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Effect of moong bean as green manuring and residue incorporation on growth, productivity of basmati rice

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Abstract
It has been discovered that treatments T_1, T_2, T_3, and T_4 that combined green manuring with residue inclusion saw less nitrogen loss. These may be the consequence of enhanced soil nutrient balance brought about by residue integration and green manuring, as well as improved soil physical qualities. Up to 20%–30% of the N taken up by the crops could be recycled by returning rice and wheat leftovers. In terms of economic return in the B:C ratio and total energy output, the treatments involving the incorporation of crop residues (rice or wheat residue or both) + green manuring (T_1 to T_4), crop residues (rice or wheat residue or both) (T_5 to T_8), or green manuring (T_1) proved to be highly effective when compared to the control (T_1). On the other hand, the integration of both residues along with green manuring (T_1) recorded the highest values of plant height, tiller density, dry weight, number of effective tiller m^{-1} row length, number of grains ear^{-1}, test weight, grain yield, straw yield, and biological yield of wheat. Remainder integration produced the best results in terms of enhanced wheat output, better soil health, financial return, and B:C ratio.

Keywords: green manuring, incorporation, residue, rice, wheat, moong bean

Introduction
A long-standing agricultural method known as "green manuring" involves incorporating crops into the soil primarily as a soil amendment and a source of plant nutrients for other crops. This approach became less important as the usage of mineral fertilizers increased. Crops planted with the purpose of improving soil fertility are sometimes referred to as green manures, or fertility building crops. They have been a part of traditional agriculture for thousands of years, but as the use of pesticides and fertilizers increased, conventional agricultural systems essentially ignored them. Despite their multiple functions, today's farmers nevertheless frequently underuse them. One of the most promising solutions to the issue of land poverty for the impoverished rural population is the use of green manure cover crops for soil fertility recoupment. Legumes fix atmospheric nitrogen and enrich the soil with a large amount of organic matter when utilized as green manures. As organic matter breaks down, it increases the amount of organic carbon in the soil and adds macro and micronutrients.

According to Mandal and Pal (2009) [5], green manuring improved the rice's root characteristics, such as root length, root volume, and root dry weight, when compared to the control. When compared to the control, the residual effect of green manuring and additional nitrogen also had a substantial impact on all of the wheat's root characteristics. When compared to the control, the majority of the yield components were raised by green manuring and its residual effect, with the exception of test weight, grain yield, and straw yield of wheat and rice. According to Sharma and Sharma (2005) [7], production and profitability increased when the rice-wheat system was somewhat diversified by adding mung bean in the summer (May-June). Compared to other rice-based cropping systems, the rice-wheat-mung bean cropping system had a superior land use efficiency as seen by its maximum harvest density index, multiple cropping index, and simultaneous cropping index.

Given that the rice-potato-mung bean, rice-clover, rice-rapeseed-mung bean, and rice-wheat mung bean cropping systems yield greater productivity and profit than the rice-wheat cropping system, it is advised to diversify this cropping system in order to ensure sustainable production.

Materials and Methods

The present investigation was conducted during two consecutive years (i. e. 2019-20 and 2020-21) at research farm of University College of Agriculture, Guru Kashi University, Talwandi Sabo. Talwandi Sabo is located at 29°-59'N latitude and 75°-4'E longitude and altitude of 213 meters above sea level. This tract is characterized by semi-arid zone, where both winters and summers extreme. A maximum temperature of about 40-41.9 °C is not uncommon during summer, while freezing temperature accompanied by frost occurrence may be witnessed in the months of January and February. The experiment was laid out in a Randomized complete block design with nine treatments *viz*; T_1: Moong bean (Wheat residue incorporated)-Basmati Rice-Wheat (residue incorporated), T_2: Moong bean (Wheat residue incorporated)-Basmati Rice-Wheat (partial burning), T_3: Moong bean- Basmati rice-Wheat (residue incorporated), T_4: Moong bean- Basmati rice-Wheat (partial burning), T_5: Basmati rice (wheat residue incorporated)-Wheat (residue incorporated), T_6: Basmati rice (wheat residue incorporated)-Wheat (partial burning), T_7: Basmati rice-Wheat (residue incorporated), T_8: Basmati rice-Wheat (partial burning), T_9: Control (basmati rice-wheat). The experimental data was recorded on plant growth and development (Plant height (cm), effective tillers, panicle length, number of grains/panicle, yield attributes and yield of rice during both the years of study.

Results and Discussion

Effect of green manuring and residue incorporation of growth characteristics of rice

Plant height

Plant height of rice was taken at three growth stages at 30, 60 DAT and at maturity. Significant effect of the treatments was noticed in the both years (Table. 1).

