

Studies on The Effect of Integrated Nutrient Management on Growth and Yield of Irrigated Sorghum (*Sorghum bicolor* L.)

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Abstract: The field experiment was conducted at Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar (Tamil Nadu) during January-May, 2024 to study the effect of Integrated nutrient management on the growth of irrigated sorghum. The experiment was laid out in a randomized block design with three replications and seven treatments with sorghum CO 30 as the test variety. There were altogether seven treatments viz., T₁-100% RDF (90:45:45 kg N: P₂O₅: K₂O ha⁻¹), T₂-50% RDF + Vermicompost @ 2.5 t ha⁻¹, T₃-50% RDF + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹, T₄-50% RDF + Azophos @ 20 kg ha⁻¹, T₅-50% RDF + Vermicompost @ 2.5 t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹, T₆-50% RDF + Vermicompost @ 2.5 t ha⁻¹ + Azophos @ 20 kg ha⁻¹, T₇-50% RDF + Vermicompost @ 2.5 t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹ + Azophos @ 20 kg ha⁻¹. The treatment T₇ with 50% RDF + Vermicompost @ 2.5 t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹ + Azophos @ 20 kg ha⁻¹ recorded higher values of growth attributes viz., plant height, leaf area index and dry matter production (kg ha⁻¹) and Crop Growth Rate (g m⁻² day⁻¹), more number of effective tillers plant⁻¹ as compared to other treatments.

Keywords: INM, ZnSO₄, FeSO₄, Soil application, RDF, Azophos, sorghum.

INTRODUCTION

Sorghum (*Sorghum bicolor* L.) commonly known as the 'king of millets', is a highly productive crop plant, that can be used for grains, livestock feed, or industrial purposes namely sorghum molasses and is also used in producing alcoholic beverages and biofuels. Sorghum is an important food grain for millions of the poorest and most food insecure people in the world (Velinov *et al.*, 2020). Globally Sorghum crop is cultivated over an area of 40.76 million hectares with a total production of 57.58 million tones with an average productivity of 1412.6 kg ha⁻¹. In India, sorghum is cultivated over an area of 3.8 million hectares with a production of 4.15

million tones with a productivity of 1092 kg ha⁻¹ (FAOSTAT, 2023). It's getting challenging to fulfil the nutrient requirements of sorghum farming solely with chemical fertilizer. Effective nutrient management involves the use of organic and inorganic resources intelligently and judiciously to maximize yields (Sivakumar, 2020). To enhance productivity, there is a need to promote the use of appropriate biofertilizers and balanced fertilization practices. Biofertilizers are indispensable additions to conventional fertilizers. The combination of various sources of Nitrogen viz. Urea, FYM, and Biofertilizers would be an ideal option to meet the higher nitrogen demands of crops. In addition, biofertilizers complement chemical fertilizers, making them perfect partners and essential supplements for sustainable agricultural practices and enhancing nutrient availability sustainably (Kusumbe *et al.*, 2023). Maintaining soil health and maximizing sorghum growth is crucial by using organic supplements alongside chemical fertilizers. Applying micronutrient fertilizers, particularly Zinc and Iron, through soil application is the most efficient and economical method of getting these nutrients into the crops. Micronutrients are important for maintaining soil health and enhancing crop productivity (Kubsad, 2019). Vermicompost and Azophos enhance the soil nutritional status, providing readily available nutrients to plants in a balanced manner, thereby increasing production and promoting nitrogen fixation (Aditi *et al.*, 2019). Integrated Nutrient Management (INM) has the complex potential to improve plant growth and efficiency of resources while additionally empowering the security of climate and supply quality (Hemashri *et al.*, 2023).

