Journal of
Advances in Agronomy and Crop Science

Research Article Open Access

Effect of Integrated Nutrient Management on Growth, Yield, Yield Attributes and Economy of *Kharif* Sorghum (*Sorghum bicolour* L.) in South-East Region of Rajasthan

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Received Date: June 03, 2024 **Accepted Date:** July 03, 2024 **Published Date:** July 06, 2024

Citation: Vinod Balai, Vinod Kumar Yadav, Rajendra Kumar Yadav, Mukesh Bhagat, Utkarsh Goyal, et al. (2024) Effect of Integrated Nutrient Management on Growth, Yield, Yield Attributes and Economy of Kharif Sorghum (Sorghum bicolour L.) in South-East Region of Rajasthan. J Adv Agron Crop Sci 3: 1-9

Abstract

A field experiment entitled "**Effect of integrated nutrient management on productivity of sorghum and soil health**" was conducted during *Kharif*, 2023 at Instructional Farm, COA, Ummedganj-Kota.With the objective to study the effect of integrated nutrient management on Growth, yields attributes and yield, effect of INM on nutrient content, uptake and quality of sorghum and to asses effect of INM on physico-chemical and biological properties of soil. The soil of the experimental site was clay loam in texture and slightly alkaline in reaction, low in available nitrogen, medium in phosphorus and high in potassium.

The experiment consisted of 8 treatments comprising inorganic fertilizers, organic manures and biofertilizers *viz.*,T_1-Control, T_2-100% Inorganic, T_3-75% Inorganic + 25% organic, T_4-75% Inorganic + biofertilizers, T_5-50% Inorganic + 50% organic, T_6-75% Organic + 25% inorganic, T_7-75% Inorganic + biofertilizer, T_8-100% Organic, respectively. These treatments were evaluated under randomized block design (RBD) with 3 replications and sorghum CSH-5 variety grown as test. The results indicated that application of 75% Inorganic + 25% organic (T_3) showed the superior results in terms of growth (plant height, leaf area index, dry matter plant g^{-1} and chlorophyll content), yield attributes (number of seed penicle^{-1} and test weight), yields (grain, straw and biological) and economy (net return and B: C ratio) of sorghum which was statically at par with 100%Inorganic (T_2) and 50% Inorganic + 50% organic (T_5).

Keywords: Inorganic; Organic; Biofertilizers; Growth; Yield and Economics

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Introduction

Sorghum [*Sorghum bicolor* (L.) Moench], commonly referred to as "king of millets," is a versatile crop utilized for food, fodder, and feed for humans, cattle and poultry. In India, it is known as "Jowar." The seeds of sorghum are composed of approximately 70% carbohydrates, 10-12% protein and 3% fat. Globally, sorghum ranks as the fourth most significant cereal crop, following rice, wheat, and corn. Globally sorghum occupied 40.16 million hectares area, 58.02 million metric tons production and 1440 kg ha^{-1} productivity [1]. In India, sorghum is cultivated over an area of 4,355 thousand hectares, producing 4,632 thousand tones with a productivity rate of 1064 kg ha^{-1} [2].

In Rajasthan, sorghum is cultivated over an area of approximately 0.62 million hectares, yielding an annual production of 0.54 metric tons and a productivity of 1,055 kg ha^{-1} [3] and total share of Rajasthan 16.28% in area and 12.67% in production of India. Sorghum is widely grown across various regions of India, including Maharashtra, Karnataka, Rajasthan, Madhya Pradesh, Andhra Pradesh, and Punjab. In Maharashtra, it is cultivated during the kharif season in the Vidarbha region and parts of Marathwada. Additionally, it is grown during the rabi season in Western Maharashtra and the Marathwada region. Recently, there has been a noticeable decline in the consumption of sorghum seeds as a staple food due to changes in dietary habits and the economic status of the rural population. However, due to its high potential, adaptability to various environmental conditions, and superior nutritional quality, the use of sorghum for cattle feed and fodder is on the rise.

