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Effect of Integrated Nutrient Management on Yield, Economics and Available Soil Nutrient of *Kharif* Sorghum (*Sorghum bicolor* L.)

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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

The field experiment was laid out at Sorghum Research Station, VNMKV, Parbhani. Dist. Parbhani during *kharif* season of 2015 to study the "Integrated Nutrient Management in *Kharif* Sorghum (*Sorghum bicolor* L.)". The experiment was laid out in randomized block design with three replications and variety CSH -16 as test crop along with nine (09) treatment combinations. The quantity of organic and inorganic fertilizer dose was calculated and applied in the plots as per the treatments. Sowing was done on 21th June 2015 by seeds are dibbling and distance between 45cm x 15 cm. The crop was harvested at physiological maturity and data on yield attributes and yield were recorded. The study revealed that the application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* (T_8) gave significantly higher GMR (76,068 ₹ ha^{-1}), NMR (37,999 ₹ 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* (T_7).

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1. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) is an important cereal crop in India popularly known as 'Jawar' and large size of among other grain millets is called 'Great millet'. It is probably originated in East Central Africa and it was introduced to India from East Africa in the year 1500 BC. Sorghum is the 5th most important cereal crop in the world after rice, wheat, maize and barley. The advantage of this cereal crop it can be cultivated in both *Kharif* and *Rabi* season. In the world, USA is the largest producer of sorghum occupying 20.03 percent of area with 16.41 per cent production. India is a major sorghum growing country in the world. It stood second largest crop till green revolution but after green revolution, it occupies the third place among food grains after rice and wheat. It is observed that area of *Kharif* sorghum is decreasing day by day while the production and productivity is in increasing trend. Increase in productivity is only due to high yielding varieties and advanced technology. According to recent estimation of planning commission of India, 30-35 million tonnes of food grains and 14-15 million tonnes of nutrients require for commercial crops.

Hence integrated nutrient management approach is the option today's to mitigate the gap of nutrients in Indian agriculture. Integrated nutrient management is the alternative to increase the productivity through proper management. Keeping in view this fact, the present investigation was undertaken to find out a suitable nutrient management system to boost yield of *kharif* sorghum.

Integrated and balanced use of nutrients through inorganic and organic sources like FYM, vermicompost and biofertilizers is pre-requisite to produce to sustain soil fertility, supply of nutrients at an optimum level and to produce maximum crop yield with minimum inputes [1]. According to Shekar [2], the basic principal of INM is the maintenance of soil fertility by using all sources of nutrient. In plant nutrition, organic matter levels of a soil are a key property that decides the availability status of essential nutrients. The INM however, helps to maintain the productivity of soil and improves fertilizer use efficiency. Thus, it economizes the use of chemical fertilizers by influencing the yield of *kharif* crop besides nutrients availability, FYM and vermicompost also improves soil physical characteristics such as structures, porosity and water holding capacity. Vermicompost when applied in conjunction with biofertilizer, supplies energy to beneficial microorganism including *Azotobacter* and PSB.

2. MATERIALS AND METHODS

The experiment was conducted during *Kharif*, 2015 at AICSIP, Sorghum Research Station, VNMKV, Parbhani (MS). Parbhani located at 190 16' N latitude and 960 41' East longitudes and has sub – tropical climatic conditions. Parbhani is grouped under assured rainfall zone. The normal rainfall of this region is around 954.9 mm, precipitating mostly between mid June–mid Novembers. The average maximum and minimum temperature recorded 31.2°C and 22.6°C, respectively. The soil was medium deep black and well drained. The topography of the experimental field was fairly uniform and leveled. Soil samples up to 30 cm were randomly collected from different locations of field before start of the experiment during *Kharif*, 2015.

