The Pharma Innovation Journal 2021; SP-10(12): 961-966

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(12): 961-966

www.thepharmajournal.com
Received: 13-10-2021
Accepted: 15-11-2021

Kasthuri Rajamani
Regional Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University, Palem, Nagarkurnool, Telangana, India

S Triveni
Department of Microbiology, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, ARI, Rajendranagar, Hyderabad, Telangana, India

Corresponding Author
Kasthuri Rajamani
Regional Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University, Palem, Nagarkurnool, Telangana, India

Efficiency of microbial fertigation to influence maize yield and uptake in Alfisols

Kasthuri Rajamani and S Triveni

Abstract
This study aimed to assess the conjoint application of microbial consortium with 100% recommended dose of maize (200:80:80 kg ha^{-1}) fertilizers through drip irrigation on yield and uptake in alfisols at Regional Agricultural Research Station, Palem, PJTSAU, Telangana, India. The experiment was laid out in randomized block design with nine treatments replicated thrice, consisted combination of two factors *i.e.,* 100 and 75% RDF with microbial consortium of nitrogen-fixing, phosphorus solubilizing, potassium releasing and zinc solubilizing bacteria. Results of the study revealed that the combination of 100% RDF of maize fertilizers (200:80:80 kg ha^{-1}) along with microbial consortium@ 1.5 L ha^{-1} through drip irrigation up to 60 DAS register significantly higher pooled grain and stover yields as 7984 and 8933 kg ha^{-1} respectively, compare to the conventional fertigation of 100% RDF in Alfisols. Total pooled uptake of NPK nutrients was significantly higher at fertigation with 100% RDF with biofertigation of microbial consortium@ 5 times (180, 90 and 185 kg ha^{-1}), compared to the other treatments consisting of microbial consortium with 100 or 75% RDF fertigation.

Keywords: microbial consortium, fertigation, rhizosphere, mineralization, drip irrigation

1. Introduction
Crop productivity is controlled by countless factors from soil, water and nutrient content. To conquer all such detriments to enhance plant growth and development, begin enormous use of inorganic fertilizers together with improved plant genotypes, which further led negative impacts on soil health (Kumar *et al.,* 2019) [19], microbial population (Pizzeghello *et al.,* 2011) [25], and environment (Czymmek *et al.,* 2020) [12]. In order to steer up these consequences while maintaining or even improving crop yields, there is a need to search for possible strategies to reduce the quantity of mineral fertilizers and to hold climate change-causing sources. Throughout modern plant science, most of rhizosphere interaction studies have focused on alleviating pathogenic effects (Zhang *et al.,* 2013) [30], or attenuating abiotic stress conditions (Yaish *et al.,* 2016) [29] with a fascination to characterize the positive ecological interactions that promote plant growth and development (Meena *et al.,* 2017) [22]. Results from such studies have shown that the rhizospheric niche is a hotspot of ecological richness, with plant roots hosting an enormous array of microbial diversification and abundance (Bulgarelli *et al.,* 2013) [10], which plays a key role in the bioavailability of insoluble nutrients through different soil functional processes and are the key drivers in the biogeochemical cycling of nutrients (Mus *et al.,* 2016) [23].
The positive impacts of microbial-based biofertilizers on the growth and yield of staple crops may be limited to single nutrient elements such as nitrogen or phosphorus (Bardi and Malusà, 2012) [4]. Moreover, the microorganisms' consortium which is a poly-microbial mixture that contains several microbial strains belonging to different functional groups may strongly promote plant growth, yields, and healthy agro-ecosystems (Arora *et al.,* 2011 & Malusa *et al.,* 2012) [2, 20]. Multifunctional microbial consortia may also involve free-living nitrogen-fixing bacteria as well as different plant growth-promoting rhizobacteria with higher abilities to maximize plant growth, yield and efficient N uptake (Vassilev *et al.,* 2015) [28]. The combined use of biological, mineral, and organic resources gaining recognition as a promising approach for sustainable agriculture, which will elaborate the efficient integrated plant nutrient management systems (IPNMSs) that address soil fertility issues, crop nutrient needs and sustainable eco-intensification (Busby *et al.,* 2017) [11].
Biofertigation allows the uniform distribution of fertilizer nutrients with efficient microbial consortium through micro-irrigation and further this method offers a reduction in chemical fertilizers, enhancing fertilizer use efficiency as well water use efficiency, and intensifying the crop growth and production.

In view of the importance of these microbial consortiums, the present study was conducted through fertigation to evaluate the field inoculation potential on maize productivity and nutrient uptake in alfisols and then to use this knowledge to inform the optimal design of microbial fertigation tailored to carry out specific functions.

