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Bioagent-mediated improvements in yield, soil nutrient availability, and leaf nutrition of banana (*Musa* spp.) cv. Grand Naine

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ABSTRACT

To ascertain the impact of bioagents on the physico-chemical properties of the soil, nutrient availability and leaf nutrition of banana (*Musa* spp.) cv. Grand Naine, a research trial was conducted at the Banana Research Station, Nanded (M.S.), VNMKV, Parbhani, India from 2019–20 to 2020–21. The experiment was laid out in randomized block design with nine treatments namely 100% RDF (Control), 75% RDF + Soil application of *Trichoderma harzianum*, 75% RDF + Soil application of *Azospirillum*, 75% RDF + soil application of PSB, 75% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB, 100% RDF + soil application of *Trichoderma harzianum*, 100% RDF + soil application of *Azospirillum*, 100% RDF + soil application of PSB and 100% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB replicated three times. The results emerged out from experimental field stated maximum plant height, stem girth, number of leaves per plant and yield of banana was improved significantly by receiving 100% RDF + soil application of *Trichoderma harzianum* @ 25 g plant^{-1} + *Azospirillum* @ 25 g plant^{-1} + PSB @ 25 g plant^{-1}. Similarly, soil pH, EC, organic carbon and calcium carbonate content were enhanced due to application 100% RDF + soil application of *Trichoderma harzianum* @ 25 g plant^{-1} + *Azospirillum* @ 25 g plant^{-1} + PSB @ 25 g plant^{-1} but soil pH and calcium carbonate content were not attained to the significant level due to application of different treatments. However, electrical conductivity of soil was found safe limit while, the highest organic carbon content, available N, P, K, DTPA- Fe, Zn, Cu and Mn were recorded maximum with application 100% RDF + soil application of *Trichoderma harzianum* @ 25 g plant^{-1} + *Azospirillum* @ 25 g plant^{-1} + PSB @ 25 g plant^{-1}. During both years of the experiment, the highest N, P, K, Fe, Zn, Cu, and Mn nutritional content were also detected in banana leaves under the same treatment.

Key words: Organic carbon, available nutrients, leaf content, bio-fertilizes, banana

INTRODUCTION

Nutritionally important banana fruit crop belongs to the genus *Musa* and family Musaceae. Mature bananas can be found in many different sizes and hues, such as yellow, purple, and red. However, in popular culture and business, the term “banana” typically refers to soft, sweet “dessert” bananas. It is appropriately called the “apple of paradise”, “Adam’s fig”, “Kalpatru”, and “Kalpavriksha” due to its increasing socio-economic significance and the virtues of the plant. The banana is the most nourishing fruit; it is rich in energy, low in protein and fat, and has numerous medical qualities. It also contains vitamins and minerals, making it a balanced food (Ranjha *et al.,* 16). With changing scenario of banana production, efficient nutritional management system needs emphasis for reduced cost of production and increased productivity. Bioagents play very significant role in improving soil fertility by fixing atmospheric nitrogen, both in associations with plant roots and without it, solubilize insoluble soil phosphates and produce plant growth substances in the soil (Gogai *et al.,* 3). The microorganisms like *Azospirillum*, *Azotobacter*, phosphate solubilizing bacteria, sulphur oxidizing culture etc. have proved to be very useful in crop production. The combination of bio-fertilizers depending on the type of crop has also proved its beneficial effects rather than its use in isolation. The use of bio-fertilizers in many crops has resulted in saving of nitrogen and phosphorus to the extent of 25%, when used either in isolation or combination (Moreira *et al.,* 10).

Since, banana production requires uptake of a significant amount of nutrients from the soil for growth, development and yield, there is a high need for nutrients. Balanced fertilisation is required due to the growing expense of chemical fertilisers and their detrimental effects on soil health and productivity. Application of bioagents is taken into consideration for the study in order to improve soil health and productivity.

