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Evaluating Yield Performance and Income Gains from an Advanced Temperate Rice Genotype in the Northwestern Himalayan Agro-Ecosystem

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Abstract

Many factors are responsible for the lower yields at farmers field which need to be identified and replaced by suitable technological interventions. Newly developed high yielding varieties and related package of practice can help bridging the yield gaps between potential and what is obtained by farmers. Keeping this inview, front-line demonstrations were conducted on a new variety (Shalimar rice -4) and crop management during 2019 to 2021. The results indicated that use of obsolete varieties, imbalanced fertilizer application, higher plant population and lack of disease management were factors responsible for low productivity at farmers' field. A positive linear correlation between grain yield and panicles m^{-2} (0.3027 and 0.2191), grains $panicle^{-1}$ (0.6597 and 0.4398) and 1000 gain weight (0. 067 and 0.0861) were recorded in Farmer's practice and Improved practice, respectively. Yield was 15.5% higher in improved practice compared to farmers' practice. An extension gap of 9.9 q ha^{-1} and a technology gap of 6.2 q ha^{-1} were observed in the study. Net returns were Rs. 129243 ha^{-1} in farmers practice and Rs.146815 ha^{-1} in improved practice. An additional income of Rs. 17572 ha^{-1} and effective gain of Rs. 14812 ha^{-1} were recorded in the improved practice. Higher benefit: cost ratio (2.9) was also registered in improved practice compared to farmers practice (2.7).

Keywords: Rice, front-line demonstrations, temperate ecology, agroecosystem and yield gap analysis.

Introduction

Despite India having the largest area under rice cultivation globally, its productivity remains considerably lower than the world average (Mubarak *et al.*, 2023a). A significant yield gap persists between the potential yield and the actual yield realized at farmers' fields (Mubarak and Shakoor, 2019). This gap is largely attributed to the continued use of traditional rice cultivars and sub-optimal crop management practices. Bridging this yield gap requires a systematic identification of the underlying constraints and large-scale demonstration of improved technologies under real farming conditions.

In Kashmir Valley, located in the north-western Himalayas, rice is not only the staple food but also a critical source of livelihood and employment for a substantial portion of the population. Therefore, the adoption of improved rice production technologies, including high-yielding varieties and better crop management practices, is directly linked to regional food security and enhancement of farmers' income. In this context, the Mountain Research Center for Field Crops (MRCFC), SKUAST-Kashmir released the variety Shalimar Rice-4 (SR-4) in 2017 through a farmers' participatory breeding programme. This variety is a disease-resistant with a yield potential of up to 10 t ha^{-1} under optimal management (Mubarak *et al.*, 2022).

Although improved varieties like SR-4 and recommended crop management practices are available, their adoption at the farmers' level remains limited. Moreover, there is inadequate location-specific information on the performance of these improved technologies under farmers' field conditions in the Kashmir Valley, as well as a lack of systematic assessment of the key factors responsible for low productivity. In view of the above, the present study was conducted during 2019-2021 with the objectives to identify the major factors responsible for low rice productivity at farmers' fields in the Kashmir Valley, to evaluate the performance of improved variety SR-4 and recommended crop management practices, under farmers' participatory conditions and to assess the potential of these interventions in bridging the yield gap and enhancing farmers' productivity and income.

