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Assessing the Impact of Previous Kharif Crops and Fertilizer Application on Growth, Yield, and Nutrient Uptake in Succeeding Wheat (Triticum aestivum)

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ABSTRACT

A field experiment was carried out during the **2022-23 and 2023-24 kharif and rabi seasons** at **Gram Dharavara, District Dhar**. The goal was to understand how different **preceding kharif crops** and **fertilizer management** affect the growth, yield, nutrient uptake, and overall economic benefits of the following wheat crop (*Triticum aestivum L.*).

The experiment was set up using a **split plot design**. The main plots included four different kharif crops: **greengram (Vigna radiata)**, **sesame (Sesamum indicum)**, **pearl millet (Pennisetum glaucum)**, and **fodder sorghum (Sorghum bicolor)**. For the subplots, five different fertilizer treatments were tested: **100%, 75%, and 50% of the recommended dose of fertilizers (RDF)**, along with combinations of **75% and 50% RDF** plus **Azotobacter** and **PSB (phosphate solubilizing bacteria)**. Each treatment was repeated four times for accuracy.

Wheat grown after **greengram** showed the best growth and yield. The wheat after greengram produced more grain (4.78 tons/ha) and straw (6.41 tons/ha) compared to other treatments. Among the fertilizer treatments, the **100% RDF** resulted in the highest yields of both grain (4.60 tons/ha) and straw (6.20 tons/ha). Nutrient uptake by the wheat was also higher when grown after greengram and fertilized with 100% RDF. The **greengram-wheat rotation**, along with either **100% RDF** or **75% RDF combined with Azotobacter + PSB**, provided the best **net profits** and **B:C ratio**.

KEY WORDS: Azotobacter, Fertilizers, Preceding Crops, Succeeding Wheat, and Yield.

1. INTRODUCATION:

Wheat (*Triticum aestivum L.*) is the second most important food grain crop in India after rice, contributing nearly one-third of the country's total food grain production. It holds significant nutritional value, especially due to its higher protein content compared to other cereals, along with the presence of gluten, which is essential for baking.

These days, it is widely understood that the nutrient requirements of a crop grown in sequence are influenced by the residual effects of the preceding crop. Typically, wheat follows kharif crops such as pulses, rice, maize, sorghum, or pearl millet. However, continuous cultivation of cereal crops in rotation can lead to imbalances in soil fertility and a decrease in yields. Growing legumes as part of the crop rotation is a beneficial practice, as they not only improve soil health but also enhance the productivity of the subsequent crops. Proper nutrient management—especially with nitrogen, phosphorus, and potassium—and the use of organic fertilizers play a key role in maintaining crop production and ecological balance.

This study highlights how choosing the right kharif crops and adopting balanced fertilizer management can boost wheat productivity while sustaining soil fertility.

Materials and Methods

This field experiment was conducted during the **2022-23** and **2023-24** consecutive **kharif (rainy)** and **rabi (winter)** seasons at the **Agronomy Instructional Farm** of **C.P. College of Agriculture**, Sardarkrushinagar (Gujarat). The climate of Sardarkrushinagar is of the **subtropical monsoon** type, falling under the **semi-arid region**. The experimental field soil was **loamy sand**, with a pH of 7.56, slightly alkaline in reaction. The soil had low organic carbon (0.16%) and available nitrogen (159.2 kg/ha), while available phosphorus (34.0 kg/ha) and potassium (240.0 kg/ha) levels were high.

The experiment was laid out in a **split-plot design**, with four preceding **kharif crops** in the main plots:

- **C1**: Green gram (*Vigna radiata*),
- **C2**: Sesame (*Sesamum indicum*),
- **C3**: Pearl millet (*Pennisetum glaucum*),
- **C4**: Fodder sorghum (*Sorghum bicolor*).

In the subplots, five **fertilizer treatments** were applied:

- **F1**: 100% RDF (120 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha),
- **F2**: 75% RDF,
- **F3**: 50% RDF,
- **F4**: 75% RDF + **Azotobacter** + **PSB** (phosphate solubilizing bacteria),
- **F5**: 50% RDF + **Azotobacter** + **PSB**.

Each treatment was replicated four times, with a gross plot size of **5.0 m × 4.5 m**. The kharif crops were sown in **July** following the recommended agronomic practices, and the wheat variety **'GW 451'** was sown in **November**.