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MATERIALS AND METHODS

The field experiment was conducted at Banana Research Station, Nanded (M.S.), Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, India during 2019-20 to 2020-21 to investigate the effect of biofertilizers on soil characteristics and leaf nutrition of banana. The experiment was planned in randomized block design with nine treatments which replicated three times. Bio-fertilizers *i.e. Azospirillum, Trichoderma harzianum* and PSB were applied @ 25g plant^{-1} at the time of planting and 75 days after planting in two equal split doses. Recommended dose of fertilizers 200g N, 160 g P_2O_5 and 200 g K_2O per plant were applied through urea, DAP and Muriate of potash in split doses.

The experimental soil was slightly alkaline in reaction (7.71), safe in soluble salt concentration (0.32 dSm^{-1}), medium in organic carbon content (5.09 g kg^{-1}) and slightly calcareous (36.25 g kg^{-1}) for banana crop. The available nitrogen (151.20 kg ha^{-1}), phosphorus (12.45 kg ha^{-1}) and potassium (534.10kg ha^{-1}) content of experimental soil were low, medium and high, respectively. While, the micronutrient status like zinc (0.54 mg kg^{-1}) , iron (4.28 mg kg^{-1}), manganese (4.49 mg kg^{-1}) and copper (2.21 mg kg^{-1}).

The soil samples were collected from banana garden within the canopy at the depth of 0-15 cm of each tree for estimation of different nutrients in order to know the soil nutrient status of the soil. The soil samples were collected initially and after harvest of banana. pH and EC of 1:2.5 soil: water suspension was determined electrometrically using pH and electrical conductivity meter, respectively (Jackson, 5).

Organic carbon was estimated by Modified Walkley and Blacks rapid titration method (Piper,15). Calcium carbonate was estimated by rapid titration method as described by Jackson,5. Available nitrogen was determined by alkaline potassium permanganate method by using Microkjeldahl's appratus (Subbiah and Asija, 20). Available phosphorus was extracted from the soil with 0.5 M sodium bicarbonate (pH 8.5) as an extractant and measured colorimetrically by using 420 nm wavelengths (Olsen *et al*., 11). Available potassium was determined by neutral normal ammonium acetate method on flame photometer (Jackson, 5). DTPA (0.005 M) extractable Fe, Mn, Zn and Cu were determined by using atomic absorption spectrophotometer (Lindsay and Norvell, 7) .

For estimation of macro and micronutrients status of foliage, fifteen fully mature petiole of 3rd open leaf from apex or Leaf Lamina 10 cm^2 in central part of the leaf on both side of midrib were collected at bud differentiation of the plant (Patel *et al.*, 14) (Plate 1).

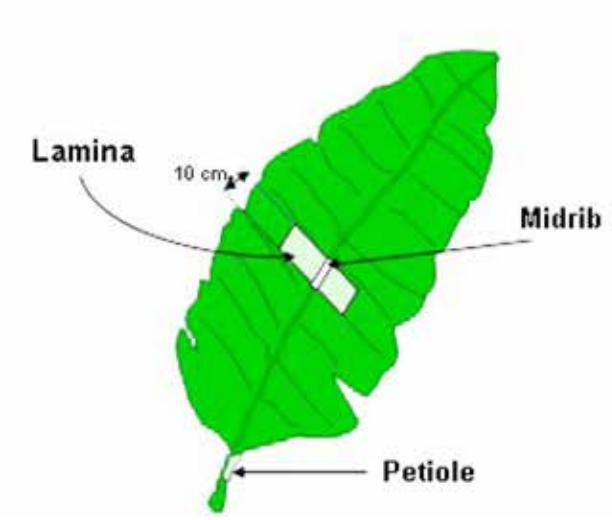

Plate 1: Sampling of banana leaf.

