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Effect of different nutrient management practices on yield and yield attributes of sorghum crop

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Abstract
The present investigation examined the effects of integrated use of organic and inorganic nutrient sources on the growth, yield, and yield-attributing characters of sorghum over two consecutive cropping seasons (2023-24 and 2024-25). Various nutrient management treatments involving chemical fertilizers, organic manures, and biofertilizers were evaluated. The findings clearly revealed that integrated nutrient management practices significantly improved all yield and yield-related attributes when compared to the control treatment. Among the different treatments, the application of 100% Recommended Dose of Fertilizers (RDF) supplemented with biofertilizers, namely *Azotobacter* and phosphate-solubilizing bacteria (PSB), consistently produced the highest yield and superior yield attributes in both years of study. The treatment comprising 75% RDF combined with vermicompost and biofertilizers ranked as the second most effective option. In contrast, the control treatment exhibited the lowest values for all measured parameters. The enhanced performance under integrated treatments was mainly due to balanced and sustained nutrient supply, improved soil microbial activity, and increased nutrient uptake efficiency. Overall, the study emphasizes that the combined use of organic manures and biofertilizers with inorganic fertilizers is an effective and sustainable approach for enhancing sorghum productivity and maintaining long-term soil fertility.

Keywords: Sorghum, organic manure, inorganic fertilizer, biofertilizers and yield

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is recognized as one of the world's most significant cereal crops owing to its diverse uses, strong adaptability, and vital role in global farming systems. It constitutes a staple food for large populations, particularly in the semi-arid regions of Africa and Asia, while also contributing substantially to livestock feed, industrial raw materials, and overall food security. The crop's notable ability to tolerate harsh environmental conditions including limited rainfall, elevated temperatures, and poor soil fertility highlights its importance in sustaining agricultural productivity under climate variability and resource-constrained conditions (Paterson *et al.*, 2009) [13]. A comprehensive understanding of sorghum's origin, botanical characteristics, agronomic importance, ecological adaptability, and socio-economic significance is therefore essential to appreciate its relevance in contemporary agriculture and to support continued research and development efforts.

The domestication of sorghum can be traced back approximately 5,000 to 8,000 years to northeastern Africa, particularly the regions corresponding to present-day Sudan and Ethiopia (Winchell *et al.*, 2017) [20]. Early farmers selectively domesticated wild sorghum populations by favoring traits such as larger grains and reduced seed shattering, ultimately giving rise to cultivated varieties. From its center of origin, sorghum gradually spread across Africa and Asia and was subsequently introduced to the Americas and Australia through trade routes and human migration. At present, sorghum is grown in over 100 countries, with the United States, Nigeria, Sudan, and India ranking among the leading producers (FAO, 2023). Its resilience to drought and erratic rainfall has historically made it a reliable crop in regions vulnerable to food shortages, earning it the description "camel of crops" due to its exceptional hardiness (Taylor *et al.*, 2019) [18]. In India, Maharashtra led sorghum production during 2023-2024 with about 1.4 million metric tonnes, followed by Karnataka and Rajasthan. Andhra Pradesh, however, recorded the highest productivity in 2024, reaching nearly 3,493 kg ha^{-1}, indicating the potential for substantial yield improvement through advanced management practices (Khalifa *et al.*, 2023) [8].

Sorghum is primarily cultivated in arid and semi-arid agro-ecological regions because of its strong drought resistance and capacity to thrive under varied climatic and soil conditions. Between 2001 and 2020, the global average area under sorghum cultivation was about 40.9 million hectares, with India, Sudan, and Nigeria contributing significantly. During this period, average annual global production was approximately 58.7 million tonnes, with mean yields around 2.5 tonnes per hectare. Marked regional differences in productivity were evident, as North America achieved considerably higher yields than South Asia and sub-Saharan Africa, where productivity remained relatively low. In India, the area under sorghum has steadily declined from 10.25 million hectares in 1999-2000 to 6.36 million hectares in 2022-23. Nevertheless, notable productivity improvements have been observed in certain systems. For instance, sorghum cultivated under zero-tillage in rice fallows of coastal Andhra Pradesh recorded yields as high as 5.32 tonnes per hectare during 2022-23, substantially exceeding the national average yield, which continues to be below 1.0 tonne per hectare.

