Original Research Article

Effect of liquid biofertilizers on productivity, quality and soil biota of fodder sorghum

ABSTRACT

The field experiment was conductedduring*Rabi*season of 2022 on sandy clay loam soils at wetland farm of the S.V. Agricultural College, Tirupati, Andhra Pradesh, India,to study the effect of liquid biofertilizers on productivity, quality, and soil biota of fodder sorghum. The treatments were allocated in randomized block design and replicated thrice.The soil was neutral in reaction (6.9 pH),low in available nitrogen (115 kg ha^{-1}), medium in available phosphorus (29 kg ha^{-1}) and low in available potassium (156 kg ha^{-1}) status. The initial soil contains bacteria(13.08X10^{7}CFU g^{-1}soil), fungi(4.04X10^{4}CFU g^{-1}soil) and actinomycetes(1.54X10^{3}CFUg^{-1}soil). The results revealed that the maximum green (32.1 t ha^{-1}) and dry (13.0 t ha^{-1}) fodder yield as well as crude protein (7.3 %) were obtained with the application of 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application). Furthermore, this treatment produced a significantly higher soilbacterial (23.2 X10^{7}CFU g^{-1}soil), fungal (13.7 X10^{4}CFU g^{-1}soil) and actinomycetes (10.3 X10^{3}CFU g^{-1}soil) population at harvest.

Comment [Ma1]: carry out

Comment [Ma2]: The treatments were distributed in randomized complete block design RCBD with three replications

Comment [Ma3]: The amount of potassium I think is too much

Comment [Ma4]: Explanation of this acronym

Keywords: Liquid biofertilizers, fodder sorghum, *Azospirillum*, Green fodder yield, Sandy clay loam soils, Productivity, Soil biota.

Comment [Ma5]: Green and dry fodder yield

1. INTRODUCTION

India's livestock production is vital to the country's Agricultural sector and considerably boosts GDP. Green fodder and dry fodder availability are currently deficient by 35.6 percent and 10.95 percent, respectively [1]. Looking ahead to 2050, the IGFRI Vision 2050 study projects a demand for 1012 million tonnes of green fodder and 631 million tonnes of dry fodder. However, the livestock industry has challenges due to a scarcity of fodder and its poor quality. The gap between the dry and green feed supply is typically 40%; by 2025, this disparity can increase to 45%. To fulfil the vast animal population in India's high fodder demand, there is a need to boost forage crop output and productivity while maintaining soil health and environmental sustainability[2].

Crops used as cereal fodder contain a high concentration of digestible starch, water-soluble carbohydrates and fibre, making them a source of high energy for animals. Sorghum (*Sorghum bicolor* (L.) *Moench*) is an essential fodder crop in India since it is the most important, adaptable and widely cultivated and meets 60% of the country's demands for livestock. It can withstand heat, drought, and waterlogging better than other fodder crops, but its output remains modest and needs adequate nutrient management [3].

Comment [Ma6]: Green and dry fodder

Comment [Ma7]: %

Comment [Ma8]: tons

Comment [Ma9]: tons

Comment [Ma10]: avhieve

Comment [Ma11]: number of animals

Comment [Ma12]: fiber

Comment [Ma13]: tolerance

Comment [Ma14]: production

A balance between raising crop productivity, preserving soil health and environmental sustainability is more important for long-term food security [4].Hence, integration of organic, chemical and biological sources of plant nutrients is essential in managing and maintaining soil health in sustainable Agriculture. Biofertilizers are the best sources for improving soil nutrient availability, leading to better nutrient uptake by plants. Nitrogenous biofertilizers are capable of fixing atmospheric nitrogen which includes *Azospirillum* species and for phosphorus, includes *phosphate solubilizing bacteria* (PSB) which solubilize the phosphorus, for potassium, it includes *potassium solubilizing bacteria* (KSB) and these variants are available in both solid and liquid consortia.

Due to their versatility and efficiency, liquid biofertilizers have become more and more well-liked in recent years. Liquid biofertilizers are formulations that include favourable bacteria, fungiand algae that promote growth of plants, enhance soil fertility and boost nutrient uptake. Compared to conventional fertilizers, liquid biofertilizers are more affordable, environmentally friendly, and sustainable[5]. They might also reduce the need for artificial fertilizers and the environmental harm caused by Agriculture.

