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Effect of Integrated Nutrient Management on Growth, Yield, Nutrient Uptake and Economics of Rabi Sorghum (*Sorghum bicolor* (L.) Moench)

**Akash Kumar Tudu ^a, Jnana Bharati Palai ^{a*},
Tanmoy Shankar ^a, Rahul Adhikary ^a,
Triptesh Mondal ^a and Suprava Nath ^a**

^a Centurion University of Technology and Management, Paralakhemundi, Gajapati, Odisha - 761211, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Long term study on different crops indicated that application of balanced NPK fertilizer couldn't meet higher yield due to poor physical properties and micronutrient deficiencies. Keeping in view to the above concept a experiment entitled "Effect of Integrated Nutrient Management on Growth and Yield of Rabi Sorghum (*Sorghum bicolor* (L.) Moench)" was conducted at post graduate experimental farm of M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi during the rabi season, 2022. The experimental soil was sandy

*Corresponding author: E-mail: jnana@cutm.ac.in;

loam with low in available nitrogen and medium in phosphorus and potassium. The experimental design was randomized block design, which consists of 10 numbers of treatments as different combinations of recommended dose of fertilizer (RDF) and farmyard manure (FYM), each treatment replicated thrice. The treatments are T₁: Control, T₂: 50% RDF, T₃: 75%RDF, T₄: 100%RDF, T₅: 50%RDF+5t FYM ha⁻¹, T₆: 50% RDF + 10t FYM ha⁻¹, T₇: 75% RDF + 5t FYM ha⁻¹, T₈: 75%RDF+10t FYM ha⁻¹, T₉: 100%RDF + 5t FYM ha⁻¹, T₁₀: 100%RDF + 10t FYM ha⁻¹. Among all the treatments significantly highest growth, yield attributes and nutrient uptake were recorded from the treatment 100% RDF + 10t FYM ha⁻¹(T₁₀). Application of 100% RDF + 10t FYM recorded highest sorghum grain yield (2416 kg ha⁻¹) and gross return (₹85108/- ha⁻¹). However, maximum net return (₹48010/- ha⁻¹) was recorded from 100%RDF + 5t FYM ha⁻¹ but B:C ratio (1.49) from 75%RDF.

Keywords: RDF; FYM; sorghum; growth; yield; nutrient uptake; economics.

1. INTRODUCTION

Sorghum, also known as 'Jowar' in India, which is considered as the most important among all millet crops. It is the fifth most important cereal in the world followed by wheat, rice, maize and barley. Worldwide, sorghum is grown on 40.25 million hectares of land, with an average yield of 58.7 million tonnes in 2020 [1]. Whereas, in India in 2020-2021 sorghum production was 4.78 million tonnes from 4.24 million hectares with an average yield of 1128 kg/ha [2]. While in Odisha the average yield was too low (633 kg/ha) with the total production of 3.68 thousand tonnes from an area of 5.81 thousand ha in 2019-20 [3]. The main sorghum production countries are the USA and India. Sorghum is grown under recommended dose of 80kg N, 40kg P₂O₅ and 40kg K₂O per hectare. Supplement of recommended dose of fertilizers (RDF) only through inorganic sources deteriorates soil health, induces environmental pollution and also increases the cost of production. Application of only organic sources to meet the demand of plant nutrient is also difficult because a huge amount of organic manure is required, which will be not available. So, the concept of integrated nutrient management (INM) in sorghum will be suitable in every aspect [4]. Integrated use of different sources of plant nutrients such as organic manure and bioinoculants in combination with chemical fertilizers improves soil fertility and crop yield [5]. Judicious use of FYM with chemical fertilizers improves soil's physical, chemical, and biological properties and improves crop productivity [6]. Conventionally, nutrient management in sorghum production has relied heavily on use of chemical fertilizers and often applied in excessive amounts without considering the crop's nutrient needs or the characteristics of the soil. This unbalanced approach has led to nutrient imbalances,

reduced soil fertility, increased fertilizer costs, and environmental pollution through nutrient runoff and leaching. Application of FYM and inorganic nitrogen levels recorded higher grain and fodder yield in sorghum fields [7]. The basic concept behind integrated nutrient management (INM) is to keep soil fertility high by using all accessible sources of fertilizer. The amount of organic matter in soil affects the nutrients that are available to plants for nutrient uptake [8]. The present experiment was conducted to study the impact of integrated nutrient management on growth, yield and economics of sorghum.

