International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

IJBSM August 2023, 14(8):1168-1174 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR3549a

Research Article Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2023.3549a

Rice Fallow No-Till Sorghum Using Inorganic Fertilizers in Combination with Biofertilizer Consortium: Nutrient Uptake, Yield Attributes and Economics

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ABSTRACT

A field investigation was carried out to study the influence of inorganic fertilizers along with biofertilizer consortium on the performance of sorghum under rice fallows at Agricultural College Farm, Bapatla, Acharya N. G. Ranga Agricultural University, Andhra Pradesh, India during *rabi* (December–April), 2018–19. There were 7 treatments tested in randomized block design (RBD) with 3 replications. Yield attributes, length of earhead (33.2 cm), number of filled grains earhead^{-1} (1359) and maximum protein content (9.1) were recorded higher in 125% RDF+biofertilizer consortium and remained significantly on par with 100% RDF+biofertilzers consortium treatment. Application of 125% RDF+ biofertilizer consortium application (T_6) significantly increased grain and stover yields by (30.3%, 26.5%) respectively, compared to control. The same T_6 treatment recorded highest nitrogen, phosphorus and potassium uptake at 30, 60, 90 DAS and at harvest in the grain and straw followed by T_5 treatment. Significantly higher grain, stover, and biological yield were obtained with 125% RDF treatment compared to 75% and 50% RDF. Improvement in N, P and K uptake in grain by (53.0, 58.0 and 74.4%) and stover by (50.5, 51.8 and 50.1%) compared with control treatment. The highest gross returns (₹ 71710 ha^{-1}), net returns (₹ 43155 ha^{-1}) and returns ₹$^{-1}$ investment (1.88) was obtained with application of 125% RDF+Biofertilizer consortium treatment. When compared to other treatments, the use of 125% RDF+Biofertilizer consortium increased the production and provided economic benefits may be adapted as choice of viable alternative in the coastal Andhra Pradesh.

KEYWORDS: Biofertilizer consortium, net returns, nutrient uptake, returns and investment

***Citation* (VANCOUVER):** Reddy et al., Rice Fallow No-Till Sorghum Using Inorganic Fertilizers in Combination with Biofertilizer Consortium: Nutrient Uptake, Yield Attributes and Economics. *International Journal of Bio-resource and Stress Management,* 2023; 14(8), 1168-1174. HTTPS://DOI.ORG/10.23910/1.2023.3549a.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 03rd May 2023 RECEIVED in revised form on 20th July 2023 ACCEPTED in final form on 01st August 2023 PUBLISHED on 23rd August 2023

1. INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) cultivation is declining, with acreage shifting to more profitable cereals (rice, wheat, corn, and pulses) and competing crops (oilseeds and cotton). The global area under sorghum cultivation is 41.97 mha, with annual production of 65.2 mt. Globally, India ranks third in sorghum area (4.82 mha) and seventh in production 4.4 mmt (Anonymous, 2021) with a productivity of 989 kg ha^{-1} (Anonymous, 2021a). The performance of the monsoon influences the annual variation in sorghum and millet output, which is largely unirrigated (Anonymous, 2021b). Sorghum is known to have adopted to marginal soils with poor nutrient supply (Hari Prasanna and Patil, 2015, Qi et al., 2016, Malobane et al., 2020) and is resilient to abiotic stresses like heat and drought (Pennisi, 2009, Sunoj et al., 2017, Chiluwal et al., 2018), allowing it to thrive even in adverse and marginal conditions (Van Oosterom et al., 2001, Saballos, 2008). However, the area under *kharif* sorghum cultivation is decreasing rapidly due to various reasons (Chapke et al., 2011, Mundia et al., 2019). This decline in yields has been attributed to the reduction in soil fertility and drought as a result of climate change (Nyamangara et al., 2014). Of late, *rabi* sorghum has also been successfully introduced in the rice fallows of coastal Andhra Pradesh (Patil et al., 2012). The highest productivity of 6.9 t ha^{-1} in 2014–15 in the country (Chapke et al., 2017) was reported in sorghum and is now grown in more than 11,000 ha area in rice-fallows areas of Guntur district in coastal Andhra Pradesh. One of the most serious challenges in agriculture is imbalanced plant nutrition (Regeo et al., 2013). A sufficient supply of nitrogen (N), for instance, led to higher grain yields in intensive agricultural systems (Chianu et al.,2012, Bollam et al., 2021). The organic fertiliser primarily enhances soil organic matter, improves soil structure, while the inorganic fertiliser supply nutrients that are easily available (Godara et al., 2012). To overcome the soil fertility constraint, smart use of a combination of organic and inorganic resources is a feasible solution (Abedi et al., 2010, Kazemeini et al., 2010, Mugwe et al., 2009). Biofertilizers improve soil organic matter, enzymatic activity, microbial population and decrease the negative effect of chemical fertilizers and also increase the yields on sustainable basis (Alizadeh and Ordookhani 2011, Jala-Abadi et al., 2012). Under IPNS, balanced application of organic amendments together with chemical fertilisers containing micronutrients and biofertilizers results in better soil fertility and crop yield through fertiliser usage efficiency (Singh et al., 2004, Guggari and Kalghatagi 2005, Jala-Abadi et al., 2012). Therefore, integrated use of inorganic and bio-fertilizers could play an instrumental role in enhancing wheat productivity (Gupta et al., 2020). Biofertilizers, which promotes plant growth by increasing supply of nutrient to the plant (Malusa and Vassilev, 2014, Thomas and Singh, 2019). The effects of biological fertilizers on the growth and yield of Sorghum have been studied by many researchers (Widada et al., 2007, Kamaei et al., 2017). By applying manures and bio-fertilizers consortia in a sensible manner, the yield and nutrient uptake of sorghum in rice fallows may be improved. In light of this, the current study was conducted to evaluate the effects of inorganic fertilisers and the biofertilizer consortia on the productivity and uptake of nutrients in sorghum.

2. MATERIALS AND METHODS

2.1. Study site and year of experimentation

The field experiment was conducted at Agricultural College Farm, Bapatla, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India during *rabi* (December–April), 2018–19. The study site located in coastal region of Krishna Agro-climatic Zone of Andhra Pradesh situated at 15º54' N latitude and 80º25' E longitude with an altitude of 5.49 m above the mean sea level (MSL) and about 8 km away from the Bay of Bengal. Weekly mean maximum temperatures ranged from 25.6 to 34.7°C with an average of 31.6°C. The weekly mean minimum temperatures ranged from 14.2 to 25°C with an average of 19.7°C. The weekly mean relative humidity was 70.3 percent on average, ranging from 40.6 to 77.9 percent. During the crop growth season, 54 mm of rain fell overall. The experimental soil was near neutral with a pH of 6.94, low in organic carbon (0.4%) and available N (224 kg ha^{-1}), medium in available P (38 kg P_2O_5 ha^{-1}) and high in K (482 kg K_2O ha^{-1}).

2.2. Details of treatments and agronomic operations

The trial comprised of seven treatments viz., T_1: Control, T_2: 100% Recommended dose of fertilizers (RDF), T_3: 50% RDF+Biofertilizer consortium, T_4: 75% RDF+Biofertilizer consortium, T_5: 100% RDF+Biofertilizer consortium, T_6: 125% RDF+Biofertilizer consortium, T_7: Biofertilizer consortium only (RDF=100,60,40 N,P,K only) (Biofertilizer Consortium= *Azospirillum*, Phosphate Solubilizing Bacteria (PSB) and Potassium releasing bacteria (KRB) in liquid form) was conducted in a randomized block design (RBD) and each replicated thrice. The trial was taken up with a Sorghum cultivar, high yielding hybrid (CSH-16) of yield potential about 5–8 t ha^{-1} and matures in 110–120 days developed by Indian Institute of Millets Research, Hyderabad. There was no land preparation for sorghum. The field was divided into the necessary number of plots as soon as the rice was harvested, and the requisite number of plots were manually sown with a seed rate of 12 kg ha^{-1} and a 45×15 cm^2 spacing. According to the treatments, nitrogen