The application of organic, inorganic, and biofertilizers either individually or in combination has a pronounced influence on sorghum (*Sorghum bicolor* L. Moench) yield and its associated yield attributes. Sorghum, being a nutrient-exhaustive crop, responds strongly to balanced nutrient supply, and integrated nutrient management plays a key role in enhancing productivity, soil health, and sustainability. Organic sources such as farmyard manure (FYM), compost, and vermicompost improve soil physical, chemical, and biological properties. Their application enhances soil structure, water-holding capacity, and microbial activity, leading to better root growth and nutrient uptake (Kumari *et al.*, 2024) [9]. In sorghum, organic manures have been reported to increase yield attributes such as panicle length, panicle weight, number of grains per panicle, and 1000-grain weight. Although organic sources release nutrients slowly and may not always meet the immediate nutrient demand of the crop, their long-term application contributes to sustained yield improvement and resilience under rainfed conditions (Pal *et al.*, 2024) [11].

Inorganic fertilizers supply nutrients in readily available forms and have a direct and significant impact on sorghum growth and yield. Adequate application of nitrogen promotes vigorous vegetative growth, increased leaf area, and higher photosynthetic efficiency, while phosphorus enhances root development, flowering, and grain formation. Potassium improves translocation of assimilates, grain filling, and stress tolerance (Shukla *et al.*, 2024) [16]. The use of recommended doses of NPK fertilizers has consistently resulted in higher grain and stover yields, along with improved yield attributes such as test weight and harvest index. However, exclusive reliance on chemical fertilizers may adversely affect soil health over time.

Biofertilizers such as *Azotobacter*, *Azospirillum*, and phosphate-solubilizing bacteria (PSB) play a complementary role by enhancing nutrient availability through biological processes. Nitrogen-fixing biofertilizers supplement nitrogen supply, while PSB increases the availability of native and applied phosphorus. Their application has been shown to improve yield attributes including number of effective tillers, grains per panicle, and grain weight. Biofertilizers also stimulate root growth and enhance microbial activity in the rhizosphere, leading to better nutrient use efficiency (Yadav *et al.*, 2025) [22].

The integrated use of organic manures, inorganic fertilizers, and biofertilizers has been found to be the most effective approach for maximizing sorghum yield and improving yield components. Such combinations ensure immediate nutrient availability from inorganic sources, sustained nutrient release from organic manures, and enhanced nutrient mobilization through biofertilizers (Verma *et al.*, 2024) [19]. Studies have consistently reported significant increases in grain and stover yield, panicle size, grain number, and test weight under integrated nutrient management compared to sole application of any single nutrient source. Moreover, this approach improves soil fertility and ensures long-term productivity, making it a sustainable strategy for sorghum cultivation (Chandra *et al.*, 2023) [2].

Materials and Methods

The present investigation entitled "Effect of organic sources and nutrients on yield, quality and nutrient uptake by sorghum (*Sorghum bicolor* L.)" was systematically conducted during the *Kharif* seasons of 2023-24 and 2024-25. The experiment was carried out at Hanumangarh district, situated in the northern region of Rajasthan, India. Geographically, the district lies between 25°46′ to 29°57′ N latitude and 74°43′ to 75°31′ E longitude. Hanumangarh shares its northern boundary with Punjab, eastern boundary with Haryana, southern boundary with Churu district, and western boundary with Bikaner and Sri Ganganagar districts, making it an agriculturally important location in the region. The field experiment was laid out in a Randomized Block Design (RBD) comprising thirteen treatments with three replications. The treatment structure included various combinations of inorganic fertilizers, organic manures, and biofertilizers. The treatments consisted of: T_1 (control), T_2 (100% RDF: 120:60:60:40 kg ha^{-1} of N:P:K:S), T_3 (100% RDF + biofertilizers (*Azotobacter* + PSB), T_4 (75% RDF + FYM @ 5 t ha^{-1}), T_5 (75% RDF + FYM @ 5 t ha^{-1} + biofertilizers), T_6 (75% RDF + vermicompost @ 2 t ha^{-1}), T_7 (75% RDF + vermicompost @ 2 t ha^{-1} + biofertilizers), T_8 (50% RDF + FYM @ 10 t ha^{-1}), T_9 (50% RDF + FYM @ 10 t ha^{-1} + biofertilizers), T_{10} (50% RDF + vermicompost @ 4 t ha^{-1}), T_{11} (50% RDF + vermicompost @ 4 t ha^{-1} + biofertilizers), T_{12} (50% RDF + FYM @ 5 t ha^{-1} + vermicompost @ 2 t ha^{-1}), and T_{13} (50% RDF + FYM @ 5 t ha^{-1} + vermicompost @ 2 t ha^{-1} + biofertilizers). The length of panicle in sorghum crop was measured at physiological maturity by selecting representative plants and recording the distance from the base of the panicle to its terminal tip using a measuring scale. The number of grains per panicle in sorghum was determined at harvest by selecting representative panicles from each plot, threshing them carefully, and manually counting the total number of well-developed grains present in each panicle to obtain accurate and reliable data. Test weight in sorghum was measured by randomly selecting a representative grain sample from each treatment and recording the weight of one thousand fully developed grains using a precision electronic balance at harvest. Grain yield in sorghum was recorded by harvesting plants from the net plot area, threshing, cleaning, and weighing the grains, and converting the values to quintals per hectare. Stover yield was determined by drying and weighing the remaining biomass after grain separation. Biological yield was calculated as the sum of grain yield and stover yield on a per hectare basis.

