wild relatives of rice exhibit variation in seed dormancy, which allows weedy rice to escape weed management practices, and increases the flowering synchronization pattern resulting in gene flow between weedy and cultivated rice. In this study, eighteen weedy rice morphotypes collected from different rice growing areas in India, along with two rice cultivars, were evaluated for their germination pattern across time. Weedy rice seed germination was recorded periodically at weekly intervals up to 35 weeks after sowing (WAS) under controlled conditions. Dormancy duration was computed and germination index was calculated at 27 WAS. Significant variability was observed in germination pattern among the weedy rice morphotypes studied. The weedy rice morphotypes collected from Uttar Pradesh (T68) attained 50% germination after a maximum duration of 13.5 WAS, while five morphotypes of weedy rice remained ungerminated at 3 WAS. Seven weedy rice morphotypes germinated at 3 WAS at which both the rice cultivars (*BPT 5204* and *Pusa 1101*) have germinated (96.7 and 83.3%, respectively). Two weedy rice morphotypes had highest germination percentage (98.3%) at 35 WAS, while least (21%) was recorded with morphotype collected from Chhattisgarh (T41). This study indicated the existence of high degree of dormancy in weedy rice morphotypes. The findings of this study might be helpful for agronomists and farmers to develop and implement effective weedy rice management strategies at different rice production systems in India.

Keywords: Cultivated rice, Dormancy, Ecological variation, Germination, Morphotypes, Weed ecology, Weedy rice

INTRODUCTION

Rice is the major food and energy source for most of the world's population. In India, out of the total cultivated area of 143 mha, rice is cultivated in around 44.36 mha across the different agro-climatic zones. The transplanted rice production system is being used by farmers of the India and other Asian countries since many years (Ghosh *et al*. 2017**).** The puddled transplanted rice utilizes huge labour, water and energy (Rao *et al*. 2007, Mahajan *et al*. 2012) resources which are becoming increasingly rare and costly, thus making puddled transplanting less cost-effective (Rao *et al*. 2007, Mahajan *et al*. 2017). The transplanting practice also degrades the soil properties and adversely affects the productivity of succeeding upland crops. Thus, farmers are increasingly shifting from puddled transplanted rice to direct-seeded rice. Weeds are the major constraints in direct-seeded rice production system that affects plants growth and development as well as crop yield also (Rao *et al*. 2007, Ghosh *et al*. 2016). In direct-seeded rice (DSR), weedy rice (*Oryza sativa spontanea* f.) has become a menace in many DSR growing areas (Rao *et al*. 2007). About 5 to 60% of rice area among the different state of India was reported to be infested with weedy rice (Varshney and Tiwari 2005, Mishra *et al*. 2017). Weedy rice having attributes similar to cultivated and wild rice, regarded as biosimilar and therefore is difficult to manage. Characterization of functional traits of Indian weedy rice population from different agroclimatic zones revealed marked differences in morphological, growth and reproductive behavior (Rathore *et al*. 2016) with the ability to survive under water deficit and salt stress condition (Mishra *et al*. 2019). Weedy rice also possesses many adoptive characteristics including ability to germinate under flooding condition, high seed persistent in soil, seed dormancy, vigorous growth and greater nitrogen use efficiency for biomass production then cultivated rice

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(Rathore *et al.* 2013, Ghosh *et al.* 2017). Most of the weedy rice biotypes have colored pericarp which as contaminant of the final rice product reduce the market value (Cao *et al.* 2007). The adoptive characteristics variations existing in weedy rice population enable their wider adaptability to varied environmental conditions making its management in rice extremely difficult.

Among the weedy traits of weedy rice, seed dormancy is of major importance to its persistent infestation in rice. The seed dormancy in weedy rice may varies from few days to years depending upon its morphotype and storage condition (Gianinetti and Cohn 2008, Tseng *et al*. 2013). Xia *et al.* (2011) also reported about weedy rice morphotypes without having seed dormancy. The dormancy in weedy rice is only due to seed-covering-imposed dormancy, whereas, cultivated rice having seed-covering-imposed and embryo-imposed dormancy (Gu *et al*. 2003). Weedy rice seeds generally have higher seed longevity and remain viable over years that the cultivated rice. This is a challenge to farmers because such diversity allows weedy rice to escape and grow along with crop cultivar. The degree of seed dormancy also varied with ripening period, storage conditions, and genotype (Gianinetti and Cohn 2008). The research on variability of seed dormancy of weedy rice occurring in different rice production system of India is limited and needs to be evaluated. Hence, this study was undertaken with the objectives of evaluating the variation in the degree of seed dormancy of Indian weedy rice morphotypes collected from different agroclimatic zones of India along with rice cultivars.

