Economic analysis of different rice cultivars against major biotic stresses

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Summary

The on-farm trials during *kharif* 2017 and 2018 were conducted to study the prevalence of major biotic stresses and benefit-cost ratio on popularly grown rice cultivars. The results revealed that non-significant variations were noticed between cultivars on the incidence of leaf folder damage, BPH & WBPH populations and severity of sheath blight disease in the stipulated period. However, the variation observed in these biotic stresses is due to the maturity period of cultivars. The long-duration cultivars result in more shelter from insects and disease due to the dense crop canopy and take more days to maturity as compared to medium-short duration cultivars. It was also found that cultivating long-duration cultivars viz; Pusa 44 and Pili Pusa gave the highest yield with a low benefit-cost ratio as compared to medium-short duration cultivars like PR 121, PR 122, and PR 126. Our study concluded that the cultivation of medium-short duration cultivars is more profitable due to the low cost of production, less use of chemical inputs and lesser requirement of irrigation water.

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INTRODUCTION

Rice (*Oryza sativa L.*) is an important *kharif* cereal crop in Punjab which was grown on an area of 31.49 lakh hectares during 2020-21 with a total production and productivity of 208.83 lakh tonnes and 66.31 q/ha, respectively in Punjab.[2] The productivity of rice in the Punjab region is mainly affected by several biotic stresses like stem borer, leaf folder, brown plant hopper, brown leaf spot, sheath blight, blast, false smut, kernel smut, sheath rot, stem rot, bacterial blight and two nutritional disorders *viz.*, khaira (zinc deficiency) and chlorosis (iron deficiency). Generally, yield loss due to insect pests in rice has been estimated at about 25%.[11] Singh et al. (2012)[27] also analyzed the effect of various meteorological parameters on the incidence of insect-pests of rice crops in Punjab during 2000-2009 and observed that infestation of plant hopper (44%) followed by leaf folder (30%) and stem borer (29%).

The diseases are considered major constraints in rice production and responsible for losses in quantity and quality of the produce. Sheath blight of rice (*Rhizoctonia solani*) was reported first time in India by Paracer & Chahal (1963)[23] from the state of Punjab. The disease appears at tillering stage on the leaf sheath as elliptical or oval to irregular, 1-3 cm long, greenish-grey spots with brown margins at or above the water line.[29] Under moist conditions, brown silky mycelium and brown to dark brown sclerotia are found loosely attached to the lesions, which easily dislodge the plants at maturity.[25] The yield losses ranging from 4-50 per cent have been reported depending on the crop stage at the time of infection, the severity of the disease and environmental conditions.[28, 36, 5] In Punjab, the losses have been reported to vary from 5.0-13.5 per cent.[34] The disease caused substantial yield loss in high-yielding varieties under intensive rice production systems.[29] The disease causes about 11.1- 58.0 per cent losses in yield depending on the disease severity and varieties.[8] But in severe cases, the disease can cause up to 100 per cent loss in grain yield as reported in variety Karuna at Central Rice Research Institute, Cuttack.[15]

False smut was previously recorded as a minor disease of rice and considered a symbol of good harvest in old times. The disease was first reported in Tirunelveli district of Tamil Nadu State of India.[9] The causal agent of false smut is an ascomycete fungal pathogen *Villosiclava virens* (anamorph: *Ustilaginoidea virens* [Cooke] Takahashi).[33] The symptoms are visible only after the flowering stage which specifically infects rice flowers and transforms the latter into smutted balls.[14] Upon infection, the grain becomes a large velvety mass (also known as 'pseudomorph') fully enclosing the floral parts. This pseudomorph is a common 'smut ball'.[16] Sinha et al. (2003)[31] indicated at high infection levels, average of 4.5–10.8 smut balls are formed on the diseased panicles, which, however, varied by variety. False smut was reported as the most devastating rice grain disease in major rice-growing states in India[12, 21] and it became an important problem in the Punjab state and caused widespread