2. Material and Methods

A field experiment was conducted at Regional Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University, Palem, Telangana state, India during *rabi*, 2017-18 and 2018-19 to find out the efficiency of microbial consortium through fertigation to influence maize yield and uptake in Alfisols. The experimental soil was sandy loam in texture, slightly alkaline (pH 7.54) in reaction, non-saline (0.31 dS m^{-1}), low in organic carbon (0.41 percent), available N (161.53 kg ha^{-1}), high in available P_2O_5 (57.04 kg ha^{-1}) and medium in K_2O (319.62 kg ha^{-1}). The experiment was laid out in randomized block design with nine treatments replicated thrice, consists combination of two factors *i.e.*, inorganic fertilizers and consortium of microbes with control treatment where no input was applied. The maize hybrid DHM 117 was used as a test crop by imposing treatment composition as T_1:Drip fertigation with 100% RDN & K, T_2:Drip fertigation with 100% RDN & K-soil application of microbial consortium, T_3:Drip fertigation with 100% RDN & K-Liquid biofertigation of microbial consortium - 3 times, T_4:Drip fertigation with 100% RDN & K-Liquid biofertigation of microbial consortium - 5 times, T_5:Drip fertigation with 75% RDN & K, T_6:Drip fertigation with 75% RDN & K-soil application of microbial consortium, T_7:Drip fertigation with 75% RDN & K-Liquid biofertigation of microbial consortium - 3 times, T_8:Drip fertigation with 75% RDN & K-Liquid biofertigation of microbial consortium - 5 times and T_9: Contol (No fertilizers & organics). All the treatments received basic fertilizers *i.e.*, 240 kg N, 80 kg P_2O_5 and 80 kg K_2O ha^{-1} through urea, diammonium phosphate, and sulfate of potash as per the treatment requirement (75% & 100% RDF) through fertigation at an interval of 3 days at 1.2 E-pan through venturi system during the entire crop growth period. The liquid Microbial consortium consisted of *Azotobacter* (Non-symbiotic heterotrophic nitrogen-fixing bacterium), phosphorus solubilizing bacteria, potassium releasing bacteria and zinc solubilizing bacteria. It was applied through a drip irrigation system @ 1.5 L having a microbial count of 10^{-12} cell ml^{-1} and diluted in 500 L of water for one hectare. Fertigation of microbial consortium was started from 10 days after sowing at every 10 days interval. In three times application, the scheduling was done at 20, 30 and 40 DAS and in 5 times application, it was extended up to 60 DAS. Soil application of microbial consortium was done at 10 days after sowing @ 1.5 L which poses a microbial count of 10^{-12} cell ml^{-1} and mixed with 200 kg of vermicompost for one acre and applied along the plant rows. The plant samples were collected for the analysis of macronutrient uptake by following the methodology of Piper (1966), finally the grain and stover yields were recorded at the time of harvesting from the randomly tagged five plants and expressed those grain and stover yields as kilograms per hectare (Kg ha^{-1}). Further, the data originated from this investigation was analyzed statistically in a randomized block design using OPSTAT, and significance of the treatment effect was determined using the F-test. The least significant differences were calculated at the 5% probability level to determine the significance of the difference between two treatments (Gomez and Gomez, 1984).

3. Results and Discussion

3.1 Grain and Stover Yield (kg ha^{-1}) of Maize

The pooled data on grain and stover yield of maize was influenced significantly by bio-fertigation combinations under the study and discussed in Table 1. The grain and stover yields of maize ranged from 2664 to 8730 & 2980 to 9762 kg ha^{-1} respectively during *rabi* 2017-18, and varied 2073 to 7237 & 2342 to 8103 kg ha^{-1} respectively during *rabi* 2018-19, whereas the pooled grain and straw yield of maize ranged from 2369 to 7984 and 2661 to 8933 kg ha^{-1}. Soil application of microbial consortium either with 100% RDNK or 75% RDNK of fertigation resulted in lowest grain and straw yields as 8318 & 9302 kg ha^{-1} during *rabi* 2017-18, 7149 & 7795 during *rabi* 2018-19, and the pooled yields as 7734 and 8549 kg ha^{-1} compared to their respective fertigation treatments along with microbial consortium as per the schedule of the treatments. It might be due to the effective translocation of nutrients to reproductive parts compared to the conventional method of microbial consortium application to the soil (Senthil Kumar and Sundaram, 2005) [27].