MATERIALS AND METHODS

The collection of weedy rice morphotypes was done by extensive surveys in different agroclimatic zones of India *viz*. Upper Gangetic Plains Region, Middle Gangetic Plains Region, Lower Gangetic Plains Region, Central Plateau and Hills region, Eastern Plateau and Hills Region and Western Coastal Plains and Ghats Region. The survey covered total seven states, *viz*. Uttar Pradesh, West Bengal, Madhya Pradesh, Chhattisgarh, Jharkhand and Kerala. Eighteen weedy rice morphotypes were collected along with their GPS coordinates (**Table 1**) and were grown under field conditions along with two rice cultivars (*BPT 5204* and *Pusa 1101*) at the ICAR-Directorate of Weed Research (DWR), Jabalpur, Madhya Pradesh, India. The emerged panicles of each morphotypes were harvested before shattering. The harvested seeds were air dried and stored in cloth bag at room temperature for further experiments on dormancy profile. Experimental soil was collected from fields of the research farm and soil was sterilized and filtrated through a 3 mm sieve before use. The soil was clay loam containing 25, 26 and 49% silt, sand and clay, respectively.

The experiment was conducted in controlled conditions at net house during rainy season. Twenty seeds of each accession were placed in plastic pots (20 cm diameter and 2.2 cm height) filled with autoclaved soil and moistened with deionized water as per requirement. The pots were arranged in completely randomized design with three replicates. The germination was recorded periodically at weekly interval from first week after sowing (WAS) to thirty five WAS. The dormancy duration was computed as

Table 1. The weedy rice morphotypes samples collected agroclimatic zones and collection sites

Morphotype	Agroclimatic zones	Name of location/State	Longitude (N)	Latitude (E)
T21	Central Plateau and Hills	ICAR-DWR, Madhya Pradesh	23^{0}13′.45.6″N	79^{0}58′.17.9″E
T28	Central Plateau and Hills	Panagar, Madhya Pradesh	23^{0}16′04.0″N	79^{0}59′55.6″E
T30	Central Plateau and Hills	Panagar, Madhya Pradesh	23^{0}16′04.4″N	79^{0}59′53.6″E
T32	Central Plateau and Hills	Mehgawa, Madhya Pradesh	23^{0}19′05.9″N	80^{0}02′16.6″E
T34	Central Plateau and Hills	Mehgawa, Madhya Pradesh	23^{0}19′02.6″N	80^{0}02′22.2″E
T36	Eastern Plateau and Hills	Jharkhand	23^{0}14′51.6″N	85^{0}16′53.7″E
T39	Lower Gangetic Plains	West Bengal	23^{0}40′07.0″N	87^{0}38′25.0″E
T41	Eastern Plateau and Hills	Chhattisgarh	21^{0}13′31.4″N	81^{0}41′ 04.7″E
T42	Eastern Plateau and Hills	Chhattisgarh	21^{0}13′32.6″N	81^{0}41′01.8″E
T44	Central Plateau and Hills	Gwalior, Madhya Pradesh	26^{0}31′07.3″N	78^{0}00′10.5″E
T45	Central Plateau and Hills	Gwalior, Madhya Pradesh	26^{0}22′59.2″N	78^{0}18′24.5″E
T64	Middle Gangetic Plains	Bihar	25^{0}59′04.0″N	85^{0}39′32.6″E
T65	Upper Gangetic Plains	Uttar Pradesh	26^{0}38′44.0″N	80^{0}12′50.0″E
T68	Upper Gangetic Plains	Uttar Pradesh	26^{0}38′42.7″N	80^{0}12′49.3″E
T69	Upper Gangetic Plains	Uttar Pradesh	27^{0}11′43.0″N	80^{0}14′37.0″E
T75	Upper Gangetic Plains	Uttar Pradesh	26^{0}31′39.2″N	79^{0}49′53.8″E
T77	Western Coastal Plains and Ghats	Kerala	10^{0}45′52.8″N	76^{0}40′23.9″E
T79	Western Coastal Plains and Ghats	Kerala	10^{0}26′24.1″N	76^{0}10′06.3″E

the period from harvest till the maximum germination reached in each entry. No morphotype has germinated after 27 WAS. Therefore, germination index (GI) was calculated at 27 WAS by following formula as follows:

$$\text{Germination index (GI)} = \frac{n_1}{1} + \frac{n_2}{2} + \cdots + \frac{n_x}{x}$$

Where:

n_1 …….. n_x are the number of seeds germinated on day 1 to day x

1 ……..... x are the number of days

The average of observations from three replications is presented. The dormancy profile of different weedy rice accessions and rice cultivars were analyzed using the general linear model procedure of the Statistical Analysis System (SAS Windows Version 9.4). Sample means of weedy rice accessions and rice cultivars were separated with the use of Tukey's Honest Significant Difference (HSD) test at a 5% level of significance. The cluster analysis of eighteen weedy rice morphotypes along with two rice cultivars was also done on the basis of their germination data at different WAS by using SAS 9.4. Dissimilarity coefficients were calculated using average linkage method of cluster analysis procedure.

