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Participatory varietal selection of chickpea in rainfed rice fallow lands of Chhattisgarh and Madhya Pradesh in India for sustainable crop production

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Abstract

Production and area of chickpea are reducing every year in India due to competition with horticulture and other cash crops in irrigated areas. There is a great scope for expanding chickpea production with or without limited irrigation in rainfed rice fallow lands (RRFL) in the states of Chhattisgarh and Madhya Pradesh. Nineteen chickpea genotypes were tested using participatory varietal selection (PVS) trials on farmers' fields in each of the four districts of Chhattisgarh and Madhya Pradesh. Among the several traits of the introduced chickpea varieties, grain yield was the most preferred trait by farmers, followed by resistance to diseases and early maturity. Selection of chickpea genotypes varied over time and location depending on agronomic and climatic pressures, indicating a preference by farmers for growing multiple, improved varieties. Yield potential of PVS genotypes averaged up to 50% greater than the local cultivar. Farmers' participation in the selection process of genotypes laid the foundation of better and sustainable yields of chickpea and thereby providing better economic returns suitable to small farmers of RRFL of Chhattisgarh and Madhya Pradesh. The results of this study can be replicated in the similar environments in Asia and Africa.

Keywords: Farmer participatory; Improved genotype; Mother and daughter trials; Plant breeding; Rainfed rice fallow; Varietal selection.

Introduction

The rainfed rice-fallow lands (RRFL) offers greater scope to address the twin problems of food and nutrition insecurities by growing chickpea in the fields vacated by rice cultivation in rainy-season. About 12 million ha RRFL remains uncultivated in the post-rainy season (rabi) in India. It has been anticipated that even if 50% of the existing RRFL are brought under cultivation, it will usher another green revolution in the predominantly RRFL states, benefiting millions of small landholders (Joshi et al., 2002). However, a number of technical, institutional, socio-economic and ecological factors limit growing of a second crop after rice in RRFL. Many of the available rainfed production technologies have either not been transferred appropriately or failed to cater to the needs of the farmers. Financial institutions are reluctant to finance rainfed agriculture. These factors affect the cropping systems, but lack of irrigation is the main limiting factor to RRFL productivity of rabi crops. Extraction and use of ground and surface water for irrigation is difficult and costly. Creation of public irrigation infrastructure involves a huge investment and social cost. Private investment in irrigation has its own limitations.

Nearly 37% of the RRFL are located in the states of Chhattisgarh and Madhya Pradesh. There is a scope for expanding chickpea production in over 500,000 ha with or without limited irrigation in RRFL in these states. The GIS analysis of these RRFL has indicated that they represent diverse soil types and climatic conditions. Available moisture holding capacity (1 m soil profile) for most of these RRFL ranges from 150-200 mm. The soils in these RRFL are fully saturated during the rice growing season, thus the residual moisture left in these soils at the time of rice harvest offer a huge potential niche for chickpea cultivation.

Chickpea (*Cicer arietinum* L.) is one of the most important grain legumes in India, grown in an area of 8.21 million ha with an annual production of 7.48 million tons of grain (FAOSTAT, 2010). But, chickpea area and production are reducing every year due to competition with high yielding boro-rice, maize, potato and vegetable crops in irrigated areas and unavailability of irrigation in RRFLs. Yield is also decreasing mainly due to cultivation of traditional and disease susceptible varieties. Attempts were made to introduce and promote chickpea production in the RRFL following PVS trials through participation of farmers in the selection process for varieties optimally adapted to their farming system and agro-environment (Witcombe et al., 1996). It is imperative to understand and expand high yielding and disease resistance varieties of chickpea through PVS trials to increase chickpea yield and production in the country.

Furthermore PVS is often considered a more cost-effective and efficient method of varietal development and dissemination than centralized breeding (Ceccarelli et al., 2000). In traditional crop improvement, farmers are usually involved only in the final stages of variety testing, generally after varieties have been identified for release. Farmers often have little or no input regarding the management of these trials or the varieties tested. Farmers' evaluations of the tested genotypes are usually not sought, or if they are, they play little or no role in the decision making process for varietal releases and recommendations (Farrington and Martin, 1988).