Comment [Ma15]: What are the damages caused by agriculture?

Keeping the above facts in view the present study was planned to investigate the effect of applying liquid bio inoculants of *Azospirillum* sp., PSB and KSB in combination on the performance of fodder sorghum under field conditions.

2. MATERIAL AND METHODS

The present investigation entitled "Effect of liquid biofertilizers on productivity, quality and soil biota of fodder sorghum"wasconductedduring*rabi*,2022in wetlandfarm of S.V.AgriculturalCollege,ANGRAU,Tirupati,whichisgeographicallysituatedat13°56'564''Nlatitudeand79°67'684''Elongitude ,withanaltitudeof182.9mabovethemeansealevel.The soil was neutral in reaction (6.9 pH) low in available nitrogen (115 kg ha^{-1}) and medium in available phosphorus (29 kg ha^{-1}) and low in available potassium (156 kg ha^{-1}) status. The initial soil contains bacteria(13.08X10^{7}CFU g^{-1}soil), fungi(4.04X10^{4}CFU g^{-1}soil) and actinomycetes(1.54X10^{3}CFUg^{-1}soil). The experiment was done using a randomized block design with three replications.Treatments includes T_1: Absolute control, T_2: 100% RDF, T_3: 75% RDF + *Azospirillum* + PSB + KSB (Seed treatment@10 ml kg^{-1}), T_4: 75% RDF + *Azospirillum* + PSB + KSB (Soil application@1.25 l ha^{-1}), T_5: 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application), T_6: 50% RDF + *Azospirillum* + PSB + KSB (Seed treatment@10 ml kg^{-1}), T_7: 50% RDF + *Azospirillum* + PSB + KSB (Soil application@1.25 l ha^{-1}), T_8: 50% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application).The crop was sown with a seed rate of 25 kg ha^{-1} at a spacing of 30 × 10 cm. Recommended dose of fertilizer was 60 - 40 - 30 N, P_2O_5, K_2O kg ha^{-1}. Soil application of biofertilizers was done by mixing 1.25 l ha^{-1} of each bio inoculant in 500 kg of well-decomposed FYM and applied as basal dose (applied 24 hrs before sowing). Seed treatment of biofertilizers was done by mixing 10 ml of each bio inoculant with 1 kg of seed and drying for 10-15 minutes under shade before sowing. Irrigation and weeding were done as and when required. At 50% flowering, harvesting was completed. The data on various parameters were statistically analysed using the randomised block design method recommended by Panse and Sukhatme[6].

2.1 Yield parameters

Green fodder yield: Forage sorghum from net plot area was harvested separately by leaving 5 cm stubbles from ground surface. Green fodder yield of sorghum was weighed in net plot area and total green fodder yield was expressed in t ha^{-1}.

Dry fodder yield: After harvesting of fodder sorghum from net plot area, plants were left in the field for a period of one week for sun drying. Then dry fodder yield of sorghum was weighed in net plot area and total dry fodder yield was expressed in t ha^{-1}.

2.2 Quality parameters

Crude protein: Totalnitrogencontent of plant samples was estimated by modified Micro kjeldhal method [7] and the crude protein content was estimated by using the following formula which was expressed in percentages.

$$\text{Crude protein (\%)} = \text{N (\%)} \times 6.25$$

Crude fibre: Crude fibre content in whole plant was estimated by acid-alkali digestion method and was expressed in percentage.

$$\text{Crude Fibre(\%)} = \frac{\text{Weight before ashing - weight after ashing}}{\text{Weight of the sample taken}} \times 100$$

2.3 Soil microbial population

Microbialmassinthesoilwasnormallyexpressedincolonyformingunits per gram of soil (CFU g^{-1} of soil). The viable count for bacteria, fungi andactinomycetes was done on Nutrient Agar (NA), Rose bengal Agar, andKenknight and Munaier'smediums,respectively. Afterincubation,coloniesdeveloped and the viable count of soil microbes was enumerated by the followingformula.

$$\text{Colony forming unit per g of sample} = \frac{\text{Number of colonies} \times \text{Dilution factor}}{\text{Quantity of sample}}$$

3. RESULTS AND DISCUSSION

Data pertaining to productivity, quality and soil microbial population at harvest, as influenced by application of liquid biofertilizers at different levels of recommended dose of fertilizers, were presented in Tables and discussed in different sections.

