ENHANCING THE PRODUCTIVITY AND PROFITABILITY OF ORGANIC BASMATI RICE (*ORYZA SATIVA* L.) -BASED CROPPING SYSTEMS UNDER SUB-TROPICAL AGROCLIMATIC CONDITIONS

PANOTRA, N.[1*] – SHARMA, V.[2] – SALGOTRA, R. K.[1] – SHARMA, M.[1] – BAKSHI, P.[3] – GUPTA, V.[4] – BHARAT, R.[5] – BHAT, A.[6] – SHARMA, R.[7] – SHARMA, V.[8] – BINDRA, H. S.[1]

[1]*Institute of Biotechnology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, 180009 Jammu, India*

[2]*Division of Soil Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, 180009 Jammu, India*

[3]*Centre for Organic and Natural Farming, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, 180009 Jammu, India*

[4]*Division of Agricultural Extension Education, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, 180009 Jammu, India*

[5]*Division of PBG, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, 180009 Jammu, India*

[6]*Division of Agricultural Economics and ABM, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, 180009 Jammu, India*

[7]*RARS-Rajouri, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, 180009 Jammu, India*

[8]*KVK-Kathua, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, 180009 Jammu, India*

**Corresponding author*
e-mail: drpanotra@gmail.com

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Abstract. The aim of this 5-year research was to generate necessary knowledge about cropping systems for sustainable organic crop production, as cropping systems are extremely important for the productive assets of agriculture and also help in maintaining soil fertility. In order to determine the most effective organic cropping system for enhancing the productivity of basmati rice, a study was conducted on ten different basmati rice-based cropping systems under organic farming conditions at the Research Farm of the Centre for Organic and Natural Farming, situated within the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu and Kashmir, INDIA. The experiments were laid out in Randomized Block Design with three replications. The results showed that the highest grain yield of 31.08 q ha^{-1}, straw yield of 54.22 q ha^{-1}, harvest index of 36.43%, 1000-grain weight of 22.93 g, number of grains/panicle of 69.20, leaf area index at 90 DAT of 4.49 cm^2, LCC at 90 DAT of 4.50, number of tillers (m^{-2}) at 90 DAT of 369 and plant height at 90 DAT of 113.14 cm were obtained in basmati rice - berseem - moong cropping system which was found to be at par with the basmati rice - berseem - mash cropping system. Moreover, both these systems also gave the highest Basmati rice equivalent yield (77.72 and 76.53 q ha^{-1}) and relative system production efficiency (110.1% and 106.9%).
Keywords: *organic basmati rice, cropping systems, productivity; equivalent yield, economics*

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Introduction

The United Nations General Assembly declared the year 2004 as the International Year of Rice (IYR) on 16 December 2002. The main theme of IYR, called "Rice is Life," arose from the fact that rice-based cropping systems are indispensable for food security, poverty control and world peace, directly or indirectly. Rice is the second most important food crop for about 70% of the world's population, cultivated on 163 million ha in more than 100 countries, with current rice production being 740.9 million tons, while global demand will reach 765 million tons by 2025. In India rice is grown in 46.38 million ha, the production level is 130.29 million tons and the productivity is about 28.09 quintals per ha (Anonymous, 2023a). India is the leading exporter of Basmati Rice to the global market. The country has exported 5242048.39 MT of Basmati Rice to the world for the worth of Rs. 48389.18 Crores/5837.12 US$ Mill.) during the year 2023-2024 (Anonymous, 2023b). The current rate of rice production growth (0.36%) is notably lower than the population growth rate of 1.63%. Consequently, there is a necessity to improve the productivity of the rice system to address the escalating food requirements of the country.

Basmati rice is primarily grown in the foothills of the Himalayas in the North-Western regions, encompassing states such as Haryana, Punjab, Uttarakhand, Western Uttar Pradesh, Jammu and Kashmir, Himachal Pradesh, and Delhi. Basmati rice is cultivated on 54.3 thousand ha of land in the subtropical zone of the Jammu region. Furthermore, Basmati 370, which makes up 69% of the Basmati acreage in Jammu, is the predominant variety grown in Jammu and Kashmir (Anonymous, 2022).