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concern in 2001 and 2002 in a commercial cultivar PR116 when environmental conditions were very favourable for the disease development.[4] In the state of Haryana, maximum infection was recorded on hybrids like PA 6444 and PA 6129 while in Punjab state, 10–20 per cent disease incidence was recorded in popular inbred rice varieties like PR 114, PR 116 and PAU 201. In the southern state of Tamil Nadu, the disease incidence varied from 5 to 85 per cent (Ladhalakshmi *et al.*, 2012).[19] The yield losses in different states of the country have been estimated to vary between 0.2–49 per cent depending on the disease intensity and rice variety (Dodan & Singh 1996)[12] yield losses up to the tune of 44 per cent as reported in Punjab by Pannu et al. (2010)[22] Bag et al. (2016)[3] observed that the false smut disease reduced the seed yield and quality which resulted in a lower germination rate and seedling vigour index.

Kernel smut (*Neovossia horrida* Takah.) is considered a minor disease worldwide, but it has reached epidemic levels at rare intervals (Carris et al. 2006; Brooks et al. 2009).[7,6] It is also known as black smut or bunt of rice was first described by Takahashi (1896)[32] from Japan and by Anderson (1899)[1] from South Carolina, USA. It is caused by *Tilletia barclayana* (Bref.) Sacc. and Syd. [Syn. *Neovossia barclayana* Bref., *Tilletia horrida* Tak; *N. horrida* (Tak.) Padwick and Khan] is a designated disease and it has been reported from almost all paddy-growing regions of the world including China, Japan, South East Asian countries, North and South America, Africa, Burma, Sri Lanka, Fiji and Philippines. In India, the disease was reported for the first time by Butler in 1913, occasionally the disease was prevalent in most of the paddy-growing states as a destructive form in Punjab, Uttar Pradesh, Haryana and Bihar states of North India (Singh 1983).[30] The disease assumed serious proportions in Punjab around 1990 when about 13.8 per cent of the total graded seeds were rejected by Seed Certification Agency based on the minimum seed certification standard (0.5%) for the disease (Sharma & Gill 1997).[26] The seed certification agency has standardized the infestation of smutted balls up to 0.1 per cent for foundation seed and 0.5 per cent for certified seed (Tunwar & Singh 1988).[35] The disease symptoms can be seen in the field during crop maturity resulting in qualitative and quantitative losses. Only a few grains in a panicle are infected. Normally only a part of the grain is affected but often the entire grain may be replaced by a black powdery mass of bunt spores. The symptoms appear first as minute black streaks bursting through the glumes at the time of ripening.[13,10]

During the last decade, insect-pests and diseases scenario of rice has witnessed considerable changes due to the inclement climatic conditions in Punjab. The hypothesis of present study was that incidence and population buildup of a pest is highly dependent on prevailing weather conditions, excessive use of nitrogenous fertilizers, irrigation and the period of maturity of the crop. The objectives of the present studies were to find out the prevalence of major biotic stresses and economic analysis of different cultivars based on their maturity period in the Punjab region. This study will be useful in formulating tools required for issuing agro-advisory on need-based pesticide spraying schedules in rice crops.

Materials and Methods

The on-farm trials were conducted to investigate the prevalence of major biotic stresses and economic returns from different rice cultivars during *kharif* 2017 and 2018 at farm of Krishi Vigyan Kendra, Kheri, district Sangrur, Punjab. The nursery of different rice cultivars were sown during the last week of May and transplanted during the last week of June and maintained spacing of 20 x 15 cm in 8 × 5 m^2 plot size. The observation of insect-pests and disease were recorded at two weeks of intervals based on different levels of maturity of rice cultivars like long duration heavy foliage cultivars Pusa 44 (162 days) & Pili Pusa (170 days), medium duration cultivars PR 121 (140 days), PR 122 (147 days) and short duration cultivar PR 126 (123 days) (Fig. 1). The damage of leaf folder and population of brown plant hopper (BPH) & white-backed planthopper (WBPH) was recorded from appearance to till maturity period of the different cultivar. The disease severity of sheath blight was recorded from appearance to till maturity by following the Standard Evaluation System (0-9) which was developed for uniform adoption in multi-location screening trials.[18] Incidence of false smut and kernel smut was recorded at the time of maturity randomly per square meter area for the number of smut balls per infected panicle and further, the disease incidence was calculated as per infected grains. The data were analyzed by using SPSS statistics version 23. The control measures were carried out after recording the data of respective insect-pests and disease parameters. The per cent damage of leaf folder, the incidence of false smut and kernel smut were calculated by using the formula as given below:

$$Incidence\ of\ leaf\ folder\ damage\ (\%) = \frac{Number\ of\ damage\ leaf\ observed}{Total\ number\ of\ leaf\ observed} \times 100$$

$$Incidence\ of\ false\ and\ kernel\ smut\ (\%) = \frac{Number\ of\ smutted\ balls\ per\ plant}{Total\ number\ of\ grains\ in\ plant} \times 100$$