MATERIALS AND METHODS

The field experiment was conducted during January-May, 2024 is moderately warm with hot summer

months. The field experiment was laid out in field number GL-5 in the garden land block of the experimental farm, Department of Agronomy, Annamalai University, Annamalai Nagar. The experimental farm is geographically located at 11°24'N latitude and 79°44' E longitude with an altitude of 5.79 m above the mean sea level (MSL). The experimental farm area comes under the North Eastern Agro climatic zone of Tamil Nadu with a prevailed mean maximum and minimum temperature of 34.13 °C and 19.82 °C, and relative humidity of 69.93 percent. The soil type of the experiment field was clay loam in texture with low in available nitrogen (230.10 kg ha⁻¹), medium in available phosphorus (16.82 kg ha⁻¹), and high in available potassium (322.6 kg ha⁻¹) with pH 7.6 and organic carbon level (0.54%). The sorghum variety CO 30 with a duration of 95-105 days was raised at 45 cm x 15 cm spacing and all the nutrients were applied at sowing as per the treatments, with three replications in randomized block design (RBD). The computed data were subjected to statistical scrutiny as per the procedure given by Gomez and Gomez (1984) for better interpretation of results and the critical difference was worked out at a 5 percent probability level for significant results.

RESULTS AND DISCUSSION

3.1. Growth attributes

3.1.1. Effect of INM on Plant height (cm)

In treatment (T₇), the sorghum plant recorded greater plant heights of 51.29 cm, 172.28 cm, and 194.55 cm at 30 DAS, 60 DAS, and 90 DAS respectively. This treatment involved 50% RDF + Vermicompost @ 2.5 t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹ + *Azophos* @ 20 kg ha⁻¹ and outperformed all other treatments [Table 1]. This was followed by the treatment (T₅) application of 50% RDF + Vermicompost @ 2.5t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹. The treatment (T₆)-50% RDF + Vermicompost @ 2.5 t ha⁻¹ + *Azophos* @ 20 kg ha⁻¹ was found to be statistically on par with (T₂) -50% RDF + Vermicompost @ 2.5 t ha⁻¹. The least Plant height of 27.52 cm, 121.06 cm, and 142.52 cm was recorded at 30 DAS, 60 DAS and at 90 DAS respectively in treatment (T₄) -50% RDF + *Azophos* @ 20 kg ha⁻¹. The increased height of the plants observed in treatment (T₇) can be attributed to the application of micronutrients, biofertilizers, and NPK sources, which play crucial roles in plant growth and development. These substances are involved in chlorophyll biosynthesis, respiration, chloroplast

development, and enhancement of photosystem performance, leading to the observed increase in plant height. The application of *Azophos* significantly contributes to plant height as biofertilizers have been shown to improve seed germination, plant growth, root length, and the availability of N, P, and K in the soil. This improvement is likely due to the ability of biofertilizers to produce auxins and other growth-promoting substances as mentioned by Cortivo *et al.* (2020). Additionally, INM boosted photosynthetic activity and cell division, which significantly improved plant height by fixing molecular nitrogen and synthesizing growth-promoting enzymes like IAA and Gibberlins, the application of RDF + Micronutrients enhanced nitrogen availability and changed the microbial balance in the rhizosphere, which in turn encourages plant growth and development.

3.1.2. Effect of INM on Leaf area index

Significantly higher leaf area index was recorded in treatment T₇ [50% RDF + Vermicompost @ 2.5 t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹ + *Azophos* @ 20 kg ha⁻¹] at 90 DAS which excelled all other treatments [Table 1]. This was followed by the treatment (T₅) application of 50% RDF + Vermicompost @ 2.5t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹. The treatment (T₆)-50% RDF + Vermicompost @ 2.5 t ha⁻¹ + *Azophos* @ 20 kg ha⁻¹ was found to be statistically on par with (T₂) -50% RDF + Vermicompost @ 2.5 t ha⁻¹. The least leaf area index values of 3.57 at 60 DAS and 3.26 at 90 DAS were recorded in (T₄) - 50% RDF + *Azophos* @ 20 kg ha⁻¹. The higher LAI is due to vermicompost which contains a high amount of macro and micronutrients that enhance the nutritional status of soil when applied to the soil in combination with inorganic fertilizers primarily NO₃, PO₄, Ca, K, Mg, S, and other essential nutrients in the forms that are readily taken up by the plants which led to higher leaf area index of sorghum (Sivakumar, 2020). Also, INM practices determine crop capacity for photosynthetic activity, and light interception and power of source/sink increase thereby resulting in higher leaf area index (Rachel *et al.*, 2023).