The cropping system refers to the specific order in which crops are grown in a particular area during a year. Variations around the world in local climatic conditions, soil types, economic conditions and social structures have led to different agricultural practices and cropping systems. This will reveal not only how the land is currently being used, but also how it has changed over time, especially in irrigated and rain-fed ecosystems (Chitale et al., 2016). Cropping systems with high productivity and low input demand are considered efficient for sustainability. In recent times, oilseeds and legumes have attracted more attention due to low production and high costs. If these crops are included in the crop rotation, the economics of the cropping system will be affected (Sajjad et al., 2019). As one of the major cropping systems used in India, rice-based cropping system can be characterized as a mix of farming approaches where rice is the primary crop grown and then followed by other crops including cereals, pulses, oilseeds, cotton, sugarcane, green manures, vegetables, etc. Both upland and lowland crops may be used in Rice-based cropping systems. Based on the agroecological conditions of a region, consumer and household demands, and the availability of resources to farmers, several cropping techniques are used in rice-growing regions (Deep et al., 2018). In Jammu and Kashmir, the primary cropping systems consist of maize-wheat and rice-wheat in rainfed and irrigated areas, respectively in the Jammu region. In the Kashmir valley, the predominant cropping systems are rice-mustard and rice-oat (fodder). The cropping system is region-specific, underscoring the significance of a comprehensive understanding of the local environment before implementing an alternative cropping system for a particular area. Suggestions for an alternative cropping system in a region generally presuppose that the physical resources are not fully utilized and that augmenting cropping intensity could address this disparity. Green manure, when integrated into cropping systems,

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plays a crucial role in enhancing soil health by improving various soil properties such as pH levels, soil structure, water retention capacity, and nitrogen content. Additionally, it contributes to the increase of organic carbon content in the soil. The nitrogen-fixing ability of leguminous plants presents a sustainable approach to agricultural production by supplying nitrogen to the current crop and subsequent crops (Foyer et al., 2016). Organic farming is a sustainable model of agriculture that can support the nutritious food needs of future generations while maintaining environmental quality and soil health. Utilizing organic nutrient sources is considered an effective strategy for enhancing the physical and biological characteristics of soil and boosting the productivity of high-value crops like rice (Yadav et al., 2013a,b). Consequently, there is a growing emphasis on promoting organic Basmati rice-based cropping systems in the sub-tropical agroclimatic conditions of Jammu and Kashmir to ensure food security and enhance overall system productivity. Therefore, this study aimed to assess the suitability of organic Basmati rice (*Oryza sativa* L)-based cropping systems in enhancing productivity under the sub-tropical agroclimatic conditions of Jammu and Kashmir.

Materials and methods

Experimental site

The experiments were carried out over a period of five consecutive years, spanning from 2017-2018 to 2021-2022, at the Research Farm of the Centre for Organic and Natural Farming, situated within the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu and Kashmir, INDIA. The research farm is positioned at 32°40′ North latitude and 74°58′ East longitude, with an elevation of 332 m above mean sea level in the Shivalik foothills of the North-Western Himalayas. Jammu is located in a subtropical region characterized by hot, arid summers in the initial months, succeeded by hot, humid monsoon seasons, and cold winters. The experimental location saw an average annual rainfall of 1198.2 mm, with 70%–75% of that total falling between June and September. The remaining 25%–30% of the precipitation received during the winter, resulting from western disturbances from January to March. The soil of the experimental site was sandy clay loam with 61.40% sand, 12.91% silt and 26.69% clay in the surface soil horizon (0-15 cm). The surface soil had neutral soil reaction (pH 6.4), 5.9 g kg^{-1} organic carbon, 0.24 dSm^{-1} EC, 255.05, 11.32, and 135.12 kg ha^{-1} available N, P and K, respectively.

Experimental design and treatments

The study examines a range of Basmati rice-based cropping systems, which include basmati rice–wheat–moong (T_1), basmati rice-wheat-dhaincha (T_2), basmati rice-mustard-moong (T_3), basmati rice-mustard-mash (T_4), basmati rice-berseem-mash (T_5), basmati rice-broccoli-moong (T_6), basmati rice-berseem-moong (T_7), basmati rice-lentil-french bean (T_8), basmati rice-methi–dhaincha (T_9), and basmati rice-pea-dhaincha (T_{10}) within an organic farming context. The treatments were thrice replicated, and the experiment was set up using a randomized block design. All the package of practices which were followed during the crop growth period was recommended for the crop undertaken for study (*Table 1*).

