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Effect of FYM, nitrogen and phosphorus levels on growth and yield attributes of *Kharif* sorghum

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Abstract
A field experiment was done under *Kharif* season 2024 at Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat to establish the effect of FYM, nitrogen and phosphorus levels on *Kharif* sorghum (*Sorghum bicolor* L.). The study involved twelve treatment combinations comprising two FYM levels (F_1: 5t/ha and F_2: 10t/ha), three Nitrogen levels (N_1: 60 kg/ha; N_2: 80 kg/ha and N_3: 100 kg/ha) and two Phosphorus levels (P_1: 20 kg/ha and P_2: 40 kg/ha) laid out in a Factorial Randomized Block Design (FRBD) with three replications. Experimental results revealed that application of farmyard manure (FYM) at 10 t/ha significantly enhanced the growth and yield performance of *Kharif* sorghum compared to the lower dose of 5 t/ha. Key improvements were noted in plant height, dry matter accumulation, and yield components such as panicle length, number of grains per earhead, grain weight per earhead, and test weight, resulting in a higher grain yield (2337 kg/ha) and straw yield (10308 kg/ha). Regarding nitrogen application, a rate of 100 kg N/ha resulted in marked improvements in growth parameters and yield traits, ultimately achieving the highest grain yield (2541 kg/ha) and straw yield (11096 kg/ha). Phosphorus applied at 40 kg/ha also had a significant positive impact on growth parameters, yield components, grain yield (9190 kg/ha), straw yield (10727 kg/ha). Interaction effects between nitrogen and phosphorus were found significant for several parameters such as plant height, dry matter accumulation, number of grains per earhead, grain weight per earhead, grain yield and straw yield. The combination of Nitrogen at 100 kg/ha + P_2O_5 at 40 kg/ha produced significantly the highest grain yield (2793 kg/ha) and straw yield (12083 kg/ha).

Keywords: *Kharif* sorghum, FYM levels, nitrogen levels, phosphorus levels, growth and yield attributes

Introduction

In the Semi-Arid Tropics (SAT) of Africa, Asia, and Latin America, subsistence farmers grow sorghum (*Sorghum bicolor L.*), the fifth most important grain crop in the world, on around 42 million hectares, mostly under rainfed conditions. Its use varies by region; in Asia and Africa, the grain is mostly used for food, but in the US, China, and Australia, it is predominantly farmed for animal feed. Grain collected during the rainy season is typically used for animal and poultry feed in India, while grain harvested during the post-rainy season is favored for human use. Beyond grain, crop residues, or "stover," continue to be an essential resource in places like Africa and India, where they are used as fuel and fodder. Additionally, due of its versatility, rapid growth, ability to produce a large amount of dry and green fodder, tolerance to drought, and potential for rapid regeneration by ratooning, sorghum shows great promise in addressing India's fodder issue. (Anonymous, 2004) [5]. Sorghum is the world's fifth most significant cereal crop, behind rice, wheat, maize, and barley. In 2021-2022, the output of sorghum was projected to be 60.06 million tonnes worldwide. Nigeria leads the world in total production (12%) with 7 million tonnes, followed by the US, Nigeria, Sudan and Mexico (Anonymous, 2022) [8]. India is the fifth-largest producer of sorghum globally, with 4.23 million tonnes produced in 2021-2022 on 3.90 million hectares of land. India produces 57.25% of its sorghum in Maharashtra and Karnataka. The next states that contribute significantly include Madhya Pradesh, Tamil Nadu, Rajasthan and Andhra Pradesh. (Anonymous, 2021-22a) [6]. Gujarat came in ninth place with a productivity of 1345.60 kg/ha and 57537 metric tons of sorghum produced on 42759 hectares