Possibilities for farmers' participation in selection are as diverse as the nature of selection itself (Ceccarelli and Grando, 2007; Dawson et al., 2008; Murphy et al., 2005; Weltzien et al., 1998) and crop varieties have been successfully released through different types of PVS programs (Ceccarelli and Grando, 2007; Joshi et al., 2001). In diverse agro-environments, PVS can provide greater varietal choice, a reliable supply of high quality seed and improved regional marketing capacity (Joshi, 2000).

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India, initiated the PVS approach of introducing and expanding improved high yielding chickpea varieties in collaboration with Indira Gandhi KrishiVishwavidyalaya-(IGKV), Raipur, Chhattisgarh and Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Madhya Pradesh and farmers of Chhattisgarh and Madhya Pradesh of India.

The specific objectives of this study were to identify chickpea varieties and their agronomic traits most preferred by farmers of the villages in the RRFL environments of Chhattisgarh and Madhya Pradesh and to understand the effect of shifting biotic and abiotic selection pressures on the relative stability of farmers' preferences over time and space.

Materials and Methods

Experimental Design

Field trials were conducted for four years from 2008/09 to 2011/12 in four districts (Raipur, Durg, Rajnandgaon and Kabirdham) of Chhattisgarh and four districts (Jabalpur, Rewa, Satna and Damoh) of Madhya Pradesh. On-farm farmers PVS trials were coordinated by the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), in active collaboration with Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh and Indira Gandhi KrishiVishwavidyalaya (IGKV), Raipur, Chhattisgarh. A baseline survey was conducted to determine socioeconomic status, production practices, problems and prospects of rice-chickpea farming in RRFL.

Following farmers' participatory rural appraisal, project locations and collaborating farmers were identified in each project district (Tables 1 and 2). Farmers from each site were selected to conduct PVS "Mother and Daughter" trials (Thapa et al., 2009) on their own fields. "Mother" trials typically consist of 7 to 12 improved chickpea varieties and a control (Ortiz-Ferrara et al., 2007). "Daughter" trials were conducted on larger plots on numerous farmers' fields and consisted of 1-3 improved chickpea cultivars from the Mother trial and a local check variety.

Table 1. List of PVS sites in Chhattisgarh from 2008/09 to 2011/12.

Season	Raipur	Durg	Rajnandgaon	Kabirdham	Mother trials and Genotypes (n)*	Daughter trials
2008/09	Kalai, Farhada	Jatadah	Jangalpur	Dharampura	8 (7)	192
2009/10	Khapridih Khurd	Mohandi	Nathunawagaon, Kumhalori	Amera	6 (8)	421
2010/11	Beldar Seoni, Budera	Chirchar, Bamhani	Penderi	Chandeni	6 (10)	984
2011/12	Elda, Nahardih	Arjuni	Makrandpur	Singhari	7 (12)	1215

* n= number of genotypes selected for mother trials.

Table 2. List of PVS sites in Madhya Pradesh from 2008/09 to 2011/12.

Season	Jabalpur	Rewa	Satna	Damoh	Mother trials and Genotypes (n)*	Daughter trials
2008/09	Paroda, Chedi	Bidwa	Katahaha	Bimori	8 (6)	400
2009/10	Saliya	Bahuribandh, Puraini	Bathiya	Hindoria	5 (8)	721
2010/11	Bhidarikala, Jatana	Maidhi	Gobraokhurd, Bairahatola	Hardua mudra, Banwar	8 (8)	992
2011/12	Barkheda, Jamgaon, Kastara, Kuhi	Amilki, Patna, Mahorba, Laxmanpur	PuranibastiJamudi, Ramasthan, NaibastiJamudi	Patinandlal, Jamnera, Parswa, Khedar	16 (8)	1200

* n= number of genotypes selected for mother trials.

Over the project period, nineteen improved chickpea genotypes were tested in RRFL of Chhattisgarh and Madhya Pradesh. Genotypes tested in Mother and Daughter trials varied each year based on their agronomic performances on-station and on farmers' fields. Sixteen genotypes were tested at 21 locations in Chhattisgarh and 33 locations in Madhya Pradesh forming 64 Mother and 6125 Daughter trials (Tables 1 and 2). Daughter trials were based on the varietal performance of Mother Trials. Plot size was 60 m^2 for Mother Trials and 0.40 hectare for the Daughter trials for each variety. Plot size of Daughter trials was determined based upon the availability of land and seed.