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Table 1. *Agronomic practices followed in different crops*

Season	Crop	Variety	Seed source	Seed rate (kg/ha)	Spacing (cm)	Nutrients provided through FYM, VC and neemcake (kg/ha)		
						N	P	K
Kharif	Rice	Basmati 370	Mega Seed Project, SKUAST-Jammu	60	20 × 15	30	20	20
Rabi	Wheat	JAUW 584	Mega Seed Project, SKUAST-Jammu	100	15 × 10	100	60	40
Rabi	Mustard	RSPR-69	Division of PBG, SKUAST-Jammu	5.0	30 × 10	60	30	20
Rabi	Berseem	Mescavi	Division of Agronomy, SKUAST-Jammu	10	Broadcasting	10	30	-
Rabi	Broccoli	Jammu Broccoli-07	Division of Veg. Sci., SKUAST-Jammu	0.60	45 × 45	50	25	25
Rabi	Lentil	Jammu Lentil 71	PRS, SKUAST-Jammu	30	30 × 10	20	40	30
Rabi	Methi	Jammu Fenugreek-07	Division of Veg. Sci., SKUAST-Jammu	12	20 × 10	40	30	20
Rabi	Pea	Arkel	Division of Veg. Sci., SKUAST-Jammu	60	20 × 10	20	30	20
Zaid	Dhaincha	Punjab Dhaincha 1	Research Farm, SKUAST-Jammu	50	45 × 20	-	30	-
Zaid	Moong	SML 668	Division of Agronomy, SKUAST-Jammu	20	30 × 10	20	40	-
Zaid	Mash	Pant U-19	Division of Agronomy, SKUAST-Jammu	20	30 × 10	20	40	-
Zaid	French bean	Pusa Parvati	Division of Agronomy, SKUAST-Jammu	60	30 × 10	30	40	20

Soil sampling analysis

Before the experiment was laid out, the soil samples were taken from depth of 0-15 cm randomly from three sites of experimental field and the composite samples were obtained by mixing them. The samples were then air dried, processed and analyzed for physical and chemical properties (Jackson, 1973; Piper, 1950).

Plant sampling and analysis

Five plants were randomly selected and marked in each plot for the growth studies carried out during the rice crop growth phase, except for leaf area measurements.

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Various observations were made for the rice crop, including plant height, leaf area index, leaf color chart (LCC), number of tillers, 1000-grain weight, grain yield, straw yield, biological yield, and harvest index. Plant height was measured using a long ruler, which assessed the distance from the soil surface to the tip of the top most fully opened leaf. For statistical analysis, plant height measurements were recorded in centimeters (cm), and the average of the five plants was taken. Number of tillers were counted from five selected plants and, averaged to get the mean number of tillers per plant.

Grain yield was calculated by harvesting each plant separately from the net plot area, threshing them manually, and expressing the grain yield for each treatment in q ha^{-1} at optimum moisture. A random sample of 1000-grains was selected from the whole produce of each treatment and weighed. It was presented as a test weight in grams (g). By subtracting the net plot grain yield from the net plot bundle weight, the straw yield was calculated and expressed as q ha^{-1}. The following formula was used to calculate the ratio of economic yield to biological yield (harvest index):

$$\text{Harvest index (\%)} = \text{Economic yield (q ha}^{-1}\text{)/Biological yield (q ha}^{-1}\text{)} \times 100$$

Relative yield increase (%)

Relative yield increase (RYi) measures the increase in Basmati rice yield due to cropping system by comparing the yield under different treatments, which can be calculated from the obtained data. The formula for Relative yield increase (RYi) is $100 \times [(Y - Ya) / Ya]$, where Y is the yield of Basmati rice crop (q ha^{-1}), minimum yield of Basmati rice crop in different treatments = Ya (Van Ittersum et al., 2013; Oliver et al., 2021).