The exclusive use of organic manures as a substitute for inorganic fertilizers is neither profitable nor adequate to sustain the current productivity levels of high-yielding crop varieties. However, the combined application of organic manures, farmyard manure (FYM) and inorganic fertilizers increases system productivity and maintains soil health over an extended period [4].

Among various agronomic practices influencing crop production, the judicious and effective use of fertilizers is widely recognized as crucial for achieving potential and targeted crop yields. However, the adverse effects of chemical fertilizers on soil health, coupled with energy crises, high input costs, and the economic challenges faced by small and marginal farmers, limit the widespread adoption of these essential inputs. Thus, there is a growing emphasis on exploring sustainable and balanced approaches to nutrient management that mitigate these challenges while promoting agricultural productivity and environmental health [5].

Hence, it is imperative to devise a strategy for the integrated utilization of organic materials alongside fertilizers to their fullest potential, employing appropriate technologies to enhance crop productivity. Among the essential nutrients, nitrogen is universally deficient in Indian soils. Nitrogen is vital for chlorophyll formation, imparting a dark green colour to plants, and is integral to amino acids. It plays a critical role in the synthesis of proteins and overall plant growth [6]. Tillering and regeneration after defoliation are processes that promote shoot growth and significantly enhance the utilization of phosphorus, potassium, and other nutrients in plants. Sorghum, compared to other fodder crops, tends to exhaust nutrients more rapidly. Being a cereal crop, sorghum requires substantial amounts of nutrients to support optimal production [7].

Organic materials serve as natural sources of slow-release nutrients, making their inclusion in nutrient management essential. Materials such as farmyard manure (FYM), poultry manure, and vermicompost have become crucial for improving soil fertility status and promoting sustainable productivity [8]. These organic amendments contribute to enriching the soil with essential nutrients over time, supporting healthier plant growth and overall agricultural sustainability. Incorporating organic matter into soil enhances microbial activities, which are crucial for nutrient transformation, recycling, and making nutrients available to crops. This process is vital for optimizing crop growth [9]. Additionally, organic matter improves soil physical properties such as structure and porosity, reducing crusting and compaction. It also enhances the soil's water intake capacity, which is beneficial for plant health and overall productivity [10]. These benefits underscore the importance of organic matter in maintaining soil fertility and supporting sustainable agriculture practices.

Therefore, it is crucial to educate farmers about the profitability of integrated nutrient management in kharif sorghum cultivation. With this in mind, the present study aims to achieve the following objectives:-

- To effect of integrated nutrient management on growth, yield attributes and yield of sorghum.
- To work out the economics of sorghum under Integrated Nutrient Management (INM)

Materials and Method

The experiment was conducted at Instructional Farm, College of Agriculture, Ummedganj-Kota (Rajasthan) during *Kharif* season, 2023. According to Agro-ecological region map brought out by National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Kota falls in Agro-ecological region No.06. Geographically, College of Agriculture, Ummedganj-Kota is situated at South-Eastern part of Rajasthan at 75°.25' E longitude, 25°.13' N latitude and an altitude of 258 meter above mean sea level. In Rajasthan, this region falls under the Agro-Climatic Zone-V (Humid South Eastern Plain Zone). The experiment consisted of 8 treatments comprising inorganic fertilizers, organic manures and biofertilizers *viz.,* T_1-Control, T_2-100% Inorganic, T_3-75% Inorganic + 25% organic, T_4-75% Inorganic + biofertilizers, T_5-50% Inorganic + 50% organic, T_6-75% Organic + 25% inorganic, T_7-75% Inorganic + biofertilizer and T_8-100% Organic, respectively. In the inorganic sources of nutrient *i.e.* Nitrogen, phosphorus, potassium and Zinc was supplied by urea, SSP, MOP and $ZnSO_4$ respectively, in organic sources of nutrient was supplied by FYM and vermicompost on nitrogen equivalent bases. These treatments were evaluated under randomized block design (RBD) with 3 replications and sorghum CSH-5 variety grown as test.