Results and Discussion

Length of panicle (cm)

The influence of organic and inorganic nutrient sources, along with biofertilizers, on panicle length in sorghum is presented in Table 1. A critical analysis of the data revealed that panicle length did not differ significantly among the various nutrient management treatments evaluated in the experiment.

During the first cropping season (2023-24), the longest panicle length (19.11 cm) was observed under treatment T_3, which comprised 100% of the recommended dose of fertilizers (RDF) supplemented with biofertilizers (*Azotobacter* and phosphate-solubilizing bacteria). This treatment was closely followed by T_7 (75% RDF + vermicompost @ 2 t ha^{-1} + biofertilizers), which recorded a panicle length of 18.94 cm. All other treatments showed marginal increases in panicle length over the control. The shortest panicle length during this season was recorded in the control treatment (T_1), measuring 17.81 cm.

A similar trend was evident during the second year (2024-25), wherein treatment T_3 again produced the maximum panicle length (19.32 cm), followed by T_7 with 19.14 cm. The control treatment once more recorded the minimum panicle length (18.01 cm). Despite these numerical variations, statistical analysis indicated that differences among treatments were non-significant. This suggests that integrated nutrient management may exert only a marginal influence on panicle length of sorghum under the prevailing experimental conditions (Mishra *et al.,* 2019; Ramesh *et al.,* 2023) [10, 14].

Number of grains per panicle

The data pertaining to the number of grains per panicle in sorghum as influenced by different combinations of organic and inorganic nutrient sources along with biofertilizers are presented in Table 1. A thorough examination of the results revealed that the number of grains per panicle differed significantly among the various nutrient management treatments imposed in the study.

During the first year of experimentation (2023-24), treatment T_7, which comprised 75% of the recommended dose of fertilizers (RDF) supplemented with vermicompost at 2 t ha^{-1} and biofertilizers, recorded the highest number of grains per panicle (1172.21). This was closely followed by treatment T_3, involving 100% RDF in combination with biofertilizers (*Azotobacter* and phosphate-solubilizing bacteria), which produced 1161.42 grains per panicle. All other treatments also resulted in significantly higher grain numbers compared to the control. In contrast, the control treatment (T_1), which did not receive any nutrient inputs, registered the lowest number of grains per panicle (891.12).

A similar trend was observed during the second year of the study (2024-25), confirming the consistency of treatment effects across seasons. Treatment T_7 again recorded the maximum number of grains per panicle (1179), followed closely by T_3 with 1168 grains. The control treatment continued to show the minimum grain count. These findings indicate that integrated nutrient management practices, particularly the combined use of vermicompost, inorganic fertilizers, and biofertilizers, significantly enhance grain formation in sorghum, thereby improving its yield potential (Jakhar *et al.,* 2018) [7]. The consistently lower grain numbers in the control further emphasize the critical role of balanced nutrient application in achieving optimal sorghum productivity (Yadav *et al.,* 2022) [21].

Test weight (g)

The data on test weight of sorghum grains as influenced by the application of organic and inorganic nutrient sources in combination with biofertilizers are presented in Table 1. Test weight is an important indicator of grain quality, as it reflects grain density and has direct implications for market value and overall produce quality.