After harvesting the preceding crops, wheat was sown at the recommended seed rate of **120 kg/ha** with a row spacing of **22.5 cm**. The recommended fertilizer dose for wheat (120 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha) was applied in the form of **urea**, **diammonium phosphate**, and **muriate of potash**. Nitrogen was applied in **two splits**: 50% as basal and 50% as top dressing **21–25 days after sowing (DAS)**. Seeds were treated with **Azotobacter** and **PSB** in the specific treatments at the time of sowing.

The first irrigation was given immediately after sowing, and the second irrigation was given at the **21 DAS** stage during the crown root initiation. Further irrigations were provided as required. Throughout the growing season, the experimental area was kept weed-free. The wheat crop was harvested during the **third week of March** in both years.

Growth, Yield Attributes, and Yield

Growth and yield attributes were recorded from **five randomly selected plants** from each net plot at various stages of the wheat crop. The grain yield was calculated after threshing, winnowing, and cleaning, and expressed in **tonnes per hectare**. The straw yield was determined by subtracting the grain yield from the total dry matter of each net plot. The uptake of nutrients was computed by multiplying the grain and straw yield by their respective nutrient percentages.

In the economic analysis, **gross and net realizations** were calculated based on the prevailing market prices of all inputs and wheat yields (grain and straw). The **Benefit-Cost (B:C) ratio** was calculated by dividing the gross realization (₹/ha) by the cost of cultivation (₹/ha). The pooled data for the two years was analyzed according to the method outlined by **Cochran and Cox (1967)**, and **Analysis of Variance (ANOVA)** was performed. Comparison of treatment means was made using **Least Significant Difference (LSD)** at **P = 0.05**.

Results and Discussion

Growth, Yield Attributes, and Yield

The preceding kharif crops and fertilizer treatments had a significant effect on the **plant height** at harvest for wheat. Among the various kharif crops, wheat following **green gram** recorded the highest plant height (**65.55 cm**), which was at par with sesame. The lowest plant height (**58.42 cm**) was observed in wheat following **fodder sorghum**. Kumar and Sharma (2000) also found that **black gram** grown as a preceding crop resulted in higher plant height, number of tillers, and dry matter per plant of wheat compared to other crops like rice, maize, sesame, sorghum, and even groundnut.

Among the fertilizer treatments, the highest plant height (**63.98 cm**) was recorded with **100% RDF (120 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha)**, which was at par with the treatment **75% RDF** and **75% RDF + Azotobacter + PSB**. Jat et al. (2013) also reported that the application of **120 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha** resulted in increased plant height and dry matter of wheat compared to the application of **80 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha**. The enhancement in growth parameters with higher fertilizer doses is likely due to the rapid conversion of synthesized carbohydrates into proteins, leading to increased cell number and size, which boosts plant height and ultimately dry matter accumulation.

Wheat following **green gram** recorded significantly higher values for the number of effective tillers per meter row length (**82.76**), spike length (**7.94 cm**), number of spikelets per spike (**13.77**), and number of grains per spike (**31.31**). In terms of spike length and number of grains per spike, **green gram** was statistically at par with **sesame**. However, the lowest values for these attributes were observed with wheat following **fodder sorghum**.

Growth, Yield, and Nutrient Uptake in Wheat

The highest values for grain yield (**4.78 t/ha**) and straw yield (**6.41 t/ha**) in wheat were recorded when **green gram** preceded the wheat crop. This was significantly higher compared to the yields from other preceding crops, as shown in the pooled data (Table 1). When compared to other kharif crops, green gram increased wheat yield by **13.2% over sesame**, **22.6% over pearl millet**, and **41.4% over fodder sorghum**. This is in agreement with findings from **Singh et al. (2008)**, who reported that crops like green gram and clusterbean as preceding crops resulted in significantly higher wheat grain yields than those following pearl millet. Similarly, **Maadi et al. (2012)** observed that a **mungbean** crop followed by wheat increased the number of spikes, test weight, and grain yield compared to a traditional **rice-wheat** cropping system.

The superior grain yield of wheat after **green gram** can be attributed to the soil-enriching effects of legumes. These crops fix atmospheric nitrogen in their root nodules, which improves soil fertility and provides residual nutrients for the succeeding crop, unlike non-leguminous crops. On the other hand, wheat following **fodder sorghum** recorded the lowest grain yield (**3.38 t/ha**) and straw yield (**4.78 t/ha**), which was consistent with the findings of **Kumar et al. (2013)**, who noted that green gram preceding wheat resulted in significantly higher wheat straw yield compared to fodder sorghum.