Materials and Methods

A detailed survey of the 13 adopted villages (**Table 1**) located in the lap of Peer Panchal Himalayan Range between 33.62 to 33.70^{0}N latitude and 74.8 to 75.02^{0}E was conducted in year 2018 to ascertain different factors responsible for low yields at farmers' field. The information was collected through face-to-face interaction and questionnaire designed for the purpose. Improved practice, which included Shalimar Rice-4 variety and related crop management was used for the demonstrations at farmers field against the existing farmers' practice, which included traditional variety (Jhelum and K-39) and farmers' crop management. Sixty-four (64) frontline demonstration programmes were sponsored by ICAR. Agricultural Technology Application Research Institute Zone-1 were conducted by Farm Science Center (KVK)-Kulgam in collaboration with Mountain Research Center for Field Crops over an area of 38.8 hectares from 2019 to 2021. Each demonstration occupied one acre area (0.5 acre under Improved practice and 0.5 acre under Farmers' practice). The details of Farmers practice and Improved practices are mentioned in **(Table 2)**. Growth and yield attributes were also recorded during the study. Mean values for plant height and tiller number were recorded from 10 randomly selected plants each from farmers practice and improved practice from each location. Panicle number and number of grains were also recorded from 10 randomly selected plants from each location and then converted to panicle number m^{-2} and grains per $panicle^{-1}$, respectively. Parameters like 1000 grain weight and grain yield were also recorded after sun drying at 14% moisture. For economic assessment, values of both grain and paddy straw were taken into consideration, as paddy straw has economic value in the valley particularly for cattle feeding and apple packing. Additional gains, effective gains, extension gap, technology gap and technology Index were calculated by using formulae given below:

- Additional gains (₹ha^{-1}) = Net returns (₹ha^{-1}) from Improved practice – Net returns (₹ha^{-1}) from farmers' practice
- Effective gains (₹ha^{-1}) = Additional returns (₹ha^{-1}) – additional costs (₹ha^{-1})
- Extension gap (q ha^{-1}) = Improved practice yield (q ha^{-1}) – farmers' practice yield(q ha^{-1}).
- Technology gap (q ha^{-1}) =Yield in demonstrated technology(q ha^{-1}) – Potential yield (q ha^{-1}).
- Technology Index (%) = $\frac{\text{Potential yield-Demo yield}}{\text{Potential yield}} \times 100$

Table 1: List of villages covered under demonstrations

S. No.	Name of Village	S. No.	Name of Village
1	Tarigam	8	Kanipora
2	Sonigam	9	Kujar
3	Yaripora	10	Brazloo
4	Home Shali bough	11	Kaladrangh
5	Frisal	12	Chimegam, Chanpora
6	T N Pora	13	Gnosargam
7	Shurat	-	

Yield and other parameters from paired observations (farmers' practice vs. improved practice within the same fields) were analyzed using Student's paired t-test to assess the significance of differences between the two practices. Prior to analysis, assumptions of normality and homogeneity of variance were examined. Statistical significance was tested at $P \leq 0.05$.

Results and Discussion

A. Factors responsible for low yields

Participatory rural appraisal revealed that low rice productivity in the study area is a consequence of multiple, interrelated agronomic and management constraints rather than a single limiting factor.

A.1 Use of obsolete varieties

A majority of farmers continued to cultivate old rice varieties (**Table 2**) characterized by low yield potential and high susceptibility to diseases, particularly blast. Under such conditions, yield stability becomes highly dependent on timely disease management, which is often lacking. Previous studies have documented substantial blast incidence in commonly grown varieties such as Jhelum and K-39 (Mubarak *et al.*, 2014), with disease severity being particularly pronounced in temperate ecosystems like Kashmir (Bhat *et al.,* 2013). The low adoption of plant protection measures, only 8.3% of farmers reported fungicide use, further exacerbates yield losses. This highlights that varietal vulnerability, when combined with weak management, creates a high-risk production system. Therefore, the introduction of disease-resistant varieties can simultaneously reduce production risk, lower dependence on fungicides, and improve environmental and human health outcomes (Mubarak *et al*., 2023c).