3.1 Yield parameters

Green fodder yield

Significantly higher green fodder yield (32.1 t ha^{-1})(Table 1) (Fig. 1) of fodder sorghum was observed with 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application) (T_5) which was on par with 100% RDF (T_2). Significantly lower green fodder yields(13.9 t ha^{-1}) were noticed with absolute control (T_1). Significantly higher green fodder yield of fodder sorghum was recorded with 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application) (T_5) due to cumulative effect of elevated growth stature as well as yield structure. Moreover, enhanced mineral and water uptake, root development and vegetative growth together with the conversion of unavailable plant nutrients into available form by biofertilizers all contribute to higher nutrient uptake, which eventually increases green fodder yield. These results are supported by findings of Yadahalli*et al*. [8] and Singh *et al*. [9].

Comment [Ma16]: Carried out

Comment [Ma17]: randomizedcomplete block design RCBD

Comment [Ma18]: control treatment

Comment [Ma19]: The name of the cultivated variety was not mentioned

Comment [Ma20]: randomizedcomplete block design RCBD

Comment [Ma21]: fiber

Comment [Ma22]: fiber

Comment [Ma23]: enhanced root development and vegetative growth ,mineral and water uptake, together

Dry fodder yield

Application of 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application) (T_5) was recorded significantlyhigher dry fodder yield (13.0 t ha^{-1}) (Table 1)(Fig. 1) of fodder sorghum which was in turn on par with 100% RDF (T_2). Significantly lower dry fodder yields(6.0 t ha^{-1}) was noticed with absolute control (T_1).Significantly higher green fodder yield of fodder sorghum was showed with 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application) (T_5) might be attributed to balanced nutrients provided to the crop which resulted in significantly increase in green fodder yield and hence dry fodder. This may also be due to increased availability and absorption of nutrients mostly nitrogen and phosphorus to plants which eventually resulted in additional vegetative growth due to improvement in plant height and tillers on account of enlargement of cells. These results are according withKumar *et al*. [10] and Verma *et al*. [11].

Comment [Ma24]: control treatment

3.2 Quality parameters

Crude protein

The highest crude protein content (7.3 %) (Table 1)(Fig. 1) of fodder sorghum was noticed with 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application) (T_5) which was on par with 100% RDF (T_2)and lower crude protein yield(5.4 %) wasrecorded with absolute control (T_1).Significantly higher crude protein yield of fodder sorghum was recorded with 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application) (T_5) due to fixation of nitrogen by *Azospirillum* inoculation resulted in increased availability of nitrogen, which has helped in the synthesis of more protein as nitrogen is a constituent of various metabolites including protein and amino acids.The increase in protein content may be due to more uptake of nutrients with combined application of nutrient sources. The results are also in close association with the results ofYadahalli*et al*. [8] and Gupta A and Mayuri D [12].

Comment [Ma25]: control treatment

Comment [Ma26]: The researcher did not measure the crudeprotein yield

Crude fibre

Comment [Ma27]: fiber

Application of different levels of liquid biofertilizers did not show any significant difference on crude fibre content. Yet with no marked differences, higher crude fibre content of fodder sorghum was recorded with the application of 100% RDF (T_2)(32.8 %) (Table 1) and low crude fibre was noticed with 75% RDF with biofertilizer combinations. This was followed by application of 50% RDF with different biofertilizers. Fodders containing low crudefibrecontentis an indication ofmorepalatabilitybyanimalsand they containdigestible nutrients.