(100 kg ha^{-1}) was administered twice in equal portions, half at 30 DAS and the other half at 30 days after the first application, in the form of urea (46% N). Application of Paraquat @ 2.5 ml l^{-1} to harvested rice stubbles to avoid ratooning. A pre-emergence herbicide, such as atrazine @ 5 g l^{-1}, was sprayed right away after sowing to control pre- and post-emergence weeds. The experimental field was then manually weeded once at 20 and 35 DAS to maintain the weed-free conditions. After 30 DAS, the crop received two irrigations to continue growing on the remaining soil moisture. Cartap hydrochloride 4G granules @ 10 kg ha^{-1} at 35 DAS and spraying Emamectin benzoate (Barazide) 20% EC, plant protection measures against shoot borer were applied.

2.3. Data collection and chemical analysis

The data on ancillary traits were recorded on five tagged plants in the net plot area. The length of earheads were measured from base to tip of the earhead and filled grain number earhead^{-1} for tagged 5 plants and the mean value was computed, the weight of 1000 grains (g) was recorded from the grain samples drawn randomly from the net plot produce of each treatment. Grain yield ha^{-1} was worked out as the sun-dried ears from net plot area were threshed, cleaned and weight of the grain was recorded as net plot area^{-1} and expressed in kg ha^{-1}

2.4. Collection, preparation and analysis of plant samples

The plant samples collected at 30, 60 and 90 DAS were washed with dilute HCl and then with distilled water. The samples were shade dried initially and then oven dried at 60°C±2°C temperature till a constant dry weight was obtained and powdered in willey mill. Nitrogen content in sorghum plants was estimated by micro Kjeldahl distillation method (Piper, 1966). Preparation of acid extract by wet digestion as one gram of powdered plant sample was taken in 150 ml Erlenmeyer flask and digested with diacid mixture (HNO_3 and $HClO_4$ in 9:4 ratio). The sample digest was filtered through Whatman No. 42 filter paper by washing the residue with double glass distilled water till chloride free and made up to 100 ml volume and the clear extract was used for the determination of P, K, Zn, Cu, Mn and Fe. Phosphorus in the diacid extract of plant samples was estimated by vanado-molybdo phosphoric yellow colour method using spectrophotometer at 420 nm wave length and potassium was determined using flame photometer as per the method described by Jackson (1973). From the chemical analytical data, uptake of each nutrient was calculated as shown below:

Nutrient uptake (kg ha^{-1})=(Nutrient content (%)×dry weight in kg ha^{-1})/100 ………………..(1)

2.5. Economics

The economics of different treatments were calculated by considering the input costs and output prices prevailing at the time of the harvest. The cost of cultivation (COC), gross returns (GRs), net returns (NRs) and Returns ₹$^{-1}$ Investment were computed by the formulas furnished below.

COC (₹ ha^{-1})=Input cost+labour cost ……….. (2)

GRs (₹ ha^{-1})=Seed yield×Market price …………… (3)

NRs (₹ ha^{-1})=GRs ha^{-1}-COC ha^{-1} …………… (4)

Returns Investment $^{-1}$ (₹)=NRs/ COC…………… (5)

2.6. Statistical analysis

Statistical analysis for the data recorded was done by following the analysis of variance technique for randomized block design with factorial concept as suggested by Gomez and Gomez (1984). Statistical significance was tested by applying F-test at 0.05 level of probability and critical differences were calculated for those parameters which turned to the significant (p<0.05) in order to compare the effects of different treatment.