3.1.3. Effect of INM on dry matter production (kg ha⁻¹)

Data concerning dry matter production were furnished in [Table 1]. Among the treatments tested in the experiment, treatment (T₇) application of 50% RDF + Vermicompost @ 2.5t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ +

FeSO₄ @ 25 kg ha⁻¹+ Azophos @ 20 kg ha⁻¹ excelled all other treatments and recorded DMP of 1810, 9174, 11977 kg ha⁻¹ at 30,60,90 DAS respectively. This was followed by the treatment (T₅) application of 50% RDF + Vermicompost @ 2.5t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹. The treatment (T₆)-50% RDF + Vermicompost @ 2.5 t ha⁻¹ + Azophos @ 20 kg ha⁻¹ was found to be statistically on par with (T₂) - 50% RDF + Vermicompost @ 2.5 t ha⁻¹. The least dry matter production 994 kg ha⁻¹, 2816 kg ha⁻¹and 6561 kg ha⁻¹ was recorded in (T₄)-50% RDF + Azophos @ 20 kg ha⁻¹ at 30 DAS, 60 DAS, and at 90 DAS respectively. The higher DMP recorded might be attributed to the continuous steady release of nutrients which might have enabled the leaf area duration to extend, thus favoring the plants to increase the photosynthetic rate thereby resulting in higher DMP. Also, iron and zinc are major constituents of carbonic anhydrase along with NPK source has many important functions in plant growth and development, such as involvement in various enzymatic and metabolic activities like biosynthesis of chlorophyll, respiration, chloroplast development, and improves the performance of photosystems and photosynthetic efficiency, which resulted in higher dry weight and dry matter production. (Srihari *et al.*, 2023; Kumar *et al.*, 2022). Also increased dry matter accumulation in vermicompost, Micronutrients and RDF treated plots

is due to steady release of nutrients which enhanced leaf area duration to extend thus led to high accumulation of dry matter (Ponmozhi *et al.*, 2019).

3.1.4. Effect of INM on Crop Growth Rate (g m⁻² day⁻¹)

Data regarding the CGR of sorghum were shown in [Table 1]. Among the treatments tested in the experiment, treatment (T₇) application of 50% RDF + Vermicompost @ 2.5 t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹+Azophos @ 20 kg ha⁻¹ recorded maximum crop growth rate of 18.47 (g m⁻² day⁻¹) and 6.10 (g m⁻² day⁻¹) at 30-60 DAS and at 60-90 DAS respectively and excelled all other treatments. The treatment (T₄) -50% RDF + Azophos @ 20 kg ha⁻¹ which recorded the lowest crop growth rate of 14.96 (g m⁻² day⁻¹) and 2.54 (g m⁻² day⁻¹) at 30-60 DAS and at 60-90 DAS, respectively. This might be due to the combined effect of organic manure, biofertilizers, and chemical fertilizers in balanced proportion played a vital role in decomposition and easy release of nutrients thereby leading to improved crop growth and development. Also, a combination of organics and inorganics boosts the number of leaves in plants and optimum nutrients to plants by modifying soil and plant environment suitable for better performance of plant morphology as well as overall crop growth rate (Tudu *et al.*, 2023).

Table 1. Effect of integrated nutrient on growth attributes of irrigated sorghum.

