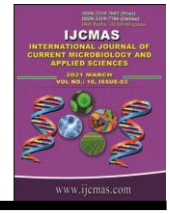
Int.J.Curr.Microbiol.App.Sci (2021) *10*(03): 1703-1711

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 10 Number 03 (2021)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2021.1003.212

Yield, Nutrient Uptake, Quality and Economics of Foxtail Millet Cultivation as Influenced by Integrated Nutrient Management with Bacterial Consortia and Liquid Manures

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Keywords

Bacterial consortia, *Beejamrutha*, Biofertilizers, Foxtail millet, *Jeevamrutha*, Liquid manures

Article Info

Accepted:
15 February 2021
Available Online:
10 March 2021

A B S T R A C T

To study the integrated effect of chemical fertilizers, bacterial consortia, liquid manures (*beejamrutha* and *jeevamrutha*) on yield, nutrient uptake, quality of grain and economics of foxtail millet cultivation, an experiment was conducted during *kharif*, 2019 at College farm, College of Agriculture, Rajendranagar, PJTSAU. Highest grain yield was obtained with application of 100% RDF + bacterial consortia + liquid manures (T_7) which was significantly superior to all the other treatments. Higher Nitrogen and Phosphorus uptake at harvest stage was recorded with100% RDF + bacterial consortia + liquid manures (T_7)which was superior to the other treatments. K uptake by the crop was also highest in the above treatment followed by50% RDF + bacterial consortia + liquid manures (T_8) which was at par with 100% RDF (T_2) or 50% RDF (T_3) alone. Similarly the uptake of Zn was also higher in T_7 which was superior to RDF alone (T_2) and the later was at par with $T_8$and T_6 (bacterial consortia + liquid manures).The quality parameters of grain like crude protein and crude fibre content were comparable between T_7 and T_2; T_8 and T_3, but superior to sole or combined application of bioagents (T_4 or T_5 or T_6).Significantly higher gross returns were realized in T_7 compared to all the other treatments. It was followed by 100% RDF alone (T_2). Higher net returns were realized with T_7 but it was at par with 100% RDF alone (T_2). The benefit: cost ratio obtained with (T_2) 100% RDF was the highest and superior to the rest of the treatments including integrated use of 100% RDF and bioagents (T_7) but it was the next best treatment.

Introduction

The world has started endorsing the food such as jowar, bajra, ragi, korra, sama and many such millets for their nutritional value. These nutrient-rich grains now called as nutri-cereals are making a quick comeback in the Indian agrarian landscape after decades of neglect. Now the time has come to replenish this treasure of Nutrition. In India, the area under nutri-cereals is about 24.21 million ha (Directorate of Economics and Statistics - India, 2017-18). If consumers see millets as a solution to lifestyle disorders, producers have realized that it requires less inputs and is an economically viable option if marketing avenues are created.

Foxtail millet (*Setaria italica*) is considered as one of the oldest cultivated millets. It contains high amount of proteins, dietary fibres, iron, zinc, calcium, phosphorus, potassium, vitamin B, and essential amino acids (Hegde *et al.,* 2005).The important foxtail millet growing districts in Telangana State are Mahabubnagar and Rangareddy whereas in Andhra Pradesh, Anantapur, Kurnool, Prakasam and Guntur are important (Hariprasanna, 2016). Generally millets require less nutrients for their growth and development, thereby less quantity of fertilizers and organics are used compared to cereal crops reducing the cost of nutrients. In this day and age, best quality grains with more fibre and protein content are preferred by the consumers. Such good quality millets can be produced through INM practices with low cost and higher profits.

Bacterial consortia is combination of plant growth promoting bacteria which is eco-friendly and add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorous, releasing potassium, zinc and stimulating plant growth through the synthesis of growth promoting substances. In simple terms it is a combination of different biofertilizers in view of nutrient requirement of a particular crop.

Liquid manures such as *jeevamrutha* and *beejamrutha* popularized by Padmashree Subhash Palekar has gained momentum among farmers (Vinay *et al.,* 2020) and are believed to produce qualitative yield. These together can help the plants to uptake more nutrients by cancelling all the adverse effects in the soil hindering nutrient availability coupled with efficient translocation, good quality produce can be assumed. Integration of the nutrient sources can sustain the production levels for future generations reflecting better economic standards.