(Anonymous, 2021-22b) [7]. Organic Manure from farms has been used as a fertilizer for a long time. Soil structure and biomass are both enhanced by the addition of FYM (Dauda *et al.*, 2009) [13]. Soil physical qualities can also be enhanced with the use of FYM. This improves the levels of organic carbon, nitrogen, phosphorous, and potassium in the soil as well as the chemical properties of the soil. (Bayu *et al.*, 2006) [10]. In many agricultural regions around the world, nitrogen (N), one of the basic plant nutrients, is frequently the most limiting factor for crop growth. In addition to increasing productivity, effective N management gives farmers significant financial gains. Nitrogen has been the most important fertilizer in increasing the yield of cereal crops, particularly sorghum, when compared to other fertilizers. N is therefore regarded as the most crucial input in contemporary intensive agricultural systems in terms of both cost and energy consumption (Yousf, 1993) [36]. Nitrogen is especially important in sorghum agriculture because it directly affects yield and quality by improving a number of yield-determining factors that greatly impact grain production. (Bayu, 2004) [10]. Second only to nitrogen as the most limiting factor in crop yield, phosphorus (P) is an essential macronutrient needed for healthy plant growth and development (Xie *et al.*, 2019) [35]. Phosphorus fertilizer has a major impact on agriculture since it raises crop yields and improves feed quality. In terms of biochemistry, phosphorus is an essential component of nucleic acids and is involved in cellular respiration as well as other metabolic activities. It takes involved in a number of enzymatic processes, such as sugar metabolism, CO_2 fixation, and plant energy storage and transmission mechanisms. Thus, effective phosphorus management and use can significantly raise production per hectare (Ros *et al.*, 2020) [27].

Materials and Methods: A field trial was carried out during the *Kharif* season of 2024 at the Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, situated at 22.54° N latitude, 72.98° E longitude, and 45 m above mean sea level. The location is in the Agro-Climatic Zone (AES-III) of Middle Gujarat. The experimental field possessed a homogenous surface with a modest slope ensuring proper drainage. Soil samples were randomly taken for analysis from a depth of 0 to 15 cm prior to sowing. With an electrical conductivity of 0.15 dS/m and a mildly alkaline reaction (pH 8.35), the soil was categorized as loamy sand. Its available nutritional status was 203.84 kg N/ha, 29.55 kilogram P_2O_5/ha, and 238.23 kg K_2O/ha, and it contained 0.36% organic carbon. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising two FYM levels (F_1: 5t/ha and F_2: 10t/ha), three Nitrogen levels (N_1: 60 kg/ha; N_2: 80 kg/ha and N_3: 100 kg/ha) and two Phosphorus levels (P_1: 20 kg/ha and P_2: 40 kg/ha). FYM incorporated in soil before one week of sowing, Nitrogen applied in two splits (50% as basal and 50% as top dressing at 30 DAS) was applied through urea and Phosphorus applied as a basal dose through SSP. The seeds of *Kharif* sorghum were sown by seed drill in previously opened furrows at the distance of 45 cm between the rows @ 15 kg/ha. After sowing seeds were covered with a thin layer of soil to avoid damage by birds in all the treatments. Weed management was carried out through spray of atrazine 50% WP, two timely hand weeding and with the help of wheel hoe which effectively removed broad-leaf and grassy weeds from the crop rows. The first irrigation was applied right before planting, and further irrigations were applied as needed by the crop. The crop was harvested when it reached the physiological maturity stage. Growth attributes like plant height in cm at 30, 60 DAS and at harvest and dry matter accumulation in g/plant at 30, 60 DAS and at harvest were recorded from five tagged plants in each net plot. Yield attributes like Panicle lengh (cm), No. of grains per earhead, grain weight per earhead (g) were recorded from five tagged plants in each net plot and test weight (g) recorded from composite grain sample from each net plot. Grain and Straw yield measured in kg/ha from each net plots after harvest.

Statistical Analysis

Statistical analysis was performed on the data for growth, yield, and quality, among other factors, using computer software made for Randomized Block Design trials. Using the approach described by Cochran and Cox (1967) [12], the Department of Agricultural Statistics at B.A. College of Agriculture, AAU, Anand, conducted this analysis. The "F-test" was used to assess the variances from the various sources of variation in the analysis of variance (ANOVA), and at a 5% significance level, the results were compared with the critical value from the F-table. Standard error (S. Em.±) and least significant difference (LSD) at 5% are included in the "experimental results" chapter.