Treatments	Plant height (cm)	Dry matter production (kg ha ⁻¹)	Leaf area index	Crop growth rate (g m ⁻² day ⁻¹)
T ₁ - 100% RDF (90:45:45 kg N: P ₂ O ₅ : K ₂ O ha ⁻¹)	153.54	9097	3.51	5.02
T ₂ - 50% RDF + Vermicompost @ 2.5 t ha ⁻¹	162.17	7396	3.72	3.11
T ₃ - 50% RDF +ZnSO ₄ @ 20 kg ha ⁻¹ + FeSO ₄ @ 25 kg ha ⁻¹	170.63	8285	3.86	3.96
T ₄ - 50% RDF + Azophos @ 20 kg ha ⁻¹	142.52	6561	3.26	2.54
T ₅ -50% RDF + Vermicompost @ 2.5 t ha ⁻¹ +ZnSO ₄ @ 20 kg ha ⁻¹ + FeSO ₄ @ 25 kg ha ⁻¹	184.49	11073	4.20	5.58
T ₆ - 50% RDF + Vermicompost @ 2.5 t ha ⁻¹ + Azophos @ 20 kg ha ⁻¹	168.49	7472	4.17	3.60
T ₇ -50% RDF Vermicompost @ 2.5 t ha ⁻¹ +ZnSO ₄ @ 20 kg ha ⁻¹ + FeSO ₄ @ 25 kg ha ⁻¹ + Azophos @ 20 kg ha ⁻¹	194.55	11977	4.46	6.10
S.Ed	4.13	386.19	0.09	0.24
CD (P=0.05)	8.69	811.01	0.19	0.52

3.2. Effect of INM on yield and yield attributes

Among all the treatments enlisted, treatment (T₇) - Application of 50% RDF+ Vermicompost @ 2.5t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹+

Azophos @ 20 kg ha⁻¹ recorded highest yield attributes like number of grains earhead⁻¹, Weight of grains earhead⁻¹ (g), thousand grain weight (g), length of earhead (cm), Harvest index (%) [Table 2]. The increase in yield attributes may be attributed to

supply of zinc and iron along with NPK to the crop which have direct role in photosynthesis, assimilation and translocation of photosynthates from source to sink and higher production of assimilates. Also, balanced fertilizers, accompanied by complementary organic and biofertilizers help reverse environmental degradation by providing nutrients to the soil, thus increasing crop yield attributes and yield (Samijan *et al.*, 2024; Souri *et al.*, 2019). Further, the vermicompost relatively added large amount of macro and micro nutrients especially P, Ca and Mg, which involved in various enzymatic and metabolic activities, impart physio-chemical changes in soil and helps in slow release, available form of nutrients in balanced form resulting in more photosynthates assimilation and higher harvest index. Also slow release of nutrients thereby protected from fixation and other leaching losses leading to better photosynthetic efficiency which resulted in higher yield attributes (Durgude *et al.*, 2019; Reddy *et al.*, 2020). Inclusion of micronutrients helps in tryptophan synthesis and provided favourable environment in rhizosphere which increased photosynthetic efficiency and ultimately resulted in higher length of earhead (cm) as well as number of grains earhead⁻¹.

3.3. Effect of INM on grain yield (kg ha⁻¹)

Data regarding grain yield is shown in [Table 2]. The beneficial influence of integrated use of organic, inorganic and micronutrient sources exhibited a profound effect. Among all the treatments enlisted above, the treatment (T₇) - application of 50% RDF + Vermicompost @ 2.5t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹ + Azophos @ 20 kg ha⁻¹ recorded higher grain yield. This was significantly followed by treatment (T₅)- 50% RDF + Vermicompost @ 2.5 t

ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹. Also, balanced proportion of nutrient availability created favourable nutritional environment in the rhizosphere and higher absorption of nutrients by plants lead to the increased photosynthetic efficiency and production of assimilates and conversion of assimilates into yield in larger fractions which ultimately resulted in higher yield (Mule *et al.*,2019); (Kumar *et al.*,2022). Furthermore, efficient translocation of photosynthate to reproductive parts through biofertilizer application enhances grain yield (Kusumbe *et al.*, 2023). The lowest grain yield was obtained from treatment (T₄) -50% RDF + Azophos @ 20 kg ha⁻¹.

