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Varietal Diversity of Rice and Wheat in Subtropical North India

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***Abstract*:** Rice (*Oryza sativa* L.) wheat (*Triticum aestivum* L.) cropping system (RWCS) is the largest grain production system in the world, including India. In India, with the introduction of high-yielding varieties of rice and wheat, RWCS emerged as the principal cropping system, ushering in the Green Revolution. However, the widespread adoption of higher-yielding varieties led to the loss of genetic diversity. A farm survey was conducted to analyse the on-farm varietal diversity of rice and wheat crops in the Jammu & Kashmir subtropics and Punjab. A multistage random sampling technique was applied to select a sample of 480 rice-wheat-cultivating farmers. In Punjab, 23 rice and 20 wheat varieties, and in Jammu, 17 rice and 19 wheat varieties were grown by the farmers. Ten and seven rice varieties were dominant varieties cultivated in Jammu and Punjab, respectively, covering a crop acreage of 76.40 and 46.86 per cent with a varietal diversity index of 0.131 and 0.106. In wheat, 88.75 per cent of wheat acreage was under two varieties with a varietal diversity index of 0.066 in the Jammu subtropics, and 82.02 per cent of total wheat acreage in Punjab was under five varieties with a mean varietal diversity index of 0.080.

Keywords: Rice-wheat cropping system, Varietal diversity, Jammu, Punjab

Rice (*Oryza sativa* L.) wheat (*Triticum aestivum* L.) cropping system (RWCS) is the largest agricultural production system in the world and covers 24 million hectares (m ha) area in Asia (Ladha et al 2000). In South Asia, RWCS covers an area of 13.5 m ha (Prasad 2005). In India, with the introduction of high-yielding varieties (HYVs) of rice and wheat, RWCS emerged as a principal cropping system, ushering in the Green Revolution. Overall, rice is cultivated in an area of nearly 43.8 m ha with a production of 177.6 Mt, and wheat acreage is 29.3 m ha area producing 103.6 Mt (FAOSTAT 2021) and is the backbone of India's Green Revolution. Out of this, the RWCS covers an area of around 9.2 m ha (Jat et al 2020). RWCS is the dominant cropping system in Punjab, Haryana, western Uttar Pradesh, parts of Bihar and sub-tropical areas of the Jammu region. However, sustainability issues about RWCS have emerged lately, such as high energy requirements, decreased water use efficiency, over exploitation of underground water, higher insect pest and disease infestation, loss of biodiversity, residue management and overuse of pesticides and nitrogenous fertilizers (Bhatt et al 2016, Peshin et al 2020).

World over, many studies conducted show varietal diversity in modern agriculture was reduced. With the advent of the Green Revolution, genetic diversity within and between the crop species has reduced. Post Green Revolution, many traditional rice varieties consumed prior to the Green Revolution have become non-existent (Nelson et al 2019). High-yielding varieties of rice and wheat were introduced as part of the Green Revolution to increase agricultural productivity replacing many local varieties (Pingali and Rajaram 1997). This resulted in reduced genetic diversity within a particular species (Keneni et al 2012). However, the Green Revolution mainly driven by HYVs of rice and wheat resulted in significant yield gains and is playing a decisive role in the world food supply to feed the growing population (Borlaug 2000).

The genetic and varietal diversity has narrowed in rice and wheat over time. The declining varietal diversity in rice and wheat is due to two fundamental concepts, namely, wide adaptation across locations, and consistent yield stability across years (Ceccarelli and Grando 2022). According to Ceccarelli et al (2013), only four varieties of rice are cultivated in 65 per cent of the world's total rice area. In Asia, two dominant varieties cover an overall area of 29 per cent in the case of cereals (Gatto et al 2021). Bangladesh and Vietnam lost varietal diversity in the rice and wheat (Muttaleb et al 2008, Jarvis et al 2008). Agricultural diversity can promote environmental health, resilience, and food production (Wolfe 2000). Crop species diversity is frequently highlighted as contributing to both nutritional security and ecological resilience (Reiss and Drinkwater 2018). It is more successful in pest management than single species or varietal stands because it contains colonies of natural enemies that protect crops (He et al 2019). Cropping systems with mixed varietal arrangements are more robust, particularly to biotic stress (Yang et al 2019). Varietal diversity has been shown to have a positive influence on dealing with abiotic stresses (Condori et al 2014) while posing a threat to food security. Heisey et al (1997) highlighted that few popular varieties cover large wheat acreage. In the recent past, wheat variety HD 2967