Table 1: Treatment Details

Treatment no.	Symbol	Treatment details
T_1	$F_1N_1P_1$	FYM at 5 t/ha + Nitrogen at 60 kg/ha + Phosphorus at 20 kg/ha
T_2	$F_1N_1P_2$	FYM at 5 t/ha + Nitrogen at 60 kg/ha + Phosphorus at 40 kg/ha
T_3	$F_1N_2P_1$	FYM at 5 t/ha + Nitrogen at 80 kg/ha + Phosphorus at 20 kg/ha
T_4	$F_1N_2P_2$	FYM at 5 t/ha + Nitrogen at 80 kg/ha + Phosphorus at 40 kg/ha
T_5	$F_1N_3P_1$	FYM at 5 t/ha + Nitrogen at 100 kg/ha + Phosphorus at 20 kg/ha
T_6	$F_1N_3P_2$	FYM at 5 t/ha + Nitrogen at 100 kg/ha + Phosphorus at 40 kg/ha
T_7	$F_2N_1P_1$	FYM at 10 t/ha + Nitrogen at 60 kg/ha + Phosphorus at 20 kg/ha
T_8	$F_2N_1P_2$	FYM at 10 t/ha + Nitrogen at 60 kg/ha + Phosphorus at 40 kg/ha
T_9	$F_2N_2P_1$	FYM at 10 t/ha + Nitrogen at 80 kg/ha + Phosphorus at 20 kg/ha
T_{10}	$F_2N_2P_2$	FYM at 10 t/ha + Nitrogen at 80 kg/ha + Phosphorus at 40 kg/ha
T_{11}	$F_2N_3P_1$	FYM at 10 t/ha + Nitrogen at 100 kg/ha + Phosphorus at 20 kg/ha
T_{12}	$F_2N_3P_2$	FYM at 10 t/ha + Nitrogen at 100 kg/ha + Phosphorus at 40 kg/ha

Results and Discussion

Further, the results are discussed in relation to findings of earlier research studies, thereby validating the experimental data. Each section under this chapter provides insight into the individual and combined effects of FYM, nitrogen, and phosphorus on the sorghum crop as below.

Effect of FYM

Growth Attributes: Data presented in Table 2, revealed that FYM levels didn't excerted influence on plant height at 30 and 60 DAS but significantly affected the plant height at harvest. Treatment F_2 (10 t FYM/ha) was recorded significantly higher plant height at harvest 180.56 cm. These improvements create a favourable root environment, encouraging better nutrient absorption and root proliferation. Moreover, FYM stimulates microbial activity and enzymatic processes that aid in the mineralization of nutrients, which support vigorous vegetative growth. Increased nutrient availability, especially of nitrogen in organic form, contributes to higher chlorophyll content, improved photosynthetic efficiency, and greater internodal elongation. These cumulative effects lead to improved plant architecture and stature during both active vegetative and later growth stages. Similar impacts of FYM on plant height have also been documented by Kushwaha *et al.* (2014), Patidar and Mali (2004), Singh and Chauhan (2021) [20, 24, 29].

While data presented in Table 2, indicated that at 30 and 60 DAS FYM levels didn't excerted any effect but significantly higher dry matter accumulation at harvest was observed in treatment F_2 (10 t FYM/ha) recorded higher dry matter accumulation at harvest (109.73 g/plant). Higher photosynthetic activity was probably caused by the leaves' higher chlorophyll content and enhanced leaf area index (LAI), which in turn raised the accumulation of photosynthates and total dry matter with FYM application.. These results are agreed with findings of Patidar and Mali (2004), Meena and Meena (2012) and Kushwaha *et al.* (2014) [20, 22, 24].

Yield Attributes and Yield

Table 3 data revealed that application of F_2 (10 t FYM/ha) significantly improved yield attributes such as panicle length (28.87 cm), number of grains per earhead (1062), and grain weight per earhead (22.43 g). Consequently, it also recorded higher grain yield (2337 kg/ha) and straw yield (10308 kg/ha) compared to F_1 (5 t FYM/ha). FYM also facilitates gradual nutrient release, particularly nitrogen and phosphorus, thereby ensuring sustained availability of essential nutrients during critical reproductive stages. Additionally, the enhanced root proliferation and moisture retention due to FYM likely contributed to improved nutrient uptake and assimilation, resulting in better grain and straw development. These results are in close agreement with the results reported by Patidar and Mali (2004), Kushwaha *et al.* (2014), and Jat *et al.* (2013) [19, 20, 24].