According to the data (Table 1), plant height was found to be significantly influenced by the treatments. Treatments that received residue incorporation (rice, wheat, or both, or partial burning) and green manuring (T_1, T_2, T_3, and T_4) recorded higher plant heights than treatments that included residue incorporation (T_5, T_6, T_7, and T_8) and control (T_9). T1 treatment, however, had the highest plant height among these treatments, with a mean value of 68.1 cm, which is comparable to treatments T_2 (68.1 cm) and T_4 (67.5 cm), respectively, and much higher than the other treatments at 30 DAT. This trend continued until maturity at 60 DAT. During both years at 60 DAT, the treatment T_1 is much higher than the treatments T_5, T_6, T_7, T_8, and T_9 and significantly on par with the treatments T_2, T_3, and T_4. T_9 was shown to be statistically comparable to treatments T_2 and T_3 at the time of maturity, but much higher than T_4, T_5, T_6, T_7, and T_8. The effects of T_4 and T_5, once more, were shown to be statistically non-significant but much greater than those of T_9, the control therapy. This result aligned with the observation made by Mukherjee and Singh (2012) [6] that plant heights in residue management treatments were statistically equivalent across all growth stages. With mean values of 48.02, 67.80, 96.15, and 95.57 cm at 25, 50, 75 DAT, and harvest, respectively, T_1 had the lowest plant height ever measured. T9 was discovered to be statistically comparable to treatments T_3, T_6, T_7, and T_8, but much higher than T_1, T_2, T_4, and T_5. At maturity, the effects of T_5, T_4, and T_2 were once more found to be statistically non-significant but much greater than those of the control treatment, or T_1. This could be the result of increased soil fertility brought about by green manuring and the integration of crop residue (either wheat or rice, or both), which in turn affected plant vigor and growth. Similar results were also reported by Singh and Sharma (2001) [8], who found that the wheat-green manuring-rice sequence considerably increased the growth parameters of plant height and the amount of dry matter accumulated per hill. In comparison to treatments T_1 and T_2, increased plant heights were also seen with residue inclusion and inorganic fertilizers (T_3, T_4, and T_5). According to Jai *et al*. (2014) [3], N fertilizers and residue management techniques have an impact on plant height and shoot growth.

Effective tiller/ m row length

Table 2 shows that treatments have a considerable impact on successful tillering in both years. The results show that, in 2019, treatment T_1 is significantly better than all other treatments. The T_2 through T_4 treatments are statistically equivalent to one another. But second-year (2020) treatments T_1 through T_3 were found to be much better than T_4 through T_8, though not as good as T_9.

Table 1: Periodic plant height of basmati rice as influenced by green manuring and residue incorporation

Treatments	Plant height (cm)							
	30 DAT		60 DAT		90 DAT		At maturity	
	2019	2020	2019	2020	2019	2020	2019	2020
T_1	69.7	71.1	99.1	102.1	110.2	114.2	118.5	124.0
T_2	68.1	70.1	99.0	102.0	112.5	112.3	118.8	123.0
T_3	66.6	67.9	98.5	101.2	110.1	112.2	116.4	122.5
T_4	67.5	68.3	90.8	90.7	108.6	109.5	110.2	111.5
T_5	57.0	59.3	86.7	89.8	100.4	102.0	108.9	108.5
T_6	55.3	57.3	85.4	88.5	94.7	100.2	104.8	105.5
T_7	56.1	57.4	84.7	87.9	94.0	98.4	101.9	104.0
T_8	55.4	55.3	84.5	87.7	92.1	93.2	100.8	104.5
T_9	53.4	55.3	83.3	82.2	92.1	94.0	100.5	100.5
LSD (P=0.05)	1.5	1.1	2.0	2.0	2.8	3.2	3.2	3.1

T_1: Moong bean (Wheat residue incorporated)-Basmati Rice-Wheat (residue incorporated), T_2: Moong bean (Wheat residue incorporated)-Basmati Rice-Wheat (partial burning), T_3: Moong bean- Basmati rice-Wheat (residue incorporated), T_4: Moong bean- Basmati rice-Wheat (partial burning), T_5: Basmati rice (wheat residue incorporated)-Wheat (residue incorporated), T_6: Basmati rice (wheat residue incorporated)-Wheat (partial burning), T_7: Basmati rice-Wheat (residue incorporated), T_8: Basmati rice-Wheat (partial burning), T_9: Control (basmati rice-wheat)

Table 2: Effect of green manuring and residue incorporation on yield attributing characteristic