2. MATERIALS AND METHODS

A field experiment [Fig. 1 (a&b)] was conducted at Post Graduate research farm of MSSoA, Centurion University of Technology and Management, Paralakhemundi (23°39' N latitude and 87°42' E Longitude) to study the effect of integrated nutrient management on the growth and yield of rabi sorghum. Meteorological data recorded during the crop period has been mentioned in Fig. 2. Initial soil analysis had been done before sowing. The soil of the experimental site was sandy loam, acidic in reaction with pH 6.4, medium in organic carbon 0.3%, deficient in nitrogen (228kg ha⁻¹) low in phosphorus (14 kg ha⁻¹), and medium in potassium (120 kg ha⁻¹). The experiment was laid out in randomized block design (RBD) with 10 treatments and each treatment was replicated thrice. The treatments are T₁: Control, T₂: 50% RDF, T₃: 75%RDF, T₄: 100%RDF, T₅: 50%RDF+5t FYM ha⁻¹, T₆: 50% RDF + 10t FYM ha⁻¹, T₇: 75% RDF+5t FYM ha⁻¹, T₈: 75%RDF+10t FYM ha⁻¹, T₉: 100%RDF + 5t FYM ha⁻¹, T₁₀: 100%RDF+10t FYM ha⁻¹. The recommended doses of fertilizer were applied through urea, SSP, and MOP. Urea application was done at two splits, one as basal and another



Fig. 1. (a) Overview of experimental plot and (b) Crop at reproductive stage

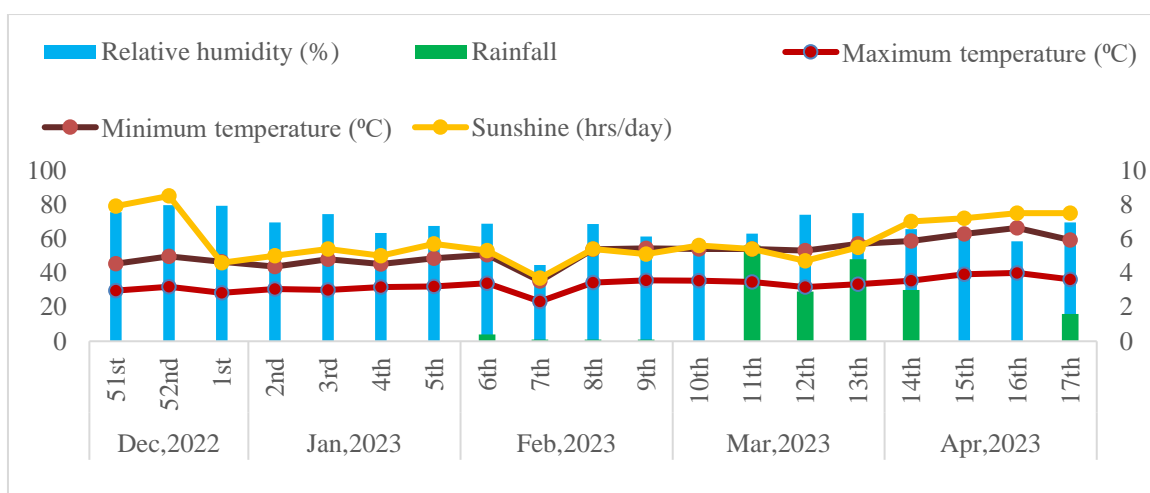


Fig. 2. Graph on meteorological data recorded during the crop period

as top dressing at 30 days after sowing DAS. Sorghum (SSG 59-3) was sown in rabi with the spacing 45 cm x 15 cm and seed rate 8 kg ha⁻¹. The growth attributes and yield attributes as per the schedule period were recorded. After harvesting the crop yield and economics was calculated. The data were analysed statistically by the analysis of variance (ANOVA) in MS excel 2010 and the significance of different sources of variation were tested by EMS and F-test at 5% probability.