During the first year of the experiment (2023-24), the maximum test weight was recorded under treatment T_3, which involved the application of 100% of the recommended dose of fertilizers (RDF) along with biofertilizers, namely *Azotobacter* and phosphate-solubilizing bacteria (PSB). This treatment resulted in the highest test weight of 15.01 g per thousand grains. Treatment T_7, comprising 75% RDF combined with vermicompost at 2 t ha^{-1} and biofertilizers, ranked second with a test weight of 14.73 g. All other nutrient management treatments produced significantly higher test weight values compared to the control (T_1), which recorded the lowest value of 9.61 g.

A comparable trend was observed during the second year (2024-25). Treatment T_3 again recorded the highest test weight (14.77 g per thousand grains), followed by T_7 with 14.48 g. The control treatment consistently exhibited the minimum test weight (9.19 g). These results clearly demonstrate that integrated nutrient management involving inorganic fertilizers, organic manures such as vermicompost, and biofertilizers significantly improves test weight in sorghum, thereby enhancing grain quality and potential economic returns (Gill *et al.,* 2018; Bekele *et al.,* 2018) [6, 1].

Seed yield (q ha^{-1})

The data on seed yield per hectare, as presented in Table 2, revealed significant differences among the various nutrient management treatments during both years of investigation. In the first year (2023-24), the highest seed yield was obtained under treatment T_3, which recorded 26.67 q ha^{-1}, closely followed by treatment T_7 with 26.37 q ha^{-1}. All nutrient-treated plots produced significantly higher yields than the control treatment (T_1), which recorded the minimum seed yield of 13.18 q ha^{-1}.

A similar pattern was observed during the second year (2024-25), where treatment T_3 again registered the maximum seed yield (26.82 q ha^{-1}), followed by T_7 with 26.57 q ha^{-1}. Treatment T_3 remained significantly superior to all other treatments in terms of grain yield, while the control once again recorded the lowest yield (13.47 q ha^{-1}). These findings are in agreement with Singh *et al.*, (2015) [17], who reported enhanced growth, grain, and straw yields with integrated nitrogen application through organic and inorganic sources. The present results further confirm that the combined use of vermicompost and biofertilizers with recommended doses of NPK fertilizers is more effective than sole nutrient application (Patil *et al.,* 2014). The integrated application of FYM and biofertilizers with inorganic fertilizers improves soil physical properties, reduces nitrogen losses through the formation of stable organic-mineral complexes, and ensures a continuous supply of nutrients throughout the crop growth period, ultimately leading to higher yields (Gill *et al.,* 2018; Deepshikha *et al.,* 2024) [6, 4].

Stover Yield (q ha^{-1})

The data related to stover yield as influenced by various treatments is comprehensively presented in Table 2. The findings clearly indicate that stover yield was significantly affected by the different nutrient management treatments applied in the study, reflecting the varying impacts these treatments had on the overall growth vigor and biomass production of the sorghum plants.

During the first year of experimentation in 2023-24, the highest stover yield of 28.85 quintals per hectare was recorded under treatment T_7, which involved the application of 75% of the recommended dose of fertilizers (RDF) combined with 2 tons per hectare of vermicompost and bio-fertilizers. This superior yield was closely followed by treatment T_3, which consisted of 100% RDF along with bio-fertilizers, specifically Azotobacter and phosphate-solubilizing bacteria (PSB), producing a stover yield of 28.32 quintals per hectare. In stark contrast, the control treatment (T_1), which did not receive any nutrient inputs, recorded the lowest stover yield of only 15.77 quintals per hectare.

Similarly, in the second year of the study conducted in 2024-25, a comparable trend was observed. Treatment T_7 again led with the maximum stover yield of 30.47 quintals per hectare, with treatment T_3 following closely behind at 29.90 quintals per hectare. The control group remained at the lowest end of the spectrum, recording a stover yield of just 16.57 quintals per hectare.

The notable improvement in green fodder yield under these treatments can primarily be attributed to the enhancement of several key agronomic traits facilitated by the judicious application of NPK fertilizers. The increased stover production observed in this study was largely a cumulative consequence of improvements in plant height, the number of branches, and dry matter accumulation, all of which are critical growth parameters contributing to biomass yield. Essentially, the positive effects on these growth characteristics collectively translated into superior green fodder and stover yields. Supporting these findings, earlier works reported significant enhancements in yield parameters following the combined use of farmyard manure (FYM) and bio-fertilizers along with varying levels of inorganic fertilizers. Organic manures like FYM contribute directly available nutrients to the plants and possess the additional benefit of solubilizing fixed forms of nutrients in the soil, thereby improving nutrient availability. Furthermore, these organic inputs significantly enhance the physicochemical properties of the soil, which in turn promotes healthier plant growth (Mishra *et al.*, 2019) [10].