The collected leaf samples were washed first with detergent followed by 0.1 N HCl and finally washed with distilled water. The samples were dried first in laboratory and then in oven at 60 to 70°C for 48 hrs. Oven dried samples were ground with electrical grinder to avoid contamination and stored in clean polythene bags (Chapman,1). Subsequently these samples were used for analysis. Total nitrogen in the plant and fruit sample was determined by modified Micro Kjeldahl's method (Piper, 15). Total phosphorus was estimated by vanadomolybdate phosphoric acid yellow colour method with spectrophotometer and total potassium content was also determined by wet digestion method using flame photometer (Jackson, 5). Total Fe, Zn, Mn and Cu content in plant were determined from the extract using Atomic Absorption Spectrophotometer (Lindsay and Norvell, 7).

RESULT AND DISCUSSION

All the traits studied exhibited (Fig 1) the plant height, stem girth and number of leaves per plant were significantly affected by different treatments of biofertilizers on banana. Received combination of 100% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB produced the tallest plant (154.67 cm) high stem girth (49.67cm) and maximum number of leaves (16.17) closely followed by 75% RDF + Soil application of *Trichoderma harzianum* + *Azospirillum* + PSB with values 148.50 cm, 46.33 cm and 15.15, respectively which was significantly superior over control and alone application. The increase in plant height could be attributed to the higher uptake of nutrients, particularly nitrogen. The uptake of N, the chief constituent of chlorophyll, protein and amino acids is accelerated through its

Fig. 1. Effect of bioagents on plant height and stem girth of banana.

increased supply at appropriate time to the plants (Pafli,12). The beneficial response of biofertilisers on plant girth might be due to the accumulation of poly hydroxy butyric acid which gives rise to vegetative cells. Pigment production is one of the important characteristics of *Azotobacter sps*. These strains are also known to produce growth substances (Mohandas, 9).

The best treatment in terms of yield (Fig. 2) was application of full recommended dose of fertilizers along with different biofertilizers like PSB, *Azospirillum and Trichoderma harzianum* noted significantly highest yield (90.04 MT/ha) than the other treatments. The result is in accordance with the findings of Hazarika *et al.* (4) which recorded maximum fingers hand^{-1}, finger length, volume, circumference and finger weight in Grand Naine treated with *Azospirillium*, PSB, VAM and *Trichoderma harzianum* . This is due to their ability to fix atmospheric nitrogen and transform native soil nutrients like phosphorus, potassium, zinc, copper, iron, sulphur from the non-usable fixed

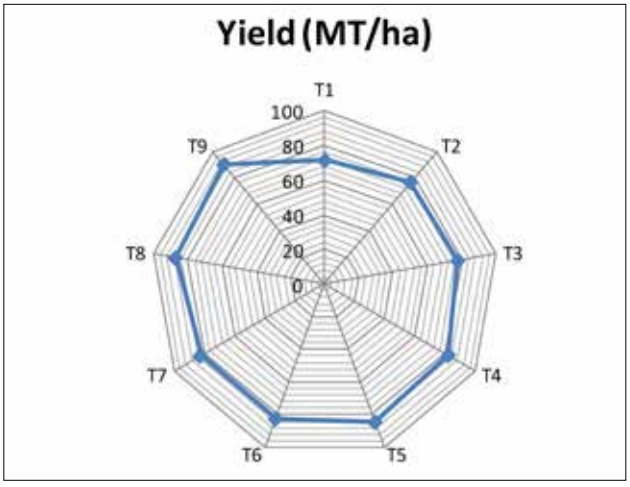

Fig. 2. Effect of bioagents on yield of banana.

to usable form and decomposed organic wastes through biological process which in turn release nutrients in a form which can be easily assimilated by plants resulting to produce more numbers of fingers.