Effect of Nitrogen

Growth Attributes

Nitrogen levels significantly affected plant height and dry matter accumulation at 60 DAS and harvest, according to Table 2 mean data. Application of N_3 (100 kg N/ha) produced the significantly higher plants at 60 DAS (168.33 cm) and (188.79 cm) at harvest, which was at par with N_2 (80 kg N/ha). Plant height increased with increasing nitrogen dosage at 60 DAS and at harvest stage, most likely as a result of improved cell division and elongation, which increased the number of internodes and length of internodes. These results are agreed with findings of Meena *et al.* (2012), Abera *et al* (2020), Gautam *et al.* (2020) [1, 14] and Meena and Meena (2012) [22]. Also revealed that nitrogen levels had found significant dry matter accumulation at 60 DAS and at harvest. Significantly recorded higher dry matter accumulation recorded with treatment N_3 (100 kg N/ha) at 60 DAS (48.65 g/plant) and at harvest (117.60 g/plant) which was at par with N_2 (80 kg N/ha). The consistent increase in dry matter production with increasing nitrogen levels reflects the role of nitrogen in supporting prolonged vegetative growth, efficient assimilation, and partitioning of biomass throughout the crop growth cycle. Similar findings were reported by Meena *et al.* (2012), Patil *et al.* (2011), Teja *et al.* (2021), Vaja *et al.* (2023) [22, 25, 32, 34].

Yield Attributes and Yield

Data presented in Table 3 revealed that Nitrogen levels significantly influenced all yield attributes and yield parameters. The application of N_3 (100 kg N/ha) resulted in maximum panicle length (30.72 cm) followed by N_2 (80 kg N/ha), number of grains per earhead (1109), grain weight per earhead (23.56 g), test weight (22.53 g) were at par with N_2 (80 kg N/ha) and highest grain yield (2541 kg/ha) and straw yield (11096 kg/ha) recorded with application of N_3 (100 kg N/ha). The improvement in yield attributes with higher nitrogen levels may be ascribed to enhanced photosynthetic activity, greater nutrient uptake, and vigorous vegetative growth, which collectively contribute to increased assimilate production and translocation to the developing grains. Moreover, adequate nitrogen promotes better spikelet fertility and grain filling, ultimately resulting in increased grain and straw yield. These findings are in agreement with those of Al-Taher *et al.* (2005), Hugar *et al.* (2010) and Malam and Solanki (2022) [3, 17, 21].

Effect of Phosphorus

Growth Attributes: Data presented in Table 2, showed that phosphorus application significantly enhanced plant height and dry matter accumulation at 60 DAS and at harvest. At 60 DAS and at harvest, plants treated with treatment P_2 (40 kg P_2O_5/ha) recorded significantly higher height of 167.40 cm and 186.40 cm respectively. Phosphorus plays a crucial role in supporting strong root development, effective nutrient uptake, and essential physiological processes, all of which contribute to better vegetative performance. Similar findings were reported by Ahmad *et al* (2003), Al-Taher *et al.* (2005) [3] and Gautam *et al.* (2020) [2, 14]. Application of P_2 (40 kg P_2O_5/ha) also recorded significantly higher dry matter accumulation of 47.17 g/plant and 113.58 g/plant respectively than P_1 (20 kg P_2O_5/ha). This continuous increase throughout the crop duration under higher phosphorus levels suggests its essential contribution to structural growth, enzymatic function, and effective translocation of photosynthates, ultimately leading to greater dry matter accumulation. Similar findings were also reported by Sumeria *et al.* (2002), Roy and Khandaker (2010), and Gautam *et al.* (2020) [14, 28, 30].