Bio-fertilizers contribute importantly by fixing atmospheric nitrogen through the proliferation of beneficial microbial populations in the soil, thereby supplying additional nitrogen to the plants. This enhanced nitrogen nutrition leads to improved yield attributes and ultimately results in higher overall yield. Beyond nitrogen fixation, bio-fertilizers promote the stimulation of rhizospheric microorganisms, modify nutrient uptake mechanisms in the plants, mobilize soil phosphates, and enhance nitrogen fixation efficiency. They also facilitate siderophore production, which aids in making essential micronutrients more accessible to the plant root system (Samruthi *et al.*, 2020) [15].

These synergistic interactions between organic manures, bio-fertilizers, and mineral fertilizers enhance the nutrient use efficiency and soil health, thereby fostering greater biomass production and culminating in significantly increased green forage and stover yields. Consequently, adopting an integrated nutrient management approach that combines organic amendments like vermicompost or FYM with bio-fertilizers and recommended doses of inorganic fertilizers is highly effective in improving the growth vigor and productivity of sorghum crops under field conditions (Delei *et al.,* 2023).

Biological Yield (q ha^{-1})

The data presented in Table 2 illustrate the effect of different organic and inorganic nutrient management practices on the biological yield of sorghum. An analysis of the results from the first year of experimentation (2023-24) revealed that the maximum biological yield (55.22 q ha^{-1}) was obtained under treatment T_7, which involved the application of 75% of the recommended dose of fertilizers (RDF) supplemented with vermicompost at 2 t ha^{-1} and biofertilizers. This treatment was closely followed by T_3, which recorded a biological yield of 54.99 q ha^{-1}. All other treatments also produced significantly higher biological yields compared to the control, which recorded the lowest value of 28.95 q ha^{-1}.

A comparable trend was observed during the second year (2024-25). Treatment T_7 once again resulted in the highest biological yield (57.04 q ha^{-1}) under integrated nutrient application, whereas the control treatment (T_1) registered the minimum biological yield of 30.84 q ha^{-1}. These consistent results across both years clearly demonstrate the superiority of integrated nutrient management practices in enhancing biological yield of sorghum, supporting earlier findings reported by Gill *et al.*, 2018; Deepshikha *et al.*, 2024 [6, 4].

Table 1: Effect of organic and inorganic sources of nutrients on length of panicle(cm), number of grains panicle^{-1} and test weight (g)

Treatment	Length of panicle (cm)			Number of grains per panicle			Test weight (g)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	17.81	18.01	17.91	891.12	898.12	894.62	9.61	9.19	9.40
T_2	18.69	18.89	18.79	1126.23	1132.34	1129.29	14.02	14.18	14.10
T_3	19.11	19.32	19.22	1161.42	1168.51	1164.97	15.01	14.77	14.89
T_4	17.94	18.14	18.04	1029.31	1036.82	1033.07	11.51	11.68	11.60
T_5	17.97	18.17	18.07	1042.39	1049.83	1046.11	11.89	11.56	11.73
T_6	18.65	18.85	18.75	1113.74	1121.73	1117.74	13.61	13.89	13.75
T_7	18.94	19.14	19.04	1172.21	1179.11	1175.66	14.73	14.48	14.61
T_8	17.90	18.10	18.00	914.46	921.64	918.05	11.04	11.26	11.15
T_9	18.02	18.22	18.12	1063.53	1071.33	1067.43	11.81	11.97	11.89
T_{10}	18.10	18.30	18.20	1098.85	1105.22	1102.04	13.02	13.19	13.11
T_{11}	18.26	18.46	18.36	1106.02	1113.85	1109.94	13.41	13.14	13.28
T_{12}	18.04	18.24	18.14	1084.11	1091.12	1087.62	12.52	13.05	12.79
T_{13}	18.06	18.26	18.16	1089.52	1096.34	1092.93	12.83	12.98	12.91
S.Em (±)	0.26	0.27	0.27	16.01	14.77	15.39	0.20	0.16	0.18
C.D. at 5%	0.77	0.81	0.79	46.98	43.37	45.18	0.61	0.48	0.55