Physico-chemical properties of banana growing soil (Table 1) examined that in both research years, the pH of the soil used to grow bananas was not significantly affected by the use of various biofertilizers. Soil had pH of 7.71 initially. The pH of the soil was raised to harvest level. It ranged from 7.56 to 7.89. In the soil solution, electrical conductivity represents the total amount of soluble salts. The administration of biofertilizer caused a minor fluctuation in EC. Minimum soil electrical conductivity was recorded with 100% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB (0.28 dSm^{-1}). Whereas, maximum soil electrical conductivity was recorded at 100% RDF (0.36 dSm^{-1}). It was decreased than the initial EC of soil. Organic carbon is one of the most effective soil property in context of soil properties and crop growth. In present study, the organic carbon content was decreased from initial stage to harvesting in the treatments devoid of RDF i.e. control. However, the highest organic carbon content was recorded in surface soil, due to application of treatment 100% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB (8.05 g kg^{-1}) and found to be at par with application of treatment 75% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB (7.88 g kg^{-1}) Further, it was very clear that the organic carbon content was increased in banana garden soils after harvest of banana than the initial organic carbon content of garden soils (5.09 g kg^{-1}). $CaCO_3$ content varied from 35.65 to 48.20 g kg^{-1}with an average content 39.43 g kg^{-1} at harvesting, respectively during pooled study. Application of treatment 100% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB showed numerical decrease in $CaCO_3$ content.

The results interpreted in table 1 regarding pH, EC, organic carbon and calcium carbonate content revealed that there was overall improvement in these properties of soil due to application of 100% RDF + Soil application of *Trichoderma harzianum* + *Azospirillum* + PSB @25 g plant^{-1}. Decrease in alkaline pH, reduction in salt concentration, increase in organic carbon content and reduction in calcareousness of soil are the positive effects recorded and in turn making a soil healthy for banana growth. These results are in accordance with the results of Chhuria *et al. (*2) in banana. The maximum reduction of soil pH and EC were recorded with application of 100% NPK + *Azotobacter* + PSB (Srivastava *et al.,* 19). It might be due to the production of acidity with fertilizer application and

Table 1: Effect of bioagents on physico-chemical properties of banana growing soil before harvest.

Treatment	Soil pH			EC (dSm^{-1})			Organic carbon (gkg^{-1})			$CaCO_3$ (gkg^{-1})		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1 100% RDF (Control)	7.90	7.88	7.89	0.39	0.33	0.36	4.41	5.03	4.72	48.7	47.7	48.20
T_2 75% RDF + Soil application of *Trichoderma harzianum*	7.86	7.83	7.85	0.37	0.30	0.34	5.11	5.15	5.13	45.3	44.7	45.00
T_3 75% RDF + Soil application of *Azospirillum*	7.74	7.72	7.73	0.35	0.29	0.32	5.09	5.12	5.11	46.0	44.7	45.35
T_4 75% RDF + Soil application of PSB	7.45	7.66	7.56	0.36	0.29	0.33	5.23	5.27	5.25	42.0	41.3	41.65
T_5 75% RDF + Soil application of *Trichoderma harzianum* + *Azospirillum* + PSB	7.71	7.47	7.59	0.36	0.29	0.33	7.86	7.89	7.88	40.7	40.0	40.35
T_6 100% RDF + Soil application of *Trichoderma harzianum*	7.66	7.63	7.65	0.35	0.29	0.32	5.55	5.57	5.56	40.7	39.3	40.00
T_7 100 % RDF + Soil application of *Azospirillum*	7.60	7.58	7.59	0.33	0.27	0.30	6.19	6.25	6.22	37.3	36.7	37.00
T_8 100% RDF + Soil application of PSB	7.68	7.65	7.67	0.32	0.27	0.30	7.50	7.54	7.52	44.8	44.0	44.40
T_9 100% RDF + Soil application of *Trichoderma harzianum* + *Azospirillum* + PSB	7.62	7.62	7.62	0.30	0.26	0.28	8.03	8.07	8.05	37.3	34.0	35.65
S.Em.±	0.09	0.10	0.06	0.01	0.009	0.005	0.21	0.2	0.10	0.2	0.42	0.43
CD at 5%	NS	NS	NS	0.03	0.02	0.02	0.64	0.59	0.32	0.59	NS	1.41
Initial value		7.71			0.32			5.09			36.25	

organic acid from FYM decomposition, resulted reduction in these parameters. The organic carbon increase significantly higher than all other treatments. This might be due to the fact that the presence of organic sources led to stabilized C:N ratio increasing the organic carbon content of the soil (Parr and Papendick, 13). The calcium carbonate content tends to decrease with application of biofertilizer and stressed that rather application of high doses of biofertilizer is the only way to mitigate the detrimental effect of high calcium carbonate on plant growth.