Table 2: Details of farmers practice and improved practice

Input/operation	Farmers practice (Control)	Improved practice
1. Variety	K-39 , Jhelum	Shalimar Rice -4
2. Seed rate for one hectare	150-200 kg ha^{-1}	60 Kg kg ha^{-1}
3. Seed treatment/ Kg seed	No seed treatment	Pre-treated seed with Carbendazim (1g) + Mancozeb (2g)
4. Seed sowing	1st May-10th May	Last week of April to 5th May
5. Fertilizer dose (N,P_2O_5,K_2O)	Haphazard, generally with higher dose of nitrogen and no or low potassium in many cases (Range of N & K_2O application 100-150 and 0-30 kg ha^{-1})	120:60:20
6. Age of seedling at transplanting	35- 43 days	30 days
7. Plants per hill	5-16	2-3
8. Time of fertilizer application	Basal application with two splits of urea. (Only 8% farmers aware about 3 split doses)	½ basal, ¼ at active tillering stage, ¼ at panicle initiation stage
9. Water management	All season flooding	Intermittent irrigation 15 days after transplantation (at saturation)

A.2 Imbalanced nutrient management

Nutrient management practices were skewed towards excessive nitrogen use with inadequate potassium application. The average application rates of 127.32 kg N ha^{-1} and only 13.97 kg K_2O ha^{-1} clearly indicate a significant imbalance. Such disproportionate fertilization not only reduces nutrient use efficiency but also increases susceptibility to lodging and diseases. Balanced fertilization, particularly the integration of potassium and organic manures, is known to enhance crop resilience and sustain productivity (Mubarak and Singh, 2011; Mubarak and Jhanger, 2023). The observed imbalance, therefore, directly contributes to sub-optimal crop performance and reinforces the need for site-specific nutrient management.

A.3 Inadequate plant protection

Despite the availability of well-established blast management strategies, their adoption was minimal among farmers. Even basic preventive measures such as seed treatment were largely absent. This management gap is critical, given that blast disease is a major yield-limiting factor in the region (Bhat *et al*., 2013). The convergence of susceptible varieties and poor disease management amplifies yield losses, suggesting that technological interventions must integrate both host resistance and improved agronomic practices rather than addressing them in isolation.

A.4 Other constraining factors

Additional constraints included low mechanization, inefficient water management, excessive plant density and weak institutional linkages between farmers and extension systems. These factors collectively limit the effective adoption of improved technologies and contribute to the persistence of yield gaps.

B. Technological intervention and its impact

Based on the identified constraints, a frontline demonstration programme was implemented to evaluate improved practices, including the adoption of the high-yielding, disease-resistant variety SR-4 along with recommended crop management practices.

B.1 Impact on crop growth and yield attributes

Improved practices consistently enhanced crop growth parameters compared to farmers' practices. Dry matter accumulation was significantly higher under improved practices at later growth stages, indicating better resource use efficiency and biomass partitioning (**Table 3, Figures 1 and 2**). Similarly, tiller density (581 m^{-2}) and plant height (130 cm) were significantly higher under improved practices. These improvements can be attributed to the combined effect of superior genetic potential (SR-4) and improved agronomic management. In contrast, lower growth under farmers' practices reflects the compounded effects of varietal limitations, nutrient imbalance, higher plant competition and disease incidence.

The observed trends align with earlier findings under similar agro-ecological conditions (Sheikh *et al.*, 2013; Mubarak and Shakoor, 2019; Mubarak *et al*., 2023b), reinforcing the role of integrated crop management in enhancing growth dynamics.

Yield attributes followed a similar pattern. Improved practices significantly increased panicle density, grains per panicle and 1000-grain weight (**Table 3**). The enhancement in these traits is a direct consequence of improved crop growth, highlighting the strong physiological linkage between source and sink (**Figures 3-7**). Comparable improvements in yield attributes under improved management have also been reported by Najeeb *et al.,* (2018), Mitra *et al*., (2014), and Singh *et al.,* (2015).