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

Growth attributes of sorghum such as plant height, no. of leaves plant⁻¹, plant dry matter accumulation, leaf area index and stem girth at 90 DAS were mentioned in Table 1. The treatment T₁₀: 100%RDF+10t FYM ha⁻¹ recorded

significantly highest plant height (250.8cm), no. of leaves plant⁻¹(9.0), plant dry matter accumulation (564 g m⁻²), leaf area index (2.88) and stem girth (4.1cm) which was also showed significantly at par with the treatments viz. T₉: 100%RDF+ 5t FYM ha⁻¹, T₈: 75%RDF+ 10t FYM ha⁻¹ and T₄:100% RDF for all the above parameters. Whereas, in case of plant height and no. of leaves plant⁻¹ T₁₀: 100%RDF+10t FYM ha⁻¹ also remained on par with T₇: 75%RDF+5t FYM ha⁻¹. But the data showed in leaf area index indicated that T₁₀ also statistically at par with T₇: 75%RDF+5t FYM ha⁻¹, T₆: 50%RDF+10t FYM ha⁻¹ and T₃: 75% RDF. However, significantly lowest growth attributes recorded from T₁: Control (where no nutrient application was done). Higher plant height, no. of leaves plant⁻¹, stem girth and LAI in T₁₀ also resulted higher plant dry matter accumulation in T₁₀. Sorghum is a very susceptible and nitro-positive crop. So, the increase of fertilizer level and FYM level

Table 1. Effect of integrated nutrient management on growth attributes of rabi sorghum at 90s DAS

Treatments	Plant height(cm)	No. of leaves plant ⁻¹	Dry matter accumulation (g m ⁻²)	LAI	Stem girth(cm)
T ₁ : Control	140.5	7.0	382	2.13	2.7
T ₂ : 50% RDF	194.9	7.3	352	2.26	2.9
T ₃ : 75% RDF	207.2	7.2	445	2.56	3.2
T ₄ :100% RDF	245.2	8.5	508	2.69	3.6
T ₅ : 50%RDF+ 5t FYM ha ⁻¹	198.6	7.4	435	2.48	3.0
T ₆ : 50%RDF+10t FYM ha ⁻¹	200.7	7.9	470	2.62	3.3
T ₇ : 75%RDF+5t FYM ha ⁻¹	243.2	8.4	504	2.63	3.4
T ₈ : 75%RDF+ 10t FYM ha ⁻¹	246.5	8.7	516	2.76	3.6
T ₉ : 100%RDF+ 5t FYM ha ⁻¹	248.6	8.8	544	2.83	3.9
T ₁₀ : 100%RDF+10t FYM ha ⁻¹	250.8	9.0	564	2.88	4.1
S. Em. (±)	14.2	0.3	19.27	0.14	0.17
C. D. (P=0.05)	42.8	0.9	57	0.4	0.5

Table 2. Effect of integrated nutrient management on yield attributes of rabi sorghum

Treatments	Yield Attributes				
	Number of earheadplant ⁻¹	Length of earhead plant ⁻¹ (cm)	Dry weight of earhead (g)	Grain weightearhead ⁻¹ (g)	Test weight (g)
T ₁ : Control	1.04	27.9	21.0	17.5	9.9
T ₂ : 50% RDF	1.18	31.0	30.2	27.1	10.5
T ₃ : 75% RDF	1.24	31.3	32.2	27.9	10.4
T ₄ :100% RDF	1.47	34.5	34.5	30.9	10.5
T ₅ : 50%RDF+ 5t FYM ha ⁻¹	1.22	31.2	32.3	28.0	10.5
T ₆ : 50%RDF+10t FYM ha ⁻¹	1.31	31.5	32.4	28.4	10.5
T ₇ : 75%RDF+5t FYM ha ⁻¹	1.44	34.2	33.4	30.7	10.5
T ₈ : 75%RDF+ 10t FYM ha ⁻¹	1.48	34.7	34.8	31.3	10.5
T ₉ : 100%RDF+ 5t FYM ha ⁻¹	1.51	35.2	36.7	31.9	10.5
T ₁₀ : 100%RDF+10t FYM ha ⁻¹	1.67	35.7	40.4	33.6	11.2
S. Em. (±)	0.09	1.4	1.3	1.7	0.23
C. D. (P=0.05)	0.2	4.2	3.8	5.1	NS

