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Review Paper

Exploring possibilities of rice-wheat cropping system under temperate hill ecology of Kashmir: progress, challenges and future prospects: a review

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ABSTRACT

Declining natural resources, increasing population and changing climatic and geo-political situation in the world demand self-reliance in food production through a productive, profitable and sustainable, system for food, nutritional and economic security. Rice-wheat cropping system (RWCS) occupies around 13.5 million ha in south Asia and contributes around 233.96 million tonnes of food grain in India, which makes around 75.29% of the total food grain production in the country. In Jammu and Kashmir UT, agriculture land under rice cultivation is shrinking at a hasty rate due to conversion into apple orchards, urbanization and other non-agriculture activities. Under this scenario every effort needs to be made to increase food production in the UT. Despite harvesting 6.9 t/ha of rice in valley, the UT is a food deficit. It has to import around 07 lakh metric tonnes of food grain every year and there seems to be no further scope to increase production through growth in area. So, increasing productivity and cropping intensity are possible means to augment production. Traditionally rice has been grown as a mono-crop on major rice area or as double cropping system with mustard or in patches with fodder oats. Although wheat is ideal crop for the temperate ago-ecology of Kashmir and wheat products are routinely consumed in the valley, the crop has not picked up well. In this paper an effort has been made to review the achievements, identify major challenges and potential for future in terms of research on rice -wheat cropping system.

Keywords: Challenges, cropping system, hills, potential, rice-wheat,

The challenge of food security is becoming intricate due to mounting population and dwindling natural resources. Shifting to medicinal, biofuel and horticulture crops further increases pressure on food security in India. The per capita land has decreased from 0.29 ha in 1970 to around 0.12 ha at present in the country (Anonymous 2022 a), indicating 170% decline in land holding over the period. The population on the other side has consistently expanded and has increased by 156% from 0.55 billion to 1.41 billion during this period. The behaviour of climate and the geopolitical situations in the world is also uncertain and may result into many challenges to the food, nutrition and economic security related to agriculture. The situation demands continuous effort in R&D for sustaining agriculture and explore every possibility to tackle any future food crisis. The contribution of rice -wheat cropping system (RWCS) in food security cannot be overemphasized. It occupies around 13.5 million ha in south Asia and contributes around 233.96 Mt of food grain in India (Anonymous 2022 b). This makes approximately 75.29% of the total food grain production in the country. These figures illustrate the significance of RWCS in Indian Agriculture and its role in food security. According to the estimates the population of the country by 2060 will be around 1.65 billion (Anonymous 2022c). Keeping pace of food grain production in view of the ever-increasing population and declining land and other natural resources is therefore a tough challenge. So, every effort in improving the productivity of RWCS will be crucial in meeting the demands. When we talk of Jammu and Kashmir, agriculture land under rice cultivation is shrinking at alarming rate. The prime reasons may be the expansion of land under apple cultivation, which has increased from 81115 ha in 2001-02 to 147130 ha in 2019-20. Agricultural land is also decreasing due to its use for non-agriculture purposes like construction of residential houses, shops,

showrooms and other activities related to urbanization. The sustainability of agricultural production systems is dependent on the diversity of the crops, but in Kashmir Valley the farming community is switching over to the apple cultivation due to its better economic returns and less water requirement as compared to traditionally grown rice (Bhat *et al.,* 2019; Ganai, 2022). Though apple cultivation has proven more profitable at traditional locations but apple mono-culture spreading at a very fast rate particularly in non-traditional areas is beset with its own problems, especially susceptibility to collapse under emerging new pest and disease attack with the changing climate scenario (Mubarak *et al.,* 2023). Cultivation of apple in areas not fit for its cultivation makes it economically nonviable and environmentally hazardous due to heavier disease incidence and pest infestation. The increased biotic stress prompts the farmers of these areas to spray pesticides intensively, thus increasing the cost of apple cultivation and reducing its quality along with adverse impact on health, ecology and environment. Under this scenario, it is imperative to motivate the farmers for cultivation of food grain crops in these areas of the valley. The main motivation would be the cultivation of rice and wheat crops for food security, better profitability and higher cropping intensity. These two crops also play a significant role in solving the fodder and feed scarcity in the valley. Both straw and bran obtained from these crops as a bi-product are used in dairy farming. Traditionally rice has been grown as a mono-crop on major rice area or as double cropping system with mustard or in patches with fodder oats. Although wheat is ideal crop for the temperate agro-ecology of Kashmir (Mubarak and Singh, 2011) and wheat products are routinely consumed by the people of Kashmir, the crop has not picked up as a component crop in rice based cropping system. The area under wheat in Kashmir region is just 12090 hectares and production is 31035 metric tonnes (JKAPD 2021), which is far less to meet the demand. The shortfalls therefore are met through imports from the neighbouring States and the UT of J&K loses a huge exchequer in arranging food grains for the general public. If we can utilize the 30 % rice area of Kashmir region (0.42 lakh hectares) and assume 2.5 t ha-1 productivity of wheat, an additional 1.05 lakh tonnes of wheat can be added to the total food grain basket. In this paper an effort has been made to review the achievements made so far, the existing challenges and potential for future in terms of research on rice -wheat cropping system.