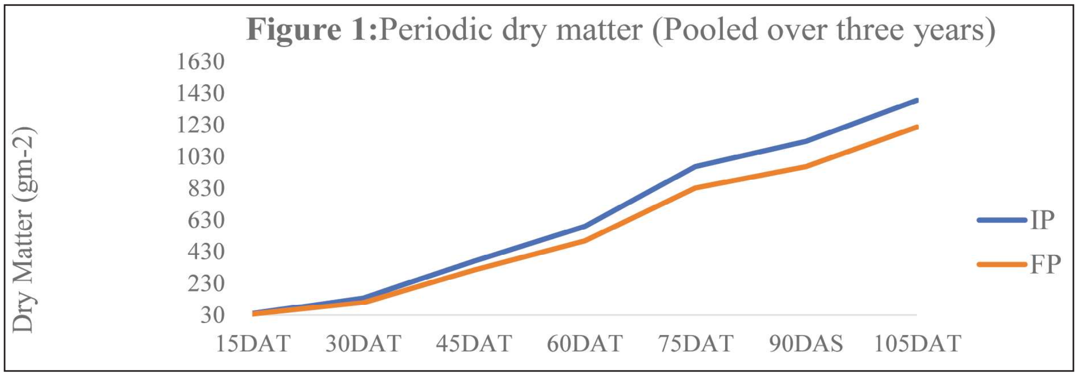

Figure 1: Periodic dry matter (Pooled over three years)

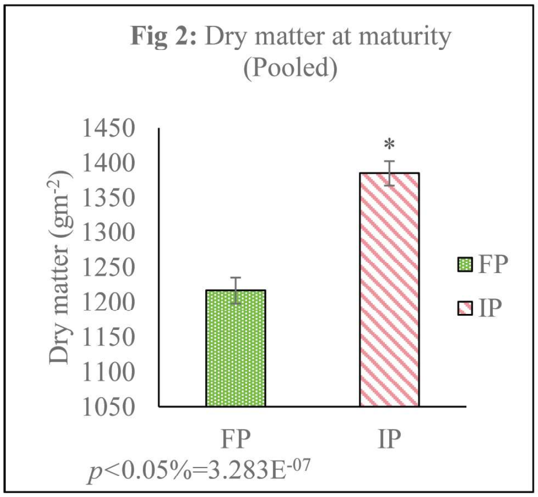

Fig 2: Dry matter at maturity (Pooled)

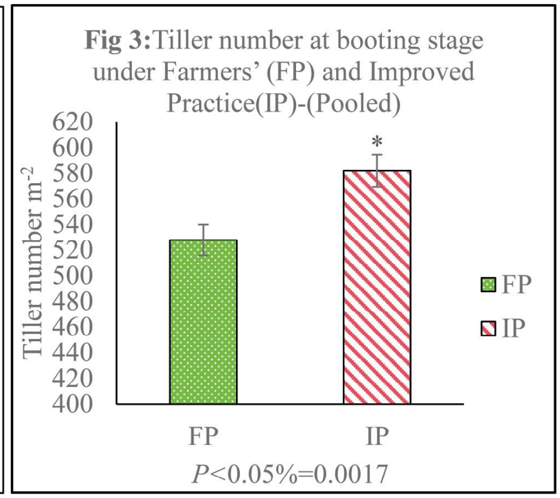

Fig 3: Tiller number at booting stage under Farmers' (FP) and Improved Practice(IP)-(Pooled)

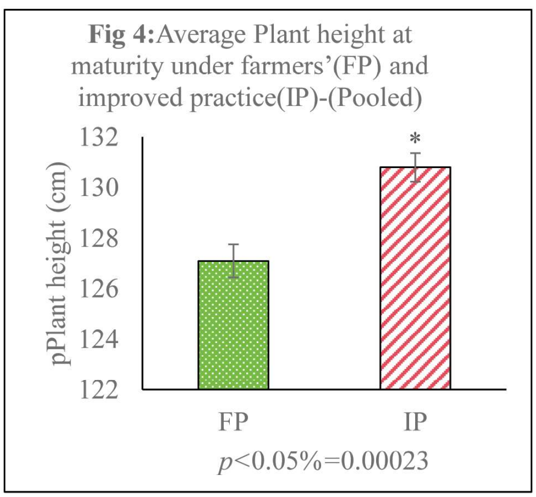

Fig 4: Average Plant height at maturity under farmers'(FP) and improved practice(IP)-(Pooled)