Table 3. Effect of integrated nutrient management on yield of rabi sorghum

Treatments	Yield (kg ha ⁻¹)		
	Grain	Stover	Harvest index (HI)
T ₁ : Control	978	2449	28
T ₂ : 50% RDF	1950	4313	31
T ₃ : 75% RDF	2103	4952	30
T ₄ : 100% RDF	2242	5065	31
T ₅ : 50%RDF+ 5t FYM ha ⁻¹	2086	4760	30
T ₆ : 50%RDF+10t FYM ha ⁻¹	2172	4879	31
T ₇ : 75%RDF+5t FYM ha ⁻¹	2240	4993	31
T ₈ : 75%RDF+ 10t FYM ha ⁻¹	2252	5198	30
T ₉ : 100%RDF+ 5t FYM ha ⁻¹	2358	5469	30
T ₁₀ : 100%RDF+10t FYM ha ⁻¹	2416	5493	31
S. Em. (±)	82.96	190.37	1
C. D. (P=0.05)	242	545	NS

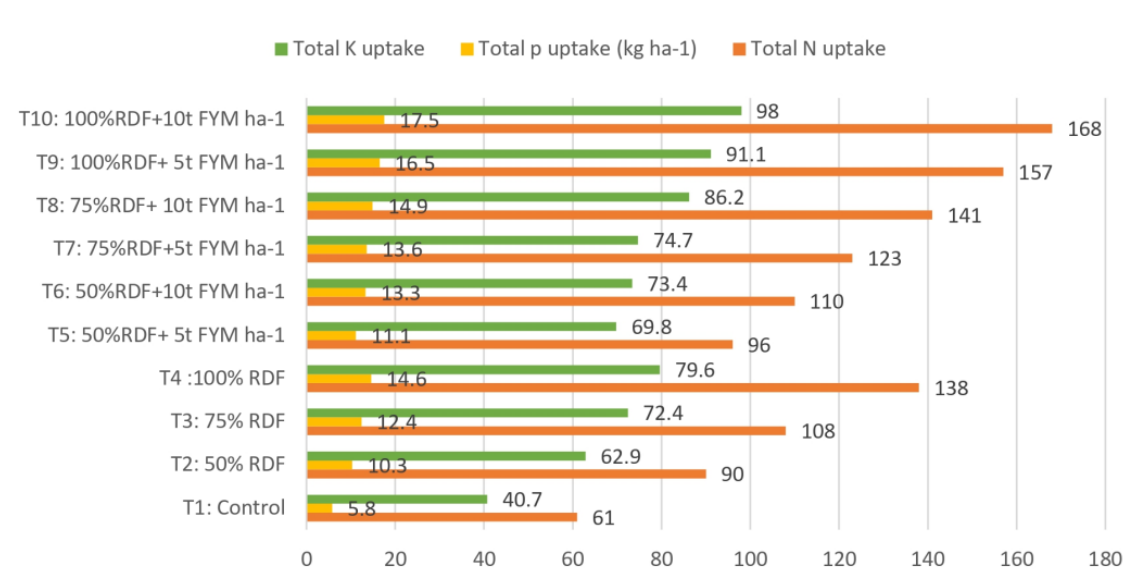


Fig. 3. Effect of integrated nutrient management on total nutrient uptake of *rabi* sorghum

Table 4. Effect of integrated nutrient management on economics of *rabi* sorghum

Treatments	Economics			
	Cost of cultivation (Rs. ha ⁻¹)	Gross return (Rs. ha ⁻¹)	Net return (Rs. ha ⁻¹)	B:C ratio
T ₁ : Control	23755	35711	11956	0.50
T ₂ : 50% RDF	28560	68653	40093	1.40
T ₃ : 75% RDF	29915	74364	44449	1.49
T ₄ :100% RDF	31265	78991	47726	1.53
T ₅ : 50%RDF+ 5t FYM ha ⁻¹	32460	73587	41127	1.27
T ₆ : 50%RDF+10t FYM ha ⁻¹	34960	76654	41694	1.19
T ₇ : 75%RDF+5t FYM ha ⁻¹	33815	79392	45577	1.35
T ₈ : 75%RDF+ 10t FYM ha ⁻¹	36315	79728	43413	1.20
T ₉ : 100%RDF+ 5t FYM ha ⁻¹	35165	83175	48010	1.37
T ₁₀ : 100%RDF+10t FYM ha ⁻¹	37665	85108	47443	1.26