Site specific components of improved chickpea production technology, such as seeds of improved chickpea cultivars, seed treatment with fungicides, fertilizer and line sowing using zero-till direct seed drill and/or traditional bullock drawn seed drill and plough were used to establish the PVS trials. Mother and Daughter trials were monitored periodically by the multi-disciplinary team of scientists, extension workers, farmers and NGOs.

Varietal evaluation and selection was done by farmers who considered the following traits: grain yield, plant height, maturity and disease resistance. Farmers ranked each cultivar for all traits. Scoring was based on the number of genotypes tested and the relative performance of each genotype. For example, if 10 genotypes were tested at a particular location, a score of 10 was given for the genotype with the best performance for each trait and 1 for the worst performance for each trait. Overall Preferential Rank (OPR) was calculated as the average of the trait scores. A Seed Distribution Ceremony was organized every year of the project period before the crop season began. Farmers, all PVS partners, official representatives and journalists were invited and seeds were distributed to respective farmers.

Statistical Analysis

Analysis of variance in GENSTAT software (edition 14.0; Rothamsted Experiment Station, Harpenden, Herts AL52JQ, UK) was used to analyze all traits evaluated. Both location and genotype were considered fixed effects in the analyses. Pearson's correlation coefficients were calculated based on mean trait values within years and used to estimate phenotypic relationships between traits of interest using in-built program in EXCEL 2010.

Results and Discussion

PVS trials were conducted in Raipur, Durg, Rajnandgaon and Kabirdham districts of Chhattisgarh and Jabalpur, Rewa, Satna and Damoh districts of

Madhya Pradesh during 2008-09 to 2011-12 (Tables 1 and 2). A total of 6125 farmers with an average landholding of less than 0.40 hectare participated in evaluation and selection of chickpea genotypes. Out of 16 chickpea varieties, JG 74 was ranked highest by farmers across the project locations, followed by Vaibhav and Vijay in Chhattisgarh. In Madhya Pradesh chickpea genotype JG 16 was ranked highest by the farmers followed by JG 130, JG 11 and JAKI 9218 (Table 3). JG 74 in Chhattisgarh and JG 16 in Madhya Pradesh were preferred by farmers because of their high grain yield, early maturity and wilt resistance (Table 4).

Table 3. Summary of Overall Preferential Rank (OPR) for chickpea genotypes in "Mother" trials from 2008/09 to 2011/12 in all locations of Chhattisgarh and Madhya Pradesh.

State	Genotype	OPR			
		2008/09	2009/10	2010/11	2011/12
Chhattisgarh	JG 315	5.30	-	-	-
	Vaibhav	8.50	8.30	7.35	7.60
	Vijay	7.05	6.90	9.15	9.00
	Digvijay	4.00	-	-	-
	DCP 92-3	4.10	-	-	-
	HC 5	4.00	-	-	-
	JG 74	8.85	7.70	7.45	7.65
	JG 14	-	6.00	5.61	5.80
	JG 11	-	6.00	6.20	5.90
	ICCC 37	-	4.00	4.90	5.30
	JGK 2	-	4.30	5.00	4.80
	JG 322	-	5.10	5.15	4.90
	Vishal	-	-	5.50	5.50
	JG 16	-	-	-	6.60
	JG 6	-	-	-	5.20
	JG 130	-	-	5.20	5.90
Madhya Pradesh	JG 11	6.00	8.00	7.50	7.45
	JG 16	8.00	9.20	8.00	7.65
	JG 315	8.00	-	-	-
	JG 130	8.50	9.00	6.20	8.50
	JG 74	9.00	8.00	5.95	-
	JAKI 9218	6.50	7.00	7.25	6.00
	JG 14	-	7.20	5.50	4.30
	JG 63	-	8.10	6.95	4.20
	JGK 2	-	5.50	4.00	-
	JG 12	-	-	-	4.20
	JG 322	-	-	-	4.70

Higher numbers indicate greater farmer preference.

Table 4. Relationship between score on Overall Preferential Rank and other traits in "Mother" trials in Chhattisgarh and Madhya Pradesh from 2008/09 to 2011/12.

