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Effect of foliar application of water soluble fertilizers and liquid plant growth promoting rhizomicrobial consortia on post-harvest soil nutrient status and microbial population on rainfed groundnut (*Arachis hypogaea* L.)

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Abstract
A field experiment using water soluble fertilizers and liquid plant growth promoting rhizomicrobial consortia was undertaken at College of Agriculture, University of Agricultural and Horticultural Sciences, Shivamogga, during *kharif* 2020-21 to know the effect of foliar application of water soluble fertilizers *viz.,* Monopotassium phosphate (00:52:34) and Sulphate of potash (00:00:50) + liquid plant growth promoting rhizomicrobial consortia along with the package of practice on post-harvest soil nutrient status and microbial population in the rhizosphere of groundnut. The results revealed that the foliar application of MPP and SOP each @ 1 per cent at 25 and 40 DAS + liquid PGPR + package of practice noticed with higher available nitrogen (233.57 kg ha^{-1}), phosphorus (78.16 kg ha^{-1}) and potassium (223.93 kg ha^{-1}) after harvest of the crop. Liquid plant growth promoting rhizomicrobial consortia (*Rhizobium sp*., *Bacillus megatherium* and *Fruturia arentia*) gave significant increase in soil microbial population *viz.,* total bacteria, fungi and actinomycetes population in the soil after harvest of the crop.

Keywords: Water soluble fertilizers, PGPR, package of practices

Introduction
India is one of the largest oilseeds producers globally and occupies an important position in the Indian agricultural economy. It ranks first to produce most of the minor oilseeds (castor, niger, safflower and sesame). In the major oilseed crops, soybean is in the first position, followed by groundnut with the production of 13.63 and 8.24 million tonnes, respectively (Anon., 2020) [3]. Among different oilseeds grown in India, groundnut is the second important oilseed crop only after soybean. It ranks first in area (40.12 lakh ha) and second in terms of production (37.70 lakh ha^{-1}) with a productivity of 931 kg ha^{-1} (Anon., 2019) [2].

Groundnut, 'the unpredictable legume' is also known as earthnut, peanut, monkey nut and manilla nut. It is the 13th most important food crop and 4th most important oilseed crop of the world. It is valued for its high edible oil (48-50%) and protein content (25-28%) and carbohydrates (10-20%). It provides 564 K calories of energy from 100 g of kernels (Jambunathan, 1991) [1]. The cake obtained after oil extraction is used in the animal feed industry to make enriched, easily digestible food for children and aged persons. Groundnut oil is an excellent cooking medium due to its high smoking point. It can widely be used in food processing industries because of a high proportion of unsaturated fatty acids (Singh and Diwakar, 1993). It is also used to make peanut butter, confectioneries and baked products. The haulm constitutes nutritious fodder for livestock. It contains protein (8-15%), lipids (1-3%), minerals (9-17%) and carbohydrates (38-45%) at higher levels compared to cereal fodders. The digestibility of nutrients in groundnut haulm is around 53 percent and that of crude protein is 88 percent in animals. Haulm release energy up to 2337 Cal kg^{-1} of dry matter and form an important source of legume fodder to animals in mixed crop-livestock systems of the semi-arid region.

During the last few years, there is a steady trend to reduce the use of mineral fertilizers, especially soil applied nitrogen, phosphorus and potassium supplement the mineral nutrition through non-conventional methods (Haytova, 2013) [5].

These facts create preconditions to increase the importance of foliar fertilization as an alternative to meet plant nutrient demand during the growing season. Foliar feeding is often the most effective and economical way to overcome plant nutrient deficiency (Dixit and Elamathi, 2007) [4]. Under rainfed conditions, when the availability of moisture becomes scarce, the application of fertilizers as foliar spray resulted in efficient absorption and usage.