RESULTS AND DISCUSSION

A significant variation was noticed in germination pattern among the 18 morphotypes of weedy rice and 2 rice cultivars at different times of the study (**Table 2**). Seven weedy rice morphotypes collected from Mehgawa, Madhya Pradesh; West Bengal; Chhattisgarh and Uttar Pradesh ('T32', 'T34', 'T39', 'T41', 'T65', 'T69' and 'T75') recorded less than 50% germination during the entire study period. The weedy rice morphotype of Uttar Pradesh (T68) recorded 50% germination at a maximum duration of 13.5 WAS, while 50% germination of five weedy rice morphotypes occurred at 1 to 1.33 WAS. The rice cultivar *BPT-5204* and *Pusa 1101* attained 50% germination at 1.33 and 2.00 WAS, respectively. The observed variation in dormancy amongst weedy rice morphotypes might be attributed to ecological conditions like temperature, moisture and other non-genetic and genetic factors (Toole *et al.* 1964). The variation in seed dormancy among the rice cultivars is due to the bred genetic characteristics (Wani *et al*. 2018, Sohn *et al*. 2021).

At 3 WAS, five morphotypes of weedy rice did not germinate while seeds of morphotypes from Eastern Plateau and Hills of Jharkhand (T-36) attained maximum germination up to 95%, while it

Table 2. The germination percentage pattern of weedy rice morphotypes and rice cultivars at different weeks after sowing (WAS)

Weedy rice morphotype accessions	50% germination at WAS	Germination (%) at 3 WAS	Germination (%) at 35 WAS	Maximum germination reached at WAS	Germination index at 27 WAS
T21 DWR	8.67	43.3^{cd}	68.3^{abc}	14.0^{abcd}	4.25^{fg}
T28 Panagar	1.00	81.7^{ab}	81.7^{ab}	3.00^{cd}	6.65^{cde}
T30 Panagar	1.00	88.3^{a}	90.00^{a}	3.33^{cd}	7.29^{bcd}
T32 Mehgawa	-	0.00^{f}	28.3^{cd}	25.7^{a}	0.32^{h}
T34 Mehgawa	-	26.7^{def}	38.3^{cd}	12.0^{abcd}	2.39^{gh}
T36 Jharkhand	1.33	95.0^{a}	95.0^{a}	2.00^{d}	9.42^{ab}
T39 West Bengal	-	0.00^{f}	31.7^{cd}	17.7^{abc}	0.47^{h}
T41 Chattishgarh	-	0.00^{f}	21.7^{d}	20.7^{a}	0.30^{h}
T42 Chattishgarh	2.00	85.0^{ab}	96.7^{a}	18.3^{abc}	7.34^{abcd}
T44 Gwalior	2.00	93.3^{a}	96.7^{a}	11.0^{abcd}	8.34^{abc}
T45 Gwalior	5.67	33.3^{cde}	93.3^{a}	16.0^{abcd}	4.54^{efg}
T64 Bihar	1.33	93.3^{a}	98.3^{a}	4.00^{bcd}	9.49^{a}
T65 Uttar Pradesh	-	6.67^{ef}	45.0^{bcd}	26.0^{a}	0.95^{h}
T68 Uttar Pradesh	13.50	15.0^{ef}	65.0^{abc}	19.0^{ab}	2.39^{gh}
T69 Uttar Pradesh	-	0.00^{f}	46.7^{bcd}	22.3^{a}	1.01^{h}
T75 Uttar Pradesh	-	0.00^{f}	36.7^{cd}	19.7^{a}	0.59^{h}
T77 Kerala	1.67	93.3^{a}	98.3^{a}	11.3^{abcd}	9.38^{ab}
T79 Kerala	3.00	60.0^{bc}	91.7^{a}	10.7^{abcd}	5.79^{def}
C2 BPT 5204	1.33	95.0^{a}	96.7^{a}	3.00^{cd}	9.40^{ab}
C10 Pusa Basmati 1101	2.00	80.0^{ab}	83.3^{ab}	3.67^{bcd}	7.00^{cd}
LSD (p=0.05)	-	15.0	22.4	8.25	1.17

was minimum (6.67%) in 'T65'. Six morphotypes (T28, T30, T42, T44, T64 and T77) attained higher germination rate of 80 to 93% and five morphotypes (T21, T34, T45, T68 and T79) germinated ranging from 15 to 60% at 3 WAS when the rice cultivars, *BPT-5204* and *Pusa Basmati* attained germination 95 and 80%, respectively. The germination percentage attained by certain weedy rice morphotypes from Panagar, Madhya Pradesh; Jharkhand; Chhattisgarh; Gwalior, Madhya Pradesh; Bihar and Kerala (T28, T30, T36, T42, T44, T64 and T77) was similar to that of both rice cultivars at 3 WAS (**Table 2**).