The precipitation is assured for *Kharif* crops so need of providing life saving irrigation. The experiment was laid out in Randomized block design with three replications constituting nine treatments of integrated nutrient management in *Kharif* sorghum. The treatments were (T_1):-100% RDN through inorganic fertilizer, (T_2):- 50% RDN through inorganic fertilizer + 50% RDN through FYM, (T_3):- 75% RDN through inorganic fertilizer + 25% RDN through FYM, (T_4) 50% RDN through inorganic fertilizer + 50% RDN through vermicompost, (T_5) 75% RDN through inorganic fertilizer + 25% RDN through vermicompost, (T_6):- 50% RDN through inorganic fertilizer + 25% RDN through FYM + 25% RDN through Vermicompost, (T_7):- 75% RDN through inorganic fertilizer + 25% RDN through FYM+ seed treatment with Microbial fertilizers like PSB + *Azospirillum*, (T_8):- 75% RDN through inorganic fertilizer + 25% RDN through Vermicompost + seed treatment with Microbial fertilizers like PSB + *Azospirillum* and (T_9) 75% RDN through inorganic fertilizer + seed treatment with Microbial fertilizers like PSB + *Azospirillum*.

The sorghum cultivar CSH-16 was obtained from AICSIP Sorghum Research Station, VNMKV, Parbhani. Sowing was done on 21st June, 2015 by dibbling 2-3 seed at each hill on a recommended spacing of 45 cm x 15cm. Seeds

were treated with Emametctin benzoyate @ 3 g kg^{-1} seeds in order to protect the crop from shoot-fly attack. Inorganic sources *viz.,* Urea, SSP, MOP and organic sources *viz.,* FYM, vermicompost, bio fertilizers were applied to respective plots as per the recommendation uniformly in the lines opened for sowing. During early growth stages of crop, to control of shoot fly (*Atherigona soccata*) and stem borer (*Chilopartellus*) in addition to seed treatment with Emametctin benzoyate two sprayings of Quinolphos and Emametctin benzoyate were taken. Five plants from each net plot were randomly selected and labeled for taking biometric observations at pre-harvest and post harvest growth stages. Available nitrogen, phosperous and potassium were determined by standard methods. Data obtained on various variables were analyzed by "analysis of variance method" [3].

3. RESULTS AND DISCUSSION

3.1 Influence of Integrated Nutrient Management on Sorghum

3.1.1 Yield attributes and yield

The main objective of the agronomist is to increase the economic yield which is grain yield in case of sorghum. The grain yield per unit area in sorghum is a function of yield attributes of an individual plant *viz.,* number of panicles m^{-2}, weight of panicle, length of panicle, number of grains $panicle^{-1}$, test weight and harvest index and ultimately the grain, straw and biological yield obtained from the crop. The application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* (T_8) recorded significantly higher weight of panicle (91.67 g), length of panicle (45.57 cm) and number of grains $panicle^{-1}$(2734) over rest of the treatments. However, it was at par with (T_7) 75 % RDN through inorganic fertilizer + 25% RDN through FYM + seed treatment with PSB + *Azospirillum* and (T_1) 100% RDN through inorganic fertilizer. It might be the effect of vigorous growth of plant under these treatments. Similar results were reported by Kharbade et al. [4], mahajan et al. [5], Cleto Namoobe et al. [6].

3.1.2 Grain yield (Kg ha^{-1})

The maximum grain yield was found to be the application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* (T_8) recorded significantly higher grain yield (2356.89 Kg ha^{-1}) over rest of the treatments, however, it was at par with (T_7) 75 % RDN through inorganic fertilizer + 25% RDN through FYM + seed treatment with PSB + *Azospirillum* and (T_1) 100% RDN through inorganic fertilizer. This might be attributed to rapid mineralization of N, P and K through inorganic fertilizer and steady supply of these nutrients from enriched vermicompost and biofertilizer, which might have met the nutrient requirement of crop at critical growth stages. The application of 50% RDN through inorganic fertilizer + 50% RDN through FYM (T_2) (1102.69 Kg ha^{-1}) is produce significantly lower grain yield respectively. Similar results were also reported by Kalibhavi et al. [7], Nawale et al. [8], Jat et al. [9], Gawai et al [10], Nemade et al. [11], Mahajan et al. [5], Bhalerao et al. [12].

3.1.3 Fodder yield (Kg ha^{-1})

The application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* (T_8) was recorded significantly higher fodder yield (5450.31Kg ha^{-1}) than other the treatments and however it was at par with (T_7) 75 % RDN through inorganic fertilizer + 25% RDN through FYM + seed treatment with PSB + *Azospirillum* , (T_1) 100% RDN through inorganic fertilizer. It may be due to higher availability of nutrients by synergistic effect of combined application of inorganic and organic sources and biofertlizers. Similar results were also reported by Bhalerao et al. [12], Mahajan and Mahajan [5], Nawale et al. [8].