Success achieved so far:

Breeding programme for the development of suitable wheat varieties: No doubt some manipulations in rice related technologies may be required to make the RWCS a possibility in the valley, but its success is primarily dependent on wheat related technologies particularly the genotypes which are extra-early, productive and resistant to biotic and abiotic stresses. A narrow window between the harvesting of wheat and transplanting of rice is considered as a major bottleneck with rice-wheat sequence. Another important reason is the low temperatures during the month of April which may also delay maturity. As a result RWCS has received less attention of the farmers and its adoption in valley is not significant. The most popular wheat varieties are long duration which don't fit in rice wheat sequence. Taking this into account, research and screening of wheat germplasm by SKUAST- K has been a continuous process and has received more attention under AICRP on wheat & Barley since 2002. Under the project multiple wheat entries are received from national and international sources like ICAR IIWBR Karnal and CIMMYT Mexico, Turkey and ICARDA. Some of the recent entries and their traits are mentioned in table 1. The received material is screened and utilized for the development of genotypes and yield potential, duration of variety and disease resistance, especially against yellow rust are some major targets of the research programme on wheat at SKUAST-Kashmir. Over the years of research and screening by SKUAST K scientists, Shalimar series of wheat varieties were developed and most recently an early maturing high yielding wheat variety Shalimar Wheat -3 with a yield potential of 3.5 t/ha has been identified for rice- wheat double cropping system. The variety was released recently in year 2022 with a yield advantage of 21.4% over the check variety Shalimar wheat-2.

The morphological traits of Shalimar wheat-2 in comparison to the check variety and disease score are presented in table 2. In-spite of the short duration the wheat variety is expected to be harvested between 10 to 15th of June, which leaves a little time for field preparation for the planting of succeeding rice crop. Delayed transplanting under Kashmir conditions results in the yield penalty as crop is exposed to adverse weather conditions during sensitive stage, especially low night temperatures during flowering which results into spikelet sterility (Mubarak *et al,* 2012). This ultimately culminates into poor yield of rice crop. The same is true for the *rabi* crops where any delay beyond optimum results in high yield penalty (Dar *et al.,* 2018, Jhangir *et al.,* 2013). Under such scenario, short duration high yielding rice and wheat varieties coupled with farm mechanization and some other agronomic manipulations discussed below, can make possible the timely harvesting of wheat and preparation of fields for sowing/planting of crops in sequence. Moutain Research Center for Field Crops, SKUAST-Kashmir has developed shalimar rice-3 a comparatively short duration and high yield rice variety.

Table 1: Agro-morphological traits and yield of different wheat entries tested at MRCFC-SKUAST-Kashmir during 2022-23