Materials and Methods

An investigation was carried out during *kharif* season, 2019 at College farm, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad. The experimental soil was sandy loam in texture with 6.42 pH, 0.08 dsm^{-1} EC, 0.45% OC, low available N (172 kg ha^{-1}), medium in P (22 kg ha^{-1}), high in K (398 kg ha^{-1}) and sufficient in Zn status (0.65 ppm). The size of gross and net plots was 4.8 m x 3.9 m and 4.2 m x 3.3 m respectively. The experiment was laid out in RBD with three replications and eight treatments *viz.*,T_1 - Control (No chemical fertilizers/bacterial consortia/liquid manures), T_2 - 100% Recommended Dose of Fertilisers (RDF) (40:20:0 kg N: P_2O_5: K_2O ha^{-1}), T_3 - 50% RDF, T_4 - Bacterial consortia @ 2.5 kg /250 kg FYM ha^{-1} through soil application, T_5 - Seed treatment with *Beejamrutha* @ 50 L ha^{-1} and soil application of *Jeevamrutha* @ 500L ha^{-1} at fortnightly interval, T_6 - T_4 + T_5, T_7 - T_6 +100% RDF, T_8 - T_6 + 50% RDF.

Line sowing was done with SiA 3085 variety seeds @ 5 kg ha^{-1}. The 100% RDF for foxtail millet crop is 40:20:0 kg N, P_2O_5 and K_2O ha^{-1}. P fertiliser was applied as basal dosage and half of the N was applied as basal and other half at 30 DAS. Similarly 50% RDF was also applied. Bacterial consortia is a combination of beneficial bacteria such as *Azotobacter*, Phosphorus Solubilizing Bacteria (PSB), Potassium Releasing Bacteria (KRB) and Zinc Solubilizing Bacteria (ZnSB) in equal proportion and was mixed with farm yard manure and applied to the soil before sowing. Liquid manure like *beejamrutha* was prepared as per Vinay *et al.,* (2020) by soaking 12.5 kg cowdung in 50 litres of water followed by mixing it with 12.5 litres of cow urine, 250 g of ant hill soil and 125 g of lime and treated to seeds before sowing. *Jeevamrutha* was prepared by mixing of 25 kg cow dung, 25 litres of cow urine, 5 kg of pulse flour and 5 kg of jaggery and 250 g of ant hill soil fermented for 72 hrs and applied at fortnightly interval.

Yield

Grain yield (kg ha^{-1})

The grains obtained from the net plot area including those from the sampled plants were sun dried thoroughly till the moisture level comes down to 14%, cleaned, weighed and expressed as kg ha^{-1}.

Straw yield (kg ha^{-1})

The straw obtained from the net plot area of all the treatments including the sampled plants were sundried for 4-5 days till the straw gets constant weight, weighed and expressed as kg ha^{-1}.

Analysis of plant samples for nutrient uptakes

The N, P, K and Zn content of the plant samples were analysed at harvest stage of the crop. The plant samples were dried in hot air oven at 60^{o}C and the dried samples were grinded in a Willey mill. The powdered samples were then used for analysis.

Nitrogen uptake (kg ha^{-1})

The nitrogen content in dried plant samples was determined by Microkjeldahl method (AOAC, 1960) after digestion of the sample with H_2SO_4 and H_2O_2.

N Uptake (kg ha^{-1}) = N content (%) x Dry matter production (kg ha^{-1})/ 100

Phosphorus uptake (kg ha^{-1})

The plant samples were digested with tri acid mixture consisting of HNO_3: $HClO_4$: H_2SO_4 (9:4:1) for the analysis of P, K and Zn in plant sample.

P Uptake (kg ha^{-1}) = P content (%) x Dry matter production (kg ha^{-1})/ 100

Potassium uptake (kg ha^{-1})

The potassium content in the triacid mixture was determined by using flame photometer (Piper, 1967).

K Uptake (kg ha^{-1}) = K content (%) x Dry matter production (kg ha^{-1})/100

Zinc uptake (g ha^{-1})

After diluting tri-acid extract, the samples were fed toatomic absorption spectrophotometer using zinc hallow cathode lamp.

Zn Uptake (g ha^{-1}) = Zn content (ppm) x Dry matter production (kg ha^{-1})/1000

Analysis of grain samples for quality parameters

Crude protein (%)

Nitrogen content in the grain was determined by Micro kjeldhal method as described by Jackson (1973). The crude protein content was worked out by multiplying the nitrogen percentage with thye factor 6.25 (AOAC, 1960).