Gross profit margin ratio (%)

The gross margin ratio, also known as the gross profit margin ratio, is a profitability ratio that compares the gross margin of a crop production to its revenue. It shows how much profit a crop makes after paying its cost of sales (COGS). The profitability was calculated by the formula cited by Kumar et al. (2019):

$$\text{Profitability (Rs ha}^{-1}\text{ day}^{-1}\text{)} = \text{Net return (Rs ha}^{-1}\text{)/365 days}$$

The relative economic efficiency was computed by the following formula cited by Kumar et al. (2019):

$$\text{Relative economic efficiency (\%)} = \{\text{Net returns (NR) of diversified cropping system} - \text{NR of existing cropping system/NR of existing cropping system}\} \times 100$$

Rice equivalent yield, system productivity

According to Lal et al. (2017), rice equivalent yield (REY) was computed for comparing the system's performance through the conversion of the yield of non-rice crops into equivalent rice yield on a pricing basis. The formula for REY is Yx(Px/Pr), where Px is the price of non-rice crops (Rs q^{-1}), Pr is the price of rice (Rs q^{-1}), and Yx is the yield of non-rice crops (q ha^{-1}). Throughout the trial period, it was believed that the prices of individual inputs and outputs would remain constant. Gomez and Gomez (1984) proposed a statistical approach for analyzing the obtained data on several parameters and the

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outcomes were assessed at the five percent critical difference level. The relative productivity efficiency was computed by the formula cited by Kumar et al. (2019):

Relative system productivity efficiency (%) = {Total productivity (TP) of diversified cropping system − TP of existing cropping system/TP of existing cropping system} × 100

Statistical analysis

The data collected on growth, yield, and yield attributing characteristics were analyzed using of Variance by Fisher and Yates (1948). The significance of treatment effects was determined using the variance ratio or 'F,' and the significance of differences between the means of the various treatments was assessed using the critical difference (C. D.) at a 5% level of significance. To compare the mean values of the different parameters examined in this study, the least significant difference (LSD) test at a 5% probability level was conducted.

Results

Growth attributes

Over a 5-year study period, the growth parameters of Basmati rice exhibited significant variations across different Basmati rice-based cropping systems. Among these systems, the basmati rice-berseem-moong (T_7) cropping system demonstrated notably higher values at 90 days after transplanting (DAT) for plant height, number of tillers, leaf color chart (LCC), and leaf area index. Specifically, the measurements were 113.14 cm, 369 m^2, 4.50, and 4.49 cm^2, respectively. Following closely was the basmati rice-berseem-moong (T_7) cropping system, with values of 112.37 cm (plant height), 367.6 (number of tillers per m^2), 4.38 (LCC), and 4.43 cm^2 (leaf area index). Moreover, the basmati rice-berseem-moong (T_7) cropping system also exhibited significantly higher figures for the number of grains per panicle and 1000-grain weight at harvest, recording 69.20 and 22.93 g, respectively (refer to *Table 2*). The second-best results were observed in basmati rice-berseem-mash (T_5) cropping system, which showed values of 68.60 and 22.83 g for number of grains per panicle and weight of 1000 grains, respectively.

The relative observation calculations revealed significant variations across the different treatments (the calculated relative value chart can be found in supplementary file marked as *Table 2*). As shown in *Figure 1*, Treatment T_7 exhibited the highest relative values in most parameters, including plant height (16.17%), number of tillers (54.00%), LCC (44.23%) and LAI (22.01%). And same as in *Figure 2*, Treatment T_7 showed the highest relative values in number of grains per panicle (28.62%), and 1000-grain weight (20.56%). The second-best results were consistently observed in Treatment T_5, with notable values in plant height (15.38%), number of tillers (53.42%), LCC (40.38%), LAI (20.38%), number of grains per panicle (27.51%), and 1000-grain weight (20.03%). Conversely, Treatment T_8 consistently showed the lowest relative values, serving as the baseline (0) for all parameters. These relative observations underscore the superior performance of Treatment T_7, followed closely by Treatment T_5, while highlighting the minimal impact of Treatment T_8, providing a clear comparative analysis of the treatments' effectiveness.

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Table 2. *Effect of different treatments on growth attributes of organic basmati rice and averaged over the 5 years*