Nine weedy rice morphotypes (T28, T30, T36, T42, T44, T45, T64, T77 and T79) had higher germination of 80 to 98% at 35 WAS at which two morphotypes (T21 and T68) germinated up to 68.3 and 65%, respectively. The germination percentage of the rest of the seven morphotypes (T32, T34, T39, T41, T65, T69 and T75) ranged from 21 to 46%. This variation may be due to the germination speed increase of red rice with the increment in temperature and changes in other climatic factors (Cho 2010). Weedy rice morphotype collected from Upper Gangetic Plains of Uttar Pradesh (T65) required longer time (26 weeks) for its maximum germination while four morphotypes of Eastern Plateau and Hills of Jharkhand, Central Plateau and Hills of Madhya Pradesh and Middle Gangetic Plains of Bihar (T36, T28, T30 and T64) required least time of 2.00, 3.00, 3.33 and 4.00 weeks, respectively for getting maximum germination. The rice cultivars *BPT-5204* and *Pusa 1101* have attained maximum germination at 3.00 and 3.67 WAS, respectively. The weedy rice morphotypes collected from different geographical location showed diversity in germination pattern, and morphotypes (T65, T68, T69 and T75) collected from same geographical location had more or less similar maximum germination time. The variability in seed dormancy among weedy rice was also observed by Rathanakumar *et al*. (2009), Wang *et al*. (2012), Gaikwad and Bharud (2016).

Significant variability in germination index (GI) of weedy rice morphotypes was observed in this study (**Table 2**). Among the tested entries, weedy rice morphotype 'T64' showed higher GI (9.49) over a period at 27 WAS. However, 'T41' morphotypes had lower GI (0.32). Seven weedy rice morphotypes (T28, T30, T36, T42, T44, T64 and T77) showed statistically similar GI to both rice cultivars. *BPT 5204* and *Pusa 1101* rice cultivars had GI of 9.40 and 7.00, respectively.

The cluster analysis of eighteen weedy rice morphotypes along with two cultivated rice was analyzed using their germination data at different WAS (**Figure 1**). In cluster analysis, there were two groups, *viz.* minor group of 8 morphotypes (T-68, T-39, T-69, T-65, T-75, T-39, T-41 and T-32) and major group of 12 morphotypes. Minor group did not include any cultivated rice members, and the morphotypes under this group showed very poor germination pattern during the course of observation. Major group was further divided into two sub-groups, *viz.* first sub-group of seven weedy rice morphotypes (T-42, T-77, T-44, T-64, T-36, T-30 and T-28) and two rice cultivars (C-2 and C-10), and second sub-group of three other weedy rice morphotypes (T-79, T-45 and T-21). In the first sub-group, weedy rice morphotypes showed promising germination pattern which was more similar to the rice cultivars. It was also noted that weedy rice morphotypes might be similar or dissimilar to that of rice cultivars. Variation in dormancy pattern in tested morphotypes might be due to genetic makeup of the seed (Wani *et al.* 2018, Sohn *et al.* 2021) or influence of the environment on the expression of the genetic capabilities (Klupczyñska and Paw³owski 2021). The impermeability of seed coat to water and the balance between the presence of germination inhibitors and promoters in the seed are also governing factor for seed dormancy.

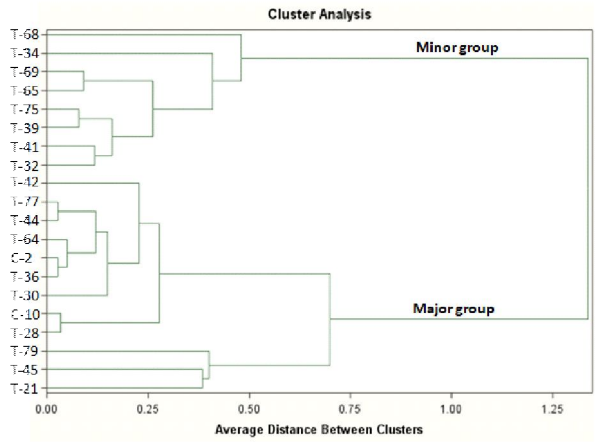

Figure 1. Cluster analysis of weedy rice morphotypes and rice cultivars on the basis of their seed germination data using dissimilarity coefficient

Conclusions

The dormancy pattern of weedy rice varied as per their genetic make-up, regardless of their ecological requirements. The dormancy profile of weedy rice might be similar or dissimilar to the cultivated rice. This information will be helpful either to maintain a time lag for rice sowing as per production system or to follow suitable cultural methods for weedy rice management.

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