The perusal of data Table 1.1 indicates that during the crop season total rainfall was 498.4 mm in 29 rainy days with maximum and minimum rainfall, ranged from 109.5 mm to 0.0 mm. The maximum temperature ranged from 31.5°C to 36.6°C was observed in 38th and 41th standard meteorological week, respectively, and the minimum temperature ranged from 21.6°C to 26.3°C was observed in 29th and 35th standard meteorological week, respectively. The maximum RH_{Mor} and RH_{Eve} of 88.4 per cent and 83.3 per cent both was recorded in 30th standard meteorological week. While the minimum RH_{Mor} and RH_{Eve} was recorded in 27th and 40th standard meteorological week (74.7 per cent and 55.0 per cent, respectively).

The texture of soil was clay loam and reaction of the soil was slightly alkaline (pH 7.61 to 7.54), available nitrogen was low (181.64 and 235.25 kg ha^{-1}), available phosphorus was medium (16.79 and 26.13 kg ha^{-1}) and available potassium high (370.69 and 433.38 kg ha^{-1})

Results and Discussion

Growth parameter

The results showed in Table 1.2 and 1.3, that maximum growth attributing parameters *i.e.* plant height (137.61, 238.18 and 247.20cm), leaf area index (3.27, 5.02 and 5.76 %) at 30, 60 DAS and at harvest and plant dry matter (51.91 and 130.81 g $plant^{-1}$), Chlorophyll content (1.93 and 3.09 mg g^{-1}) at 30 and 60 DAS respectively with the application 75% Inorganic + 25% organic, it was statically at par on 100% Inorganic and 50% Inorganic + 50% organic sources of nutrient management.

The increase in growth parameters is evidently due to the integrated nutrient management system, which ensures an early supply of primary nutrients from inorganic sources and a later supply from organic manure such as vermicompost and FYM. These organic sources provide primary and also secondary elements like calcium, magnesium, and sulphur but also significant amounts of micronutrients. The nutrients are absorbed by the plant through the cuticle or stomata, potentially enhancing photosynthesis and regulating other metabolic processes, leading to improved plant growth [6]. Additionally, the use of Vermicompost and FYM improves the soil cations exchange capacity, water holding capacity and phosphate availability. This balanced nutrition, facilitated by the release of macro and micronutrients in a favourable environment, enhances nutrient uptake. Consequently, this promotes the growth of new tissues and shoots, ultimately increasing plant height and dry matter accumulation. These findings are consistent with those of [11-15].

Table 1.1: Mean standard week-wise meteorological parameters during experimental crop season (*Kharif*, 2023)

Date	SMW	T_{Max} (^{0}C)	T_{Min} (^{0}C)	RH_{Mor}	$RH_{Eve.}$	BSS (hr)	Rain (mm)	Evap. (mm)	Rainy days
02 Jul –08 Jul	27	31.8	23.4	74.7	64.8	6.9	109.5	5.3	4
09 Jul – 15 Jul	28	36.2	21.7	85.7	72.9	7.1	23.0	3.5	2
16 Jul – 22 Jul	29	35.3	21.6	76.6	74.7	6.7	90	5.2	4
23 Jul – 29 Jul	30	34.7	21.9	88.4	83.3	7.4	101.5	9.8	5
30 Jul – 05 Aug	31	33.8	24.9	85.6	81.4	4.4	27.5	7.4	1
06 Aug – 12 Aug	32	33.0	25.4	86.0	76.7	3.7	00	5.5	0
13 Aug – 19 Aug	33	33.1	25.3	88.0	72.6	4.3	12.7	6.9	2
20 Aug – 26 Aug	34	33.1	25.1	83.7	74.1	4.0	9.0	5.5	2
27 Aug – 02 Sep	35	35.0	26.3	79.0	67.9	5.5	00	7.7	0
03 Sep – 09 Sep	36	35.1	26.1	81.7	75	5.9	26.3	7.8	3
10 Sep – 16 Sep	37	32.6	25.4	83.3	76.9	3.9	87.9	5.1	4
17 Sep – 23 Sep	38	31.5	24.4	85.0	73.2	4.1	11.0	4.5	2
24 Sep – 30 Sep	39	34.2	25.7	79.0	63.1	8.2	00	5.1	0
01 Oct – 07 Oct	40	36.0	22.3	82.7	55.0	8.7	00	4.2	0
08 Oct – 14 Oct	41	36.6	22.7	86.0	57.3	9.1	00	5.2	0
Total							**498.4**		**29**