Treatments	effective tillering		panicle length		no. of grains/panicle		1000 Grain weight	
	2019	2020	2019	2020	2019	2020	2019	2020
T_1	42.2	44.8	30.1	30.3	93.0	97.5	20.6	21.9
T_2	40.2	42.4	28.0	28.4	91.5	96.5	20.4	21.3
T_3	40.4	42.3	27.2	27.9	92.4	94.6	21.3	21.2
T_4	38.5	39.3	27.4	27.7	93.4	94.1	20.2	20.4

T_5	35.7	38.0	26.1	27.4	86.1	89.0	20.0	20.2
T_6	34.0	37.0	26.7	27.4	83.3	88.9	19.8	19.6
T_7	34.7	36.4	26.3	27.0	85.7	87.9	19.8	19.9
T_8	34.5	36.0	26.4	26.8	86.0	86.5	19.6	19.5
T_9	33.4	32.5	26.0	25.7	84.8	83.1	19.5	19.5
LSD	1.8	2.1	1.2	1.9	2.8	2.7	NS	1.4

T_1: Moong bean (Wheat residue incorporated)-Basmati Rice-Wheat (residue incorporated), T_2: Moong bean (Wheat residue incorporated)-Basmati Rice-Wheat (partial burning), T_3: Moong bean- Basmati rice-Wheat (residue incorporated), T_4: Moong bean- Basmati rice-Wheat (partial burning), T_5: Basmati rice (wheat residue incorporated)-Wheat (residue incorporated), T_6: Basmati rice (wheat residue incorporated)-Wheat (partial burning), T_7: Basmati rice-Wheat (residue incorporated), T_8: Basmati rice-Wheat (partial burning), T_9: Control (basmati rice-wheat)

Panicle length

The data for panicle length is shown in Table 2. Treatment T_1 was found to have a considerably higher panicle length during the first year of 2019 compared to all other treatments, including T_2, T_3, T_4, T_5, T_6, T_7, and T_8, which was statistically at par but longer than T_9. But in the second year (2020), it was discovered that the panicle duration with treatment T_1 was noticeably longer than with any other treatment, from T_2 to T_9. Singh and Sharma (2001) [8] found that the wheat-green manuring-rice sequence increased the number of productive shoots, panicle length, number of fertile spikelets/panicle, and 1000-grain weight substantially. The results corroborate those of Das *et al*. (2002) [2], who also noted that adding crop residues to rice improved its growth, yield characteristics, and grain yield.

Number of grains panicle^{-1}

Number of grains per panicle during the first year (2019) was found to be statistically comparable to treatments T_1 to T_4 compared to all other treatments T_5 to T_9. Table 2. But in contrast to other treatments T_2 through T_9, T_1 had a noticeably higher number of grains per panicle in the second year of 2020. Treatments T_2 through T_4 are substantially better than T_9, but still on par. The crop may have produced more grains panicle^{-1} under this treatment as a result of improved soil health, as seen by the soil's nutritional status.

1000 grain weight

The test weight data is shown in Table. 2. The 1000 grain weight in the first year (2019) was not found to be statistically different, but in the second year (2020), the test weights of treatments T_1, T_2, and T_3 were significantly higher than those of all other treatments. T_4 through T_9 were determined to be statistically equivalent. The crop would have had better vigor and healthier seed production if there had been more microbial activity as a result of residue decomposition.

Grain Yield q ha^{-1}

Grain yield was significantly influenced by the treatments in both the years as revealed by the data presented in the Table 3. However, the influence was more pronounced in the second year except for the treatments T_9 and T_8. Which might be due to better nutrient availability in the plots receiving treatments T_1 to T_4 because of the effect of crop residues incorporation(rice or wheat or both) and green manuring.

Table 3: Effect of green manuring and residue incorporation on grain yield, straw yield biological yield and harvest index%

Treatments	Grain yield q/ha		Straw yield quintal/ha		biological yield q/ha		Harvest index %	
	2019	2020	2019	2020	2019	2020	2019	2020
T1	34.3	37.5	108.3	118.0	140.7	155.5	23.0	24.1
T2	33.4	34.5	107.3	113.5	140.7	148.0	23.7	23.3
T3	30.7	32.0	97.3	106.0	128.1	138.0	24.3	23.2
T4	31.1	32.5	98.5	101.0	129.6	133.5	23.9	24.3
T5	29.7	30.1	96.7	97.5	126.8	127.6	23.6	23.8
T6	27.6	27.4	90.0	90.0	117.4	117.4	23.7	23.4
T7	25.1	26.0	80.7	86.0	105.9	112.0	24.1	23.2
T8	26.0	26.0	88.3	85.5	114.0	111.5	22.6	23.3
T9	24.3	22.9	84.3	82.5	108.6	105.4	22.6	21.7
LSD	2.5	3.6	17.1	16.7	18.9	17.1	NS	NS