3. RESULTS AND DISCUSSION

3.1. Changes in yield traits and yield due to inorganic and biofertilzer consortium application

A perusal of data in table 1 indicated that yield of sorghum was highest when the crop received recommended dose of fertilizer (RDF) along with biofertilizer consortium and resulted in significantly higher grain yield (4135 kg ha^{-1}) and stover yield (7524 kg ha^{-1}), were recorded in T_6 treatment and remained on par with T_5 and T_2 treatments. The yield attributes were greatly enhanced by the use of increased levels of inorganic fertilizers upto 125% RDF and biofertilizers consortium (T_6) treatment. With the application of T_6 treatment improved ear head length (33.2 cm), filled grains ear head^{-1} (1359) as compared to control treatment. The data revealed that with different dose of fertilizers did not bring out any significant change in 1000 seed weight (Table 1). Among the different treatments T_6 treatment significantly increased grain (30.3%) and stover (26.5%) yields compared to control. In addition to grain yield and biomass, several studies have confirmed that there is an increase in grain-protein content in sorghum with an increase in available N (Kaufman et al., 2013). Increased N, P, and K uptake as well as increased panicle number and test weight may also contribute to higher grain and stover yields at higher recommended dose of fertilizers (Uchino et al., 2013, Sami et al., 2014) showed similar gains with increased fertiliser levels. Further, this could be ascribed to its positive influence on both vegetative and reproductive phases of the crop which lead to increase in stover yield. Increased photosynthetic rate might have also resulted in higher accumulation of dry matter and ultimately enhanced stover yield (Reddy et al., 2021).

Table 1: Effect of inorganic fertilizers along with biofertilizers consortium on yield attributes and yield of sorghum under rice fallow

Treatments	Earhead length (cm)	Test weight (g 1000 grains^{-1})	No. of filled grains ear head^{-1}	Protein content (%)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1	27.3^{c}	24.6^{a}	1032^{c}	6.5^{d}	2880^{c}	5529^{c}
T_2	32.1^{ab}	25.6^{a}	1198^{abc}	8.5^{ab}	3854^{ab}	7129^{ab}
T_3	29.5^{abc}	25.2^{a}	1149^{bc}	7.3^{cd}	3184^{c}	6049^{bc}
T_4	31.4^{abc}	25.3^{a}	1197^{abc}	7.9^{bc}	3460^{bc}	6505^{abc}
T_5	32.5^{ab}	25.8^{a}	1283^{ab}	8.7^{ab}	3918^{ab}	7209^{ab}
T_6	33.2^{a}	26.3^{a}	1359^{a}	9.1^{a}	4135^{a}	7524^{a}
T_7	28.8^{bc}	24.9^{a}	1050c	7.2^{cd}	3016^{c}	5706^{c}
SEm±	1.22	1.20	49.60	0.34	198.40	419.30
LSD (p=0.05)	3.80	NS	152.80	1.04	612.00	1292.10

T_1: Control; T_2: 100% Recommended dose of fertilizers; T_3: 50% RDF+Biofertilizer consortium; T_4: 75% RDF+Biofertilizer consortium; T_5: 100% RDF+Biofertilizer consortium; T_6: 125% RDF+Biofertilizer consortium; T_7: Biofertilizer consortium only

Improvement in various yield attributing characters and yield due to N and P fertilization is in close conformity with the findings (Singh and Sumeriya, 2012).

3.2. Nutrient uptake at different crop growth stages and in grain and stover

Uptake of N, P and K varied significantly due to different treatments. T_6 treatment recorded significantly higher N, P and K uptake in grain (61.8, 9.7 and 34.8 kg ha^{-1}) and stover (46.1, 19.3 and 81.7 kg ha^{-1}) compared to the control treatment as described in (Table 2). Improvement in N, P and K uptake in grain (53.0, 58.0 and 74.4%) and stover (50.5, 51.8 and 50.1%) was also noticed with T_6 over control. Application of nutrients to crop noted significantly higher uptake of NPK at 30, 60 and 90 DAS of sorghum crop over no fertility (control). Application of 125% RDF+BFC treatment resulted significantly higher NPK accumulation in grain and stover at harvest over rest of the nutrient management practices. Due to enhanced availability of these nutrients, which led to a larger biomass production, the absorption of N, P, and K increased with progressively increasing NPK supply to the crops. The results of the treatments have also been reflected in the crop's performance in terms of growth and output. This is because the plants under these treatments are able to absorb more nutrients (Bejbaruha et al., 2009).The application of biofertilizers plays an important role in the supply of nutrients to the sorghum by increasing the availability of

Table 2: Effect of inorganic fertilizers along with biofertilizers consortium on nutrient uptake at different crop growth stages of rice fallow sorghum