Table 1.2: Effect of integrated nutrient management on plant population, plant height and plant dry matter at different stages of sorghum

Treatments	Plant population(No of plant m^{-1} row length)		Plant height (cm)			Plant dry matter (g)	
	30 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS
T_1: Control	6.27	6.18	86.84	158.25	170.53	28.86	74.45
T_2: 100% Inorganic.	7.33	7.00	131.50	223.03	235.05	49.22	124.13
T_3: 75% Inorganic + 25% Organic.	**7.33**	**7.00**	**137.61**	**238.18**	**247.20**	**51.91**	**130.81**
T_4: 75% Inorganic + Biofertilizer.	6.67	6.50	121.80	211.35	222.36	40.32	115.95
T_5: 50% Inorganic + 50% Organic.	7.33	7.00	128.96	218.76	229.79	46.27	119.48
T_6: 25% Inorganic + 75% Organic.	6.67	6.49	120.77	207.37	219.39	38.85	114.79
T_7: 75% Organic + Biofertilizer	6.47	6.30	114.60	197.31	213.34	35.90	107.47

T_8: 100% Organic	7.00	6.43	118.69	205.87	218.88	38.30	113.12
SEm±	**0.32**	**0.41**	**5.12**	**8.31**	**7.94**	**1.94**	**4.59**
CD at 5 %	**NS**	**NS**	**15.52**	**25.21**	**24.09**	**5.88**	**13.91**

Table 1.3: Effect of integrated nutrient management on leaf area index and chlorophyll content at different stages of sorghum

Treatments	Leaf area index (%)			Chlorophyll content (mg g-1)	
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS
T1 : Control	2.45	3.35	3.52	1.27	1.82
T2 : 100% Inorganic.	3.19	4.77	5.41	1.88	3.00
T3 : 75% Inorganic + 25% Organic.	3.27	5.02	5.76	1.93	3.09
T4 : 75% Inorganic + Biofertilizer.	2.90	4.39	5.09	1.80	2.81
T5 : 50% Inorganic + 50% Organic.	3.06	4.63	5.36	1.84	2.97
T6 : 25% Inorganic + 75% Organic.	2.88	4.35	5.06	1.78	2.75
T7 : 75% Organic + Biofertilizer	2.82	4.21	4.90	1.67	2.65
T8 : 100% Organic	2.85	4.32	5.01	1.76	2.73
SEm±	0.12	0.18	0.22	0.03	0.04
CD at 5 %	0.36	0.54	0.66	0.09	0.12

Table 1.4: Effect of integrated nutrient management on yield attributes and yields of sorghum

Treatments	**No. of seed penicle^{-1}**	**Test weight (g)**	**Grain yield kg ha^{-1}**	**Straw yield kg ha^{-1}**	**Biological yield kg ha^{-1}**	**Harvest index (%)**
T_1: Control	1611	24.36	1103	3926	5029	21.89
T_2: 100% Inorganic.	2381	29.27	2015	7028	9043	22.37
T_3: 75% Inorganic + 25% Organic.	**2420**	**29.62**	**2086**	**7227**	**9313**	**22.41**
T_4: 75% Inorganic + Biofertilizer.	2073	28.00	1811	6335	8146	22.26
T_5: 50% Inorganic + 50% Organic.	2253	28.14	1962	6832	8794	22.31
T_6: 25% Inorganic + 75% Organic.	2061	27.95	1803	6322	8126	22.22
T_7: 75% Organic + Biofertilizer	1988	26.10	1649	5885	7534	21.96
T_8: 100% Organic	2044	27.87	1792	6310	8102	22.12
SEm±	**113.35**	**1.17**	**86.78**	**292.94**	**325.25**	**0.97**