Yield Attributes and Yield: Data shown in Table 3, revealed that phosphorus levels significantly influenced yield traits and yield of sorghum. Application of P_2 (40 kg P_2O_5/ha) produced longer panicles (29.50 cm), higher grain count (1071), and higher grain weight per earhead (23.00 g), leading to higher grain yield (2468 kg/ha) and straw yield (10727 kg/ha) than lower level P_1 (20 kg P_2O_5/ha). Phosphorus is known to play a vital role in cell division and the formation of reproductive structures, which supports the elongation of panicles. Phosphorus facilitates early flowering, enhances pollination success, and strengthens the grain setting process, thereby contributing to a higher number of grains per panicle. Adequate phosphorus ensures improved reproductive efficiency and enhances the translocation of photosynthates to the developing grains, thereby contributing to higher grain weight leading to higher yield. These results are in line with the findings of Sumeria *et al.* (2002), Gautam *et al.* (2020), Gojariya *et al.* (2021) and Getinet and Afinasu (2022) [14, 15, 30].

N * P Interaction Effect

Growth Attributes: At 60 DAS and at harvest, the interaction effect between nitrogen and phosphorus levels found significant. The data presented in Table 2.1 revealed that highest plant height at 60 DAS (179.84 cm) and at harvest (206.13 cm) recorded with treatment combination 100 kg N/ha + 40 kg P/ha which was found to be at par with treatment combination 80 kg N/ha + 40 kg P/ha. The significant interaction between nitrogen and phosphorus levels on plant height at 60 DAS and at harvest can be attributed to the synergistic effect of these nutrients on vegetative growth, as nitrogen enhances cell elongation and phosphorus supports root development and nutrient uptake; these results are in agreement with the findings of Gautam *et al.* (2020), Tudu *et al.* (2023), and Surve *et al.* (2020) [14, 31, 33].

At 60 DAS, the interaction between nitrogen and phosphorus was found significant as per Table 2.2, indicating a synergistic effect during the active vegetative growth stage. The maximum dry matter accumulation (52.58 g/plant) was recorded with treatment 100 kg N/ha + 40 kg P/ha which was statistically comparable with 80 kg N/ha + 40 kg P/ha (49.32 g/plant) over rest of combinations. The interaction of nitrogen and phosphorus continued to show significant differences in dry matter accumulation at harvest stage. The treatment combination 100 kg N/ha + 40 kg P/ha (127.53 g/plant) recorded the highest dry matter accumulation which was on par with 80 kg N/ha + 40 kg P/ha (121.29 g/plant), significantly superior over all other combinations, while the lowest was recorded in 60 kg N/ha + 20 kg P/ha (89.39 g/plant). This indicates that prolonged and adequate supply of nitrogen and phosphorus throughout the crop period results in increased biomass due to enhanced photosynthetic activity and nutrient assimilation. These results corroborate the findings of Gautam *et al.* (2020), Bhunwal *et al.* (2016), Bayu *et al.* (2006) [10, 11, 14].

Yield Attributes and Yield

No. of Grains per Earhead

The interaction effect between nitrogen and phosphorus levels on the number of grains per earhead was observed significant as per data presented in Table 3.1, indicating a strong synergistic influence of these nutrients on spikelet fertility and grain setting. Among the treatment combinations, 100 kg N/ha + 40 kg P_2O_5/ha recorded the maximum number of grains per earhead (1143), on par with 80 kg N/ha + 40 kg P_2O_5/ha (1133) and 100 kg N/ha + 20 kg P_2O_5/ha (1076), whereas the lowest grain count (936) was noted in 60 kg N/ha + 20 kg P_2O_5/ha. The improved performance with higher nitrogen and phosphorus levels can be attributed to their critical roles during the reproductive phase. Nitrogen facilitates better flowering synchronization, enhances pollen viability, and supports floret fertility, leading to more successful pollination and grain set. Adequate nitrogen supply prevents floret abortion, ensuring the survival of more spikelets. Phosphorus, meanwhile, enhances root activity and energy metabolism (via ATP), promoting early reproductive development and strengthening spikelet support structures. These findings are in close agreement with Rashid *et al.* (2008), Meena *et al.* (2012) and Gautam *et al.* (2020) [14, 22, 26].