3.4. Effect of INM on stover yield (kg ha⁻¹)

Among all the treatments enlisted above, the treatment (T₇) - application of 50% RDF + Vermicompost @ 2.5t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹ + Azophos @ 20 kg ha⁻¹ recorded higher stover yield [Table 2]. This is due to the application of nitrogen in ammonium ions help in nitrogen fixation and phytohormone production thereby improves nutrient use efficiency and ultimately higher yield and productivity (Kumar *et al.*, 2017). Further by checking N losses and protecting soil N by forming organic -mineral complexes, continuous N availability and greater stover yield is ensured (Jagadeesha *et al.*, 2020). Also biofertilizes and micronutrients improve stover yield by improving the absorption rate of nutrients and photosynthetic efficiency by production of photosynthates leading to increased yield (Jakhad and Deberma,2023). The lowest stover yield was obtained from treatment (T₄) -50% RDF + Azophos @ 20 kg ha⁻¹.

Table 2. Effect of integrated nutrient on yield attributes and yield of irrigated sorghum.

Treatments	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Number of grains earhead ⁻¹	Thousand grain weight (g)	Length of earhead (cm)	Harvest index (%)
T ₁ - 100% RDF (90:45:45 kg N: P ₂ O ₅ : K ₂ O ha ⁻¹)	2764	7769	717	27.54	20.83	26.57
T ₂ - 50% RDF + Vermicompost @ 2.5 t ha ⁻¹	2231	6511	596	26.50	17.46	25.51
T ₃ - 50% RDF +ZnSO ₄ @ 20 kg ha ⁻¹ + FeSO ₄ @ 25 kg ha ⁻¹	2483	6913	645	27.51	19.36	26.42
T ₄ - 50% RDF + Azophos @ 20 kg ha ⁻¹	1856	5935	504	26.31	16.59	23.52
T ₅ - 50% RDF + Vermicompost @ 2.5 t ha ⁻¹ +ZnSO ₄ @ 20 kg ha ⁻¹ + FeSO ₄ @ 25 kg ha ⁻¹	3354	8789	859	27.89	18.40	27.38

T ₆ - 50% RDF + Vermicompost @ 2.5 t ha ⁻¹ + Azophos @ 20 kg ha ⁻¹	2293	6566	602	26.52	20.83	25.88
T ₇ - 50% RDF Vermicompost @ 2.5 t ha ⁻¹ + ZnSO ₄ @ 20 kg ha ⁻¹ + FeSO ₄ @ 25 kg ha ⁻¹ + Azophos @ 20 kg ha ⁻¹	3689	9401	941	28.00	24.25	28.18
S.Ed	90.03	290.57	23.69	0.90	0.37	0.18
CD (P=0.05)	189.07	610.21	42.75	NS	0.98	0.39

CONCLUSION

The results of the field experiment on sorghum crop revealed that growth attributes such as plant height (cm), Leaf area index, dry matter production (kg ha⁻¹), Crop growth rate (g m⁻² day⁻¹), and yield attributes such as the number of grains earhead⁻¹, Weight of grains earhead⁻¹(g) , thousand-grain weight (g),harvest index (%), length of earhead (cm), grain yield (kg ha⁻¹) and stover yield (kg ha⁻¹) were significantly influenced by the integrated application of 50% RDF Vermicompost @ 2.5 t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹ + Azophos @ 20 kg ha⁻¹ treatment (T₇) at various growth stages of sorghum. The lowest values were recorded in treatment (T₄). Based on the perspective of crop growth and yield it can be concluded that the treatment (T₇) 50% RDF Vermicompost @ 2.5 t ha⁻¹ + ZnSO₄ @ 20 kg ha⁻¹ + FeSO₄ @ 25 kg ha⁻¹ + Azophos @ 20 kg ha⁻¹ was highly impressive and more promising as efficient integrated nutrient management system for enhancing crop yield in sorghum, ecologically safe and also improving soil fertility which is felt need of present-day agriculture and cost-effective approach to sorghum cultivation. Therefore, this treatment (T₇) helps to enhance the yield of irrigated sorghum, as it reduces the need for inorganic fertilizers, improves soil health and minimizes environmental pollution by conjunctive use of organics, in-organics and bio fertilizers.

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