Regarding fertilizer treatments, wheat fertilized with **100% RDF** produced significantly higher values for effective tillers per meter row length (**83.63**), spike length (**8.11 cm**), number of spikelets per spike (**13.67**), number of grains per spike (**31.08**), grain yield (**4.60 t/ha**), and straw yield (**6.20 t/ha**) (Table 1). This treatment was statistically comparable to **75% RDF + Azotobacter + PSB**, demonstrating a positive impact of full recommended fertilizer doses. The increase in grain yield (**32.66%**) and straw yield (**28.8%**) from **100% RDF** over **50% RDF** was evident in the pooled data. Similarly, **Patidar and Mali (2002)** noted that residual effects of **75% RDF** and **100% RDF** in sorghum significantly improved plant height and tiller number in succeeding wheat crops.

Interaction Effect

The interaction between the preceding kharif crops and fertilizer treatments significantly influenced the grain and straw yield of wheat (Table 2). Wheat grown after **green gram** and treated with **100% RDF (C1F1)** recorded the highest grain yield (**5.25 t/ha**) and straw yield (**7.00 t/ha**) over the two years. This was comparable to the treatment of **green gram × 75% RDF + Azotobacter + PSB (C1F4)**. In contrast, the lowest grain yield (**2.63 t/ha**) and straw yield (**4.02 t/ha**) were observed when wheat was grown after **fodder sorghum** and treated with **50% RDF (C4F3)**.

Nutrient Uptake

The highest nitrogen, phosphorus, and potassium uptakes by both the grain and straw of wheat were observed under treatments with **green gram** as the preceding crop and **100% RDF** as the fertilizer treatment. These results indicate that the combination of leguminous crops as preceding crops and full recommended fertilizer doses can enhance the nutrient uptake by wheat, ultimately improving both grain and straw yields.

Table 2: Interaction Effect of Preceding Kharif Crops and Fertilizer Treatments on Grain and Straw Yield of Wheat (Pooled Data of 2 Years)

Treatment	**Greengram**	**Sesame**	**Pearl Millet**	**Fodder Sorghum**
Grain Yield (t/ha)				
100% RDF (F1)	5.25	4.90	4.40	3.86
75% RDF (F2)	4.75	4.13	3.68	3.34
50% RDF (F3)	4.12	3.83	3.28	2.63
75% RDF + Azotobacter + PSB (F4)	5.19	4.34	4.23	3.92
50% RDF + Azotobacter + PSB (F5)	4.59	3.91	3.91	3.15
SEm ±	0.09			
CD (P=0.05)	0.24			
Treatment	Greengram	Sesame	Pearl Millet	Fodder Sorghum
Straw Yield (t/ha)				
100% RDF (F1)	7.00	6.35	5.92	5.55
75% RDF (F2)	6.45	5.62	5.49	4.47
50% RDF (F3)	5.61	5.27	4.36	4.02
75% RDF + Azotobacter + PSB (F4)	6.97	5.95	5.78	5.32
50% RDF + Azotobacter + PSB (F5)	6.05	5.44	5.43	4.52
SEm ±	0.13			
CD (P=0.05)	0.37			

Nutrient Uptake in Wheat Following Preceding Kharif Crops

Wheat crops that followed **green gram** showed the highest nitrogen, phosphorus, and potassium uptake in both grain and straw, compared to those preceded by other kharif crops (Table 3). The lowest nutrient uptake was observed in wheat grown after **fodder sorghum**. This supports the findings of **Chaman and Singh (2007)**, who reported that wheat following legumes absorbs more nitrogen than wheat grown after cereal crops. Similarly, **Singh et al. (2008)** found that green gram and clusterbean as preceding crops resulted in significantly higher nitrogen and phosphorus uptake by wheat compared to wheat following **pearl millet**.

Regarding the fertilizer treatments, the application of **100% RDF** resulted in the highest uptake of nitrogen, phosphorus, and potassium in both the grain and straw of wheat. However, for potassium uptake by the straw, the results were statistically similar between **100% RDF** and the treatment of **75% RDF + Azotobacter + PSB** in the pooled mean data (Table 3). The higher nutrient uptake observed under **100% RDF** can be attributed to the increased availability of nutrients, which enhanced crop growth, leading to higher grain and straw yields. This ultimately resulted in a higher uptake of nutrients by the wheat crop, as **Khandare et al. (2012)** also noted in their studies.