Grain Weight per Earhead

The perusal of mean data of Table 3.1 indicate that combined effects of different levels of nitrogen, and phosphorus were found significant with respect to grain weight per earhead in *Kharif* sorghum. Among the treatments, the highest grain weight per earhead was recorded in 100 kg N/ha + 40 kg P_2O_5/ha (25.01 g), which was significantly superior to all other combinations except 80 kg N/ha + 40 kg P_2O_5/ha (24.33 g) which was remained at par. The lowest grain weight (19.42 g) was observed under 60 kg N/ha + 20 kg P_2O_5/ha, significantly inferior to the higher-level combinations. These results suggest that adequate nitrogen enhances assimilate supply and grain sink strength, leading to better grain development, while phosphorus improves energy availability and root efficiency, supporting better grain filling. The significant increase under 100 kg N/ha + 40 kg P_2O_5/ha reflects the combined effect of both nutrients on panicle productivity and grain maturation. The present findings are in close agreement with Amiri *et al.* (2014), Gautam *et al.* (2020), Hailu and Kedir (2022) [4, 14, 16].

Grain Yield

The mean data of Table 3.2 revealed that interaction between nitrogen and phosphorus levels had a significant effect on grain yield of sorghum. The highest grain yield (2793 kg/ha) was recorded with the combined application of 100 kg N/ha + 40 kg P_2O_5/ha, which was statistically at par with 80 kg N/ha + 40 kg P_2O_5/ha (2660 kg/ha). At each nitrogen level, increasing the phosphorus dose from 20 to 40 kg P_2O_5/ha led to a notable improvement in grain yield. Likewise, within each phosphorus level, higher nitrogen application consistently enhanced grain yield. The lowest yield (1798 kg/ha) was observed under 60 kg N/ha + 20 kg P_2O_5/ha, which was significantly lower than all other treatments. The positive interaction between nitrogen and phosphorus can be attributed to their complementary roles: nitrogen promotes vigorous vegetative growth and enhances grain filling, while phosphorus facilitates early root development, energy transfer, and reproductive success. Their combined application ensures better nutrient uptake and translocation, leading to higher grain productivity. These findings align with those of Jodhao *et al.* (2019), Gautam *et al.* (2020) and Hailu and Kedir (2022) [14, 16, 18].

Straw Yield

The average values presented in Table 3.2 revealed that the interaction between nitrogen and phosphorus levels exerted a statistically significant influence on straw yield of *Kharif* sorghum. Among the different treatment combinations, the application of 100 kg N/ha with 40 kg P_2O_5/ha resulted in the maximum straw yield of (12083 kg/ha), which was statistically comparable to the yield observed under 80 kg N/ha + 40 kg P_2O_5/ha which recorded (11419 kg/ha). These combinations significantly outperformed the remaining treatments, confirming the beneficial effect of nitrogen and phosphorus. A progressive improvement in straw yield was evident with the increase in phosphorus dosage from 20 to 40 kg P_2O_5/ha at each nitrogen level. Similarly, higher nitrogen levels consistently promoted straw biomass across both phosphorus rates. The lowest straw yield (8490 kg/ha) was recorded under 60 kg N/ha + 20 kg P_2O_5/ha, indicating that inadequate nutrient supply limited biomass production. The synergistic impact of nitrogen and phosphorus likely contributed to enhanced plant growth, greater dry matter production, and improved nutrient uptake. Nitrogen encourages vigorous vegetative growth and photosynthetic activity, while phosphorus supports root development and energy metabolism together contributing to higher straw accumulation. These findings are consistent with the results of and Jat *et al.* (2013), Gautam *et al.* (2020) and Hailu and Kedir (2022) [14, 16, 19].

Table 2: Periodical plant height and Dry matter accumulation per plant as influenced by different FYM, Nitrogen and Phosphorus levels.