Comment [Ma28]: fiber

Comment [Ma29]: fiber

Comment [Ma30]: fiber

3.3 Soil microbial population

Significantlythehighestsoilbacterial (23.2 X10^{7}CFU g^{-1}soil), fungal (13.7 X10^{4}CFU g^{-1}soil) and actinomycetes (10.3 X10^{3}CFU g^{-1}soil) (Table 2) (Fig. 2) populations at harvest wereobserved in 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application) (T_5) whichwasonparwith75% RDF + *Azospirillum* + PSB + KSB (Soil application @1.25 l ha^{-1}) (T_4). The lowest soil bacterial, fungal and actinomycetespopulationswere observed in absolute control(T_1) atharveststageoffodder sorghumcrop.Among all the treatments the highest number of soil microorganisms(soil bacteria, fungi and actinomycetes) were found with the 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application) (T_5) treatmentfollowed by 75% RDF + *Azospirillum* + PSB + KSB (Soil application @1.25 l ha^{-1}) (T_4) and this might be due to use of liquidbiofertilizersinconjunctionwithchemicalfertilizersprovided soil with more easily mineralizable and hydrolysable carbon, increasing microbial activity and microbial biomass carbon. Datt *et al*. [13] have also reported similar findings. The application of organic fertilizers supplemented with different kinds of biofertilizers could be responsible for the increasing biomass levels of microorganisms in the soil. These fertilizers, in turn, give bacteria enough nutrients and promote the rapid growth of the microbial population in the soil. [14]. The populations of microbes were considerablyhighestwhen FYM was used along with biofertilizers as soil application and the FYM containedmore growth-promoting elements like micronutrients, vitamins, and enzymes,which in turn increased the microbial population. In addition, *Azospirillum*+PSB + KSB increased the production of root biomass, whichled to the highest production of root exudates, which increased the population ofhelpful bacteria, fungi, and actinomycetes in the rhizosphere soil [15].

Comment [Ma31]: control treatment

Comment [Ma32]: may be increasing number or population of microorganisms in the soil

Comment [Ma33]: This means an increase in the exudation of allelopathic compounds by the roots of sorghum plants, which may affect the microorganisms in the soil.

Table 1Effect of liquid biofertilizers at different levels of recommended dose of fertilizers on productivity, quality of fodder sorghum

Treatment Combinations	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})	Crude Protein (%)	Crude fibre (%)
T_1 : Absolute control	13.9	6.0	5.4	32.6
T_2 : 100% RDF	30.6	12.8	6.8	32.8
T_3 : 75% RDF + *Azospirillum* + PSB + KSB (Seed treatment @10 ml kg^{-1})	26.5	11.3	6.4	31.4
T_4 : 75% RDF + *Azospirillum* + PSB + KSB (Soil application @1.25 l ha^{-1})	27.3	11.3	6.5	31.9
T_5 : 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application)	32.1	13.0	7.3	31.4
T_6 : 50% RDF + *Azospirillum* + PSB + KSB (Seed treatment @10 ml kg^{-1})	21.9	9.7	6.1	32.5
T_7 : 50% RDF + *Azospirillum* + PSB + KSB (Soil application @1.25 l ha^{-1})	22.2	9.8	6.2	32.3
T_8 : 50% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application)	25.5	11.2	6.3	31.4
SEm.(±)	1.03	0.41	0.19	0.75
CD (*P*=0.05)	3.1	1.3	0.6	NS

Comment [Ma34]: fiber

Table 2 Effect of liquid biofertilizers at different levels of recommended dose of fertilizers on Soil microbial population at harvest

Treatment Combinations	Bacteria (No.X 10^7 CFU g^{-1})	Fungi (No.X 10^4 CFU g^{-1})	Actinomycetes (No.X 10^3 CFU g^{-1})
T_1 : Absolute control	11.7	6.3	3
T_2 : 100% RDF	12.3	7.3	4.3
T_3 : 75% RDF + *Azospirillum* + PSB + KSB (Seed treatment @10 ml kg^{-1})	17.6	9.3	6.7
T_4 : 75% RDF + *Azospirillum* + PSB + KSB (Soil application @1.25 l ha^{-1})	21.9	12.3	9.3
T_5 : 75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application)	23.2	13.7	10.3
T_6 : 50% RDF + *Azospirillum* + PSB + KSB (Seed treatment @10 ml kg^{-1})	15.2	9	5.7
T_7 : 50% RDF + *Azospirillum* + PSB + KSB (Soil application @1.25 l ha^{-1})	16.5	9.3	6.3
T_8 : 50% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application)	18.9	10	8
SEm.(±)	0.69	0.46	0.41
CD (*P*=0.05)	2.2	1.4	1.2