Interaction Effect

The interaction between the preceding kharif crops and fertilizer treatments significantly influenced both the grain and straw yield of wheat (Table 2). Wheat grown after **green gram** and treated with **100% RDF (C1F1)** recorded the highest grain yield (**5.25 t/ha**) and straw yield (**7.00 t/ha**) over the two years. This was closely followed by the treatment of **green gram × 75% RDF + Azotobacter + PSB (C1F4)**. In contrast, the lowest grain yield (**2.63 t/ha**) and straw yield (**4.02 t/ha**) were observed with **fodder sorghum** as the preceding crop and **50% RDF** as the fertilizer treatment.

Nutrient Uptake by Wheat

The uptake of nitrogen, phosphorus, and potassium in both grain and straw was highest when **green gram** preceded wheat, and **100% RDF** was applied. As shown in Table 3, **green gram** promoted the highest nutrient uptake, while **fodder sorghum** resulted in the lowest values. The results indicate that **green gram** as a preceding crop provides a favorable environment for nutrient availability, enhancing the wheat crop's ability to absorb essential nutrients.

Table 3: Effect of Preceding Kharif Crops and Fertilizer Treatments on Nutrient Uptake by Grain and Straw of Wheat (Pooled Data of 2 Years)

Treatment	Nitrogen (kg/ha)	Uptake Phosphorus (kg/ha)	Uptake Potassium (kg/ha)	Uptake
Grain	**Straw**	**Grain**	**Straw**	
Kharif Crops (C)				
Greengram (C1)	86.27	32.41	20.29	
Sesame (C2)	74.97	28.41	17.72	
Pearl Millet (C3)	69.78	26.92	16.16	
Fodder Sorghum (C4)	59.37	23.49	13.81	
SEm ±	1.63	0.69	0.37	
CD (P=0.05)	4.85	2.05	1.09	
Fertilizer Treatments (F)				

Treatment	Nitrogen (kg/ha)	Uptake Phosphorus (kg/ha)	Uptake Potassium (kg/ha)	Uptake
100% RDF (F1)	85.94	32.49	20.13	
75% RDF (F2)	70.71	27.43	16.57	
50% RDF (F3)	57.93	22.44	13.57	
75% RDF + Azotobacter + PSB (F4)	80.28	30.46	18.76	
50% RDF + Azotobacter + PSB (F5)	68.13	26.21	15.96	
SEm ±	1.13	0.48	0.29	
CD (P=0.05)	3.18	1.35	0.82	

Soil Fertility and Nutrient Status After Wheat Harvest

According to data from Table 4, the effect of different **preceding kharif crops** on the available nitrogen in the soil after the harvest of the wheat crop was significant. However, the levels of available phosphorus and potassium in the soil after the wheat harvest did not show significant differences due to the preceding crops. This suggests that while nitrogen levels are impacted by the previous crop, phosphorus and potassium remain relatively unaffected.

The available nitrogen in the soil was highest after wheat grown following **greengram**, with a value of **180.94 kg/ha**. **Sesame** and **pearl millet** also resulted in relatively high nitrogen availability, but **fodder sorghum** showed the lowest nitrogen level, at **167.71 kg/ha**. As for phosphorus and potassium, the variations between different crops were minor, and no significant differences were noted across treatments.

In terms of fertilizer application, **100% RDF** (120 kg N + 60 kg P2O5/ha) resulted in the highest levels of available nutrients in the soil after wheat harvest. **50% RDF** treatments led to the lowest nutrient availability, while the application of **75% RDF + Azotobacter + PSB** was similar to **100% RDF** in terms of available nitrogen and potassium, but phosphorus levels were slightly lower.

Table 4.Effect of preceding kharif crops and fertilizer treatments on available nutrients status in soil after harvest of wheat (Pooled data of2 years)

Treatment	Avaliable nutrient status (kg/ha)		
	N	P2O5	K2O
Kharif crop (C)			
C1 Green gram	180.94	38.47	282.6
C2 Sesame	175.23	37.44	275.1
C3 Pearl millet	170.05	37.15	273.08
C4 Fodder sorghum	167.71	36.82	270.62
SEm±	1.69	0.41	3.35
CD (P=0.05)	5.83	NS	NS
Fertilizer to wheat (F)			
F1 100% RDF	178.33	38.32	2.79.89

F2 75% RDF	173.66	37.57	274.46
F3 50% RDF	167.86	36.28	269.19
F4 75% RDF +Azotobacter + PSB	175.26	37.91	278.9
F5 50% RDF + Azotobacter + PSB	172.29	37.27	274.31
SEm±	1.57	0.36	2.9
CD (P=0.05)	4.41	1.01	NS

Economic Analysis of Preceding Kharif Crops-Wheat Sequence

Table 5 presents the economics of different preceding **kharif crops** and fertilizer treatments in the **wheat sequence**, considering both the gross realization and cost of cultivation. The net benefit and benefit-cost ratio were also evaluated for each combination.