SN	Entry	Agro-morphological Traits					Yield	
		Days to heading	Days to maturity	Height (cm)	Lodging (%)	1000 grain weight (gm)	Grain yield (q ha^{-1})	Biological yield (q ha^{-1})
1.	NHIVT201	178	238	96.2	0	55	28.33	123.33
2.	NHIVT202	177	237	113.7	0	63	32.61	138.09
3.	NHIVT203	179	240	117	0	63	33.57	139.28
4.	NHIVT204	180	240	116.4	0	61	37.14	136.9
5.	NHIVT205	177	237	99.5	0	65	35.23	137
6.	NHIVT206	180	239	118.6	0	56	30.71	118.57
7.	NHIVT207	178	237	98.3	0	61	31.66	137.61
8.	NHIVT208	177	237	105.3	0	49	28.57	122.9
9.	NHIVT209	177	238	109.3	0	58	45.23	144.04
10.	NHIVT210	179	239	106.5	0	50	30.95	126.19
11.	NHIVT211	179	239	106.6	0	56	30.95	138.09
12.	NHIVT212	180	238	100.4	0	63	33.33	135.7
13.	NHIVT213	177	236	99	0	59	40.47	140
14.	NHIVT214	180	239	108.3	0	53	30.95	144
15.	NHIVT215	179	238	105	0	50	30.95	118
16.	NHIVT216	181	241	100	0	58	41.9	138
17.	NHIVT217	180	240	110.3	0	46	33.33	144.28
18.	NHIVT218	177	237	98	0	49	48.57	139.28
19.	NHIVT219	180	239	117.2	0	50	33.33	144.46
20.	NHIVT220	179	238	118.2	0	51	29.52	134
21.	NHIVT221	177	237	95.1	0	59	46.9	133
22.	NHIVT222	179	237	108	0	52	34.76	140.5
23.	NHIVT223	179	238	114.5	0	53	34.76	135
24.	NHIVT224	180	240	99.6	0	46	29.76	120
25.	NHIVT225	180	239	110	0	59	50	145
26.	NHIVT226	179	238	104	0	52	35.71	137.61

Standardization of production technologies of wheat crop: Research work done regarding standardizing the technologies related to wheat cultivation and development of package of practice under Kashmir conditions stands documented in the package of practices by Directorate of Extension. So far as rice-wheat cropping sequence is concerned, studies indicate that it could be a productive and profitable under Kashmir valley conditions (Mubarak and Singh, 2009). Early demonstration programmes at farmers field conducted jointly by the SKUAST-Kashmir and Development Department confirm that with mechanization a great success can be achieved in this direction (Zargar and Mubarak, 2011). The data on comparison of rice-based cropping systems (Table 3) at farmers field reveals that rice -wheat sequence has the potential not only to augment food grain production but the income of farmers. However, due to fragment land, lack of group farming, custom hiring services and suitable machinery, mechanization has not picked up well.

Table 2: Morphological characters of test entry Shalimar wheat-3 against Shalimar Wheat-2

Characters	Test variety	Check variety
Name of variety	(Shalimar wheat-3)	(Shalimar Wheat-2)
Early Growth Habit	Erect	Erect
Auricle Pubescence	Hairy	Sparsely hairy
Flag Leaf Angle	Semi-erect	Semi erect
Maturity	Early	Medium
Days to Heading	170	176
Plant Height (cm)	92	90
Angle of Ear	Semi-erect	Semi-erect
Ear Colour	Light brown	White
Ear density	Medium	Medium
Density	Dense	Medium
Ear Length	Medium	Medium
No. of Spikelets/Ear	22	18
Awn Length (cm)	7.5	8.0
Awn colour	White	White
Awn attitude	Medium	Medium
Grain Colour	Amber	Deep amber

From farmers' perspective widening the window between harvesting and planting of respective crops has more relevance in terms of making any progress in this direction. This would not be possible with early duration varieties only but also through other agronomic manipulations. There has been isolated research done on some agronomic aspects like impact of sowing dates and fertility management, but study on impact of all possible agronomic manipulations together like use of early varieties both in rice and wheat, altering sowing dates, varying fertility levels in terms of nitrogen and phosphorous, water management, nursery establishment methods and so on is lacking. Scientist team from MRCFC have initiated research programme on these in *rabi* 2022 to see the impact not only on individual crops but also on system productivity, profitability and resource conservation. In future there may be horizontal spread in area under rice-wheat cropping system as the technologies which seem irrelevant today may be the relevant in future.

So anticipatory research must be a continuous process taking into consideration the assumptions related to climatic change, declining natural resource base, increasing population, geo-political situation and so on. It is difficult however to