CD at 5 %	343.80	NS	263.21	888.54	986.55	NS

Table 1.5: Effect of integrated nutrient management on Net return and B: C ratio of sorghum cultivation

Treatment	Net Return (₹ ha^{-1})	B: C Ratio (%)
T_1: Control	26811	1.22
T_2: 100% Inorganic.	59505	2.01
T_3: 75% Inorganic + 25% Organic.	**61204**	**2.04**
T_4: 75% Inorganic + Biofertilizer.	52080	1.88
T_5: 50% Inorganic + 50% Organic.	54503	1.71
T_6: 25% Inorganic + 75% Organic.	46371	1.40
T_7: 75% Organic + Biofertilizer	41394	1.31
T_8: 100% Organic	44651	1.30
SEm±	**3170.38**	**0.12**
CD at 5 %	**9616.35**	**0.36**

Yield and yield attributes

Further results revealed under Table 1.4, that test weight (g) found not significantly and higher number of seeds penicle^{-1} (2420), grain yield (2086 kg ha^{-1}), straw yield (7227 kg ha^{-1}) and biological yield (9313 kg ha^{-1}) recorded with application of 75% Inorganic + 25% organic, it was going to at par with application of 100% Inorganic (T_2) and 50% Inorganic + 50% organic (T_5) sources of nutrient management.

The significant synergistic effect observed from the combined application of chemical fertilizer, vermicompost and farm yard manure can be attributed to the improved nutritional status of the soil, leading to enhanced biomass production in the crop. This enhancement may be further linked to the positive impact of vermicompost and farm yard manure on soil microbial activity and root proliferation, resulting in the solubilization of native nutrients. Integrated nutrient management emerges as a promising approach, not only for sustaining higher productivity but also for enhancing stability in crop production through the synergistic effects of vermicompost and farm yard manure on optimizing the efficiency of nitrogen, phosphorus, and potassium. These findings are consistent with previous studies by [14,16].

Figure 1: View of Experimental field

Figure 2: Penicle

Economics

The higher net returns (61204 ₹ ha^{-1}) with a benefit-cost (BC) ratio of 2.04 were achieved through the application of 75% Inorganic with 25% organic sources of nutrient management as compared to other treatment levels indicated in Table 1.5, this treatment lead to the higher grain and straw yields without incurring additional input costs compared to other treatments [17-19].

This outcome can be attributed to the increased grain, straw and overall biological yield of sorghum under this treatment which significantly contributed to the net return. Consequently, the application of 75% Inorganic + 25% organic resulted in higher net treatments [17-19].

The computation of the cost of cultivation is particularly significant as it guides farmers in selecting production practices aligned with their investment capacity. This cost is determined based on the expenses associated with common agro-inputs used in field operations, considering variable inputs and operations tailored to each treatment on a per hectare basis.

Due to the increased cultivation costs, the organic treatment had lower net returns and B: C ratio, nevertheless it was still economical since the nutrients were released gradually over two to three years from the organic manure.

By conducting economic analysis, farmers and planers can make informed decisions to optimize returns while considering investment constraint and resource availability.

Conclusion

Based on the results of present investigation, it can be concluded that higher improvement in growth parameters, yield attributes, yields, net returns and benefit cost of sorghum crop could be obtained with application of 75% Inorganic + 25% organic sources of nutrient management.

However, the application of 75% Inorganic+ 25% organic sources of nutrient is being recommended as a most profitable dose for higher grain yield, net returns and benefit cost ratio. Above conclusion is based on one season experiment and it needs further confirmation by repeating the experiment.

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