T_1: Moong bean (Wheat residue incorporated)-Basmati Rice-Wheat (residue incorporated), T_2: Moong bean (Wheat residue incorporated)-Basmati Rice-Wheat (partial burning), T_3: Moong bean- Basmati rice-Wheat (residue incorporated), T_4: Moong bean- Basmati rice-Wheat (partial burning), T_5: Basmati rice (wheat residue incorporated)-Wheat (residue incorporated), T_6: Basmati rice (wheat residue incorporated)-Wheat (partial burning), T_7: Basmati rice-Wheat (residue incorporated), T_8: Basmati rice-Wheat (partial burning), T_9: Control (basmati rice-wheat

The absence of organic nutrient management or integration may have contributed to the gradual decline in fertility in the plots receiving treatments T_9 and T_8. Treatments T_3 through T_6 were determined to be statistically equivalent but significantly higher than control (T_9) in the first year (2019), as most of the yield-attributing features followed the same trend as shown in the tables above. T_1 did, however, record the highest yield (34.3q ha^{-1} and 37.53q ha^{-1}, respectively), which was shown to be considerably higher than all other treatments over both research years, but on par with treatment T_2. Similar results were also reported by Jai *et al*. (2014) [4] and Vinay (2006) [9], who found that rice grain yields were considerably higher with crop residue incorporation + green manuring treatment than with other crop residue management procedures. When compared to the only inclusion of wheat straw, either with or without green manuring, the solo incorporation of rice residues yielded statistically greater grain yield values. In contrast to the only integration of rice or wheat residues or the combination of both with fertilizer and the sole application of chemical fertilizers, it was discovered that sole green manuring in conjunction with fertilizer application produced more influence. The results are consistent with those of Aulakh *et al*. (2001) [1], who found that adding crop leftovers and/or growing green manure crops to a rice-wheat system can improve SOM (soil organic matter) while preserving high grain yields.

Straw yield q ha^{-1}

Straw yield was significantly influenced in both the years but the influence was more pronounced in second year (2020) especially in the treatments where crop residues (rice or wheat or both) were incorporated along with or without green manuring (T1 to T4) as depicted in Table-3. This might be due to enrichment of soil fertility because of crop residue incorporation and green manuring. From the data of both the years it has been observed the significant influences of the treatments on straw yield. While straw yield was affected in both years, it was more noticeable in second year (2020), particularly in the treatments (T_1 to T_4) that included crop residues (rice, wheat, or both) with or without green manuring. This is shown in Table 3. This could result from green manuring and the integration of crop residue, which enhance soil fertility. It has been found from the data of both years that the treatments had a considerable impact on the yield of straw in both research years, T1 was shown to have the highest mean straw yield (108.3 q ha-1 and 118.0 q ha-1, respectively). Nonetheless, during the first year, the straw yield using treatments T1 through T6 was shown to be statistically equivalent to one another. During the second year of the trial, a considerably higher straw yield was seen with the treatment T1. The results corroborated those of Das *et al*. (2003) [3] and Jai *et al*. (2014) [4], who found that rice straw yields were significantly higher when crop residue incorporation (CRI) was used, whether or not *Sesbania* green manure (SGM) was present. During the two study years, the control T_9 yield showed the lowest value, with mean values of 84.3 q ha^{-1} and 82.5 ha^{-1}, respectively.

Biological Yield

The data in Table 3 showed that the treatments had a considerabl e impact on biological yield in both years.the pattern of biologic al yield was similar to that of grain and straw yield, with greater values observed in the second year.

Treatment T_1 yielded a significantly larger biological production compared to T_2, T_3, T_4, T_5, and T_6 over the first year, with the re sults being statistically equivalent. However, treatments T_1 to T_4 found to be statistically at par during second year of study. The findings were in accordance with Das *et al*. (2003) [3] and Jai *et al*. (2014) [4] who reported that crop residue incorporation (CRI) with or without *Sesbania* green manure (SGM) were observed significantly greatest straw yields in rice. The lowest yield was obtained from control T_9 with mean value of 105.4 q ha^{-1} during second year. Lower values of growth and yield attributes might have influenced lower straw yield in control plots receiving no nutrients either in chemical or organic forms what so ever.

Harvest index %

Harvest index was not significantly influenced during both years of study.

Conclusion

Plant height, tiller count, effective tiller count, dry matter accumulation, panicle length, number of grains per panicle, test weight, grain yield, straw yield, and biological yield were all increased when rice and wheat residues were added with green manuring. Also enhances soil fertility by improving the physical characteristics of the soil and increases the uptake of available nutrients.

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