Among the different treatment combinations, significantly superior grain and stover yields (8730 & 9762 kg ha^{-1} during *rabi* 2017-18 and 7237 & 8103 kg ha^{-1} during *rabi* 2018-19, while the pooled yields were 7984 and 8933 kg ha^{-1} respectively) registered with the conjoint application of 100% RDNK fertigation along with microbial consortium @5 times *i.e.*, up to 60 DAS and was on par with the treatments, which received nutrients from 100% RDNK fertigation based combinations compared to the 75% RDNK fertigation integrated treatments.

This may be possible due to applied microbial consortium successfully colonizing the rhizospheric niche, and then mediating nutrient mobilization that benefits plant growth. This can be tested through plant-microbe interaction assays, where candidate strains are tested for their ability to promote plant growth and nutrient acquisition (Ahemad and Kibret, 2014) [1]. In addition, carbon allocation (quantitatively and qualitatively) to roots and rhizo-deposition are presumably important factors that may plausibly control above- and below-ground plant biomass. Those factors may modify rhizosphere traits and shape the rhizosphere microbial community (Hernández *et al.*, 2015) [16], particularly via the development of robust rooting system and associated rhizosphere-induced changes including plant-microbe mutualism efficiency, biological nitrogen fixation (Bargaz *et al.*, 2017) [6], soil respiration (Ibrahim *et al.*, 2013) [17], rhizosphere acidification, and availability of nutrients. (Latati *et al.*, 2016). Further, significantly lowest grain and stover yields (2664 & 2980 kg ha^{-1} during *rabi* 2017-18 and 2073 & 2342 kg ha^{-1} during *rabi* 2018-19, while the pooled yields as 2369 and 2661 kg ha^{-1} respectively) were recorded in control treatment where no input was applied for crop growth and development.

Table 1: Influence of biofertigation on maize grain and stover yield (kg ha^{-1}) during *rabi* 2017-18 & 2018-19

Treatments	2017-18		2018-19		Pooled	
	Grain Yield	Straw Yield	Grain Yield	Straw Yield	Grain Yield	Straw Yield
	Kg ha^{-1}					
T_1: Drip fertigation with 100% RDN & K	8441	9439	7001	7720	7721	8580
T_2: Drip fertigation with 100% RDN & K-soil application of microbial consortium	8318	9302	7149	7795	7734	8549
T_3: Drip fertigation with 100% RDN & K-Liquid biofertigation of microbial consortium - 3 times	8586	9601	7190	7890	7888	8746
T_4: Drip fertigation with 100% RDN & K-Liquid biofertigation of microbial consortium - 5 times	8730	9762	7237	8103	7984	8933
T_5: Drip fertigation with 75% RDN & K	6401	7158	6346	7068	6374	7113
T_6: Drip fertigation with 75% RDN & K-soil application of microbial consortium	6578	7355	6506	7125	6542	7240
T_7: Drip fertigation with 75% RDN & K-Liquid biofertigation of microbial consortium - 3 times	6852	7662	6624	7207	6738	7435
T_8: Drip fertigation with 75% RDN & K-Liquid biofertigation of microbial consortium - 5 times	6956	7778	6761	7303	6859	7541
T_9: Contol (No fertilizers & organics)	2664	2980	2073	2342	2369	2661
SE (m)±	473	529	211	251	324	404
CD (*P=0.05*)	1432	1601	654	782	1209	1471

3.2 Major nutrient (NPK) uptake in grain and stover (kg ha^{-1}) of Maize

Nutrient uptake (NPK) of maize was significantly influenced by various combinations of microbial consortia with inorganic fertigation (Fig 1 to 5). The grain NPK uptake ranged from 49 to 117; 15 to 51 and 21 to 29 kg ha^{-1} respectively during *rabi* 2017-18, and it varied 41 to 109; 20 to 56 and 16 to 44 kg ha^{-1} respectively during *rabi* 2018-19. The NPK uptake of stover varied from 33 to 78; 9 to 37 and 53 to 143 kg ha^{-1} respectively during *rabi* 2017-18, while it ranged 38 to 83; 7 to 35 and 50 to 137 kg ha^{-1} respectively during *rabi* 2018-19. Pooled total uptake of NPK was ranged from 79 to 180; 26 to 90 and 70 to 185 kg ha^{-1} respectively. The nutrient uptake variation among the treatments showed the importance of microbial inoculant's application to increase organic matter concentration at rhizosphere (Bargaz *et al.*, 2018) [7]. With the combination of 100% recommended dose of maize (240:80:80 kg ha^{-1}) nutrients + microbial consortium of 1.5 L ha^{-1}@ 5 times application up to 60 DAS resulted in significant higher NPK uptake in grain was registered as 117, 51, 49 kg ha^{-1} during *rabi* 2017-18, and it was 109, 56, 44 kg ha^{-1} during *rabi* 2018-19 respectively. The applied microbial consortium may enhance the nutrient mineralization mediated by microbial enzymatic activities, which degrade organic polymers to release nutrients for root uptake (Ferreira *et al.*, 2019). Further, these results indicated that conjoint application of microbial consortium with a recommended dose of fertilizers through drip irrigation increased the absorption of N by plants, with the urea mineralization capacity of the microbial consortium, and a similar tendency was found for P and K absorption in the plant. The stover uptake of NPK followed the similar trend in both the years (78, 37, 140 during *rabi* 2017-18 and 83, 35, 137 kg ha^{-1} during *rabi* 2018-19 respectively).