3.1.4 Biological yield (Kg ha^{-1})

Biological yield was recorded significantly higher (7807.20 Kg ha^{-1}) that the application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* (T_8) over rest of the treatment and however, it was at par with (T_7) 75 % RDN through inorganic fertilizer + 25% RDN through FYM + seed treatment with PSB + *Azospirillum* and with (T_1) 100% RDN through inorganic fertilizer. This might be due higher grain and fodder yield because attributed to rapid mineralization of N, P and K and steadily supply of these nutrients from enriched vermicompost and biofertilizer, which might have met the requirement of crop at the critical stages.

Table 1. Grain yield, fodder yield, biological yield and harvest index of sorghum as influenced by different treatments

Treatment	Grain yield (Kg ha^{-1})	Fodder yield (Kg ha^{-1})	Biological yield (Kg ha^{-1})	Harvest Index (%)
T_1: 100% RDN through inorganic fertilizer	2190.65	5303.00	7493.65	29.23
T_2: 50% RDN through inorganic fertilizer + 50% RDN through FYM	1578.28	4013.03	5591.30	28.23
T_3: 75% RDN through inorganic fertilizer + 25% RDN through FYM	1662.45	4208.73	5871.18	28.32
T_4: 50% RDN through inorganic fertilizer + 50% RDN through vermicompost	1698.22	4229.78	5928.00	28.72
T_5: 75% RDN through inorganic fertilizer + 25% RDN through vermicompost	1752.94	4492.82	6245.76	28.06
T_6: 50% RDN through inorganic fertilizer + 25% RDN through FYM + 25% RDN through vermicompost	1763.46	4566.48	6329.93	27.86
T_7: 75% RDN through inorganic fertilizer + 25% RDN through FYM+ seed treatment with PSB + *Azospirillum*	2220.11	5366.14	7586.24	29.27
T_8: 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum*	2243.25	5387.18	7630.43	29.41
T_9: 75% RDN through inorganic fertilizer + seed treatment with PSB + *Azospirillum*	1397.30	3667.91	5065.21	27.59
S.E. $\pm$	19.49	80.59	79.8963	-
C.D. at 5 %	58.66	242.59	240.511	-
G. Mean	1834.07	4581.67	6415.75	28.52

Table 2. Cost of cultivation, gross and net return (₹ ha^{-1}) and B:C ratio of sorghum as influenced by different treatments

Treatment	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B: C ratio
T_1: 100% RDN through inorganic fertilizer	35200	72126	36926	2.05
T_2: 50% RDN through inorganic fertilizer + 50% RDN through FYM	38200	53118	14918	1.39
T_3: 75% RDN through inorganic fertilizer + 25% RDN through FYM	36200	55841	19641	1.54
T_4: 50% RDN through inorganic fertilizer + 50% RDN through vermicompost	38500	56626	18126	1.47
T_5: 75% RDN through inorganic fertilizer + 25% RDN through vermicompost	36500	59211	22711	1.62
T_6: 50% RDN through inorganic fertilizer + 25% RDN through FYM + 25% RDN through vermicompost	38100	59847	21747	1.57
T_7: 75% RDN through inorganic fertilizer + 25% RDN through FYM+ seed treatment with PSB + *Azospirillum*	35500	73047	37547	2.06
T_8: 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum*	35600	73599	37999	2.07
T_9: 75% RDN through inorganic fertilizer + seed treatment with PSB + *Azospirillum*	34900	47718	12818	1.37
S.E. $\pm$	-	555	555	-
C.D. at 5 %	-	1671	1671	-
G. Mean	36522	61237	24715	1.68

Table 3. An extract of data on the important growth, development, yield attributing characters, yield, (at harvest) economics and N, P, and K content (Kg ha^{-1}) in soil after harvest of sorghum as affected by the different treatments