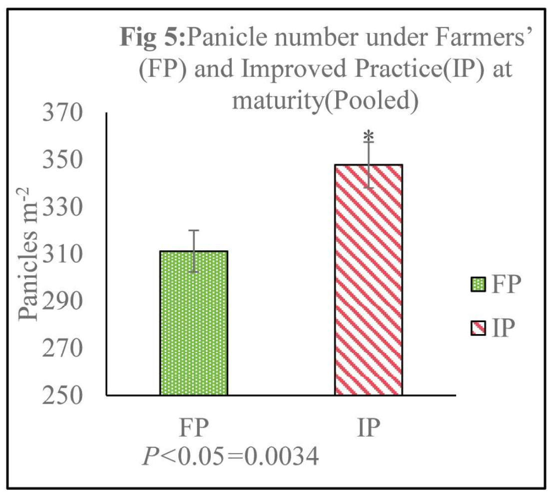

Fig 5: Panicle number under Farmers' (FP) and Improved Practice(IP) at maturity(Pooled)

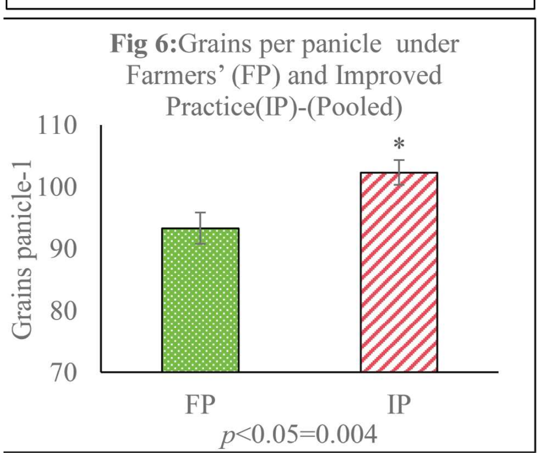

Fig 6: Grains per panicle under Farmers' (FP) and Improved Practice(IP)-(Pooled)

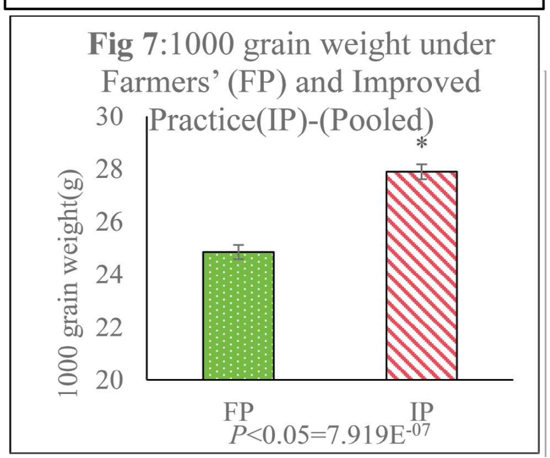

Fig 7:1000 grain weight under Farmers' (FP) and Improved Practice(IP)-(Pooled)

Table 3: Crop growth and yield parameters under farmers' Practice (FP) and Improved Practice (IP)

Parameters	2019		2020		2021		Mean	
	FP	IP	FP	IP	FP	IP	FP	IP
Plant height (cm)	126.4	131.7	128.2	132.9	126.7	130.8	127.1	130.8
Dry matter (gm^{-2})	1276	1392	1238	1415	1134	1348	1216	1385
Tiller number m^{-2}	563	576	533	612	487	557	527	581
Panilce number m^{-2}	334	356	297	363	302	324	311.2	347.7
Grians panicle^{-1}	101.4	108.3	92.3	96.7	86.3	102.1	93.3	102.3
1000 grain weight (g)	25.3	28.42	24.69	28.13	24.61	27.18	24.86	27.9