Application of alone mineral fertilizers @100% RDF through fertigation extracted significantly lower NPK uptake in grain and stover as 107, 39, 41 and 69, 26, 131 kg ha^{-1} during *rabi* 2017-18, while it was 97, 44, 36 and 74, 24, 128 kg ha^{-1} during *rabi* 2018-19 respectively compared to the 100% RDF fertigation along with microbial consortium treatments, because of the lack of sufficient organic matter to be mineralized by microorganisms (Martínez, 2015 and Dhaliwal *et al.*, 2019) [21, 13]. The same trend was noticed with the alone application of 75% RDF fertigation compared to its combination with microbial consortium. Total pooled uptake of NPK nutrients was significantly higher at fertigation with 100% RDF with biofertigation of microbial consortium@ 5 times (180, 90 and 185 kg ha^{-1}), compared to the other treatments consisting of a microbial consortium with 100 or 75% RDF fertigation. The absorption efficiency indicated that added microbial consortium in conjunction with chemical fertilizers promotes the NPK uptake and nutrient use efficiency, which is usually associated with larger root density (Assainar *et al.*, 2019).

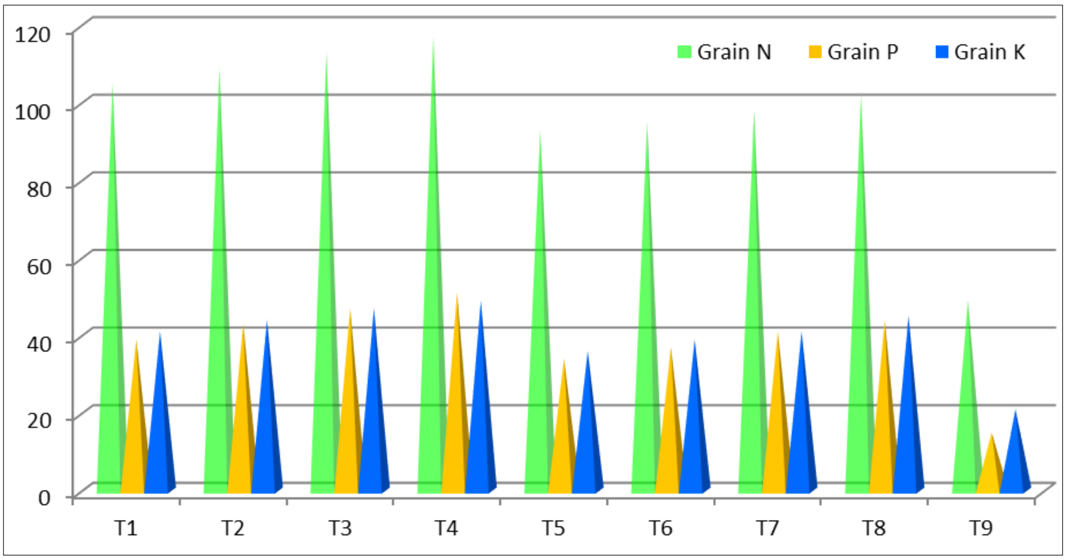

Fig 1: Influence of biofertigation on maize grain NPK uptake (kg ha^{-1}) during *rabi* 2017-18