Crude fibre (%)

Crude fibre content was estimated by acid-alkali digestion method. The residue obtained after digestion was dried in a crucible and its weight was recorded (We). The dried residue was then ashed in a muffle furnace at 600^{oC} for 3 to 4 hours and its weight (Wa) was recorded. The difference between the two weights (We-Wa) was taken as the weight of the crude fibre (AOAC, 2005).

Economics

Cost of cultivation (Rs.. ha^{-1})

The total cost of cultivation ha^{-1} was calculated for each treatment on the basis of all input costs including labour wages.

Gross returns (Rs.. ha^{-1})

Gross monetary returns for each treatment were calculated by multiplying the economic yield with the prevailing market price.

Net returns (Rs.. ha^{-1})

Net returns for each treatment were estimated at harvest by deducting the cost of cultivation of respective treatments from their gross returns.

Net returns (Rs.. ha^{-1}) = Gross returns (Rs.. ha^{-1}) – Cost of cultivation (Rs.. ha^{-1})

Benefit: Cost ratio (B:C ratio)

Benefit: Cost ratio was worked out for each treatment by using the following formula.

Benefit: Cost ratio = Gross returns (Rs.. ha^{-1})/ Cost of cultivation (Rs.. ha^{-1})

Statistical analysis

The data generated on various parameters of growth, yield and soil components during the course of investigation were analysed statistically, applying the technique of analysis of variance procedure as outlined for simple randomized block design (RBD) suggested by Gomez and Gomez (1984).

Results and Discussion

The grain yield of foxtail millet as influenced by the treatment combination is presented in Table 1. The perusal of the data reveals that among the treatments, highest yield was obtained in 100% RDF + bacterial consortia + liquid manures (T_7) which was significantly superior to all the other treatments including 100 % RDF alone (T_2). Similarly, 50% RDF + bacterial consortia + liquid manures (T_8) was also superior to 50 % RDF alone (T_3) over the later treatment. However, all the treatments consisting of inorganic fertilizers, biofertilizers and bio-enhancers alone or in combination enhanced the yield over control.

With the conjunctive use of bacterial consortia, liquid manures and inorganic fertilizers, the plants obtain nutrients steadily during the critical stages of growth leading to improved growth and yield parameters. With the inclusion of biofertilizers and liquid manures in nutrient supply, the fertilizer use efficiency was enhanced by 5.5% in T_7 over T_2 and 7.6% in T_8 over T_3.

Till recently, most of the research on organic production of crops was mainly concentrated on the use of FYM, compost, green manure, oil cakes etc. which needs large quantities to compensate the crop yields obtained with inorganic fertilizers. But, decrease in cattle population in recent years and utilization of agricultural wastes into valuable by products have made the availability of organic manures in agriculture questionable both in time and quantity besides the escalated prices. Hence, biofertilizers and liquid manures appear to be the best alternative in such situations.

The data recorded on straw yield is presented in Table 1. On observing the data, it is evident that significantly higher yield was obtained with T_7 in which 100% RDF was appended with bacterial consortia and liquid manures but it was at par with 100% RDF alone (T_2). Similarly the combination at 50% RDF (T_8) was also comparable with 50% RDF alone (T_3), in producing the straw yield. Similar to grain yield, significantly higher straw yield was recorded in the treatment consisting of conjunctive use of bacterial consortia + liquid manures (T_6) over their individual application (T_4 or T_5) which were at par with each other but superior to control (T_1).

Conjunction of nutrient sources lead to the better performance of the plant by improving physiological activities such as better uptake, translocation and accumulation leading to production of more dry matter thus contributing to the yield.

Our results are in line with findings of Monisha *et al.*, (2019) in foxtail millet, Ahiwale *et al.*, (2011), Kumari *et al.*, (2017), Ananda *et al.*, (2017) in other millets.

The amount of nutrients accumulated by foxtail millet at harvest were determined and presented in Table 2. In general, the uptake of NPK and Zn was found to be influenced by the different treatments. Similar trend was observed with respect to N and P uptake. Highest uptake was recorded with T_7 where 100% RDF was augmented with bioagents and it was superior to the rest of the treatments. Liquid manures alone (T_5) and bacterial consortia (T_4) were at par with each other but superior to control (T_1). K uptake by the crop was also highest in T_7 followed by the T_8 (50% RDF + bioagents) which was at par with 100% RDF (T_2) or 50% RDF (T_3) alone. Similarly the uptake of Zn was also higher in T_7 which was superior to RDF alone (T_2) and the later was at par with T_8 and T_6. The uptake of both K and Zn in conjunction of bioagents (T_6) was significantly superior to their individual application (T_4 or T_5) which were at par with each other but superior to control (T_1).