Standard Evaluation System (0-9) based on the relative lesion height of sheath blight (IRRI, 2002).

Scale	Description of disease symptoms
0	No infection observed
1	Lesions limited to lower 20% of the plant height
3	20-30%
5	31-45%
7	46-65%
9	More than 65%

$$\text{Disease severity (\%)} = \frac{Sum\ of\ all\ numerical\ ratings}{Total\ number\ of\ observations \times\ Maximum\ disease\ rating\ of\ scale} \times 100$$

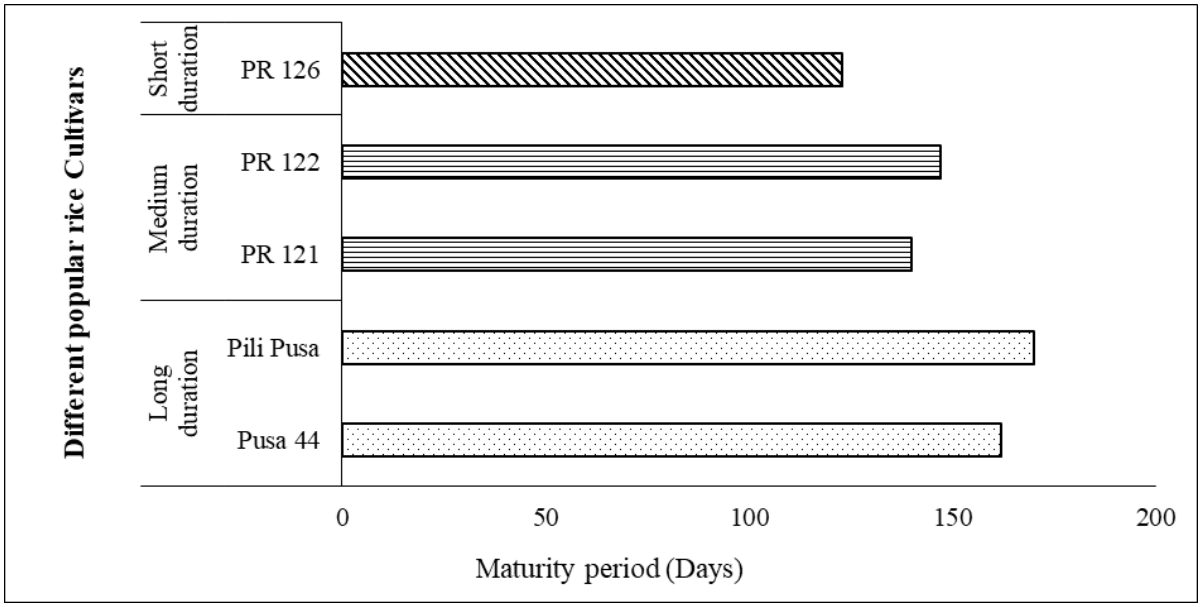

Figure 1: Characterization the different rice cultivars based on days to maturity

Economics analysis

The input use and labour/machine costs were recorded for cultivation practices followed during the growing season for the different rice cultivars. The cost of production, yield, total returns, net returns and cost of pest management were compared between treatments using SPSS statistics version 23. The benefit-cost ratio is defined as the total return: cost of production was calculated for each treatment.