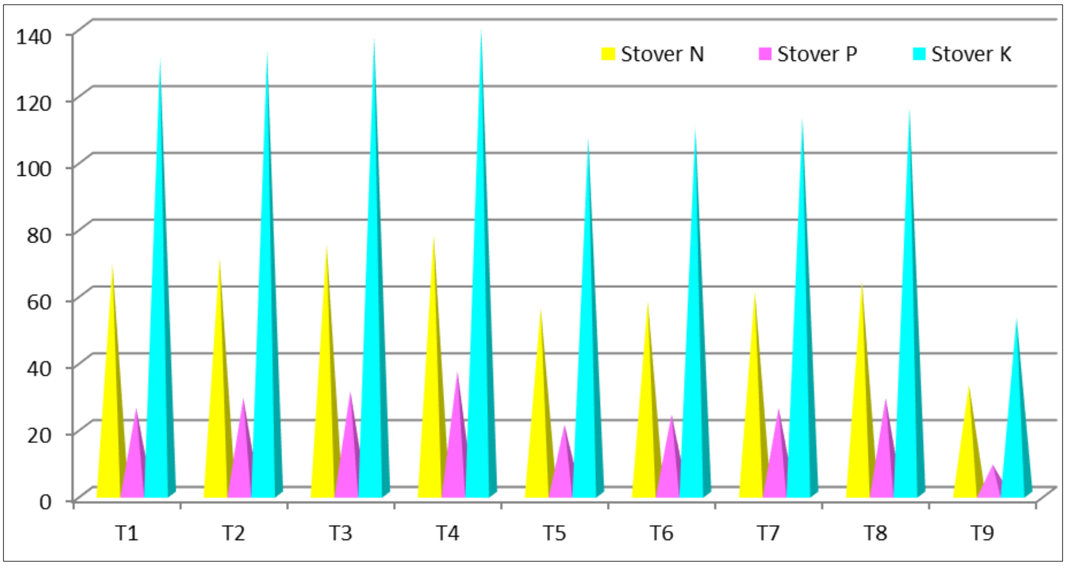

Fig 2: Influence of biofertigation on maize stover NPK uptake (kg ha^{-1}) during *rabi* 2017-18

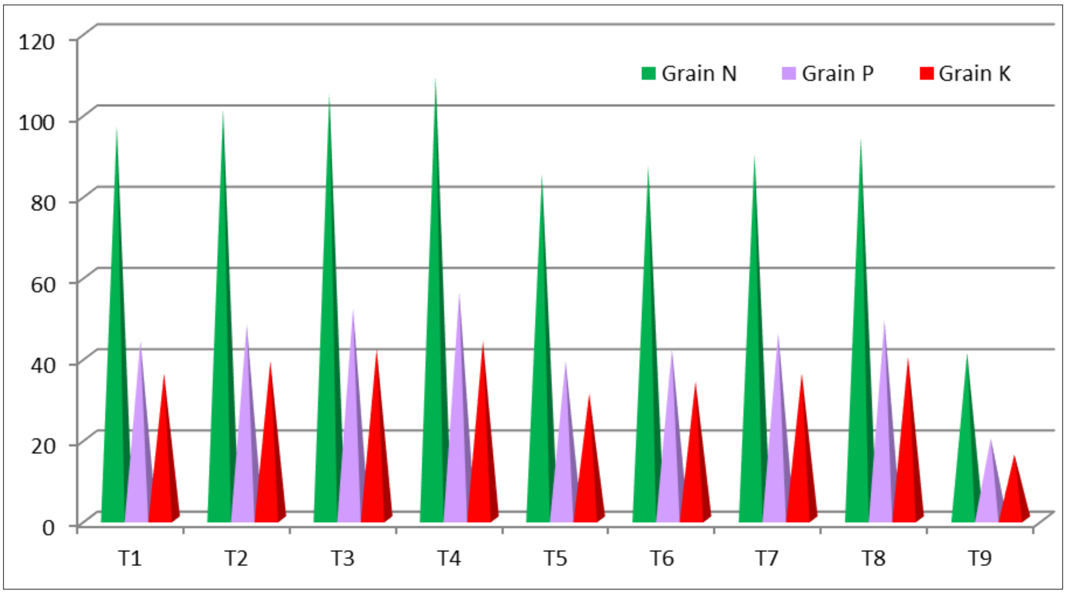

Fig 3: Influence of biofertigation on maize grain NPK uptake (kg ha^{-1}) during *rabi* 2018-19