was the most popular wheat variety accounting for 11 per cent of wheat acreage in six states namely Haryana, Rajasthan, Bihar, Uttar Pradesh, Punjab, and Madhya Pradesh. Only five wheat varieties, namely, HD 2967, PBW 343, PBW 550, PBW 502 and Lok 1 accounted for major wheat areas in the six states mentioned above (Pavithra et al 2017). In this article, we have analyzed farm-level varietal diversity in RWCS in the Jammu subtropics and Punjab.

MATERIAL AND METHODS

Profile of the study area: The study was conducted in rice-wheat growing sub-tropical area of Jammu and Kashmir (J&K) and Punjab. Union Territory of J&K is in the northwestern Himalayan region. It has three distinct agro-climatic zones namely sub-tropical Jammu region (up to 800 meters above mean sea level), intermediate/semi-temperate mid-hills (800-1500 meters above mean sea level), and temperate (1500-2500 meters above mean sea level). In J&K, only sub-tropical area of Jammu region was selected for the study. Punjab is also located in sub-tropical zone and its average elevation is 300 meters above mean sea level with a range from 180 meters in the southwest to more than 500 meters around the northeast border (Anonymous 2024).

Sampling plan: A multistage sampling technique was used to draw the sample of farmers. In Punjab, six districts were selected using a proportionate random sampling technique from the three regions of Malwa, Majha and Doaba. The districts were: Barnala, Ludhiana, Mansa and Moga in the Malwa region; Gurdaspur in Majha region and Kapurthala in Doaba region (Fig. 1). From the sub-tropical Jammu region, three representative districts namely Jammu, Samba and Kathua were selected purposively (Fig. 1). In each selected district of Punjab, two blocks were selected randomly. The blocks selected were Barnala and Tappa from Barnala district; Pakhowal and Khanna from Ludhiana district; Bhikhi and Budhlada from Mansa district; Moga I and Moga II from Moga district; Derababa Nanak and Dinanagar from Gurdaspur district, and Kapurthala I and Sultanpur Lodhi from Kapurthala district. In the subtropical Jammu region, four blocks each were selected from Jammu, Samba and Kathua districts. R.S Pura, Bishnah, Marh and Jourian were selected from Jammu district; Ghaghwal, Vijaypur, Ramgarh and Rajpura from Samba district, and Barnoti, Nagri, Marheen and Hiranagar from Kathua district.

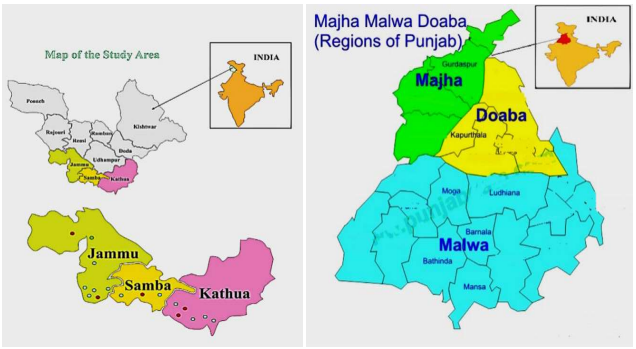


Fig. 1. Location of surveyed villages in the subtropical Jammu region and in Punjab

Further, from the selected blocks, a list of villages practising rice-wheat cropping systems was prepared. Simple random sampling without replacement technique was applied to select two villages from each block. A total number of 48 villages (24 villages each from Jammu and Punjab) were chosen for the study. Lists of the farmers cultivating rice-wheat crops were prepared by meeting Sarpanches/ progressive farmers of each village. From the lists prepared, a sample of 10 farmers was drawn from each village by employing random sampling without replacement. Thus, a total sample size of 480 farmers was selected for the study (Table 1). The data were collected through the personal interview method with the help of two semi-structured interview schedules from the sampled farmers.