Sr No.	Characters	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	CD at 5%
1)	Plant height (cm)	224.33	207.00	212.00	213.33	214.33	210.00	225.00	229.33	212.67	5.42
2)	Number of functional leaves plant^{-1}	5.97	3.87	4.40	5.40	5.37	5.10	6.03	6.43	5.10	0.99
3)	Leaf area plant^{-1}(dm^2)	10.60	8.53	8.37	9.10	9.03	8.30	10.77	11.13	9.37	0.61
4)	Total dry matter (g)	121.67	112.33	118.33	115.00	118.33	118.33	127.00	131.67	114.67	10.83
5)	Circumference of stem (cm)	6.93	5.80	5.83	6.174	6.37	6.33	7.07	7.43	6.43	0.67
6)	Number of internodes	9.57	8.10	8.50	9.03	9.00	8.83	9.77	10.02	8.97	0.47
7)	Length of internodes (cm)	12.13	11.10	11.43	11.33	11.40	11.60	12.33	12.37	11.67	0.64
8)	Length of panicle(cm)	39.13	30.83	32.64	33.38	32.47	30.48	39.60	45.57	28.00	8.86
9)	Weight of panicle (g) plant^{-1}	88.67	73.33	79.33	83.00	86.67	87.00	90.33	91.67	86.00	3.47
10)	Number of panicle m^{-2}	14.00	15.00	14.67	15.00	14.67	13.00	14.00	15.00	14.67	NS
11)	Number of grains panicle^{-1}	1256.7	1050.0	1120.0	1136.7	1153.3	1240.0	1263.0	1280.0	1353.3	24.48
12)	Wt. of grain plant^{-1}	15.77	11.17	11.83	12.04	12.07	12.10	16.00	16.07	11.77	0.43
13)	Grain yield (Kg ha^{-1})	2190.65	1578.28	1662.45	1698.22	1752.94	1763.46	2220.11	2243.25	1397.30	58.66
14)	Fodder yield (Kg ha^{-1})	5303.00	4013.03	4208.73	4229.78	4492.82	4566.48	5366.14	5387.18	3667.91	242.59
15)	Biological yield (Kg ha^{-1})	7493.65	5591.30	5871.18	5928.00	6245.76	6329.93	7586.24	7630.43	5065.21	240.51
16)	Test wt. (g)	29.67	29.50	29.70	28.50	29.13	29.57	29.60	29.17	29.90	NS
17)	Harvest index	29.23	28.23	28.32	28.72	28.06	27.86	29.27	29.41	27.59	-
18)	Net monitory returns	36926	14918	19641	18126	22711	21747	37547	37999	12818	1671.17
19)	Gross monitory returns	72125.90	53118.42	55841.47	56625.98	59210.99	59846.50	73046.78	73598.96	47717.78	1671.17
20)	Cost of cultivation	35200	38200	36200	38500	36500	38100	35500	35600	34900	-
21)	B:C ratio	2.05	1.39	1.54	1.47	1.62	1.57	2.06	2.07	1.37	-
22)	N content in soil after harvest (Kg ha^{-1})	131.30	156.20	149.60	146.00	143.00	140.20	124.50	121.30	132.25	0.15
	P content in soil after harvest (Kg ha^{-1})	16.20	19.80	19.20	19.30	19.00	18.90	15.60	13.90	14.30	0.13
	K content in soil after harvest (Kg ha^{-1})	358.9	368.4	364.2	366.9	363	364.2	357.9	356.2	358.2	0.15

The lower biological yield (Kg ha^{-1}) was produced by the application of 50% RDN through inorganic fertilizer + 50% RDN through FYM (T_2) (4469.67 Kg ha^{-1}). Similar results were also reported by Bhalerao et al. [12]. Kachpur et al. [13].

3.1.5 N, P and K content (Kg ha^{-1}) in soil after harvest

The available N, P and K content of soil after harvest of sorghum were influenced significantly by different treatments during the experimentation. The application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* (T_8) and with (T_7) 75 % RDN through inorganic fertilizer + 25% RDN through FYM + seed treatment with PSB + *Azospirillum* more nutrient uptake by crop as compared to inorganic fertilizer over rest of the treatments during the field investigation and the treatments significantly improved available N, P and K status of soil after harvest of sorghum treatment T_2 application of 50% RDN through inorganic fertilizer + 50% RDN through FYM.