In the case of **greengram** followed by wheat (C1), the highest gross realization was recorded in treatments with **100% RDF** and **75% RDF + Azotobacter + PSB**, which both yielded a net benefit of **117.44 × 10³ ₹/ha** and a benefit-cost ratio of **2.48** and **2.48**, respectively. These treatments were significantly more profitable than other treatments.

Similarly, **sesame (C2)** and **pearl millet (C3)** as preceding crops resulted in moderate gross realizations and net benefits, with **100% RDF** producing the best returns. The **fodder sorghum (C4)** treatment consistently yielded lower returns across all fertilizer treatments.

Table 5. Economics of preceding kharif crops-wheat sequence (Pooled data of 2 years)

Treatment Gross Realization Cost of Cultivation Net Benefit Benefit-Cost Ratio

	Kharif Crops	**Wheat**	**Total**	**Kharif Crops**
C1F1	60.31	136.45	196.76	30.46
C1F2	60.31	123.96	184.28	30.46
C1F3	60.31	107.56	167.88	30.46
C1F4	60.31	135.17	195.48	30.46
C1F5	60.31	119.17	179.48	30.46
C2F1	36.32	126.93	163.25	28.07
C2F2	36.32	115.89	152.21	28.07
C2F3	36.32	100.16	136.48	28.07
C2F4	36.32	113.43	149.75	28.07
C2F5	36.32	102.48	138.80	28.07
C3F1	45.36	114.48	159.84	31.28
C3F2	45.36	97.51	142.86	31.28
C3F3	45.36	85.35	130.71	31.28
C3F4	45.36	110.30	155.66	31.28
C3F5	45.36	102.39	147.75	31.28
C4F1	66.00	101.61	167.61	30.25
C4F2	66.00	86.87	152.87	30.25

Treatment	Gross Realization	Cost of Cultivation	Net Benefit	Benefit-Cost Ratio
C4F3	66.00	69.99	135.99	30.25
C4F4	66.00	102.28	168.28	30.25
C4F5	66.00	83.05	149.05	30.25

Effect of Preceding Crops on Soil Fertility and Wheat Yield

The results (Table 4) showed that the **highest available nitrogen** in the soil after the wheat harvest was recorded in the **greengram-wheat crop sequence** (180.94 kg N/ha). In contrast, the lowest nitrogen content (167.71 kg N/ha) was observed when **fodder sorghum** preceded the wheat crop. This can likely be attributed to the fact that **sorghum** tends to deplete and immobilize soil nitrogen, while **leguminous crops**, like **greengram**, enhance the available nitrogen content in the soil.

As for the fertilizer treatments, the application of **100% RDF** (120 kg N + 60 kg P2O5/ha) resulted in the highest available nitrogen (178.33 kg N/ha) and phosphorus (38.32 kg P2O5/ha) in the soil after the wheat harvest. However, there were no significant differences observed in the available potash in the soil, regardless of the fertilizer treatment used. The increase in the available nutrient status with each successive increase in fertilizer levels was likely due to the direct contribution of the added fertilizers, which enhanced the nutrient availability for the wheat crop, ultimately impacting its content in the post-harvest soil.

Economic Analysis of Wheat-Growing Sequences

Data from Table 5 reveal that the **highest gross realization** (196.76 × 10^3/ha) and **net realization** (117.44 × 10^3/ha), along with a **benefit-cost ratio (BCR)** of 2.48, were achieved when **greengram** was grown as the preceding crop with **100% RDF** (C1F1). This was followed by **greengram × 75% RDF + Azotobacter + PSB** (C1F4), which also yielded high economic returns. On the other hand, the combination of **pearl millet × 50% RDF** (C3F3) resulted in the lowest gross realization (130.71 × 10^3/ha) and net realization (53.34 × 10^3/ha), with a BCR of 1.69.

This aligns with the findings of **Singh et al. (2008)**, who reported that the **greengram-**wheat sequence resulted in significantly higher net returns and BCR compared to the **pearl millet**-wheat sequence.

Conclusion

To maximize both **wheat yield** and **net realization**, it is recommended to grow wheat after **greengram** in the **kharif season**, and apply either **100% RDF** (120 kg N + 60 kg P2O5 + 40 kg K2O/ha) or **75% RDF + Azotobacter + PSB**. This combination has proven to be highly effective in enhancing both crop productivity and profitability.

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