Descriptive statistics of farmers: The descriptive statistics of farmers are given in Table 2. The average age of farmers in the Jammu region and Punjab was 51.68 and 45.34 years respectively. The average formal education of Jammu farmers was 9.75 years whereas Punjab farmers' average education was 10.36 years. A majority of farmers of Jammu and Punjab were literate. The average farm size of Jammu farmers was 1.97 ha with an average farming experience of 31.68 years whereas, Punjab farmers' average operational landholding was 6.31 ha (that includes: owned landholding of 4.71 ha and leased-in landholding of 1.61 ha) with farming experience of 25.34 years (Table 2).

Measurement of extent of adoption: The adoption of rice and wheat varieties/hybrids was measured by the percentage of farmers cultivating and the area under a crop variety.

Measurement of varietal diversity: For estimation of varietal diversity of rice and wheat varieties, Theil's entropy index (1972) was used.

$$E = \sum_{i=1}^{n} P_i \log(1/P_i)$$

Where,

E is the entropy index,

P i is the proportion of area under i^{th} variety to total area under the crop (rice/wheat),

n is the number of varieties raised by the farmers

Statistical analysis: A z-test of proportion was applied to compare the proportions from two independent groups to determine if they were significantly different from one

another. Two sample t-test was used to compare means from independent samples from rice and wheat growers of Jammu and Punjab to test whether the two samples differ significantly in their mean concerning socio-personal and biophysical variables.

RESULTS AND DISCUSSION

Extent of adoption of rice and wheat varieties/hybrids: In Jammu subtropics, the extent of adoption with respect to area coverage was dominated by hybrid rice (54.04%) followed by basmati varieties, coarse varieties, and semi-fine varieties. However, in Punjab, major rice acreage was under coarse varieties (53.42 %), followed by hybrid rice, basmati varieties and semi-fine varieties. In Jammu, the major rice varieties cultivated or adopted in 2021-22 were Basmati 370 (48%) followed by Pusa Basmati 1121 and in Punjab Pusa 44 and PR 121 (Table 3). In the Jammu sub-tropics, though 19 wheat varieties were cultivated by the farmers, only one variety namely HD 2967 covered an area of 81.53 per cent of wheat acreage and two varieties HD 2967 and HD 3086 covered 88.75 per cent of wheat acreage. In the case of Punjab, 20 wheat varieties were cultivated but three varieties namely HD 2967, HD 3086 and WH 1105 covered an area of 71.23 per cent of total wheat acreage . The extent of adoption of HD 2967 and HD 3086 concerning the percentage of farmers was 94 per cent in Jammu. In Punjab, the extent of adoption of HD 2967 and HD 3086, with respect to farmers was 81 per cent (Table 3).

In the case of rice crop, though the number of varieties cultivated by the farmers in Jammu and Punjab were 17 and 23 respectively, however, the varieties with more than five per cent of crop acreage were only nine in the Jammu sub-tropics and seven in Punjab (Table 3). On the other hand, in the case of wheat, only two varieties were cultivated on more than five per cent of wheat acreage in the Jammu sub-tropics. In Punjab, five varieties were cultivated on more than five per cent of the wheat acreage.

Varietal diversity of rice-wheat: In 2020-21, 23 rice varieties/ hybrids were cultivated by the farmers of Punjab. Out of which, seven rice varieties/hybrids were cultivated on more than five per cent of rice acreage (Table 3). In 1984-85 and 1990-91, nine rice varieties were cultivated, which two major rice varieties were PR 106 and Jaya. PR 106 was cultivated in 57 per cent area in 1984-85, which decreased to 41 per cent (1987-88), again increased to 62 per cent (1990-91) and then declined to 23 per cent (1998-99) (Singh and Kalra 2002). The other variety was Jaya, cultivated in an area of 20 per cent in 1984-85 which further increased to 25 per cent (1985-86) and then decreased to nine per cent (1990-91) (Singh and Kalra 2002). Thereafter, in 1990-91 and 1998-

Table 1. Sampling plan

State/Region	Districts selected	Blocks selected	Villages selected	Farmers selected from each village	Total
Sub-tropics of Jammu	3	12	24	10	240
Punjab	6	12	24	10	240
Total	9	24	48	10	480