Treatments	Plant height (cm)			Dry matter accumulation (g/plant)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
FYM (F)						
F_1: 5 t/ha	70.08	157.55	171.15	8.67	43.00	102.32
F_2: 10 t/ha	71.53	161.58	180.56	8.93	45.22	109.73
S.Em ±	1.43	2.69	3.14	0.15	0.89	2.02
CD at 5%	NS	NS	9.20	NS	NS	5.93
Nitrogen (N)						
N_1: 60 kg/ha	67.40	147.90	158.95	8.42	38.58	90.66
N_2: 80 kg/ha	71.43	162.46	179.83	8.92	45.10	109.83
N_3: 100 kg/ha	73.60	168.33	188.79	9.07	48.65	117.60
S.Em ±	1.75	3.29	3.84	0.18	1.08	2.48
CD at 5%	NS	9.65	11.27	NS	3.18	7.27
Phosphorus (P)						
P_1: 20 kg/ha	69.70	151.72	165.31	8.60	41.05	98.47
P_2: 40 kg/ha	71.91	167.40	186.40	9.01	47.17	113.58
S.Em ±	1.43	2.69	3.14	0.15	0.89	2.02
CD at 5%	NS	7.88	9.20	NS	2.60	5.93
Interaction (F x N)						
S.Em ±	2.48	4.65	5.43	0.26	1.53	3.50
CD at 5%	NS	NS	NS	NS	NS	NS
Interaction (F x P)						
S.Em ±	2.02	3.80	4.44	0.21	1.25	2.86
CD at 5%	NS	NS	NS	NS	NS	NS
Interaction (N x P)						
S.Em ±	2.48	4.65	5.43	0.26	1.53	3.50
CD at 5%	NS	13.64	15.94	NS	4.50	10.28
Interaction (F x N x P)						
S.Em ±	3.51	6.58	7.68	0.36	2.17	4.95
CD at 5%	NS	NS	NS	NS	NS	NS
CV (%)	8.58	7.14	7.57	7.16	8.52	8.09

Table 2.1: Interaction effect (N x P) on plant height at 60 DAS and at harvest

Nitrogen levels Phosphorus levels	60 DAS			At harvest		
	N_1	N_2	N_3	N_1	N_2	N_3
P_1	147.23	151.12	156.82	157.29	167.21	171.45
P_2	148.57	173.80	179.84	160.62	192.45	206.13
S.Em ±	4.65			5.43		
CD at 5%	13.64			15.93		

Table 2.2: Interaction effect (N x P) on dry matter accumulation at 60 DAS and at harvest

Nitrogen levels Phosphorus levels	60 DAS			At harvest		
	N_1	N_2	N_3	N_1	N_2	N_3
P_1	37.94	40.87	44.32	89.39	98.36	107.66
P_2	39.21	49.32	52.98	91.92	121.29	127.53
S.Em ±	1.53			3.50		
CD at 5%	4.50			10.28		

Table 3.1: Interaction effect (N x P) on yield attributes of *Kharif* sorghum

Nitrogen levels Phosphorus levels	No. of Grain/Earhead			Grain weight/Earhead		
	N_1	N_2	N_3	N_1	N_2	N_3
P_1	936	946	1076	19.42	20.01	22.11
P_2	938	1133	1143	19.67	24.33	25.01
S.Em ±	36			0.75		
CD at 5%	105			2.19		

Table 3.2: Interaction effect (N x P) on grain and straw yield of *Kharif* sorghum

Nitrogen levels Phosphorus levels	Grain Yield (kg/ha)			Straw Yield (kg/ha)		
	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		

Conclusion

Based on the findings, it can be concluded that under limited availability of farmyard manure (FYM), application at 5 t/ha is beneficial. When FYM is readily available, applying 10 t/ha along with 80 kg/ha nitrogen and 40 kg/ha phosphorus significantly enhances the growth, yield, and profitability of *Kharif* sorghum, while improving soil organic matter, microbial activity, and overall soil fertility. In the absence of FYM, the application of nitrogen and phosphorus alone at the same rates can still support sustainable production, though with comparatively lesser benefits to long-term soil health.

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Competing interests

The authors declare that there is no conflict of interest related to this article.

Author's contributions

- **V. M. Parmar:** Conceptualization, Methodology, data collection, Analysis, Writing, editing.
- **Dr. G. L. kadam:** Conceptualization, discussion, Review and editing, Supervision.
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