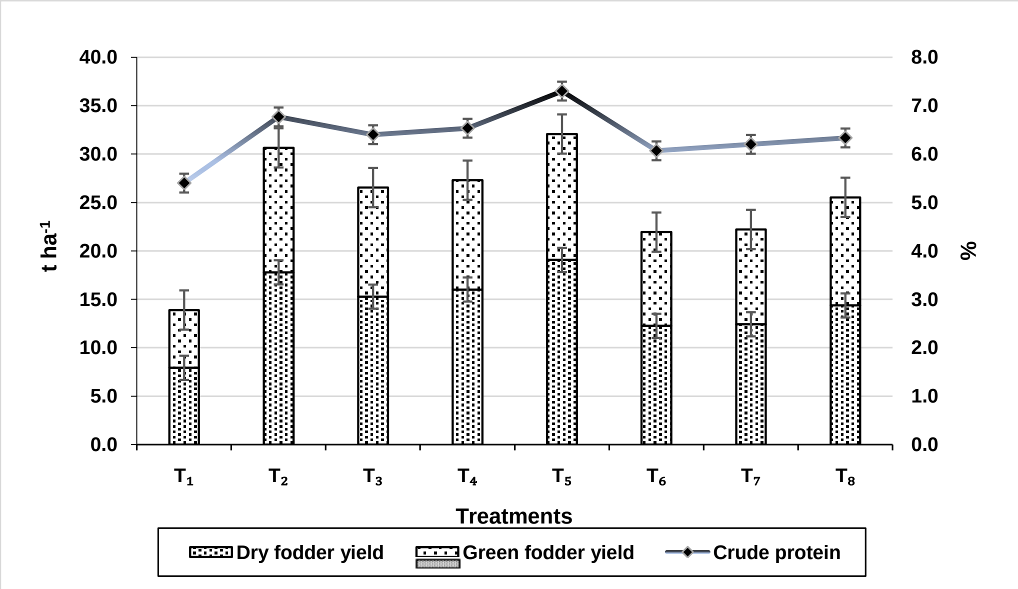

Fig. 1. Green fodder yield and dry fodder yield (t ha^{-1}) and crude protein content (%) of fodder sorghum as influenced by application of liquid biofertilizers atdifferent levels of recommended dose of fertilizers.

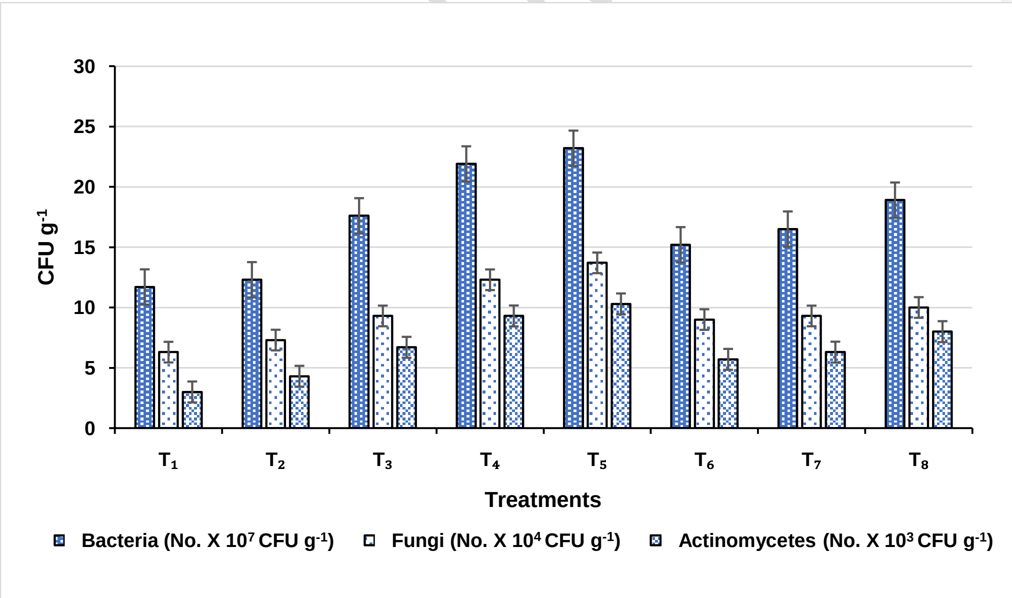

Fig. 2. Soil microbial population at harvest as influenced by application of liquid biofertilizers at different levels of recommended dose of fertilizers.

4. CONCLUSION

In conclusion, the present study indicated that combined application of75% RDF + *Azospirillum* + PSB + KSB (Both seed & soil application) isthemostefficientnutrientmanagementpractice. Which recorded highest green and dry fodder yield with high crude protein. Further this treatment resulted in higher soil microbial population which helps in sustainability of soil health.Since these findings are based on a single season, further investigation may be required to support them.