Table 2. Descriptive statistics of sampled farmers

Parameter	Jammu (n=240)	Punjab (n=240)	Difference
Average age (in years)	51.68±0.65	45.34±0.70	6.34 (t=6.59*)
Literate (% farmers)	96	99	03 (z=2.1*)
Average formal schooling	9.75±3.49	10.36±2.46	0.61 (t=2.83)
Education level (% farmers)			
i. Upto Primary (1-5)	05	04	01 (z=0.3)
ii. Upto Middle (6-8)	15	08	07 (z=1.6)
iii. Upto Matriculation (9-10)	51	55	04 (z=0.6)
iv. Upto Senior secondary (11-12)	17	23	06 (z=1.1)
v. Graduate and above	08	09	01 (z=1.1)
Average family size	6.01±0.17	5.87±0.11	0.14 (t=0.69)
Average farming experience of respondent farmers (years)	31.68±0.66	25.34±0.70	6.34 (t=6.60*)
Average operational landholding (ha)	1.97±0.16	6.31±0.36	4.34 (t=11.13*)

*Significant at p≤ 0.05

Table 3. Extent of adoption of rice and wheat varieties/hybrids with respect to percent farmers and area (2021-22)

Rice variety/ hybrid	Jammu	Punjab	Jammu	Punjab	Wheat variety	Jammu	Punjab	Jammu	Punjab
	(% farmers)[1]		(% area)			(% farmers)[1]		(% area)	
Basmati variety			32.00	15.19	HD 2967#	87	28	81.53	17.42
Pusa 1121#	45	10	5.77	5.45	HD 3086#	7	53	7.22	47.70
Basmati 370#	48	-	11.22	-	HD 3226#	2	1	1.2	0.07
Un-descript (Komo Basmati)	6	-	6.87	-	PBW 175#	1	-	0.35	-
Pusa 1718	1	5	5.00	0.43	RAJ 3765#	1	-	0.01	-
Pusa Basmati 1509#	-	4	-	3.65	RAJ 3077#	1	-	0.2	-
Pusa 1401/ Muchhal Basmati	-	2	-	5.66	WH 1105#	1	8	0.5	6.11
CSR-30#	1	-	3.12	-	HD 3043#	2	3	0.54	1.96
Semi- fine variety			4.98	2.55	PBW 550#	1	3	0.20	1.33
Sharbati	15	3	2.48	2.55	PBW 723	1	-	0.2	-
Devgoda	4	-	2.5	-	HD 1553	1	-	0.2	-
Coarse variety			8.97	53.42	JK Vijay	1	-	0.2	-
Jaya#	2	-	2.34	-	Ankur	3	-	4.64	-
Pusa 44	-	60	-	9.7	HD 2329	1	1	0.05	0.75
PR 106	-	1	-	3.65	PBW 343#	1	1	0.15	0.40
PR113#	11	-	6.63	-	PBW 644	1	-	0.50	-
PR 114#	-	2	-	5.20	DBW 168	1	-	1.0	-
PR 118#	-	1	-	7.30	DBW 222#	1	1	0.25	0.60
PR 121#	-	30	-	6.25	HS 507	3	-	1.07	-
PR 122#	-	2	-	3.65	DBW 187#	-	5	-	3.80
PR 126#	-	11	-	3.79	HD 2687	-	3	-	3.1
PR 127#	-	2	-	4.01	PBW 725#	-	3	-	2.7
PR 128#	-	3	-	3.65	PBW 118	-	1	-	0.24
PR 129#	-	1	-	2.55	Shree Ram 272	-	3	-	5.27
PR 201	-	1	-	3.65	DBW 173#	-	1	-	0.15
Hybrid			54.04	28.82	Krishna	-	1	-	0.12
Arize 6444	1	-	5.62	-	DBW 88#	-	1	-	0.30
BH 21	1	-	2.5	-	JK 5501	-	1	-	0.66
Dhanya 748	4	-	7.60	-	Ganga	-	8	-	5.52
Dhanya 834	2	4	8.44	3.28	Sunehri#	-	1	-	0.15
HKR 47	-	1	-	7.30					
HK 100	1	-	7.50	-					
Hybrid 28P67	-	1	-	4.37					
Kaveri 468	-	1	-	2.2					
Paddy 105	-	1	-	3.65					
PHB 71#	1	-	3.75	-					
Sawa 127	1	-	10.00	-					
Super hybrid 901	-	1	-	3.65					
Tata RIL 666	-	1	-	4.38					
VNR 2355	3	-	8.62	-					