Table 2: Effect of organic and inorganic sources of nutrients on crop yield (q ha^{-1})

Treatment	Seed yield (q ha^{-1})			Stover yield (q ha^{-1})			Biological yield (q ha^{-1})		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	13.18	13.47	13.33	15.77	17.37	16.57	28.95	30.84	29.90
T_2	24.85	24.35	24.60	26.69	28.27	27.48	51.54	52.62	52.08
T_3	26.67	26.82	26.75	28.32	29.90	29.11	54.99	56.72	55.86
T_4	18.96	18.39	18.68	20.27	26.87	23.57	39.23	45.26	42.25
T_5	19.03	19.05	19.04	21.87	23.45	22.66	40.90	42.50	41.70
T_6	24.11	23.47	23.79	25.72	23.30	24.51	49.83	46.77	48.30
T_7	26.37	26.57	26.47	28.85	30.47	29.66	55.22	57.04	56.13
T_8	16.40	15.87	16.14	19.31	20.91	20.11	35.71	36.78	36.25
T_9	20.03	19.58	19.81	22.09	23.67	22.88	42.12	43.25	42.69
T_{10}	22.63	22.16	22.40	24.04	26.01	25.03	46.67	48.17	47.42
T_{11}	22.78	22.81	22.80	24.56	26.13	25.35	47.34	48.94	48.14
T_{12}	22.17	21.08	21.63	23.86	25.45	24.66	46.03	46.53	46.28
T_{13}	22.10	20.64	21.37	23.32	24.90	24.11	45.42	45.54	45.48
S.Em (±)	0.37	0.19	0.28	0.47	0.38	0.43	0.66	0.46	0.56
C.D. at 5%	1.08	0.56	0.82	1.27	1.14	1.21	1.93	1.36	1.65

Conclusion

The results of the present study clearly demonstrate that integrated nutrient management practices exert a pronounced and consistent influence on the yield and yield attributes of sorghum across both years of experimentation. While panicle length was not significantly affected by different nutrient treatments, key reproductive and yield parameters such as number of grains per panicle, test weight, seed yield, stover yield, and biological yield responded significantly to the combined application of organic, inorganic, and biofertilizer sources. Treatments involving the integration of recommended doses of NPK fertilizers with vermicompost or farmyard manure and biofertilizers (notably T_3 and T_7) consistently outperformed the control and sole nutrient applications. The enhanced performance under these treatments can be attributed to improved nutrient availability, greater nutrient use efficiency, enhanced soil physical and biological properties, and sustained nutrient release throughout the crop growth period. Overall, the study confirms that the synergistic use of organic manures, biofertilizers, and inorganic fertilizers is a highly effective and sustainable strategy for improving sorghum productivity and biomass yield under field conditions.

