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Effect of FYM, nitrogen and phosphorus levels on productivity and economics of *Kharif* Sorghum

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Abstract
A field experiment was conducted during the kharif season of 2024 at the Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, to evaluate the effect of farmyard manure (FYM), nitrogen, and phosphorus levels on the productivity and economics of sorghum (*Sorghum bicolor* L.). The experiment was laid out in a factorial randomized block design with twelve treatment combinations comprising two levels of FYM (5 and 10 t ha^{-1}), three levels of nitrogen (60, 80, and 100 kg ha^{-1}), and two levels of phosphorus (20 and 40 kg P_2O_5 ha^{-1}), replicated thrice. Results indicated that application of 10 t FYM ha^{-1}, 100 kg N ha^{-1}, and 40 kg P_2O_5 ha^{-1} significantly improved grain yield, straw yield, and economic returns. The interaction between nitrogen and phosphorus was significant for grain and straw yield, indicating synergistic nutrient effects. The highest gross (₹1,34,326 ha^{-1}) and net realization (₹72,367 ha^{-1}) were recorded under the treatment combination of 10 t FYM ha^{-1} + 100 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}. However, the maximum benefit-cost ratio (2.38) was obtained with 5 t FYM ha^{-1} + 100 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}, reflecting greater economic efficiency at lower organic input levels. The study highlights the importance of integrated nutrient management for achieving higher productivity and profitability in kharif sorghum.

Keywords: Sorghum, farmyard manure, nitrogen, phosphorus, yield, economics

Introduction
Sorghum (*Sorghum bicolor* L.) is one of the most important cereal crops cultivated in semi-arid and arid regions of the world due to its drought tolerance and adaptability to marginal soils. In India, sorghum plays a vital role in ensuring food, fodder, and livelihood security, particularly in rainfed ecosystems. Despite its adaptability, productivity of sorghum remains relatively low, primarily due to imbalanced and inadequate nutrient management.

Nitrogen is the most yield-limiting nutrient in sorghum, governing vegetative growth, photosynthetic efficiency, and sink development. Phosphorus is equally important for early root establishment, energy transfer, and reproductive development. Continuous reliance on chemical fertilizers, however, has resulted in declining soil organic carbon and nutrient-use efficiency. Farmyard manure (FYM) serves as a valuable organic amendment that improves soil physical, chemical, and biological properties while supplying nutrients in a slow and sustained manner.

Integrated use of FYM with inorganic fertilizers has been widely advocated as a sustainable nutrient management strategy, improving crop productivity while maintaining soil health. Considering these aspects, the present investigation was undertaken to study the individual and combined effects of FYM, nitrogen, and phosphorus levels on yield parameters and economics of kharif sorghum under middle Gujarat conditions.

Materials and Methods
The field experiment was conducted during the kharif season of 2024 at the Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat. The soil of the experimental field was loamy sand (Goradu), slightly alkaline in reaction (pH 8.35), low in organic carbon (0.46%) and available nitrogen (203.84 kg ha^{-1}), medium in available phosphorus (29.55 kg ha^{-1}), and high in available potassium (238.23 kg ha^{-1}).

The experiment was laid out in a factorial randomized block design with three replications.

Treatments consisted of two FYM levels (5 and 10 t ha⁻¹), three nitrogen levels (60, 80, and 100 kg ha⁻¹), and two phosphorus levels (20 and 40 kg P_2O_5 ha⁻¹), forming twelve treatment combinations. FYM was incorporated into the soil before sowing. Nitrogen was applied in two splits, half as basal and the remaining half at 30 days after sowing (DAS), while the entire dose of phosphorus was applied basally. Sorghum variety GJ 44 was sown at a spacing of 45 cm, and all recommended agronomic practices were followed uniformly.

Results and Discussion

Yield Parameters (Grain yield, Straw yield and Harvest index)

The yield performance of kharif sorghum as influenced by different levels of FYM, nitrogen, and phosphorus is presented in Table 1 and the interaction effects in Table 1.1. The results clearly indicated that individual application of FYM, nitrogen, and phosphorus significantly influenced grain and straw yields, whereas harvest index remained statistically non-significant across treatments.

Effect of FYM: Application of 10 t FYM ha⁻¹ (F_2) recorded significantly higher grain yield (2337 kg ha⁻¹) and straw yield (10,308 kg ha⁻¹) compared to 5 t FYM ha⁻¹ (F_1). The improvement in yield with higher FYM application can be attributed to enhanced soil physical properties, improved moisture retention, and sustained nutrient release throughout the crop growth period. FYM also stimulates microbial activity, resulting in improved mineralization and nutrient availability, particularly nitrogen and phosphorus, which ultimately enhances biomass production and yield formation. Similar yield improvements due to FYM application in sorghum have been reported by Patidar and Mali (2004) [13], Kushwaha *et al*. (2014) [11], and Jat *et al*. (2013) [9].