Notes: #Resistant/recommended varieties. [1] Multiple responses. Figures corresponding to percentage of famers have been rounded up to the nearest whole number

99, 12 rice varieties were cultivated, out of which two major rice varieties were cultivated namely PR 111 and Pusa 44. PR 111 was cultivated in an area of four per cent in 1995-96 which further increased to 26 per cent (1998-99) and Pusa 44 was cultivated in an area of six per cent (1991-92) which increased to 27 per cent (1998-99) (Singh and Kalra 2002). In 2016, 18 rice varieties were cultivated in Punjab, out of which three major rice varieties, namely, Pusa 44, Basmati 1121 and PR 121 were cultivated on an area of 27.23, 23.0 and 20.71 per cent of rice acreage respectively (Peshin et al. 2017; Peshin et al. 2023). Over time, the number of rice varieties cultivated by the Punjab farmers has increased. The results of this study revealed that Punjab farmers had cultivated 23 rice varieties in 2021-22 (Table 3). In Jammu subtropics, seven rice varieties were cultivated by farmers in 2016, out of these, Basmati 370 was the dominant variety (58.49%), followed by PR 113 (16.13%) and Pusa 1121 (12.42%) (Peshin et al 2017). However, another study conducted by Bano (2019), reported that about 17 rice varieties were cultivated in 2016, and the dominant varieties were: Basmati 370 and Basmati 1121. The result of this study show that 16 rice varieties were cultivated (which include hybrids) and the dominant varieties cultivated were Basmati 370 (11.22%), Basmati 1121 (5.77%) and PR 113 (6.63%).

In the case of wheat, the area sown has constantly increased in Punjab from about 28 per cent (mid-1980s) to 42 per cent (1990-91) to 50 per cent (1995-96) and further to 62 per cent in 1998-99 (Singh et al 2004). The varieties which were cultivated namely C 303 and C 306 covered 70 per cent of the area under wheat up to the mid-1960s. Later, Kalyan Sona (K 227) and PV 18 (semi-dwarf varieties) dominated through the mid-1970s. In 1970-71 and 1980-81, 17 wheat varieties were cultivated, out of these only 3 major wheat varieties namely Kalyan Sona (K 227), WG 357 and WL 711 were cultivated widely. In 1970-71, Kalyan Sona alone covered 80 per cent of the wheat area in 1975-76. From 1980-81 to 1989-90, 19 wheat varieties were cultivated out of which, 2 major wheat varieties were WL 711 and WL 1562 were cultivated. In 1980-81, WL 711 variety covered 73 per cent of wheat acreage which later decreased to one per cent only (1995-96) and WL 1562 variety was cultivated in an area of 22 per cent (1984-85) which also decreased to one per cent only by 1996-97 (Singh et al 2004). From 1990-91 to 1998-99, the number of wheat varieties cultivated decreased to 13. It was observed that there were two major wheat varieties namely HD 2329 and PBW 343. HD 2329 had an area of 80 per cent (1990-91) which later increased to 86 per cent (1993-94) and then decreased to 11 per cent (1998-99) and at the same time PBW 343 covered 82 per cent (1998-99) and further increased to 86 per cent in 1999-2000 (Singh et al., 2004). A review of the literature shows, that only 2-3 varieties dominated the area coverage at different points in time.