State	Year	Maturity	Grain yield	Dry root rot	Collar rot	Pod borer
Chhattisgarh	2008/09	0.79*	0.75*	0.45 (NS)	0.41(NS)	0.49(NS)
	2009/10	0.91***	0.64*	0.08 (NS)	0.17(NS)	0.11(NS)
	2010/11	0.78**	0.56*	0.10 (NS)	0.07(NS)	0.21(NS)
	2011/12	0.86***	0.73**	0.40 (NS)	0.56(NS)	0.08(NS)
Madhya Pradesh	2008/09	0.68*	0.86*	0.37 (NS)	0.22(NS)	0.33(NS)
	2009/10	0.79**	0.89**	0.21 (NS)	0.56(NS)	0.08(NS)
	2010/11	0.62*	-0.53	0.48 (NS)	-0.58	0.41(NS)
	2011/12	0.93***	-0.22	-0.30	-0.57	0.14(NS)

*, **, *** correlations are significant at P<0.05, <0.01 and <0.001, respectively. NS= non-significant.

During 2008/09, 5 villages in four pilot districts (Raipur, Durg, Rajnandgaon and Kabirdham) in Chhattisgarh and 5 villages in four pilot districts (Jabalpur, Rewa, Satna and Damoh) were chosen for the PVS program (Tables 1 and 2). One hundred ninety two farmers in Chhattisgarh and 400 farmers in Madhya Pradesh participated in these trials. Local disease susceptible cultivar had been predominantly grown on these sites with an average annual productivity of approximately 0.79 t/ha. In 2008-09/2009-10, genotypes were significantly different for all the traits. JG 74 and JG 16 was the highest grain yielder, as 102% and 173% higher than local cultivar, respectively (Table 5). Farmers selected JG 74 and JG 16 due to their short duration, wilt resistance, higher grain yield and uniform crop stands.

In 2010-11 and 2011-12, PVS trials were conducted in 11 villages in Chhattisgarh and 22 villages in Madhya Pradesh (Tables 1 and 2). In these two seasons, Vijay and JGK 2 had the highest grain yield over local cultivar (Table 5). Farmers preferred Vijay and JGK 2 for all the traits except insect-pests (data not shown). JG 130, JG 315, JG 11 and Vaibhav were also highly rated genotypes (Table 3).

Overall preferential rank (OPR) was positively correlated with grain yield (Table 5). Grain yield and maturity showed the strongest correlation with OPR, ranging from 0.56 to 0.89 and 0.62 to 0.93, respectively. Dry root rot, collar rot and pod borer incidence were not correlated with grain yield and maturity during 2008-09 to 2011-12 crop seasons.

Table 5. Percent yield of 17 chickpea genotypes over traditional (local) variety in PVS trails in 2008/09 to 2011/12 across all locations in Chhattisgarh and Madhya Pradesh.

Genotype	Yield increase over local variety (%)			
	2008/09	2009/10	2010/11	1011/12
JG 315	47.44	-	-	-
Vaibhav	62.24	56.33	34.52	48.38
Vijay	48.97	35.21	59.52	61.29
DCP 92-3	55.10	-	-	-
JG 74	102.04	100.70	23.21	50.53
JG 11	19.38	100.70	14.88	47.84
JG 16	44.89	173.23	33.33	27.95
JG 130	48.97	170.42	25.00	46.77
JAKI 9218	32.65	119.71	13.09	24.73
ICCC 37	-	40.84	17.85	37.50
JGK 2	-	52.81	57.14	30.55
JG 322	-	39.43	26.19	36.55
JG 14	-	95.07	13.09	38.17
JG 63	-	152.11	7.14	54.83
Vishal	-	-	23.80	38.70
JG 12	-	-	-	31.18
JG 6	-	-	-	30.10

Predominance of old cultivars and the limited resource of irrigation are common in RRFL of Chhattisgarh and Madhya Pradesh. Newly released cultivars, JG 74, JG 130 and DCP 92-3 were only grown in limited areas of RRFL in these provinces. Though seed multiplication occurs in sufficient quantity to meet producer needs, minimal seed dissemination is likely due to poor communication between extension and research personnel resulting in low levels of farmers' awareness and knowledge about the new varieties. The consequences included insignificant improvement of productivity and production of chickpea in India.