Treat-ments	Nitrogen uptake (kg ha^{-1})					Phosphorus uptake (kg ha^{-1})					Potassium uptake (kg ha^{-1})				
	30 DAS	60 DAS	90 DAS	Harvest		30 DAS	60 DAS	90 DAS	Harvest		30 DAS	60 DAS	90 DAS	Harvest	
				Grain	Stover				Grain	Stover				Grain	Stover
T_1	2.9	15.2	29.3	28.8	22.8	1.1	6.2	12.2	3.1	9.3	3.3	17.1	37.4	8.9	40.8
T_2	5.6	26.7	51.0	52.4	37.7	2.3	11.5	22.5	6.9	15.8	5.7	27.2	63.1	28.0	75.3
T_3	3.6	18.9	35.4	37.5	24.3	1.4	8.1	14.9	4.5	10.3	3.6	19.3	48.7	14.7	49.8
T_4	4.0	21.2	39.1	42.9	26.4	1.7	9.3	17.6	5.2	12.6	4.1	20.7	54.3	19.3	56.5
T_5	6.0	28.5	54.3	53.4	38.4	2.5	12.1	23.7	7.8	16.5	6.1	28.5	65.9	26.5	78.1
T_6	8.4	35.2	64.7	61.8	46.1	3.4	14.6	27.6	9.7	19.3	8.6	35.2	79.2	34.8	81.7
T_7	3.0	15.6	30.4	32.7	24.0	1.2	6.4	12.6	3.9	10.2	3.4	17.2	39.7	11.7	44.9
SEm±	0.23	1.40	3.30	2.63	2.15	0.08	0.60	1.30	0.31	0.99	0.30	1.25	3.90	1.24	3.90
LSD (p=0.05)	0.70	4.20	10.20	8.10	6.60	0.25	1.80	3.90	0.95	3.04	0.65	3.86	12.23	3.80	12.10

nutrients (N, P, and K) because of which encouraged a proliferous root system resulting in better absorption of water and nutrients from lower layers and thus resulting in higher yield and nutrient uptake (Thenmozhi and Paul Raj, 2009) and higher availability of nutrients resulted in improved nutrient availability in the rhizosphere, leading to higher uptake of nutrients by vegetative & reproductive structures at different growth stages of plants were similar with the findings of Mudalagiriyappa et al. (2012) , Jat et al. (2013)

3.3. Economics

The gross returns (₹ 71710 ha^{-1}), net returns (₹ 43154 ha^{-1}) as well as and returns ₹$^{-1}$ invested (1.88) were also highest with 125% RDF combined with biofertilizer consortium (T_6) treatment (Table 3) due to higher grain and stover yields. However, the latter T_5 treatment gave on par net returns (₹ 38143 ha^{-1}) and 1.85 returns ₹$^{-1}$ invested. The treatment effect on the grain and stover production are the primary cause of this trend in economic returns. The results confirm the findings of Jat et al. (2013) and Mishra et al. (2009).

Table 3: Effect of inorganic fertilizers along with biofertilizers consortium on economics of rice fallow sorghum

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Returns ₹$^{-1}$
T_1	20750	49005	28256	1.56
T_2	24994	64912	37918	1.86
T_3	23372	52667	27296	1.53
T_4	24433	57059	30626	1.63
T_5	25494	65637	38143	1.85
T_6	26555	71710	43154	1.88
T_7	21250	51829	30579	1.63
SEm±	-	3842	1975	0.1
LSD (p=0.05)	-	11838	6085	0.4

1US$=69.46 average value during the harvesting month of sorghum

4. CONCLUSION

Integrated application of 125% RDF+biofertilizers consortium resulted in significantly higher nutrient content and uptake in grain and straw and remained at par with treatment of 100% RDF+biofertilizer consortium in almost all parameters. From the experiment findings, it suggests using BFC along with inorganic sources helped the system use nutrients more effectively in sorghum under rice fallow no-till condition.

5. ACKNOWLEDGEMENT

The authors duly acknowledge to Acharya N.G. Ranga Agricultural University for providing financial support. Our sincere thanks are also to the Department of Agronomy, Agricultural College Farm, Bapatla, ANGRAU, India for providing the facilities required for this experiment.

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