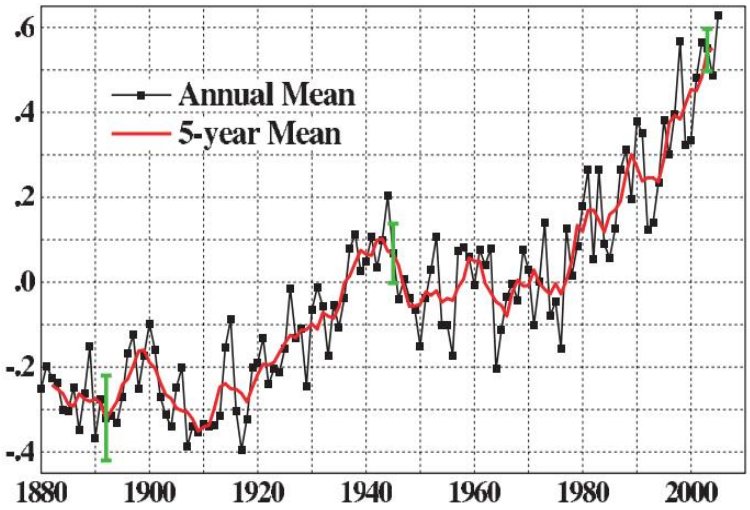

Fig. 1: Global Land-Ocean Temperature Anomaly (°C). Hansen *et al.* 2006

make exact estimates because one does not know how things will move in future. The climate change for instance has strong relation with human activities related to emission of Green House Gases, but no one can exactly predict how contributors to this will behave in future. Despite this we must run assumptions and work in advance for any anticipatory situation. Research on wheat and wheat based cropping systems could be a part of this programme because of its potential. According to Hansen *et. al.* (2006) global warming is a real climate change and there has been a slow global warming with large fluctuations, over the century up to 1975, followed by rapid warming at a rate ⊐ 0.2^0C per decade. Global temperature anomalies over the time presented by the authors are depicted in Fig 1. This trend of global warming is predicted to have a diverse impact on crops and recent study by NASA indicates a positive gain of around 17% in wheat production (Jagermeyr *et al.,* 2021). There may be regional variations in climate change but this probably may help not only increase yields in our conditions but also resolve the issue of late maturity of wheat crops to some extent as the crops may acquire heat units in comparatively lesser time.

Challenges of food security and RWCS

Shrinking agriculture land and need to augment production through RWCS*:* Despite the fact that we harvest 6.9 t/ha of rice per hectare on an average in the valley, which is around 190% higher than the national average 2.4t ha (Mubarak *et al.* 2022), the Jammu and Kashmir UT is food deficit. This is due to multiple reasons discussed elsewhere (Sofi *et al.*, 2020). There is a huge gap between production and demand of food grains and UT has to import around 07 lakh MTs of food grain every year. Shrinking agriculture land due to competition with other sectors indicates that there is no further scope to increase production through growth in area but instead through growth in yield and cropping intensity (Hobbs and Gupta, 2003). In India farming, preferences are also changing and economics seems to be the driving force. In a study conducted by Ganaie *et al.* (2017), the area under paddy has recorded a negative growth of -29.92 percent and wheat, which is a major rabi crop of Jammu division, has registered a negative growth of -21.47 percent in the area. In view of these, working both on yield and other aspects related to RWCS need to be taken into consideration. So far as rice is concerned, its production has increased from 3.9 lakh tonnes in 1999-2000 to 13.5 lakh tonnes at present, but there has been a continuous decline in the area. Even though the area under rice has virtually declined but the production has increased by more than 3 times during the period. This may be attributed to the development of rice technologies and their dissemination through frontline and mainstream agriculture extension agencies at grass root level. The major contribution in rice production comes from Kashmir division with a production of 9.8 lakh Mt at present which is 72.6 % of the total production in UT. The case however is opposite with wheat. The total area under wheat in the UT is 2.5 lakh ha of which only 0.12 lakh ha falls in Kashmir Division. Wheat production in the UT is around 5 lakh Mt of which 4.87 Mt comes from Jammu Division which is 97.4 % of the total production. Thus, the contribution from temperate Kashmir side is meagre. However, there is a huge potential which can be explored if more focus is laid both on short and long term research projects on RWCS in this part of the UT. Intervention of mechanization for instance can help a lot even with the existing technologies and research for further widening the window between planting and harvesting of respective crops and other aspects related to sustainability may need medium to long term approach. In addition to this strict enforcement of law should be there to prevent conversion of irrigated agriculture land to horticulture and other non- agriculture purposes to strike a balance and avoid problems related to mono-cropping.

Competition with other rabi crops: Studies indicate that rice-wheat sequence could be more productive and profitable than rice -sarsoon and rice–fodder oat cropping system (Table 3), but being well adjusted as a component crop in rice -based cropping systems prevalent in Kashmir valley, brown-sarsoon stands as a major competitor to wheat crop (Sheikh *et al.,* 2013).