Treatment	Plant height (cm) at 90 DAT	No. of tillers at 90 DAT	LCC at 90 DAT	LAI (cm^2) at 90 DAT	No. of grains/panicles at harvest	1000-grain weight (g) at harvest
T_1	98.55	261.00	3.15	3.83	56.00	19.77
T_2	101.50	315.60	3.70	4.19	59.80	20.54
T_3	104.16	341.40	3.92	4.27	62.00	21.56
T_4	102.43	337.20	3.76	4.26	61.20	20.91
T_5	112.37	367.60	4.38	4.43	68.60	22.83
T_6	101.24	281.60	3.63	3.97	55.20	19.95
T_7	113.14	369.00	4.50	4.49	69.20	22.93
T_8	97.39	239.60	3.12	3.68	53.80	19.02
T_9	106.15	348.60	4.23	4.29	63.40	22.04
T_{10}	107.22	354.40	4.27	4.37	65.60	22.23
S.Em. ±	**2.89**	**12.88**	**0.20**	**0.11**	**2.05**	**0.32**
CD (P = 0.05)	**8.29**	**36.94**	**0.56**	**0.30**	**5.89**	**0.92**

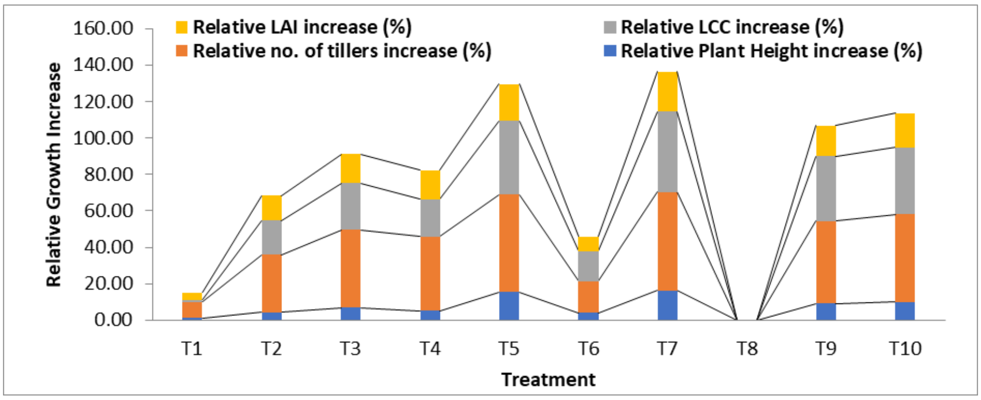

Figure 1. *Relative plant height, no. of tillers, LCC and LAI increase (%) of organic basmati rice at 90 DAT averaged over the 5 years*

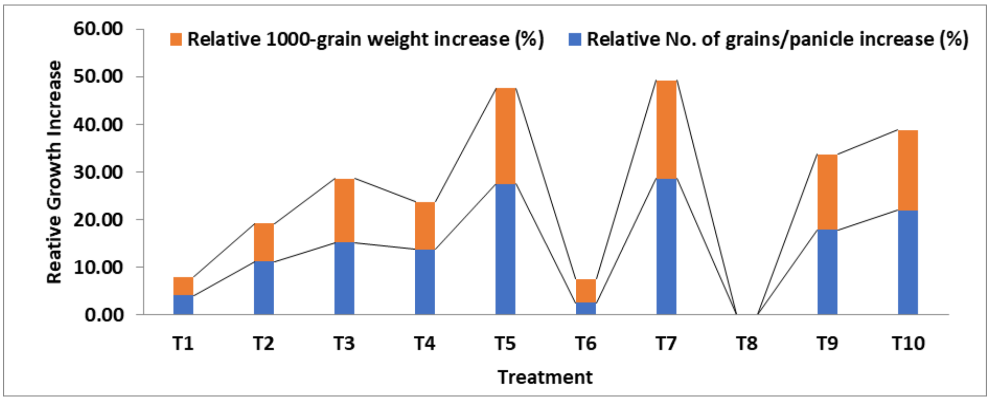

Figure 2. *Relative no. of grains/panicles and 1000-grain weight increase (%) of organic basmati rice at harvest averaged over the 5 years*

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Yield components

The yield of Basmati rice exhibited significant variations across different Basmati rice-based cropping systems. Analysis from *Table 3* indicates that within the various Basmati rice-based cropping systems, the basmati rice-berseem-moong (T_7) cropping system demonstrated the highest grain yield and harvest index at 31.08 q ha^{-1} and 36.43%, respectively. This performance was statistically the second best result in the Basmati rice-Berseem-Mash (T_5) cropping system with a grain yield of 30.65 q ha^{-1} and a harvest index of 36.42%. Additionally, the basmati rice-berseem-moong (T_7) cropping system showed a higher straw yield and biological yield at 54.22 and 85.30 q ha^{-1}, respectively. The second higher results of straw yield and biological yield in Basmati rice-Berseem-Mash (T_5) cropping system were observed at 53.51 and 84.16 q ha^{-1}, respectively.