Results and Discussion

Prevalence of major biotic stresses

The observations recorded those major attacks of biotic stresses such as insects like leaf folder, BPH & WBPH and diseases like sheath blight, false smut and kernel smut. The perusals of fig. 2 revealed that non-significant variations were noticed between cultivars on the incidence of leaf folder damage, BPH & WBPH populations and severity of sheath blight in the stipulated period. It was also observed that the major attack of leaf folder and BPH & WBPH in the year 2017 was due to the continuous presence of high humidity, high temperature and less rainfall at the crop growth stage in all cultivars, while due to high rainfall the disease severity of sheath blight recorded maximum in all cultivar during the year 2018. Fig. 3 revealed that the long-duration cultivars Pili Pusa and Pusa 44 have the maximum mean incidence of leaf folder damage, BPH&WBPH population and severity of sheath blight due to prolonged time standing in the field till 42 standard weeks. The maximum mean incidence of leaf folder damage (23.58%), BPH&WBPH (22.94 nymph and adults per plant) and severity of sheath blight (21.26%) recorded in Pili Pusa cultivar followed by Pusa 44 and medium duration cultivars PR 122 and PR 121. However, the least mean incidence of leaf folder damage (16.04%), BPH&WBPH (3.91 nymph and adults per plant) and severity of sheath blight (8.24%) recorded in short duration cultivar PR 126 due to early harvested in 38 standard weeks in the year 2017. The non-significant variation recorded in leaf folder damage and BPH&WBPH population in all cultivars due to unfavourable weather conditions to the development of these insects due to the occurrence of continuous rainfall in the year 2018. However, the mean variations were recorded in the severity of sheath blight due to the length of maturity of cultivars and observed the maximum in long duration cultivars Pili Pusa (32.16%), Pusa 44 (28.68%) and medium duration cultivars PR 122 (21.08%) and PR 121 (17.70%) and least disease severity in short duration cultivar PR 126 (13.61%). The long-duration cultivars take

more days to maturity, having heavy foliage and high tillering capacity resulting in more disease incidence and shelter insects due to dense crop canopy as compared to medium-short duration cultivars. Similarly, the disease occurred more severely in dense crop canopies with high contact frequency between leaves,[17] in early maturing and in short, highly tillering and compact cultivars.[24, 5] Similarly, in the southern United States, short and medium-grain japonica-type rice possessed a higher resistance level than long-grain indica-type cultivars.[20]