Table 3: Summery of Front-line Demonstration programme conducted by SKUAST- Kashmir in district Anantnag (2007-2010)

Area covered under demonstrations (ha)	No. of Farmers involved	Economics of different rice-based cropping systems			
18.2	65	Cropping System	Gross returns (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)
		Rice-fallow	51040	14500	36690
		Rice-mustard	74092	27561	46530
		Rice-Fodder oat	66376	29280	37096
		Rice-wheat	80113	30681	49431

Source: *Zargar and Mubarak 2011*

Although being the 4th largest producer of oilseed, India is one of the largest importers of vegetable oil. That is why there is a great thrust of government of India and the UT government on area expansion under oilseed. Besides demand for green fodder has increased in recent years and will further increase with the increase in livestock population and thus wheat will face more competition with fodder oat as well. Despite these competitions, wheat can occupy place in the cropping system on rotation basis as crop rotations have multiple advantages (Larkin *et al.,* 2012; Zohry *et al.,* 2018).

Lack of mechanization: Agriculture extension services through the Krishi Vigyan Kendras and agriculture production and farmers welfare department serve as a bridge between farmers and the agriculture researchers/policymakers. The feedback from these agencies is valuable because of being closely associated with famers at grass root level. Regarding the bottlenecks in the popularization of rice-wheat sequence, lack of farm mechanization has been reported a major one by these agencies. Farm mechanization has a huge role in agriculture (Ravinder *et al.,* 2019) and rice-wheat cropping system is not an exception. Delay in field operations and broadcast sowing are two important reasons for lower productivity and late maturity of crops in sequence and mechanization has role in both. Appropriate machinery suitable to the fragmented land, custom hiring centres and FPO based approach may help even under existing situations. Mechanization indeed is very important to reduce drudgery, ensure timely and speedy field operations and make farming attractive for the farmers, especially the new generation who distance themselves from agriculture. Replacement of the traditional arduous and time-consuming methods of threshing, processing and packing by modern machinery is also required to popularize RWCS.

Depleting water resources: Water is a critical input in agriculture. The availability of water determines the fate of agriculture across the space and time. In major rice growing states like Punjab, the deficit in surface water resources pushed farmers to exploit underground water resources and that resulted in highest decline in groundwater levels in the country. The state known for its contribution during green revolution and in shaping the food scenario of the country is facing grim water resources scenario at present. Since around 73% of irrigation is from ground water in the state and area under rice-wheat sequence has the major share of it, the demand for irrigation water is very high. This is mainly because of rice which consumes around 5000 lt. water to produce one kg of grain (Bhatt *et al.,*2016). The experience from our neighbouring state gives an insight to the water scenario and may help in planning future agriculture which must be water efficient. In view of declining water resources, we cannot rule out situation when we start talking about wheat based cropping system instead of rice-based cropping system in future in Jammu & Kashmir UT. With wheat we don't have any problem as it is mainly grown as rainfed but rice indeed would be under scanner. For wheat pre-sowing soil moisture is important as September and October are often dry in Kashmir. Thus, soil and atmospheric moisture deficit leads to low water availability in soil for seed germination and early establishment of crop. Light Pre sowing irrigation may therefore be recommended under situation when soil moisture is detected low.

Other research area in RWCS: Being a different ecology, the challenges and potentials may vary between Kashmir valley and other parts of the country. Learning from the neighbouring states and given to the exhaustive nature of rice and wheat, investigation in addition to crop maturity , disease resistance and water management must also cover the impact on soil fertility, nutrient balance, soil heath, soil structure, weed dynamics & management. Being consumed on daily basis, biofortification of these crops may also be an area of research.

CONCLUSION

In view of increasing population and shrinking agriculture land, food security will be a big challenge for India as well as for the UT of Jammu and Kashmir. Adoption of rice-wheat cropping system can help in improving the food grain production and reduce food deficit to a great extent in the UT. The popularization of this cropping system however needs a focused research and also introduction of suitable implements and tools for mechanized farming of the sequence particularly under Kashmir valley conditions. Since productivity can be increased to certain biological limits, so to keep the pace of food grain production with demand, law enforcement is also needed to prevent conversion of irrigated agriculture land to non-agriculture purposes.

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