B.2 Impact on Grain Yield

Grain yield was significantly higher under improved practices across all years of study (**Table 4; Figures 8-10**), clearly demonstrating the effectiveness of the intervention. Yield under improved practices ranged from 73.2 to 74.5 q ha^{-1} compared to 62.0 to 65.2 q ha^{-1} under farmers' practices, resulting in an average gain of 9.9 q ha^{-1} (15.5%). The yield advantage can be attributed to the cumulative effects of improved variety, balanced nutrition and better crop management. Notably, the highest yield gain (11.2 q ha^{-1}) observed in 2021 suggests a positive interaction between improved practices and favourable environmental conditions. This supports earlier reports that improved varieties like SR-4 exhibit better responsiveness to inputs and resilience to biotic and abiotic stresses (Parray *et al.*, 2020). The variation in yield advantage across years further indicates the influence of environmental variability on technology performance, a phenomenon also reported by Singh *et al.,* (2015). Overall, the results confirm that bridging the yield gap requires both technological innovation and adaptation to local conditions.

B.3 Relationship Between Yield Attributes and Grain Yield

Correlation and regression analyses revealed significant positive relationships between yield attributes and grain yield across both practices (Fig. 8). Among the attributes, grains per panicle showed the strongest association with yield (R^2 = 0.659 in farmers' practice and 0.439 in improved practice), followed by panicle density. This indicates that grain number is the primary determinant of yield variability in the study area, while the relatively weaker association of 1000-grain weight suggests limited variability in this trait. Regression analysis further showed that grains per panicle alone explained 43-65% of yield variation, highlighting its critical role in yield formation. Interestingly, the stronger correlations observed under farmers' practices suggest greater variability and instability in traditional systems, whereas improved practices appear to stabilize yield components. Similar relationships between yield attributes and grain yield have been reported by Imade *et al.* (2015), Kumar *et al.* (2016) and Karki *et al.* (2018).

Table 4: Yield of rice varieties under Frontline Demonstration programme at farmers' field

Year	Name of Varieties	Ecology	No. of demons.	Area under demonstration (ha)	Average yield in Improved Practice (q ha^{-1})	Average yield in Farmers practice (q ha^{-1})	Additional yield in the improved practice	% age yield increase
2019	• Jhelum/ K-39(FP)* • Shalimar Rice -4(IP)**	Irrigated valley planes	25	10	73.9	65.2	8.7	13.3
2020	• Jhelum/ K-39(FP) • Shalimar Rice-4(IP)	Irrigated valley planes	14	5.6	74.5	64.7	9.8	15.1
2021	• Jhelum/ K-39(FP) • Shalimar Rice-4 (IP)	Irrigated valley planes	25	23.2	73.2	62.0	11.2	18.0
Total (Demos & Area) / Mean yield & % increase in yield			64	38.8	73.8	63.9	9.9	15.5

*FP: Farmers' Practice **IP: Improved Practice

B.4 Gap analysis

Yield gap analysis revealed that extension gap ranged between 8.7 to 11.2 q ha^{-1} **(Table 5)** with average value of 9.9 q ha^{-1}. The Technology gap varied between 5.5 to 6.8 with an average value of 6.2. These figures indicate that there is scope for enhancing the rice production in the valley by popularizing the latest high yielding varieties like Shalimar Rice-4 along with its package of practices. This can be achieved through collaborative efforts of extension functionaries involving Farm Science Centers (KVKs) and department of agriculture existing in each district of the valley. Earlier Mubarak and Sheikh (2014) and Sheikh *et al.,* (2014) also reported similar results during their studies on demonstration of rice technologies under Kashmir conditions. Technology Index also varied between 6.8 to 8.5% with an average value of 6.2%. Since technology index is an indicator of the feasibility of the evolved technology at the farmers' fields, so lower value of technology index would mean more feasibility of the technology. Technology index of 6.2% indicates that there is scope for further improvement in productivity of rice in Valley. These findings are in line with those of Mitra *et al.,* (2014) and Singh *et al.,* (2015).