Material and Methods

The field experiment was conducted during *Kharif* 2020-21 at College of Agriculture, University of Agricultural and Horticultural Sciences, Navile, Shivamogga that comes under Southern Transitional Zone (STZ) of Karnataka. The geographical reference point of the experimental site is 13°58' to 14°1' North latitude and 75°34' to 75°42' East longitude with an altitude of 650 m above the mean sea level. The soil of the experimental site was sandy loam in texture, slightly acidic (pH 6.10), normal in electrical conductivity (0.4 dS m^{-1}) high in organic carbon content (2.15 g kg^{-1}), low in nitrogen (230.22 kg N ha^{-1}), high in phosphorus (75.89 kg P_2O_5 ha^{-1}) and medium in potassium (201.23 kg K_2O ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with fourteen treatments and three replications. Treatment consisting of different combination of water soluble fertilizers *viz.*, Monopotassium phosphate (00:52:34) and Sulphate of potash (00:00:50) sprayed at 25 and 40 days after sowing with or without application of liquid plant growth promoting rhizomicrobial consortia along with the package of practice *viz.*, T_1: Control= Package of practice (FYM at 7.5 t ha^{-1}, 25:50:25 N: P_2O_5: K_2O, and 10 kg ha^{-1} $ZnSO_4$), T_2: T_1 + MPP @ 1% at 25 DAS, T_3: T_1 + MPP @ 1% at 25 and 40 DAS, T_4: T_1 + SOP @ 1% at 25 DAS, T_5: T_1 + SOP @1% at 25 and 40 DAS, T_6: T_1 + MPP + SOP each @ 1% at 25 DAS, T_7: T_1 + MPP + SOP each @ 1% at 25 and 40 DAS, T_8: T_1 + MPP @ 1% at 25 DAS + liquid PGPR, T_9: T_1 + MPP @ 1% at 25 and 40 DAS + liquid PGPR, T_{10}: T_1 + SOP @ 1% at 25 DAS + liquid PGPR, T_{11}: T_1 + SOP @ 1% at 25 and 40 DAS + liquid PGPR, T_{12}: T_1 + MPP + SOP each @ 1% at 25 DAS + liquid PGPR, T_{13}: T_1 + MPP + SOP each @ 1% at 25 and 40 DAS + liquid PGPR, T_{14}: Package of practice + liquid PGPR. Liquid plant growth promoting rhizomicrobial (*Rhizobium sp*., *Bacillus megatherium* and *Fruturia arentia*) consortia is applied to the soil at the rate of 625 ml ha^{-1} through soil drenching at 25 and 40 days after sowing. The test variety used in the present investigation was TMV-2, it is a Spanish bunch type of groundnut.

Soil samples after the harvest of the crop from 0 to 30 cm soil depth were collected from all the treatments. The soil samples were analysed for pH, EC, organic carbon, available nitrogen, phosphorus and potassium using the standard procedure. The microbial population in the soil at initial and after harvest was determined by serial dilution pour plate method. Soil samples from different treatments were collected separately from each replication and then they were pooled. Ten grams of pooled soil (treatment wise) weighed and mixed in 90 ml sterilized water blank to give 10^{-1} dilutions. Subsequent dilutions up to 10^{-6} were made by transferring serially 1 ml of each dilution to 9 ml sterilized water blanks. The population of fungi, bacteria and actinomycetes were estimated by pour plate serial dilution method and by taking 1 ml from selected dilution of 10^{-3},10^{-5} and 10^{-2}, respectively were transferred aseptically to petridishes and the desired agar media was prepared by using appropriate ingredients and melted by using hot air oven, then added to their respective dilutions. Plating on appropriate media *viz*., martins rose Bengal agar (MRBA) media, nutrient agar media and kusters agar media, respectively. Similarly the population of N_2- fixers, P-solubilizer's and K- solubilizer's were also estimated by pour plate serial dilution method by taking 1 ml from selected dilution of 10^{-5} and plating on appropriate media *viz*., Walksman media, Pikovskaya's media and Aleksandrov's agar media, respectively. The inoculated plates were kept for incubation at 30°C ± 10°C for a week time and emerged colonies were enumerated by digital colony counter and expressed in colony forming units per gram of soil (CFU× g^{-1} of soil).

Results and Discussion

Significantly higher amount available nitrogen (233.57 ha^{-1}), phosphorous (78.16 ha^{-1}) and potassium (223.93 kg ha^{-1}) were noticed in the treatment which received foliar application of MPP and SOP each @ 1 per cent at 25 and 40 DAS + liquid PGPR along with the package of practice. The soil microbial population after harvest of the crop was also statistically higher (Bacteria: 131.33 CFU × 10^5 g^{-1}, fungi: 32.67 CFU × 10^3 g^{-1}, actinomycetes: 13.33 CFU × 10^2 g^{-1}, N_2-fixers: 46.67 CFU × 10^5 g^{-1}, PSB: 39.33 CFU × 10^5 g^{-1}, KSB: 30.00 CFU × 10^5 g^{-1}) in the above treatment. This may be due to foliar application of water soluble fertilizers and liquid PGPR act as an extra input in addition to package of practice. This applied extra input can fulfil the nutrient demand of the crop and also helps to maintain high soil nutrient status after harvest of the crop. Application of PGPR inoculants may increased the soil microbial population in the rhizosphere by interacting synergistically with native microorganisms (Gupta *et al.*, 2014) [6]. Application of FYM at 7.5 t ha^{-1} also promote microbial activity and accelerated the breakdown of organic substances in the added manure which helps to stimulate the enzyme activity and in turn enhanced the soil microbial activity (Parewa *et al.*, 2014) [7]. This enhanced microbial population in the soil play a significant role in increasing available soil nutrient status through performing various activities like solubilization and minerlization of major nutrients.