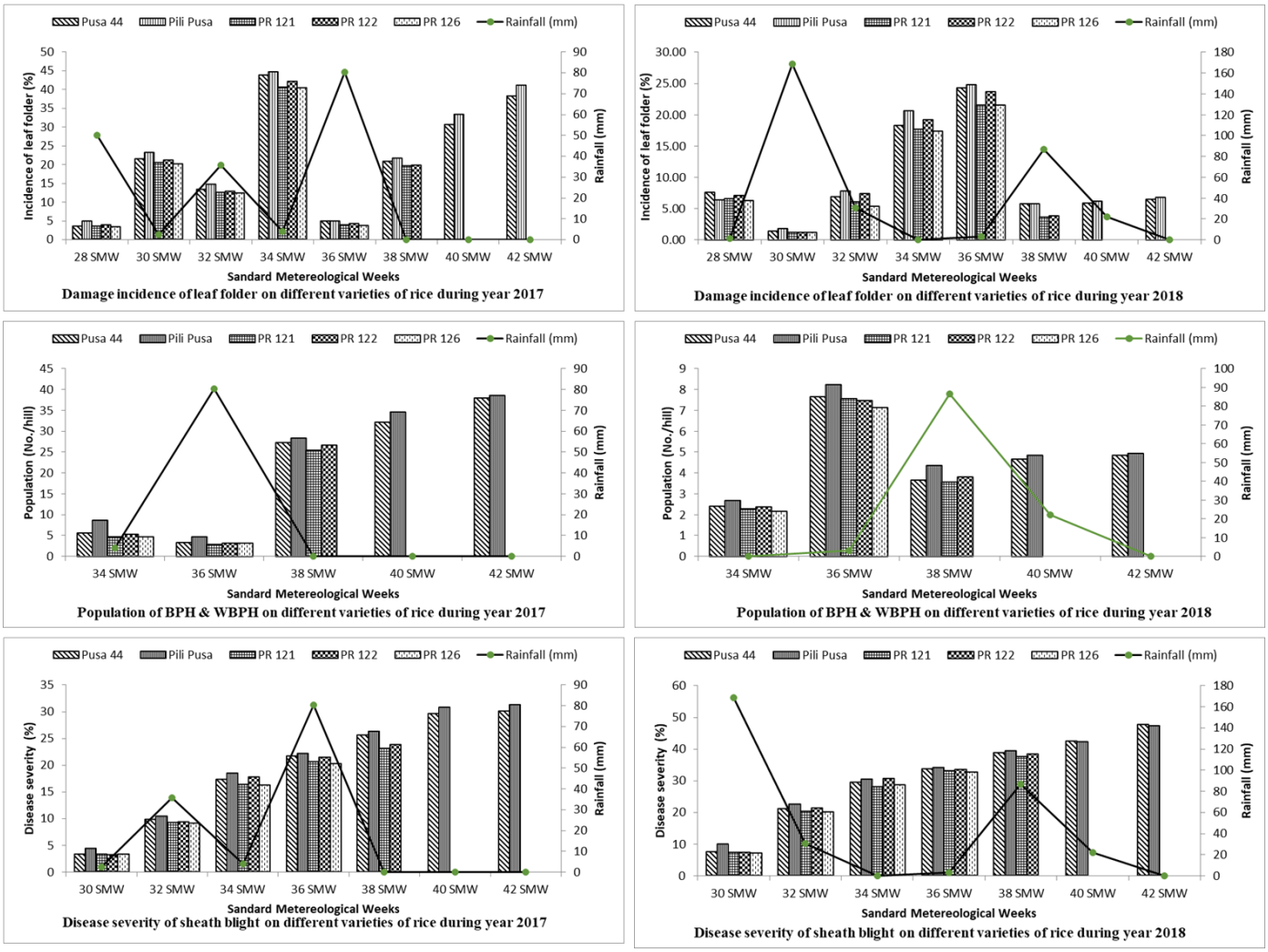

Figure 2: Prevalence of major biotic stresses in different cultivars of rice during year 2017 and 2018