Table.1 Yield of foxtail millet as influenced by integrated nutrient management

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1- Control (No chemical fertilizers/ bacterial consortia/ liquid manures)	709	1400
T_2- 100% Recommended Dose of Fertilizers (RDF) (40:20:0 kg N:P_2O_5: K_2O ha^{-1})	1760	2800
T_3- 50% RDF	1342	2256
T_4- Bacterial consortia @ 2.5 kg/250 kg FYM ha^{-1} through soil application	916	1714
T_5- Seed treatment with *Beejamrutha* @ 50 L ha^{-1} and soil application of *Jeevamrutha* @ 500L ha^{-1} at fortnightly interval	933	1692
T_6- T_4 + T_5	1117	2003
T_7- T_6 + 100% RDF	2093	2933
T_8- T_6 + 50% RDF	1570	2526
SEm±	**56.4**	**89.8**
CD (P=0.05)	**171.0**	**272.5**

Table.2 Nutrient uptake at harvest stage in foxtail millet as influenced by integrated nutrient management

Treatment	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	Zn uptake (g ha^{-1})
T_1- Control (No chemical fertilizers/ bacterial consortia/ liquid manures)	20.51	8.62	24.79	94.17
T_2- 100% Recommended Dose of Fertilizers (RDF) (40:20:0 kg $N:P_2O_5: K_2O$ ha^{-1})	39.57	19.43	43.99	155.53
T_3- 50% RDF	32.29	13.67	40.08	135.10
T_4- Bacterial consortia @ 2.5 kg / 250 kg FYM ha^{-1} through soil Application	23.42	9.13	28.53	112.40
T_5- Seed treatment with *Beejamrutha* @ 50 L ha^{-1} and soil application of *Jeevamrutha* @ 500 L ha^{-1} at fortnightly interval	24.41	10.27	29.67	115.67
T_6- T_4 + T_5	28.01	11.92	35.36	130.10
T_7- T_6 + 100% RDF	43.10	22.01	52.73	171.00
T_8- T_6 + 50% RDF	35.61	16.1	44.39	152.67
SEm±	**1.05**	**0.50**	**1.47**	**4.27**
CD (P=0.05)	**3.19**	**1.52**	**4.44**	**12.96**

Table.3 Crude protein and crude fibre of foxtail millet grain as influenced by integrated nutrient management

Treatment	Crude protein (%)	Crude fibre (%)
T_1- Control (No chemical fertilizers/ bacterial consortia/ liquid manures)	9.97	4.35
T_2- 100% Recommended Dose of Fertilizers (RDF) (40:20:0 kg $N:P_2O_5: K_2O$ ha^{-1})	12.47	5.56
T_3- 50% RDF	11.25	5.24
T_4- Bacterial consortia @ 2.5 kg / 250 kg FYM ha^{-1} through soil application	10.03	4.48
T_5- Seed treatment with *Beejamrutha* @ 50 L ha^{-1} and soil application of *Jeevamrutha* @ 500L ha^{-1} at fortnightly interval	10.10	4.56
T_6- T_4 + T_5	10.13	4.78
T_7- T_6 + 100% RDF	12.50	5.64
T_8- T_6 + 50% RDF	11.32	5.31
SEm±	**0.37**	**0.16**
CD (P=0.05)	**1.12**	**0.48**

Table.4 Economics of foxtail millet cultivation as influenced by integrated nutrient management

Treatment	COC (Rs.. ha^{-1})	Gross returns (Rs.. ha^{-1})	Net returns (Rs.. ha^{-1})	B:C ratio
T_1- Control (No chemical fertilizers/ bacterial consortia/liquid manures)	16150	21929	5779	1.36
T_2- 100% Recommended Dose of Fertilizers (RDF) (40:20:0 kg $N:P_2O_5: K_2O$ ha^{-1})	18568	54200	35632	2.92
T_3- 50% RDF	17859	41378	23519	2.32
T_4- Bacterial consortia @ 2.5 kg / 250 kg FYM ha^{-1} through soil Application	17025	28327	11302	1.66
T_5- Seed treatment with *Beejamrutha* @ 50 L ha^{-1} and soil application of *Jeevamrutha* @ 500L ha^{-1} at fortnightly interval	21300	28836	7536	1.35
T_6- T_4 + T_5	22175	34501	12326	1.56
T_7- T_6 + 100% RDF	24593	64266	39673	2.61
T_8- T_6 + 50% RDF	23884	48363	24479	2.02
SEm±	**-**	**1712.4**	**1712.4**	**0.08**
CD (P=0.05)	**-**	**5193.3**	**5193.3**	**0.25**