increases the height of the plant. Similar results showed that application of 100% recommended dose of fertilizer (RDF) significantly increased plant height than by using 75% or 50% RDF and applying 10 tons of FYM ha⁻¹ (Kushwaha *et al.*, 2014).The combination of organics and inorganics will boost the leaf number of plants, this concept was mentioned by Sher *et al.* [9], Sabhad *et al.* [10] and Afzal *et al.* [11]. Combination of fertilizer and FYM might be provided optimum nutrient to plants by modifying soil and plant environment suitable for better performance of plant morphology as well as physiology, which resulted overall crop growth [12]. Singh *et al.* [13] found that highest plant height (199.1 cm) and dry matter accumulation (72.8 q ha⁻¹) were recorded with application of 50% RDF + 50% N (FYM) followed by 50% RDF + 50% N (crop residues) and 100% RDF +

ZnSO₄ 20 kg ha⁻¹. Similar findings also earlier reported by others [14,15]. Increased cell division and photosynthetic activity because of adequate supply of nutrients for longer periods might be the reason for increase in growth parameters [13].

3.2 Yield Attributes

After the sorghum crop was harvested, yield parameters viz., number of earhead plant⁻¹, length of earhead plant⁻¹(cm), dry weight of earhead (g), grain weight earhead⁻¹(g), and test weight(g) were recorded and presented in Table 2. Effect of integrated nutrient management (INM) significantly influenced yield attributes of *rabi* sorghum such as no. of ear head plant⁻¹, length of ear head, dry weight of earhead and grain weight earhead⁻¹. Whereas, weight of 1000

seeds (test weight) were not influenced by treatments of INM. Among all the treatments significantly highest no. of earhead plant⁻¹ (1.67), length of earhead (35.7cm), dry weight of ear head (40.4g) and grain weight ear head⁻¹ (33.6g) were recorded from T₁₀ (100%RDF+10t FYM ha⁻¹). Whereas T₁ (control) resulted lowest value of all the parameters. In case of length of ear head plant⁻¹ and grain weight ear head⁻¹ the treatment T₁₀ was statistically at par with T₄, T₆, T₇, T₈ and T₉. The data on no. of ear head plant⁻¹ showed that T₁₀ was statistically on par with T₄, T₈ and T₉ but the data on dry weight of earhead showed that T₁₀ was statistically at par with only T₉. Additional supply of FYM with 75% RDF and 100% RDF recorded higher yield attributes, which might be due to better nutrient supply through organic and inorganic sources for long period that affects crop growth and photosynthetic activity [16].

3.3 Yield

The grain yield, stover yield and harvest index are presented in Table 3. The highest grain yield was recorded from 100%RDF+10t FYM ha⁻¹(T₁₀) which was statistically at par with 100%RDF+5t FYM ha⁻¹ (T₉), 75%RDF+10t FYM ha⁻¹ (T₈), 75%RDF+5t FYM ha⁻¹ (T₇) and 100%RDF ha⁻¹ (T₄). With the application of extra 10 t FYM in a hectare there was increase in 7.2% grain yield in the treatment 100%RDF+10t FYM ha⁻¹(T₁₀) over 100%RDF. This shows that addition of FYM with RDF has effect on improving sorghum yield. Similar findings are also recorded by Raja *et al.*, [17]. The lowest grain yield was recorded from the control (T₁) where no nutrient application was done. The highest stover yield was found from the T₁₀ and T₁₀ was statistically remained on par with the treatments viz., T₃, T₄, T₇, T₈ and T₉. The lowest stover yield was obtained from the control treatment (T₁) where no nutrient application has done. Harvest index of sorghum was not influenced significantly by the different treatments of integrated nutrient management. The beneficial effect of 100%RDF along with FYM might be associated with sufficient availability of nutrients throughout the growth period especially during critical growth stages, which resulted vigorous growth and yield attributes that ultimately resulted better yield [18]. Singh *et al.*, [13] found that significantly higher grain yield of maize (1759 kg ha⁻¹) was recorded in 50% RDF + 50% N (FYM) over all the other integrated nutrient management treatments, however it was on par with 50% RDF + 50% N (crop residues).