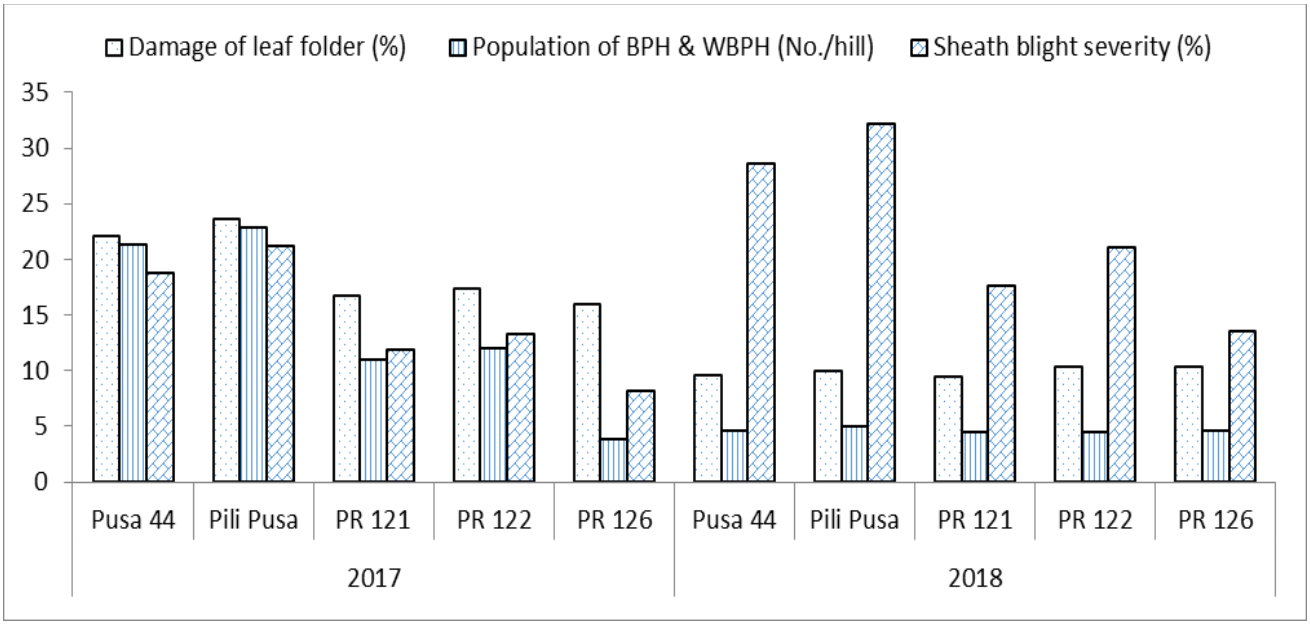

Figure 3: Mean incidence of leaf folder, BPH & WBPH and severity of sheath blight disease in rice cultivars

The disease false and kernel smut were recorded more in year 2018 due to prevalence of conducive weather for longer time coinciding with rainy days at the time of flowering stage of the crop, ultimately increasing the relative humidity which is a crucial factor for the development of disease. Table 1 revealed that the false smut varied depending on the cultivars. The incidence of smutted balls was recorded in per meter square area of the most infected site in the field. The mean incidence of smutted balls per meter square area in different cultivars ranged between 0.058 – 0.188 per cent in 2017 whereas more diseases were 0.124 – 0.348 per cent in 2018. The maximum mean incidence of false smut was recorded in susceptible cultivar PR 122 (0.268%), followed by PR 126 (0.178%), Pusa 44 (0.132%) Pili Pusa (0.116%) and PR 121 (0.091%). Sinha *et al.* (2003)[31] indicated at high infection levels, 4.5 – 10.8 smuts balls formed on the diseased panicle, which, however, varied from variety to variety. In Punjab, 10 to 20 per cent of infected tillers were recorded in popular inbreds of rice like PR 114, PR 116 and PAU 201.[19] The infection of kernel smut was observed highest in the PR 126 cultivar with 0.148 per cent and 0.264 per cent in the year 2017 and 2018, respectively and observed mean incidence of 0.206 per cent followed by Pusa 44 (0.059%) and PR 121 (0.054%). Duhan & Jakhar (2000)[13] reported incidence of bunt across different rice cultivars ranged from 0.05 to 1.20 per cent.

Table 1: Prevalence of false smut and kernel smut based on days to maturity of rice cultivars

Rice Cultivars	Disease incidence of false smut (%)			Disease incidence of kernel smut (%)		
	Year 2017	Year 2018	Pooled	Year 2017	Year 2018	Pooled
Pusa 44	0.087 ^{c}	0.178 ^{c}	0.132 ^{c}	0.043 ^{b}	0.076 ^{b}	0.059 ^{b}
Pili Pusa	0.073 ^{d}	0.160 ^{c}	0.116 ^{d}	0.035 ^{c}	0.047 ^{c}	0.041 ^{c}
PR 121	0.058 ^{e}	0.124 ^{d}	0.091 ^{e}	0.031 ^{c}	0.078 ^{b}	0.054 ^{b}
PR 122	0.188 ^{a}	0.348 ^{a}	0.268 ^{a}	0.021 ^{d}	0.056 ^{c}	0.039 ^{c}
PR 126	0.141 ^{b}	0.215 ^{b}	0.178 ^{b}	0.148 ^{a}	0.264 ^{a}	0.206 ^{a}
LSD (P<0.05)	0.012	0.023	0.013	0.0074	0.010	0.0067