Nutrient uptake is a function of dry matter production and concentration of the respective nutrient. Hence, in the present study also the superiority of conjunctive use of 100% RDF with bioagents (T_7) was maintained. Basha (2015) and Patidar (2017), Vinay *et al.*, (2020) also reported the improved nutrient uptake with the conjunctive use of bioagents with inorganic fertilisers in various crops.

The data recorded on protein content of the harvested grain was presented in Table 3. The data revealed highest protein content with the application of 100% RDF along with bacterial consortia + *beejamrutha* and *jeevamrutha* (T_7) but it was on par with the application of 100% RDF (T_2) alone. Same trend was obtained with 50% RDF as well. This implies no significant influence with conjunctive usage of bioagents along with inorganic fertilizers on protein content. The remaining treatments were at par with each other and with control.

The crude fibre percent is a measure of the quantity of indigestible cellulose, pentosans, liginin and other such components present in the grain. The data presented in Table 3. shows that even though highest crude fibre content was recorded in T_7 (100% RDF + bioagents), it was comparable to 100% RDF alone (T_2), 50% RDF alone (T_3) and 50% RDF + bioagents (T_8) and superior to the rest of the treatments. Further, the crude fibre per cent in the treatments which received bacterial consortia (T_4) or *beejamrutha and jeevamrutha* (T_5) or their combination (T_6) was at par with control (T_1) only.

Economics of foxtail millet as influenced by various treatments was presented in Table 4. The cost of cultivation was found to be more with T_7 in which, apart from 100% RDF, cost had to be incurred for the application of bioagents. It was followed by T_8 where 50% RDF was appended with bioagents. In general, the cost of cultivation in the treatments which received bioagents was higher because of repeated preparation and application of *jeevamrutha* at fortnightly interval. However, significantly higher gross returns were realized in T_7 as well, compared to all the other treatments. It was followed by 100% RDF alone (T_2) and again it was significantly superior to the rest of the treatments. Conjunctive use of both the bioagents was better in gross returns over their individual application due to increased grain yield. On observing the net returns, it is evident that the trend is different to gross returns. Higher net returns were realized with T_7 (100% RDF + bioagents) but it was at par with 100% RDF alone (T_2). The additional gross returns obtained with T_7 were offset with the increased cost of cultivation compared to T_2. But, both the treatments were superior to the rest of the treatments. Between the two, net returns in T_5 where liquid manures were applied, was very less owing to the increased cost of application of *jeevamrutha* over T_3. Least returns were obtained with control. The benefit: cost ratio obtained with T_2 (100% RDF) was the highest and superior to the rest of the treatments including T_7 (conjunction of 100% RDF + bioagents) but it was the next best treatment.

Vinay *et al.,* (2020) also reported lower returns and negative B:C ratio in natural farming with liquid manures. However, favourable premium prices for the organic as well as quality produce can offset the higher COC in non-chemical methods of nutrient management systems.

In conclusion the higher grain yield, nitrogen and phosphorus uptake at harvest was recorded in T_7 which was superior to the other treatments. Potassium uptake by the crop was also highest in T_7 followed by the T_8 (50% RDF + bioagents) which was at par with 100% RDF (T_2) or 50% RDF (T_3) alone. Similarly the uptake of Zn was also higher in T_7 which was superior to RDF alone (T_2) and the later was at par with T_8 and T_6. Crude protein and crude fibre content were comparable between T_7 and T_2; T_8 and T_3, but superior to sole or combined application of bioagents (T_4 or T_5 or T_6). Higher B: C ratio was realized with 100% RDF alone followed by bacterial consortia + liquid manures with 100% RDF.

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How to cite this article:

Manduri Veerendra, B. Padmaja, M. Malla Reddy and Triveni, S. 2021. Yield, Nutrient Uptake, Quality and Economics of Foxtail Millet Cultivation as Influenced by Integrated Nutrient Management with Bacterial Consortia and Liquid Manures. *Int.J.Curr.Microbiol.App.Sci.* 10(03): 1703-1711.
doi: https://doi.org/10.20546/ijcmas.2021.1003.212