3.4 Nutrient Uptake

The data on total nutrient uptake (N, P and K uptake) of sorghum is presented in Fig. 2. Total N (168 kg ha⁻¹), P (17.5 kg ha⁻¹) and K (98 kg ha⁻¹) uptake of sorghum were recorded significantly highest from the treatment 100%RDF+10t FYM ha⁻¹(T₁₀) and all the values are lowest in T₁ (Control).

Whereas, total N uptake showed that T₁₀ is statistically at par with T₉. But total P uptake showed that T₉, T₈ and T₄ were statistically significant with highest recorded treatment T₁₀. Though fertilizer supplies plant nutrient quickly, but judicious and combined application of both fertilizer and FYM might be improved soil microbial activity, which helped in better root proliferation as well as increased different plant nutrient availability. This might be the reason for higher biomass production and nutrient uptake in 100%RDF+10t FYM ha⁻¹. Similar results also found by Tomar *et al.*, [16]. Significantly higher total nutrient uptake (NPK) by maize was recorded in 50% RDF + 50% N (FYM) over all the other INM treatments [13]. Higher NPK uptake might be due to the favorable effect of incorporation of organic sources along with inorganic fertilizers which was previously mentioned by Sharma *et al.* [19] and Gupta *et al.* [20].

3.5 Economics

Cost of cultivation, gross return, net return and benefit: cost ratio of sorghum for different treatments has been calculated and presented in Table 4. The cost of cultivation (Rs. 37665/- ha⁻¹) and gross return (Rs. 85108/- ha⁻¹) of sorghum were highest in the treatment 100% RDF+10t FYM ha⁻¹ (T₁₀) due to higher application of fertilizer and FYM. Moreover, in terms of benefit: cost ratio, the highest (1.53) results were obtained with the application of 100% RDF and in terms of net returns the highest (Rs. 48010/- ha⁻¹) value was obtained with the application of 100%RDF+ 5t FYM ha⁻¹. Application of higher quantity of FYM increased cost of cultivation and decreased benefit: cost ratio in treatments where RDF and FYM applied combinedly. But due to high yield and 5t less FYM application resulted maximum net return from the treatment 100%RDF+ 5t FYM ha⁻¹ (T₉). In line with the above result Tomar *et al.* (2017) reported that application of 75%NPK + 5t FYM ha⁻¹ in maize recorded higher net return (Rs. 29634/- ha⁻¹) and lower B:C ratio (2.57) as compared to the

treatment 75%NPK, Rs. 27789/- ha⁻¹ and 2.62 respectively in 2011. Soil application of 5t/ha of FYM+ biofertilizer+ 50% RDF recorded highest gross and net return over RDF and 75% RDF +5t/ha of FYM in sorghum based intercropping system [21]. Sallawar et al., [22] revealed that the application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + Azospirillum gave significantly higher gross monetary return (Rs. 76068 ha⁻¹), net monetary return (Rs. 37999 ha⁻¹) and B:C ratio (2.07) over rest of the treatments, however it was at par with application of 75 % RDN through inorganic fertilizer + 25% RDN through FYM + seed treatment with PSB + Azospirillum.

4. CONCLUSION

Integrated Nutrient Management plays a crucial role in well growth and development of sorghum plants. By incorporating the recommended doses of fertilizers and farm yard manure, farmers can promote balanced nutrition, enhance soil fertility, and improve overall plant growth. However, it is important to consider other agronomic practices and environmental factors that influence plant growth for successful sorghum production. It should be emphasised that although utilising simply 100% RDF of inorganic fertilisers would improve benefit-cost ratio, but considering the net return, soil health, environmental well-being and sustainability taking into account the integrated strategy of applying 100% RDF+5t FYM ha⁻¹ would be advantageous.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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