Table 3. *Effect of different treatments on yield attributes of organic basmati rice, relative yield increase, rice equivalent yield of the system, and relative system production efficiency (%) averaged over the 5 years*

Treatment	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest index (%)	Rice equivalent yield (q/ha)	Relative rice equivalent yield increase (%)	Relative system production efficiency (%)
T_1	20.16	39.50	59.66	33.73	55.75	34	50.7
T_2	23.50	45.09	68.59	34.24	45.88	19	24.0
T_3	25.64	48.80	74.44	34.45	62.43	41	68.8
T_4	25.41	48.34	73.75	34.45	61.15	40	65.3
T_5	30.65	53.51	84.16	36.42	76.53	52	106.9
T_6	21.91	42.25	64.16	34.14	47.98	23	29.7
T_7	31.08	54.22	85.30	36.43	77.72	52	110.1
T_8	19.56	38.43	57.99	33.72	36.99	0	0.0
T_9	26.82	50.90	77.72	34.51	38.37	4	3.7
T_{10}	27.04	51.24	78.28	34.54	44.25	16	19.6
S.Em. ±	**0.46**	**0.63**	**0.71**	**0.59**	**1.58**	**1.03**	**0.72**
CD (P = 0.05)	**1.32**	**1.80**	**2.04**	**1.69**	**4.52**	**2.96**	**2.06**

The relative observation calculations for the yield and production efficiency data revealed significant variations across the different treatments (the calculated relative value chart can be found in supplementary file marked as *Table 3*). As shown in *Figure 3*, Treatment T_7 exhibited the highest values in most parameters, including relative grain yield increase (58.89%), relative straw yield increase (41.09%) and relative biological yield increase (47.09%). The second-best results were consistently observed in Treatment T_5, with notable values in relative grain yield increase (56.70%), relative straw yield increase (39.24%) and relative biological yield increase (45.13%). Conversely, Treatment T_8 consistently showed the lowest relative values, serving as the baseline (0) for all parameters. These relative observations underscore the superior performance of Treatment T_7, followed closely by Treatment T_5, while highlighting the minimal impact of Treatment T_8, providing a clear comparative analysis of the treatments' effectiveness in terms of yield and production efficiency.

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System productivity

Basmati rice equivalent yield (REY) varied significantly among different cropping systems, as shown in *Table 3*. The basmati rice-berseem-moong (T_7) cropping system exhibited the highest basmati rice equivalent yield at 77.72 q ha^{-1}, with relative rice equivalent yield increase of 52% and relative system production efficiency of 110.1%. This performance was notably superior to that of other systems. Following closely was the basmati rice-berseem-mash (T_5) cropping system, which achieved a basmati rice equivalent yield of 76.53 q ha^{-1}, a relative rice equivalent yield increase of 52%, and a Relative System Production Efficiency of 106.9%.

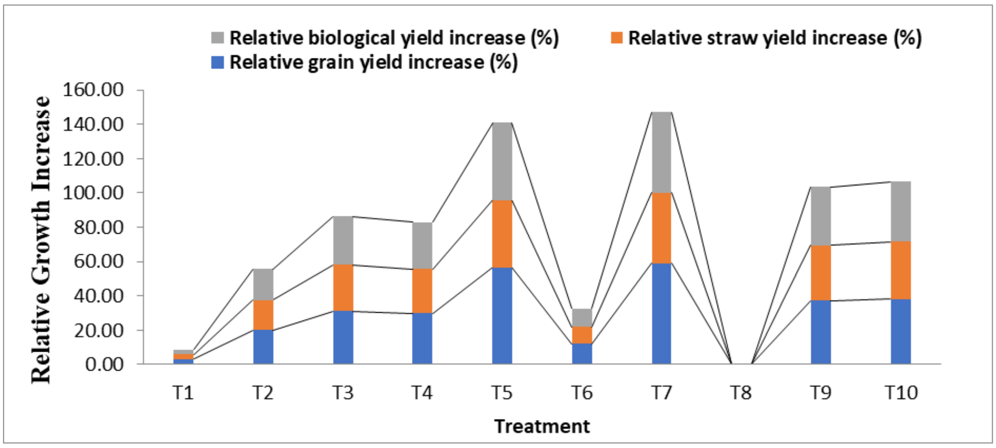

Figure 3. *Effect of different treatments on yield attributes of organic basmati rice, relative yield increase (%) averaged over the 5 years*