References

1. Bekele A, Kibret K, Bedadi B, Balemi T, Halla MY. Effects of lime, vermicompost and chemical P fertilizer on yield of maize in Ebantu District, Western Highlands of Ethiopia. African Journal of Agricultural Research. 2018;13(10):477-489.
2. Chandra J, Sachan R, Kumar D, Kumar C, Tiwari T, Singh A, *et al*. Integrated effect of synthetic fertilizers and bio-inoculant on growth, yield attributes and yield of wheat (*Triticum aestivum* L.). International Journal of Plant & Soil Science. 2023;35(23):175-181.
3. Dalei BB, Rath BS, Mohapatra AK, Patnaik GP, Phonglosa A, Sahoo S, Senapati N. Residual effect of integrated nutrient management in kharif maize (*Zea mays* L.) on growth and yield of toria (*Brassica campestris* L. var. toria) during rabi season in Odisha, India. International Journal of Environment and Climate Change. 2023;13(1):266-275.
4. Deepshikha LKS, Singh V, Kumar A, Singh V, Kushwaha A. Response of integrated nutrient management and different varieties on growth and yield of pearl millet (*Pennisetum glaucum* L.). International Journal of Research in Agronomy. 2024;SP-7(6):145-148.
5. Food and Agriculture Organization of the United Nations. FAOSTAT: sorghum production. Rome: FAO; 2023.
6. Gill R, Singh P, Kumar R, Kumar B. Effect of integrated nutrient management on plant growth and yield of rabi maize under irrigated conditions of Ajmer. International Journal of Current Microbiology & Applied Sciences. 2018;7(3):2103-2112.
7. Jakhar RR, Shekhawat PS, Yadav RS, Kumawat A, Singh SP. Integrated nutrient management in pearl millet (*Pennisetum glaucum*) in north-western Rajasthan. Indian Journal of Agronomy. 2018;63(2):192-196.
8. Khalifa M, Eltahir EA. Assessment of global sorghum production, tolerance, and climate risk. Frontiers in Sustainable Food Systems. 2023;7:1184373.
9. Kumari M, Meena R, Kumar C, Kumar D. Efficacy of rock phosphate enriched compost on growth, yield and uptake of nutrients by summer mung bean (*Vigna radiata* (L.) Wilczek) in inceptisol of Varanasi. Journal of Ecofriendly Agriculture. 2024;19(2):287-293.
10. Mishra A, Kumar P, Shamim M, Tiwari KK, Fatima P, Srivastava D, *et al*. Genetic diversity and population structure analysis of Asian and African aromatic rice (*Oryza sativa* L.) genotypes. Journal of Genetics. 2019;98(3):92.
11. Pal SK, Kumar N, Ram CN, Kumar D, Maurya S, Singh A, *et al*. Effect of organic, inorganic and biofertilizers on soil characteristics and potato tuber yield (Solanum tuberosum L.). Journal of Scientific Research and Reports. 2024;30(11):494-500.
12. Patel PR, Patel BJ, Vyas KG, Yadav BL. Effect of integrated nitrogen management and bio-fertilizer in kharif pearl millet (*Pennisetum glaucum* L.). Advance Research Journal of Crop Improvement. 2014;5(2):122-125.
13. Paterson AH, Bowers JE, Bruggmann R, Dubchak I, Grimwood J, Gundlach H, *et al*. The Sorghum bicolor genome and the diversification of grasses. Nature. 2009;457(7229):551-556.
14. Ramesh B, Kaur M, Chhabra V. Effect of integrated nutrient management on growth and yield parameters of

maize (*Zea mays* L.). International Journal of Environment and Climate Change. 2023;13(8):874-880.
15. Samruthi M, Kumar R, Maurya RP, Kumar YS. Effect of integrated nutrient management on yield and yield attributes of pearl millet (*Pennisetum glaucum* L. R. Br. emend. Stuntz). International Journal of Current Microbiology and Applied Sciences. 2020;8(10):2733-2737.
16. Shukla AK, Singh RR, Mishra T, Tripathi KM, Mishra S, Kumar D. Optimizing nutrient uptake in rice crops through integrated organic manure application: A comprehensive analysis of grain and straw composition. Asian Journal of Soil Science and Plant Nutrition. 2024;10(1):167-174.
17. Singh K, Joshi YP, Chandra H, Singh DK, Singh R, Kumar M. Effect of integrated nutrient management on growth, productivity and quality of sweet sorghum (*Sorghum bicolor*). Indian Journal of Agronomy. 2015;60:291-296.
18. Taylor JRN, Duodu KG. Sorghum and millets: Chemistry, technology and nutritional attributes. Cambridge: Woodhead Publishing; 2019.
19. Verma N, Kumar R, Yadav AK, Kumar D, Baheliya AK, Chandra J. Effect of farm yard manure, green manure and vermicompost on growth and yield of rice. International Journal of Environment and Climate Change. 2024;14(1):581-585.
20. Winchell F, Stevens CJ, Murphy C, Champion L, Fuller DQ. Evidence for sorghum domestication in fourth millennium BC eastern Sudan: Spikelet morphology from ceramic impressions of the Butana Group. Current Anthropology. 2017;58(5):673-683.
21. Yadav RC, Niwas R, Yadav AS, Sachan R. Effect of integrated nutrient management on growth, yield and economics of maize (*Zea mays* L.) under central plain zone of Uttar Pradesh. The Pharma Innovation Journal. 2022;11(7):1795-1798.
22. Yadav V, Pandey AK, Kumar N, Yadav SK, Kumar S, Yadav DN, *et al*. Optimization of organic and inorganic sources of nutrient and their impact on nutrient content, uptake and yield of kabuli chickpea under partially reclaimed sodic soil. Ecology, Environment & Conservation. 2025;31:1-9.