Table 5: Gap analysis and technology Index in Frontline Demonstration on rice at farmers' field

Year	Name of Varieties	Ecology	Extension gap	Technology Gap	Technology Index
2019	Jhelum/ K-39(FP) Shalimar Rice -4(IP)	Irrigated plains of Kashmir valley	8.7	6.1	7.625
2020	Jhelum/ K-39(FP) Shalimar Rice-4(IP)	Irrigated plains of Kashmir valley	9.8	5.5	6.875
2021	Jhelum/ K-39(FP) Shalimar Rice-4 (IP)	Irrigated plains of Kashmir valley	11.2	6.8	8.5
Mean			9.9	6.2	7.75

B.5 Economic impact:

Economic benefits varied during different years of study both in the improved technology and farmers practice (**Table 6**). The cost of cultivation ranged between ₹47280 ha^{-1} in year 2019 in farmers' practice to Rs.53068 ha^{-1} in the improved practice in year 2020. This was due to variation in cost of inputs in different years and comparatively higher input requirement in the improved practice. On an average, the cost of inputs was Rs.47647 ha^{-1} and Rs.50407 ha^{-1} for farmers practice and improved practice, respectively. Improved practice involved an additional cost of cultivation of Rs.2760 ha^{-1}. Gross and net returns fluctuated during the years of study with maximum values recorded for improved practice (**Table 6**). Gross returns of Rs.176890 ha^{-1} and Rs. 197222 ha^{-1} were registered under farmers practice and improved practice, respectively (**Figure 8**). Net returns were Rs. 129243 ha^{-1} in farmers practice against Rs.146815 ha^{-1} in improved practice. An additional income of Rs. 17572 ha^{-1} and effective gain of Rs. 14812 ha^{-1} was therefore obtained from improved practice. Benefit : cost ratio (2.9) was also high in improved practice compared to farmers practice (2.7). The additional returns, effective gain and higher net returns obtained under improved practices could be may be attributed to high yield potential of SR-4 variety and optimal crop management under existing ecology and environmental conditions (Najeeb *et al.,* 2020).

Table 6: Economic Analysis of frontline demonstration programme on rice at farmers' field

Year	Input cost (₹ ha^{-1})		Additional cost in IP	Gross returns* (₹ ha^{-1})		Net returns (₹ ha^{-1})		Additional returns from IP (₹ ha^{-1})	Effective Gain from IP (₹)	B:C ratio	
	Farmers Practice (FP)	Improved Practice (IP)		FP	IP	FP	IP			FP	IP
2019	47280	49242	1962	176536	195694	129256	146452	17196	15234	2.7	3.0
2020	48229	53068	4839	180899	200300	132670	147232	14562	9723	2.8	2.8
2021	47432	48912	1480	173234	195672	125802	146760	20958	19478	2.6	3.0
Average	47647.0	50407.3	2760.3	176890	197222	129243	146815	17572	14812	2.7	2.9

It also includes the returns from paddy straw owing to its demand in the valley for apple packing and as cattle fodder for lean winter season.