The enhanced available nitrogen may be because of more availability of nitrogen in the soil due to application of chemical fertilizers and N_2-fixation by microorganisms (*Rhizobium sp.*). The higher availability of phosphorous might be due to greater mineralization and production of organic acids due to decomposition of organic matter by microorganisms, which cover on sesquioxides and thus reduce the phosphate fixing capacity and increases the available phosphorus in soil (Parewa *et al.*, 2014) [7]. Similarly potassium availability also increased due to reduced potassium fixation by clay lattice and increasing in solubilization process.

Table 1: pH, EC, Organic carbon and available nutrient status of soil as influenced by foliar application of water soluble fertilizers and liquid PGPR after the harvest of groundnut

Treatments	pH	EC (dS m^{-1})	Organic Carbon (g kg^{-1})	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	5.73	0.33	4.05	208.40	66.83	181.93
T_2	5.74	0.32	4.26	213.90	70.70	188.40
T_3	5.78	0.33	4.11	217.13	72.93	189.97
T_4	5.70	0.31	4.04	213.20	68.37	184.87
T_5	5.75	0.33	4.02	216.40	71.60	189.40
T_6	5.74	0.31	4.01	216.13	71.33	187.90
T_7	5.88	0.33	4.12	222.60	74.97	195.93
T_8	5.62	0.32	4.26	219.40	73.83	191.20
T_9	5.75	0.31	4.29	225.77	76.30	210.70
T_{10}	5.71	0.32	4.24	218.17	73.80	190.00
T_{11}	5.82	0.32	4.34	223.30	76.00	206.57
T_{12}	5.70	0.32	4.26	221.33	75.97	197.30
T_{13}	5.77	0.31	4.38	233.57	78.16	223.93
T_{14}	5.73	0.32	4.22	212.93	67.40	184.00
S.Em.±	0.08	0.01	0.01	4.18	1.94	5.17
CD (P=0.05)	NS	NS	NS	12.16	5.63	15.05

Note: POP (Package of practice) - 25:50:25 kg ha^{-1} N, P_2O_5, K_2O + 7.5 t ha^{-1} FYM + 10 kg ha^{-1} $ZnSO_4$, MPP- Mono potassium phosphate (00:52:34), SOP- Sulphate of potash (00:00:50), PGPR- Plant Growth Promoting Rhizomicrobial consortia, DAS - Days after sowing, NS- Non significant

Table 2: Soil microbial population as influenced by foliar application of water soluble fertilizers and liquid PGPR after the harvest of groundnut

Treatments	Total Bacteria (CFU×10^5 g^{-1})	Total Fungi (CFU×10^3 g^{-1})	Total Actinomycetes (CFU×10^2 g^{-1})	N_2-fixers (CFU×10^5 g^{-1})	PSB (CFU×$10^5$$g^{-1}$)	KSB (CFU×10^5 g^{-1})
T_1	91.00	18.33	4.00	27.67	20.33	12.33
T_2	104.00	23.33	5.00	30.67	22.67	13.67
T_3	110.33	25.67	5.67	33.33	24.33	14.33
T_4	106.00	22.00	5.00	31.67	24.67	15.67
T_5	102.00	24.00	6.33	33.00	25.00	15.67
T_6	101.33	24.00	5.00	35.00	26.00	15.67
T_7	103.00	20.33	6.33	35.00	23.00	16.00
T_8	125.00	26.00	11.33	41.67	33.33	23.33
T_9	127.33	29.00	11.67	45.67	38.00	28.33
T_{10}	122.00	28.33	12.00	41.33	35.67	24.00
T_{11}	122.67	28.62	11.33	44.33	37.67	27.00
T_{12}	121.33	26.00	12.00	42.33	34.67	25.67
T_{13}	131.33	32.67	13.33	46.67	39.33	30.00
T_{14}	109.33	24.33	8.33	40.00	28.33	21.00
S.Em.±	3.82	1.71	1.15	1.79	1.25	1.11
CD (P=0.05)	11.11	4.97	3.33	5.22	4.43	3.24

Note: POP (Package of practice) - 25:50:25 kg ha^{-1} N, P_2O_5, K_2O + 7.5 t ha^{-1} FYM + 10 kg ha^{-1} $ZnSO_4$, MPP- Mono potassium phosphate (00:52:34), SOP- Sulphate of potash (00:00:50), PGPR- Plant Growth Promoting Rhizomicrobial consortia, DAS - Days after sowing, NS- Non significant

Conclusion

From the above findings it is concluded that foliar application of water soluble fertilizers and liquid plant growth promoting rhizomicrobial consortia along with package of practice significantly influence on the soil nutrient status and microbial population in the rhizosphere. The enhanced microbial population helped to increase the soil fertility status and in turn help the crop for better growth and development.

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