Effect of Nitrogen: Increasing nitrogen levels significantly increased grain and straw yields. The highest grain yield (2541 kg ha⁻¹) and straw yield (11,096 kg ha⁻¹) were recorded with 100 kg N ha⁻¹ (N_3), which was significantly superior to 60 and 80 kg N ha⁻¹. Nitrogen plays a crucial role in chlorophyll synthesis, photosynthetic activity, and vegetative growth, which enhances dry matter accumulation and translocation of assimilates towards the sink. These findings corroborate the results of Meena *et al*. (2012) [12], Al-Taher *et al*. (2005) [1], and Gautam *et al*. (2020) [6], who also reported significant yield enhancement in sorghum with increasing nitrogen levels.

Effect of Phosphorus: Application of 40 kg P_2O_5 ha⁻¹ (P_2) significantly increased grain yield (2468 kg ha⁻¹) and straw yield (10,727 kg ha⁻¹) over 20 kg P_2O_5 ha⁻¹ (P_1). Phosphorus enhances root development, energy transfer, and reproductive growth, which improves nutrient uptake efficiency and grain formation. These results are in close agreement with those reported by Sumeria *et al*. (2002) [16], Roy and Khandaker (2010) [15], and Getinet and Atinafu (2022) [7].

Interaction effect (N × P): The interaction between nitrogen and phosphorus levels was found significant for grain and straw yields (Table 1.1). The treatment combination of 100 kg N ha⁻¹ + 40 kg P_2O_5 ha⁻¹ (N_3P_2) produced the highest grain yield (2793 kg ha⁻¹) and straw yield (12,083 kg ha⁻¹). The synergistic interaction suggests that adequate phosphorus availability enhances nitrogen use efficiency, resulting in improved vegetative growth, reproductive development, and assimilate partitioning. Similar synergistic effects of N and P on sorghum yield were also reported by Rashid *et al*. (2008) [14], Gautam *et al*. (2020) [6], and Hailu and Kedir (2022) [8].

Harvest index was not significantly influenced by FYM, nitrogen, phosphorus, or their interactions, indicating that increases in grain yield were largely proportional to total biomass production. This trend is in agreement with the findings of Donald and Hamblin (1976) [5] and Tudu *et al*. (2023) [17].

Table 1: Effect of treatments on yield parameters of *kharif* sorghum

Treatments	Grain Yield (kg/ha)	Straw Yield (kg/ha)	Harvest Index
FYM (F)			
F_1: 5 t/ha	2176	9610	18.47
F_2: 10 t/ha	2337	10308	18.49
S.Em ±	48	220	0.37
CD at 5%	141	645	NS
Nitrogen (N)			
N_1: 60 kg/ha	1875	8585	17.95
N_2: 80 kg/ha	2354	10195	18.81
N_3: 100 kg/ha	2541	11096	18.68
S.Em ±	59	269	0.46
CD at 5%	173	791	NS
Phosphorus (P)			
P_1: 20 kg/ha	2045	9190	18.24
P_2: 40 kg/ha	2468	10727	18.72
S.Em ±	48	220	0.37
CD at 5%	141	645	NS
Interaction (F x N)			
S.Em ±	83	381	0.65
CD at 5%	NS	NS	NS
Interaction (F x P)			
S.Em ±	68	311	0.53
CD at 5%	NS	NS	NS
Interaction (N x P)			
S.Em ±	83	381	0.65
CD at 5%	245	1118	NS
Interaction (F x N x P)			
S.Em ±	118	539	0.91
CD at 5%	NS	NS	NS
CV (%)	9.08	9.38	8.57

Table 1.1: Interaction effect (N x P) on yield parameters of *kharif* sorghum

Nitrogen levels	Grain Yield (kg/ha)			Straw Yield (kg/ha)		
Phosphorus levels	N_1	N_2	N_3	N_1	N_2	N_3
P_1	1798	2048	2290	8490	8970	10109
P_2	1951	2660	2793	8680	11419	12083
S.Em ±	83			381		
CD at 5%	245			1118		