The PVS Program proved to be a successful approach in the identification of promising genotypes in RRFL of Chhattisgarh and Madhya Pradesh. Seventeen genotypes were tested through PVS trials at RRFL of Chhattisgarh and Madhya Pradesh. Ten genotypes, including JG 74, JG 11, JG 16, JG 130, JAKI 9218, JG 63, Vijay, JGK 2, Vaibhav and JG 14 were grown by farmers individually as well as in large areas in RRFLs. This emphasized the appreciation of farmers for growing multiple, narrowly adapted improved varieties that are optimally adapted to their unique agro-ecosystem micro-niches.

More than 75% genotypes were preferred by farmers in RRFL of Chhattisgarh and Madhya Pradesh due to high grain yield, early maturity and resistance to wilt. Vaibhav was ranked the highest in overall performance followed by Vijay and JG 74 in all the four selected districts (Raipur, Durg, Rajnandgaon and Kabirdham) of Chhattisgarh. Similarly in Madhya Pradesh JG 16 was ranked the highest in overall performance followed by JG 130, JG 11 and JAKI 9218. In 2009-10, JG 16 and JG 130 had grain yields of up 170% higher than local cultivar. The early maturing improved cultivars of chickpea escape terminal drought hence most suitable for RRFL environment.

In Raipur, Durg, Rajnandgaon and Kabirdham districts in Chhattisgarh and Jabalpur, Rewa, Satna and Damoh districts in Madhys Pradesh, individual farmers preferred varieties of JG 74, Vaibhav and Vijay. JG 130, JG 16, JG 11 and JAKI 9218 were superior to other genotypes in Jabalpur, Rewa, Satna and Damoh districts of Madhya Pradesh due to its high yield, early maturity and wilt resistance traits. These results were in agreement with studies showing that PVS increased varietal diversity and was most effective within complex farming communities (Joshi et al., 1997).

In ICRISAT, chickpea breeders select primarily for grain yield, biotic stresses, early maturity and drought tolerance. In this study, ten cultivars were preferred in RRFLs of Chhattisgarh and Madhya Pradesh. Vaibhav, Vijay and JG 74 and JG 130, JG 16, JG 11 and JAKI 9218 were among the highest OPR across the RRFLs of Chhattisgarh in 2008-09 to 2011-12 because of resistance to wilt and early maturity and high yield potential (~1.2 t/ha).

Fusarium wilt is an important disease limiting chickpea cultivation and selection for wilt resistance genotypes was significantly correlated with OPR. Vaibhav, Vijay, JG 74, JG 11, JG 16, JG 130 and JAKI 9218 were selected by farmers because of their high yields resulting from resistance to the new races of Fusarium wilt pathogen (Figures 1 and 2).

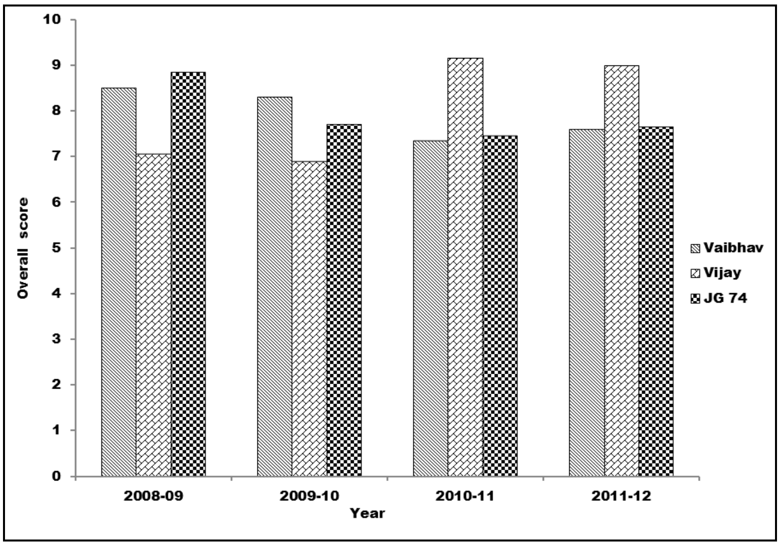

Figure 1. Overall Preferential Rank (Overall Score) as given by farmers in "Mother" trials for three genotypes, Vaibhav, Vijay and JG 74 across all locations in RRFL of Chhattisgarh, in 2008/09 to 2011/12. Higher numbers indicate greater farmer preference.