REFERENCES

1. Singh DN, Bohra JS, Tyagi V, Singh T, Banjara TR, Gupta G. A review of India's fodder production status and opportunities. Grass Forage Sci. 2022;77(1):1-10
2. Kumari VV, Gopinath KA, Venkatesh G, Chandran MAS, Rao CS. Fodder constraints in rainfed areas of India: constraints and strategies. Forage Res. 2017;43(2):81-8.
3. Singh K, Joshi YP, Chandra H, Singh DK, Singh R, Kumar M.Effectofintegratednutrientmanagementongrowth,productivity and quality of sweet sorghum (*Sorghum bicolour*). Indian JournalofAgronomy. 2016;60(2):291-6.
4. Aulakh MS, Malhi SS. Interactions of nitrogen with other nutrients and water: Effect on crop yield and quality, nutrient use efficiency, carbon sequestration, and environmental pollution. Advances in Agronomy. 2005;86: 341-409.
5. Verma NP, Kuldeep YK, Yadav N. Study of liquid biofertilizer as an innovative agronomic input for sustainable agriculture. International Journal of Pure and Applied Bioscience. 2018;6(1):190-4.
6. Panse VG, Sukhatme PV. Statical methods for Agricultural workers. ICAR. New Delhi. 1985; 100-174
7. Helrich K. Official methods of analysis: Changes in Official methods of Analysis. 14th edition. Arlington, U.S.A: Association of Official Analytical Chemists. 1990.
8. Yadahalli VR, Thiruppathi M, Patil SB, Immanuel RR, Gnanasekar R. Quality characters and yield of fodder maize as influenced by inorganics, organics and biological sources of nutrients. The Pharma Innovation Journal. 2022;11(11): 2138-44.
9. Singh K, Joshi YP, Chandra H, Singh DK, Singh R and Kumar M. Effect of integrated nutrient management on growth, productivity and quality of sweet sorghum (*Sorghum bicolor*). Indian Journal of Agronomy. 2015;60(2):291-6.
10. Kumar A, Chaplot PC, Purohit HS, Upadhyay B, Kaushik MK. Effect of fertility levels, biofertilizers and organic manure on fodder yield of sorghum and its residual effect on barley. J Pharm Innov. 2022;11: 1760-63.
11. Verma N, Swarnkar VK, Das GK. Effect of organic and inorganic sources of nitrogen with biofertilizer on forage sorghum [*Sorghum bicolor* (L.) *Moench*]. Biosciences. 2014:986.
12. Gupta A, Mayuri D. Varietal response to graded levels of nitrogen and biofertilizers on forage yield of sorghum (*Sorghum bicolor* L. *Moench*) during the summer season. International Journal of Current Microbiology and Applied Sciences. 2022;11(07):44-59.
13. Datt N, Dubey YP, Chaudhary R. Studies on impact of organic, inorganic and integrated use of nutrients on symbiotic parameters, yield, quality of French-bean (*Phaseolus vulgaris* L.) vis-à-vis soil properties of an acid Alfisol. African Journal of Agricultural Research. 2013 Jun 13;8(22):2645-54.
14. Kuchay MA, Sharma DD, Kumar V. Evaluation of microbial and enzyme activity of rhizospheric soils under integrated nutrient management of apricot. Int. J. Curr. Microbiol. App. Sci. 2019;8(11):2381-9
15. Panchal BH, Patel VK, Patel KP, Khimani RA. Effect of biofertilizers, organic manures and chemical fertilizers on microbial population, yield and yield attributes and quality of sweetcorn (*Zea mays* L., *saccharata*) cv. Madhuri. International Journal of Current Microbiology and Applied Sciences. 2018;7(09):2423-31.

Comment [Ma35]: complete this number

Comment [Ma36]: *bicolor*L.

Comment [Ma37]: complete this number

Comment [Ma38]: complete this number

Comment [Ma39]: pp.

Comment [Ma40]: complete this number

Comment [Ma41]: L.

Comment [Ma42]: complete this number

Comment [Ma43]: complete this number

Comment [Ma44]: complete this number

Comment [Ma45]: complete this number

Comment [Ma46]: complete this number