Table 2: Effect of treatments on economics of *kharif* sorghum

Treatments	Cost of cultivation (₹/ha)	Gross realization (₹/ha)	Net realization (₹/ha)	B:C ratio
FYM (F)				
F_1: 5 t/ha	53493.33	103731.13	50237.80	1.94
F_2: 10 t/ha	60947.50	111369.67	50422.17	1.83
S.Em ±	-	1892.01	1892.01	0.03
CD at 5%	-	5549.08	NS	0.10
Nitrogen (N)				
N_1: 60 kg/ha	56969.00	90594.57	33625.57	1.59
N_2: 80 kg/ha	57222.25	111412.34	54190.09	1.95
N_3: 100 kg/ha	57470.00	120644.28	63174.28	2.10
S.Em ±	-	2317.23	2317.23	0.04
CD at 5%	-	6796.21	6796.21	0.12
Phosphorus (P)				
P_1: 20 kg/ha	56458.33	98130.90	41672.57	1.74
P_2: 40 kg/ha	57982.50	116969.89	58987.39	2.02
S.Em ±	-	1892.01	1892.01	0.03
CD at 5%	-	5549.08	5549.08	0.10
Interaction (F x N)				
S.Em ±	-	3277.06	3277.06	0.06
CD at 5%	-	NS	NS	NS
Interaction (F x P)				
S.Em ±	-	2675.71	2675.71	0.05
CD at 5%	-	NS	NS	NS
Interaction (N x P)				
S.Em ±	-	3277.06	3277.06	0.06
CD at 5%	-	9611.29	9611.29	0.17
Interaction (F x N x P)				
S.Em ±	-	4634.47	4634.47	0.08
CD at 5%	-	NS	NS	NS
CV (%)	-	7.46	15.95	7.34

Table 2.1: Interaction effect (N x P) on Gross realization and Net realization

Nitrogen levels	Gross realization (₹/ha)			Net realization (₹/ha)		
Phosphorus levels	N_1	N_2	N_3	N_1	N_2	N_3
P_1	87918	97328	109147	31711	40868	52439
P_2	93272	125496	132142	35541	67512	73910
S.Em ±	3277			3277		
CD at 5%	9611			9611		

Table 2.2: Interaction effect (N x P) on B:C ratio

Nitrogen levels	B:C ratio		
Phosphorus levels	N_1	N_2	N_3
P_1	1.57	1.73	1.93
P_2	1.62	2.17	2.28
S.Em ±	0.06		
CD at 5%	0.17		

Economics

Economic analysis of kharif sorghum under different nutrient management treatments is presented in Table 2, with interaction effects shown in Tables 2.1 and 2.2. The cost of cultivation increased with higher levels of FYM and fertilizers; however, higher yields resulted in increased gross and net returns.

Effect of FYM: Application of 10 t FYM ha^{-1} recorded higher gross realization (₹111,369.67 ha^{-1}) compared to 5 t FYM ha^{-1}, though net realization was statistically at par due to the increased cost of FYM application. Consequently, the benefit-cost ratio was higher with 5 t FYM ha^{-1} (1.94), indicating better economic efficiency at lower FYM levels. Similar economic trends with FYM application were reported by Meena and Meena (2012) [12] and Bhunwal *et al*. (2016) [4].

Effect of Nitrogen: Nitrogen application significantly influenced economic returns. The highest gross realization (₹120,644.28 ha^{-1}), net realization (₹63,174.28 ha^{-1}), and benefit-cost ratio (2.10) were recorded with 100 kg N ha^{-1}. Improved profitability at higher nitrogen levels was mainly due to substantial yield gains outweighing the marginal increase in fertilizer cost. These results are in line with the findings of Al-Taher *et al*. (2005) [1], Meena *et al*. (2012) [12], and Amiri *et al*. (2014) [2].

Effect of Phosphorus: Application of 40 kg P_2O_5 ha^{-1} resulted in significantly higher gross (₹116,969.89 ha^{-1}) and net returns (₹58,987.39 ha^{-1}) along with a higher benefit-cost ratio (2.02) compared to 20 kg P_2O_5 ha^{-1}. Enhanced economic returns under higher phosphorus levels can be attributed to improved yield performance and better nutrient use efficiency, as also reported by Arunakumari *et al*. (2021) [3] and Kumar *et al*. (2023) [10].

Interaction effect (N × P): The interaction between nitrogen and phosphorus levels significantly influenced gross and net realization as well as benefit-cost ratio (Tables 2.1 and 2.2). The highest gross (₹132,142 ha^{-1}) and net realization (₹73,910 ha^{-1}) along with the maximum B:C ratio (2.28) were recorded under 100 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}. This clearly demonstrates the economic advantage of balanced N and P fertilization in sorghum. Similar observations were made by Rashid *et al*. (2008) [14], Bhunwal *et al*. (2016) [4], and Hailu and Kedir (2022) [8].

Conclusion

The present investigation clearly demonstrated that integrated nutrient management through combined application of FYM, nitrogen, and phosphorus significantly improved yield and economic returns of kharif sorghum. Application of 10 t FYM ha^{-1} along with 100 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} proved superior in maximizing grain and straw yields as well as gross and net realization. However, the highest benefit-cost ratio was recorded with 5 t FYM ha^{-1} combined with 100 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}, indicating greater economic efficiency under moderate organic input levels. Balanced and integrated use of organic and inorganic nutrient sources thus emerges as a sustainable and profitable nutrient management strategy for sorghum cultivation under middle Gujarat agro-climatic conditions.

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