Economics analysis

The perusal of Table 2 revealed that the average total operational cost incurred in growing long, medium and short-duration cultivars on sample farms was calculated to be Rs. 45610/-, Rs 38937/- and Rs 35037/- respectively in the year 2017. and Rs. 44277/-, Rs. 39580/- and Rs. 34887/- for growing long, medium and short-duration cultivars in the year 2018, respectively. The yield on sample farms was recorded to be 85.0 q, 79.37 q and 78.87 q per hectare for long, medium and short duration cultivars respectively in the year 2017 whereas it was 81.75 q, 75.45 q and 74.25 q in the year 2018 respectively for long, medium and short duration cultivars. The average net returns were Rs. 86140/-, 84086/- and 87211/- in the case of long, medium and short duration cultivars in the year 2017 while the net returns were Rs 98785/-, 92457/- and 95050/- respectively by growing long, medium and short duration rice cultivars in the year 2018. The benefit-cost ratio was estimated to be 2.89, 3.16 and 3.49 in the case of long, medium and short-duration cultivars receptively in the year 2017 while the same was estimated to be 3.23, 3.34 and 3.72 respectively for long, medium and short duration cultivars in the year 2018. It was interesting to note that although the total, as well as net return, turn was higher for the growing of long-duration varieties but the benefit-cost ratio favoured the cultivation of short-duration cultivars followed by medium-duration cultivars during both years. The yield of long-duration cultivars was recorded to be higher than short-duration cultivars due to more tillering, heavy foliage and longer maturity period in the field. Wherever, more use the inputs like fertilizers, irrigation and pesticides increased the total cost of production in long-duration cultivars resulting in squeezing the profit margin. The share of pesticide use in the total cost of production was recorded to be the highest in case of long duration cultivars *i.e.,* to the tune of 23.20% in year 2017 and 19.75% in year 2018 in long-duration cultivars which comes to around one-fifth of the total operational cost. The requirement of pesticides was also found to be more in the case of long-duration varieties by 2-4 sprays in years 2017 and 2018 than in medium and short-duration cultivars. The yield performance of medium and short-duration cultivars was recorded as slightly lower than long-duration cultivars but the benefit-cost ratio was recorded to be higher due to the low cost of production as compared to long-duration cultivars. It was observed that the cultivation of short-duration cultivars is more profitable due to the low cost of production, less use of chemical inputs and less irrigation water requirement followed by medium-duration cultivars.

Table 2: Production costs, gross returns, net returns and benefit-cost ratio of on-farm trials based on days to maturity of rice cultivars in district Sangrur

Parameter	Economics analysis of rice cultivars during *kharif* 2017			Economics analysis of rice cultivars during *kharif* 2018		
	Long duration	Medium duration	Short duration	Long duration	Medium duration	Short duration
Cost of production						
(a) Land preparation operation	8125	8125	8125	8625	8625	8625
(b) Seed and transplanting	8450	8250	8250	8450	8250	8250
(c) Fertilizer and its application	4930	4195	4195	4930	4195	4195
(d) Irrigation	5525	3575	2762	5525	3575	2762
(e) Herbicide and its application	3250	3250	3250	3250	3250	3250
(f) Insecticide and its application	6375	4350	1825	3825	3175	1175
(g) Fungicide and its application	4205	2442	1880	4922	3760	1880
(h) Harvesting & transport	4750	4750	4750	4750	4750	4750
Total cost of production (a+h) Rs./ha	45610	38937	35037	44277	39580	34887
Percent share of pesticide in total cost of production	23.20%	17.44%	10.57%	19.75%	17.52%	8.75%
Yield (q/ha)	85.00	79.37	78.87	81.75	75.45	74.25
Gross return (Rs./ha)	131750	123023	122248	143062	132037	129937
Net return (Rs./ha)	86140	84086	87211	98785	92457	95050
Benefit: cost ratio	2.89	3.16	3.49	3.23	3.34	3.72
Average number of pesticide application	7	5	3	6	4	2

Selling price: Rs. 1550/- in year 2017; Rs. 1750/- in year 2018
Each comparison between treatments within a year showed significant differences between means
Significance at P<0.05 for the parameters compare

Conclusion

The findings of the on-farm trials indicated that the cultivation of medium-short duration cultivars is more profitable due to lower attack of pests in the region except for grain diseases which can be effectively managed with the application of suitable systemic fungicide at the boot stage of the crop. The yield performance of medium-short duration cultivars was noted to be slightly lower than long-duration cultivars but the benefit-cost ratio was recorded to be higher due to the low cost of production. It was also observed that the cultivation of medium-short duration cultivars is more profitable due to the low cost of production with less use of chemical inputs and irrigation water. Therefore, the cultivation of medium-short duration rice cultivars needs to be further promoted in this region by following the need-based application of pesticides for managing the major pests.

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Declaration of interests

The authors have no conflict of interest to declare.

Data sharing

All relevant data are within the manuscript.

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