This might be due to higher availability of nutrients by synergetic effect of combined application of organic and inorganic sources and biofertilizer, *Azospirillum* produce photo-hormones which can stimulate root growth and induce change in root morphology and root proliferation, which in turn increase assimilation of nutrients. Similar results were also reported by Patidar et al. [14], Kausadikar et al. [15], Jat et al. [9], Bhande et al. [16], Tamboli et al. [17].

3.2 Economics

Bhagat, et al. [18] reported that influence of INM on (T_8) 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* gave maximum gross returns (76,068.65 ₹ ha^{-1}), net returns (39,569 ₹ ha^{-1}) and B:C ratio (2.03) over rest of the treatments, however it was at par with (T_7) and (T_1). These increased in economic parameters were due to significant improvement in grain and straw yield of sorghum under this integrated nutrient management in different treatments. Similar results were also reported by Nawale et al. [8], Mahajan et al. [5], Jat et al. [9].

3.2.1 Cost of cultivation

Data presented in Table 2 implies total cost of sorghum cultivation. The mean value of total cost was 36552 ₹ ha^{-1}. Glimpse of the Table 2 insinuated that, the cost of cultivation was higher under application of 50% RDN through inorganic fertilizer + 50% RDN through vermicompost (T_4) (38500 ₹ ha^{-1}) followed by (T_2) 50% RDN through inorganic fertilizer + 50% RDN through FYM and lowest cost of cultivation (35200 ₹ ha^{-1}) was under treatment (T_1) 100% RDN through inorganic fertilizer.

3.2.2 Gross returns

Data on gross return are presented in Table 2. The mean gross returns were (612367 ₹ **ha^{-1}**) Scrutiny of the Table 1 implies that the application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* (T_8) recorded significantly higher gross returns ₹ha^{-1} *i.e.* (73599 ₹ ha^{-1}) over rest of the treatments. But it was at par with (T_7) 75 % RDN through inorganic fertilizer + 25% RDN through FYM + seed treatment with PSB + *Azospirillum* and (T_1) 100% RDN through inorganic fertilizer. Similar result found Patil et al. [19]

Application of 75% RDN through inorganic fertilizer + seed treatment with PSB + *Azospirillum* (T_9) (47718 ₹ ha^{-1}) is recorded significantly lower gross returns ₹ha^{-1}. Similar results were also reported by Jat et al. [9], Afzal M et al. [20].

3.2.3 Net returns

Data presented in Table 2 revealed that the mean net return of sorghum was 24715 ₹ **ha^{-1}**. The application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* (T_8) recorded significantly higher net returns ₹ha^{-1} *i.e.* (37999 ₹ ha^{-1}) over rest of the treatments, but it was at par with (T_7) and (T_1). Application of 75% RDN through inorganic fertilizer + seed treatment with PSB + *Azospirillum* (T_9) (12818 ₹ ha^{-1}) is recorded significantly lower net returns ₹ ha^{-1}. Similar results were also reported by Mahajan et al. [5], Abdelmuniem et al. [21].

3.3 B:C Ratio

Data on B:C ratio as influenced by various treatments are presented in Table 2 The mean B:C ratio was (1.68). The application 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* (T_8) was found highest (2.07) B:C

ratio over rest of the treatments. But it was at par with (T_7) and (T_1). Similar results were also reported by Nawale et al. [8], Gaikwad et al. [22].

4. CONCLUSIONS

On the basis of present investigation following conclusions can be drown.

Sorghum (jowar) is a cereal crop which require more nutrients than the other fodder crops. Application of the chemical fertilizers to the crop will not fulfill its nutrient requirement and it is damaging the soil fertility and soil health. INM is good approach for the economical benefit of the farmer and increases the soil fertility and nutrient availability to the crops.

1. In *kharif* sorghum the application of 75% RDN through inorganic fertilizer along with 25% organic sources + seed treatment with *Azospirillum* and PSB produced higher grain and fodder yield and also improve the soil fertility.
2. The application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + seed treatment with PSB + *Azospirillum* recorded higher gross monetary returns (76,068 ₹ ha^{-1}), net monitory returns (37,999 ₹ ha^{-1}) and B:C ratio (2.07).

Above conclusions are based on single season research finding and it needs further confirmation by repeating the trial for at least one more season.

CONFERENCE DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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