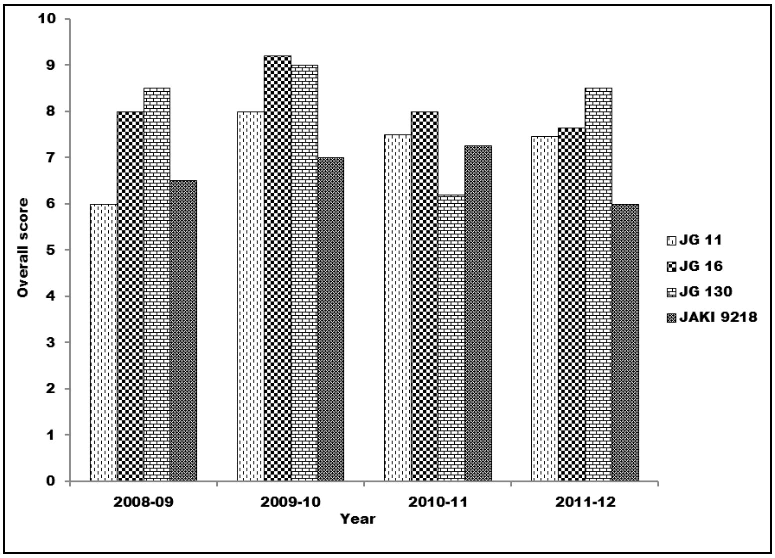

Figure 2. Overall Preferential Rank (Overall Score) as given by farmers in "Mother" trials for three genotypes, JG 11, JG 16, JG130 and JAKI 9218 across all locations in RRFL of Madhya Pradesh, in 2008/09 to 2011/12. Higher numbers indicate greater farmer preference.

Increased spatial genetic diversity reduced the overall vulnerability to climate weather patterns and diseases. This illustrated that farmer OPR will change over locations and years in response to biotic stress. Because of this stress it is often difficult to predict, thus, cultivation of multiple varieties is an effective method of maintaining farm level yield stability. Broadly adapted cultivars may not be as effective in achieving yield stability across the diverse micro-niches present in the RRFLs of Chhattisgarh and Madhya Pradesh.

Majority of crop seed in India is disseminated through informal seed supply systems. Seed recovery is generally quite low in RRFL districts of Chhattisgarh and Madhya Pradesh due to nutrition deficiencies at the producer level and lack of awareness. A potential impact of the PVS approach in Chhattisgarh and Madhya Pradesh would be a strengthening of nutrition security and farmer to farmer seed supply systems through increases in varietal diversification, productivity, quality and knowledge transfer. Because farmers in Chhattisgarh and Madhya Pradesh often produce seeds of preferred cultivars and distribute them to neighboring farmers, the PVS approach may overcome the perceived slow and hierarchical process of varietal testing in formal systems. Project interventions used key villages, formal and informal seed sector merchants and Non-Government Organizations in the production and dissemination of new varieties of chickpea. The project collaborated with JNKVV, a State University in India, particularly involved in seed production and distribution. The involvement of women in cultivar identification and adoption was also increased greatly through the PVS approach.

Conclusion

Result of PVS research in Chhattisgarh and Madhya Pradesh indicated that Vaibhav, Vijay and JG 74 in Chhattisgarh and JG 16, JG 130, JG 11 and JAKI 9218 in Madhya Pradesh consistently produced higher yields both in mother and daughter trials. These genotypes also got high farmers' overall preferential ranks. They had high grain yield, early maturing and wilt resistance trait and farmers expressed their opinion to cultivate those in the following years. Farmers' selected varieties were extending very rapidly and farmers to farmers seed transfer was found very effective in scaling-up seed transfer and increase varietal diversity. Identification and potential adoption of niche specific genotypes using PVS has the potential to promote stable seed and grain production, through increased genetic diversity, across dissimilar landscapes. Thus, the results of this study can be replicated in the similar environments in Asia and Africa.

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