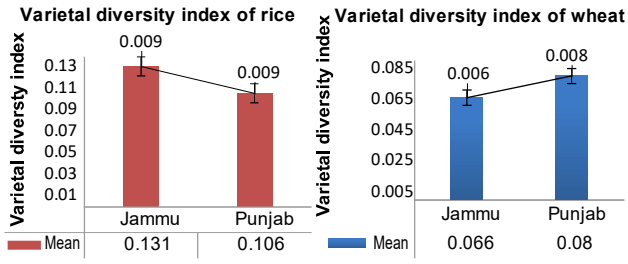


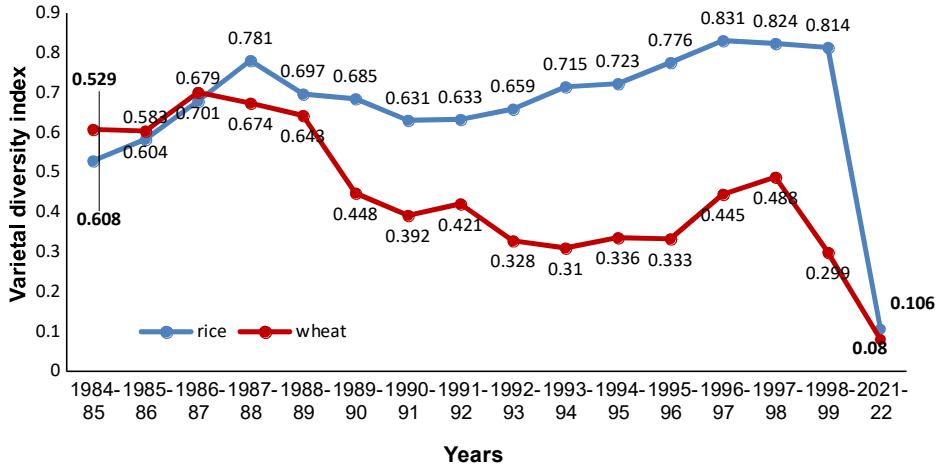
Fig. 2. Varietal diversity index of rice and wheat crops in the subtropical Jammu and Punjab 2021-22

In the case of subtropics of Jammu, around 19 wheat varieties were cultivated in 2013-14, the five dominant wheat varieties were RAJ 3077 (33.23%) followed by hybrid JK Vijay (28.68%), PBW 550 (16.14%), PBW 175 (14.51%), PBW 343 (14.12%) (Peshin et al 2014). However, Bano (2019) reported that farmers cultivated around 11 wheat varieties which include HD 2967 (occupied 72% of wheat acreage) followed by PBW 550 (11.27%). The results of this study show that around 19 wheat varieties were cultivated by farmers, out of which, 81.53 per cent was under HD 2967 and 7.22 per cent under HD 3086.

From the above-reviewed literature and the results of this study, it can be concluded that the number of rice varieties cultivated at the farm level has increased both in Punjab and in the sub-tropics of Jammu and there have always been two to three dominant varieties in Punjab since 1980-81 and no change was observed in 2021-22. Unlike Punjab, in Jammu subtropics, the number of dominant varieties (with more than 5% of wheat acreage) has decreased and only two varieties were covering more than five per cent of wheat acreage (Table 3).

Varietal diversity index: The varietal diversity of rice and wheat varieties was measured on Theil's entropy index (1972). The varietal diversity index of rice in Jammu and Punjab was 0.131 and 0.106 respectively, and in the case of wheat, the varietal diversity index of Jammu and Punjab was 0.066 and 0.080 respectively in 2021-22. The varietal diversity index shows that in Jammu subtropics, the mean varietal diversity index of rice was higher as compared to Punjab with a difference of 23 per cent (Fig. 2). But, in the case of wheat, the varietal diversity index was higher in Punjab compared to the sub-tropical Jammu with a difference of 21 per cent (Fig. 2). The varietal diversity of rice was higher than wheat in the Jammu subtropics and as well in Punjab.

The varietal diversity of rice has decreased in Punjab from 0.529 in 1984-85 to 0.106 in 2021-22, a decrease of 80 per



(Data source: 1984-85 to 1998-99 Singh and Kalra 2022; Singh et al 2004; 2021-22 own data)

Fig. 3. Varietal diversity of rice and wheat in Punjab overtime

cent whereas in the case of wheat, the varietal diversity has decreased from 0.608 post-green revolution (1984-85) to 0.080 in 2021-22, a decrease of 86.8 per cent (Fig. 3).

CONCLUSION

From the study, it is concluded that over time, in the case of rice crop, the varietal pool has increased resulting in more than five per cent of rice acreage under each of the six rice varieties and thus, higher varietal diversity. Besides, there is diversity in different rice types cultivated by the farmers such as basmati, semi-fine and coarse rice. Unlike rice, in wheat, the varietal pool is narrow as only two to three varieties covered more than 71.23 per cent of wheat acreage in Punjab and in the case of Jammu; only two wheat varieties covered 88 per cent of wheat acreage. The varietal diversity of rice and wheat in Punjab has also decreased by more than 80 per cent over time. The decrease in varietal diversity reduces the resilience from the biotic and abiotic stresses. Further, research is needed to study why the varietal diversity of wheat is lower than rice.

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