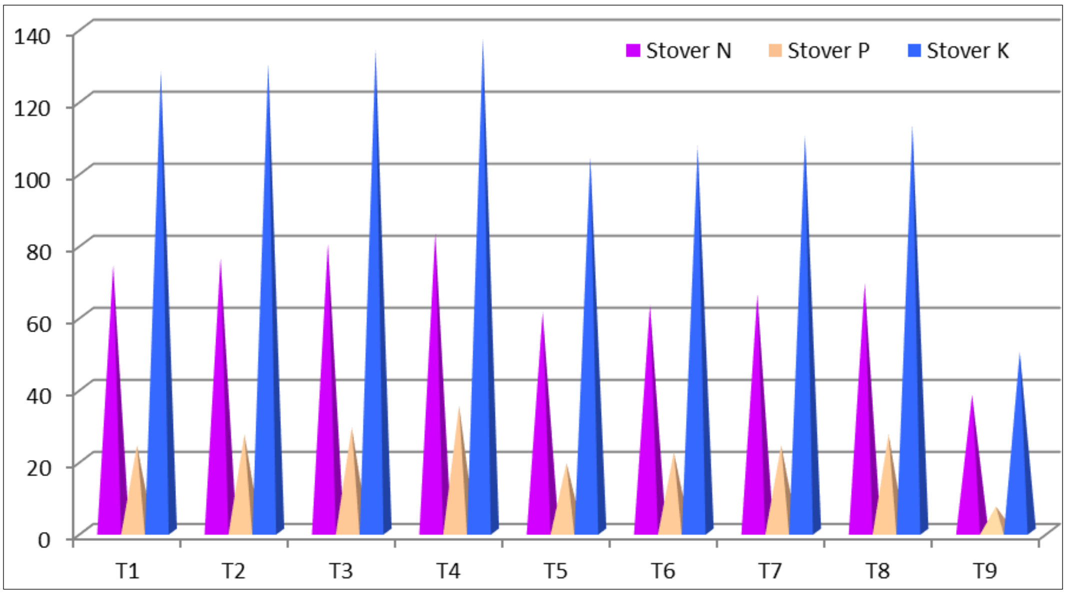

Fig 4: Influence of biofertigation on maize stover NPK uptake (kg ha^{-1}) during *rabi* 2018-19

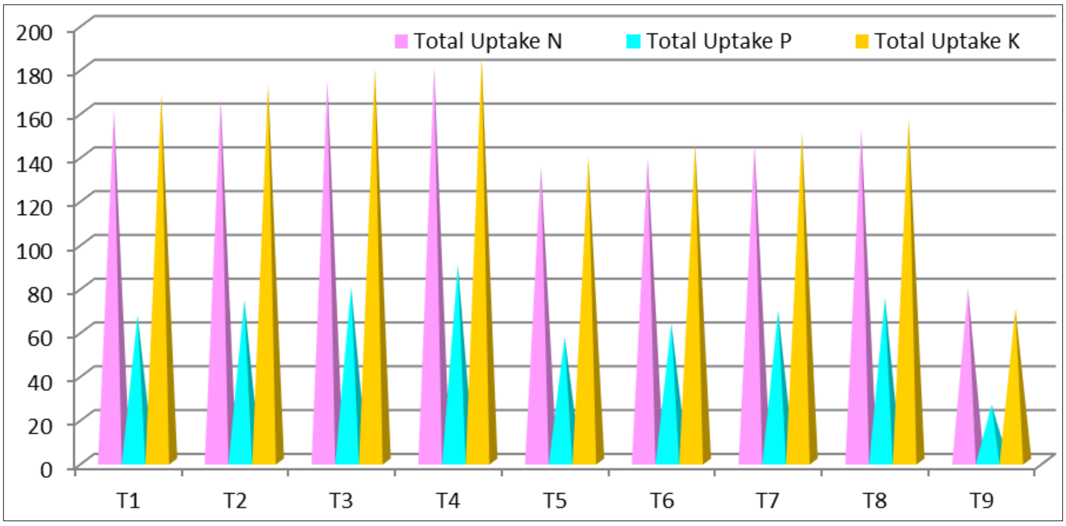

Fig 5: Influence of biofertigation on pooled total NPK uptake (kg ha^{-1}) of maize during *rabi* 2017-18 & 2018-19

3.3 Correlation of grain and stover yields with total nutrient uptake of maize

Correlation analysis was carried out among pooled yields (grain & stover) of maize and pooled total NPK uptake (kg ha^{-1}) to find out the highly correlated nutrients to the grain and stover yields (Table.2). Among the pooled variables, total nitrogen and potassium uptakes (r = 0.98** and 0.99** respectively) existed significant and positive correlation with grain and stover yields than total P uptake (r = 0.94**). Combination of microbial consortium and mineral fertilizers through drip irrigation might have increased mineralization of organic carbon, thereby improving nutrient release and their availability to the plant (Birkhofer *et al.*, 2008) [9] uptake, which also affirmed the enhanced nutrient cycling and nutrient use efficiencies (Schoebitz *et al.*, 2016) [26].