Economics

The treatment of basmati rice-berseem-moong (T_7) cropping system demonstrated the highest gross returns and net returns for organic basmati rice, amounting to Rs 202747 ha^{-1} and Rs 142050 ha^{-1}, respectively, surpassing other treatments (*Table 4*). Following closely, the basmati rice-berseem-mash (T_5) cropping system yielded the second-highest gross returns and net returns for organic basmati rice, reaching Rs 199964 ha^{-1} and Rs 139267 ha^{-1}, respectively. The basmati rice-berseem-moong (T_7) and basmati rice-berseem-mash (T_5) cropping systems achieved the highest benefit-to-cost (B:C) ratios for organic basmati rice, standing at 2.34 and 2.29, respectively. Moreover, the basmati rice-berseem-moong (T_7) and basmati rice-berseem-mash (T_5) cropping systems exhibited the highest relative profit increase (RPI) for organic Basmati rice. The maximum Gross Profit Margin Ratio (%), Profitability (Rs/ha/day) and Relative economics efficiency of organic basmati rice (%) (70.0, 389.18 and 108.31) were recorded in basmati rice-berseem-moong (T_7). The second highest Gross Profit Margin Ratio (%), Profitability (Rs/ha/day) and Relative economics efficiency of organic basmati rice (%) (69.65, 381.55 and 104.23) were recorded in basmati rice-berseem-mash (T_5) cropping systems, respectively.

The relative observation calculations for the economic efficiency data revealed significant variations across the different treatments (the calculated relative value chart can be found in supplementary file marked as *Table 4*). As shown in *Figure 4*, Treatment T_7 exhibited the highest relative values in most parameters, including gross

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revenue (57.30%) and net revenue (108.31%). The second-best results were consistently observed in Treatment T_5, with notable values in gross revenue (55.14%) and net revenue (104.23%). Conversely, Treatment T_8 consistently showed the lowest relative values, serving as the baseline (0) for all parameters. These relative observations underscore the superior economic performance of Treatment T_7, followed closely by Treatment T_5, while highlighting the minimal impact of Treatment T_8, providing a clear comparative analysis of the treatments' economic effectiveness.

Table 4. *Relative economics of different treatments in organic basmati rice*

Treatment	Gross revenue (Rs/ha)	Net revenue (Rs/ha)	B. C ratio	Gross profit margin ratio (%)	Profitability (Rs/ha/day)	Relative economics efficiency (%)
T_1	132809	72112	1.19	54.30	197.57	5.75
T_2	154538	93841	1.55	60.72	257.10	37.61
T_3	168503	107806	1.78	63.98	295.36	58.09
T_4	166939	106242	1.75	63.64	291.07	55.80
T_5	199964	139267	2.29	69.65	381.55	104.23
T_6	144136	83439	1.37	57.89	228.60	22.36
T_7	202747	142050	2.34	70.06	389.18	108.31
T_8	128889	68192	1.12	52.91	186.83	0.00
T_9	176213	115516	1.90	65.55	316.48	69.40
T_{10}	177612	116915	1.93	65.83	320.32	71.45