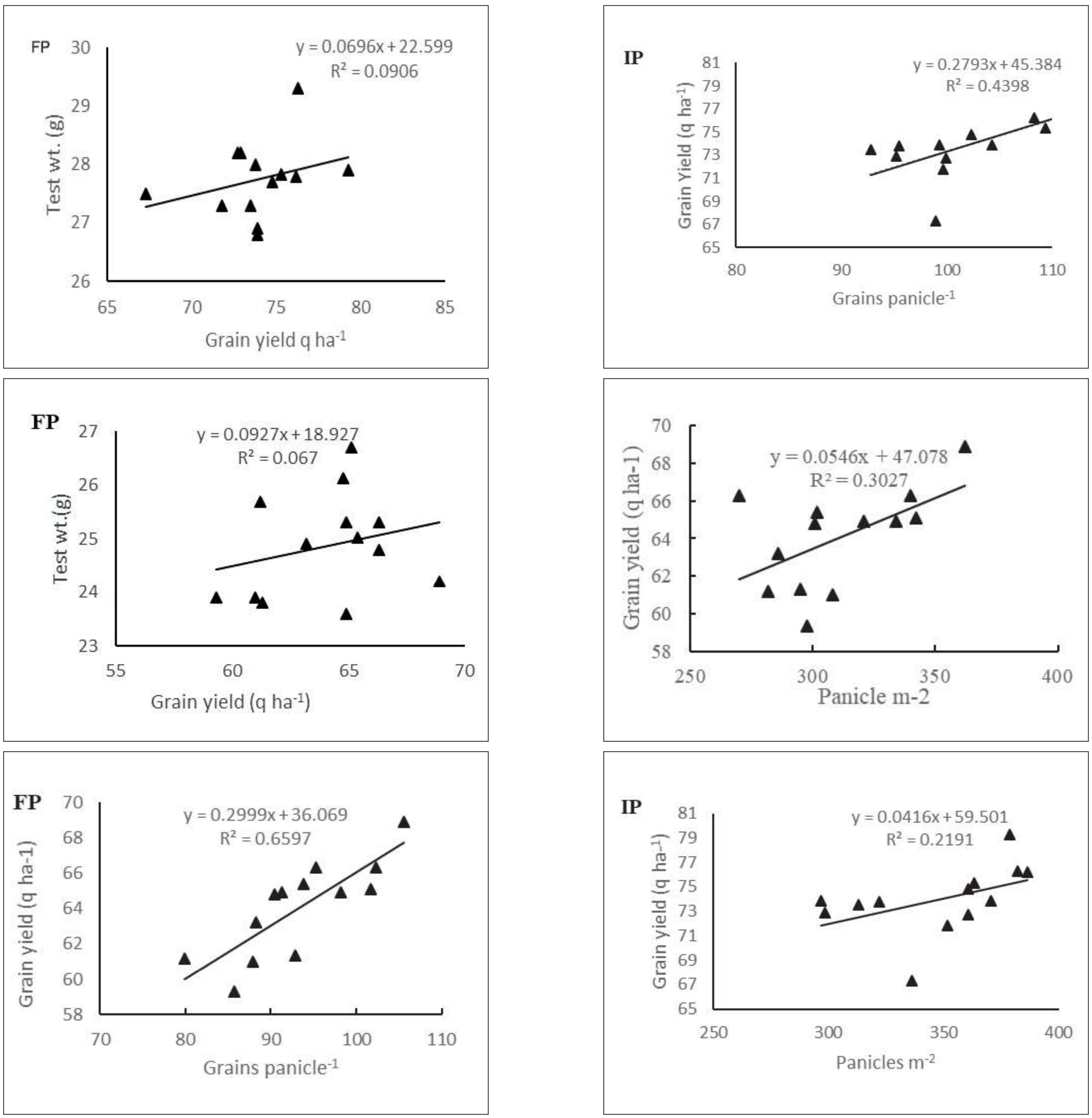

Figure 8: Relationship between yield attributes and grain yield

Conclusion

Rice being staple food for majority of the population possesses a significant status in the Union territory of Jammu and Kashmir. Area under rice however is declining at a fast pace due to diversification into other sectors especially horticulture and non-agriculture activities. This indicates that more production is required from less land. Restricting unabated land conversion through policy measures and technological interventions such as new varieties with high yield potential and resilience to biotic and abiotic stresses coupled with optimum management seem to be way out. Present study highlights the benefits of adopting improved rice practices over traditional practice in terms of rice production and profitability.

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