Table 2: Correlation analysis of pooled yield and total nutrient uptake of maize under biofertigation

Parameters	Pooled Grain Yield (Kg ha^{-1})	Pooled Stover Yield (Kg ha^{-1})	Pooled Total N uptake (Kg ha^{-1})	Pooled Total P uptake (Kg ha^{-1})	Pooled Total K uptake (Kg ha^{-1})
Pooled Grain Yield (Kg ha^{-1})	1.00				
Pooled Stover Yield (Kg ha^{-1})	0.99**	1.00			
Pooled Total N uptake (Kg ha^{-1})	0.98**	0.98**	1.00		
Pooled Total P uptake (Kg ha^{-1})	0.94**	0.94**	0.97**	1.00	1.00
Pooled Total K uptake (Kg ha^{-1})	0.99**	0.99**	0.99**	0.97**	1.00

4. Conclusion

Conjoint application of 100% recommended dose of maize fertilizers (200:80:80 kg ha^{-1}) along with microbial consortium@ 1.5 L ha^{-1} through drip irrigation up to 60 DAS had a strong effect on nutrient absorption to register significantly higher pooled grain and stover yields as 7984 and 8933 kg ha^{-1} respectively, compare to the conventional fertigation of 100% RDF in Alfisoils to produce plant-growth-stimulating phyto-horrmones with antibiotic activity.

5. References

1. Ahemad M, Kibret M. Mechanisms and applications of plant growth promoting rhizobacteria: current perspective. J King Saud Univ. Sci. 2014;26:20. DOI: 10.1016/j.jksus.2013.05.001
2. Arora NK, Khare E, Maheshwari DK. Plant growth promoting rhizobacteria: constraints in bioformulation, commercialization, and future strategies, in: Plant Growth and Health Promoting Bacteria, Microbiology Monographs, Chap. 18, ed. D. K. Maheshwari (Berlin: Springer). 2011. DOI: 10.1007/978-3-642-13612-2
3. Assainar SK, Abbott LK, Mickan BS, *et al*. Response of wheat to a multiple species microbial inoculant compared to fertilizer application. Frontiers in Plant Science. 2018;9:1601.
4. Bardi L, Malusà E. Drought and nutritional stresses in plant: alleviating role of rhizospheric microorganisms, in Abiotic Stress: New Research, eds N. Haryana and S. Punj (Hauppauge: Nova Science Publishers Inc). 2012, 1-57.
5. Bargaz A, Lyamlouli K, Chtouki M, Zeroual Y, Dhiba D. Soil Microbial Resources for Improving Fertilizers Efficiency in an Integrated Plant Nutrient Management System. Front. Microbiol. 2018;9:1606. DOI: 10.3389/fmicb.2018.01606
6. Bargaz A, Noyce GL, Genevieve FR, Carlsson C, Furze JR, Jensen EJ, *et al*. Species interactions enhance root allocation, microbial diversity and P acquisition in intercropped wheat and soybean under P deficiency. Appl. Soil Ecol. 2017;120:179-188. DOI: 10.1016/j.apsoil.2017.08.011
7. Bargaz A, Lyamlouli K, Chtouki M, *et al*. Soil microbial resources for improving fertilizers efficiency in an integrated plant nutrient management system. Frontiers in Microbiology. 2018;9:1606.
8. Battaglia ML, Groover G, Thomason WE. Harvesting and nutrient replacement costs associated with corn stover removal in Virginia; Virginia Cooperative Extension Publication CSES-229NP; Virginia Tech: Blacksburg, VA, USA. 2018.
9. Birkhofer K, Bezemer TM, Bloem J, Bonkowski M, Christensen S, Dubois D, *et al*. Long-term organic farming fosters below and aboveground biota: implications for soil quality, biological control and