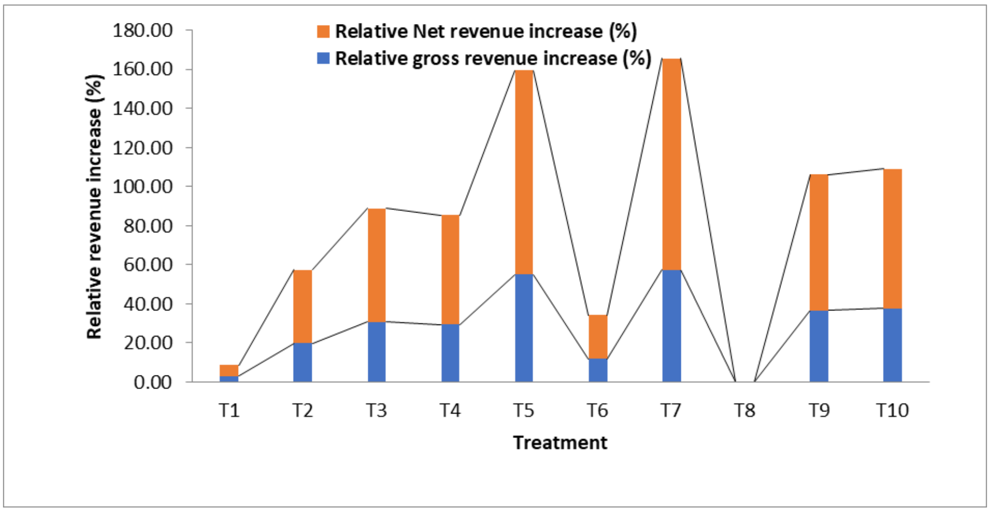

Figure 4. *Relative economics of different treatments in organic basmati rice*

Discussion

Growth attributes, yield components, and grain yield

Growth attributes of organic Basmati rice under different Basmati rice-based cropping systems, such as plant height at 90 days, number of tillers at 90 days, leaf color chart at 90 days, leaf area index at 90 days, number of grains per panicles at harvest and 1000-grain weight at harvest were significantly affected by basmati rice-berseem-moong and basmati rice-berseem-mash (*Table 2*). This can be attributed to the

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inclusion of Berseem and Moong crops in the rotation, as legume crops contribute to soil nitrogen content by fixing atmospheric nitrogen, thereby increasing nitrogen availability in the soil. This enriched nitrogen content can be used by the subsequent rice crop to support its vigorous vegetative growth. Porpavai et al. (2011) revealed similar results, highlighting the superiority of leguminous crops in raising the production of the subsequent rice crop. Similarly, yield attributes of organic Basmati rice, including the number of grains per panicles at harvest and 1000-grain weight at harvest, were significantly affected by basmati rice-berseem-moong and basmati rice-berseem-mash (*Table 2*).

The data on yield of organic basmati rice shows that this parameter was affected by both cropping systems viz. basmati rice-berseem-moong and basmati rice-berseem-mash. This can be attributed to the legume crop, which increased the available NPK and organic carbon levels within the system (*Table 3*). Sharma et al. (2004) reported that rice yield is higher when it is grown in crop rotation with fodder crops or green manure crops. According to Nanda et al. (2018), the elevated nitrogen input from the preceding crop facilitated the enhancement of basmati-based cropping systems (such as Basmati rice-chickpea + coriander and/or basmati rice-vegetable pea + coriander), leading to increased development and productivity of basmati rice. Same results were also observed by Gangadhar et al. (2018).

System productivity

The system productivity of Basmati rice has increased due to higher yield under the both cropping systems basmati rice-berseem-moong and basmati rice-berseem-mash. Lal et al. (2017) noted that the highest REY values were observed in systems that included sequences of green gram and black gram. This phenomenon could be linked to the incorporation of leguminous crops during the Rabi and summer seasons within the sequences. This practice likely enhanced nutrient utilization, consequently boosting the productivity of the system in relation to REY (Singh et al., 2013). The higher yield of the Berseem crop in the system also contributed to higher rice equivalent yield (Dubey et al., 2014).

Economics

Basmati rice-berseem-moong and basmati rice-berseem-mash cropping systems did significantly affect net returns of organic basmati rice. Basmati rice-berseem-moong and basmati rice-berseem-mash cropping system demonstrated the highest gross returns, net returns, and B:C ratio. This was primarily attributed to the incorporation of legume crops into the system, which led to an increase in yield and consequently resulted in a significantly higher REY production. Same results were also observed by Mangal et al. (2018). This system gave higher net returns and B:C ratio than cereals since it required less land preparation, irrigation, fertilizer, and cultivation costs. These results were supported by the findings of Thakur et al. (2009), Lal et al. (2017), and Banjara et al. (2022).

Conclusions

The analysis of the 5-year results from the current study indicates that the Basmati rice-Berseem-Moong cropping sequence is the most optimal choice, exhibiting the highest system productivity under organic conditions in the sub-tropical agroclimatic conditions of Jammu and Kashmir. This cropping system demonstrated the highest

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grain yield, rice equivalent yield, net returns, and B:C ratio. Nutrient rich Basmati rice–Barseem-Moong cropping system has tremendous benefits through saving of nitrogen fertilizer, increased crop yield and higher income per unit area.

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