productivity. Soil Biol. Biochem. 2008;40:2297-2308.
10. Bulgarelli D, Schlaeppi K, Spaepen S, Van Themaat EVL. Schulze-Lefert P. Structure and functions of the bacterial microbiota of plants. Annu. Rev. Plant Biol. 2013;64:807-838. DOI: 10.1146/annurev-arplant-050312-120106
11. Busby PE, Soman C, Wagner MR, Friesen ML, Kremer J, Bennett A, *et al*. Research priorities for harnessing plant microbiomes in sustainable agriculture. PLOS Biol. 2017;15:e2001793. DOI: 10.1371/journal.pbio.2001793
12. Czymmek K, Ketterings Q, Ros M, Battaglia M, Cela S, Crittenden S, *et al*. The New York Phosphorus Index 2.0; Agronomy Fact Sheet Series; Fact Sheet #110; Cornell University Cooperative Extension: Ithaca, NY, USA. 2020.
13. Dhaliwal SS, Naresh RK, Mandal A, *et al*. Dynamics and transformations of micronutrients in agricultural soils as influenced by organic matter build-up: A review. Environmental and Sustainability Indicators. 2019;1:100007.
14. Ferreira CMH, Soares HMVM, Soares EV. Promising bacterial genera for agricultural practices: An insight on plant growth-promoting properties and microbial safety aspects. Science of the Total Environment. 2019;682:779-799.
15. Good AG, Beatty PH. Fertilizing Nature: A Tragedy of Excess in the Commons. PLoS Biol. 2011;9:e1001124.
16. Hernández M, Dumont MG, Yuan Q, Conrad R. Different bacterial populations associated with the roots and rhizosphere of rice incorporate plant-derived carbon. Appl. Environ. Microbiol. 2015;81:2244-2253. DOI: 10.1128/AEM.03209-14
17. Ibrahim H, Hatira A, Pansu M. Modelling the functional role of microorganisms in the daily exchanges of carbon between atmosphere, plants and soil. Proc. Environ. Sci. 2013;19:96-105. DOI: 10.1016/j.proenv.2013.06.011
18. Kumar P, Lai L, Battaglia ML, Kumar S, Owens V, Fike J, *et al*. Impacts of nitrogen fertilization rate and landscape position on select soil properties in switchgrass field at four sites in the USA. Catena. 2019;180:183-193.
19. Kumar S, Lai L, Kumar P, Feliciano YMV, Battaglia ML, Hong CO, *et al*. Impacts of nitrogen rate and landscape position on soils and switchgrass root growth parameters. Agron. J. 2019;111:1046-1059.
20. Malusa E, Sas-Paszt L, Ciesielska J. Technologies for beneficial microorganisms inocula used as biofertilizers. Sci. World J. 2012, 491206. DOI: 10.1100/2012/491206.
21. Martínez M. Microbial bioproducts for agriculture. Acta Horticulture. 2015;1076(1076):71-76.
22. Meena KK, Sorty AM, Bitla UM, Choudhary K, Gupta P, Pareek A, *et al*. Abiotic stress responses and microbe-mediated mitigation in plants: the omics strategies. Front. Plant Sci. 2017;8:172. DOI: 10.3389/fpls.2017.00172.
23. Mus F, Crook MB, Garcia K, Costas AG, Geddes BA, Kouri ED, *et al.* Symbiotic nitrogen fixation and the challenges to its extension to nonlegumes. Appl. Environ. Microbiol. 2016;82:3698-3710. DOI: 10.1128/aem. 01055-16.
24. Pierre MJ, Sopan Bhople DB, Kumar DA, Erneste H, Emmanuel B, Singh YN. Contribution of arbuscular mycorrhizal fungi (AM fungi) and rhizobium inoculation on crop growth and chemical properties of rhizospheric soils in high plants. IOSR J Agric. Vet. Sci. 2014;7:45-55.
25. Pizzeghello D, Berti A, Nardi S, Morari F. Phosphorus forms and p-sorption properties in three alkaline soils after long-term mineral and manure applications in north-eastern Italy. Agric. Ecosyst. Environ. 2011;141:58-66.
26. Schoebitz M, Vidal G. Microbial consortium and pig slurry to improve chemical properties of degraded soil and nutrient plant uptake. J Soil Sci. Plant Nutr. 2016;16(1):226-236.
27. Senthil Kumar M, Sundaram SP. *In vitro* study of Methylotrophs with other bioinoculants on cotton. In: National symposium on Microbial technology for productive agriculture Lead papers and research notes. 7-8 October 2005 Tamil Nadu Agricultural University Coimbatore India. 2005, 44-45.
28. Vassilev N, Vassileva M, Lopez A, Martos V, Reyes A, Maksimovic I, *et al*. Unexploited potential of some biotechnological techniques for biofertilizer production and formulation. Appl. Microbiol. Biotechnol. 2015;99:4983-4996. DOI: 10.1007/s00253-015-6656-4.
29. Yaish MW, Al-Lawati A, Jana GA, Vishwas Patankar H, Glick BR. Impact of soil salinity on the structure of the bacterial endophytic community identified from the roots of caliph medic (*Medicago truncatula*). PLOS ONE. 2016;11:e0159007. DOI: 10.1371/journal.pone.0159007.
30. Zhang Y, Lubberstedt T, Xu ML. The genetic and molecular basis of plant resistance to pathogens. J Genet. Genomics. 2013;40:23-35. DOI: 10.1016/j.jgg.2012.11.003.