Available nitrogen, phosphorus and potassium were ranged between 152.54 - 189.72, 12.56 - 17.23 and 554.88 - 660.43 kg ha^{-1}, respectively after harvest of banana during both the year of experimentation (Fig. 3). Application of 100% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB recorded maximum available nitrogen (189.72 kg ha^{-1}), available phosphorus (17.23 kg ha^{-1}) and available potassium (660.43 kg ha^{-1}) than the other treatments, which was found to be at par with application of 75% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB with values 188.09, 16.25 and 634.14 kg ha^{-1}, respectively.

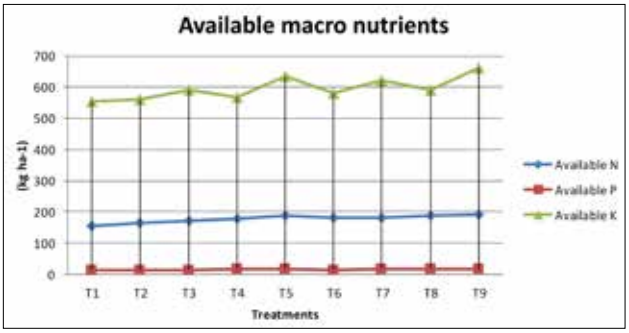

Fig. 3: Effect of bioagents on available macronutrients (kg ha^{-1}) of banana growing soil before harvest.

The plants inoculated with *Azospirillum* derive positive benefit in terms of enhancement in uptake of $N0^{3-}$, NH^{4+}, H_2 $P0_4$,' K^+ and Fe^{2+} increased nitrate reductase activity in plants and production of antibacterial and antifungal compounds (Wani, 22). The combined application of inorganic fertilizer and biofertilizers in banana cv. 'Barjahaji' significantly increased the available NPK status (Gogoi *et al.*, 3). Increase in P_2O_5 and K_2O may also be attributed to the initial content of potash and phosphorus in the organic

supplements which on decomposition contributed to the available P and K.

DTPA extractable Fe, Zn, Cu and Mn were varied from 4.50 - 5.33, 0.54 - 1.51, 2.29 - 3.56 and 4.51 - 5.61 mgkg^{-1}, respectively after harvest of banana during both the year of trial (Fig. 4) Maximum DTPA extractable Fe (5.33 mgkg^{-1}), Zn (1.51 mgkg^{-1}), Cu (3.56 mgkg^{-1}) and Mn (5.61 mgkg^{-1}) were noted with application of 100% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB in banana growing soil. However, minimum DTPA extractable Fe, Zn, Cu and Mn were noted at 100% RDF i.e. Control. Further, result showed that DTPA extractable Fe, Zn, Cu and Mn content in soil was increased than the initial content of soil due to addition of biofertilizers along with RDF.

The results inferred that in the present study the availability of micronutrients *viz.* Fe, Zn, Cu, Mn and B were higher due to application of different biofertilizers. Generally, the increase in available micronutrients status of soils in organically treated plots might be due to release of chelating agents from organic matter decomposition which might have prevented micronutrients from precipitation, oxidation and leaching (Shivakumar *et al.,*17). There was a reduction in micronutrients content in the treatments receiving only inorganic fertilizers. It was attributed to non-replenishment of micronutrients through chemical fertilizers. Application of bio-fertilizers 80 g/tree, and recommended dose of fertilizers (RDF) resulted in significantly maximum Fe, Zn, Cu and Mn in pomegranate orchard soil (Mir *et al.,* 8).

All of the leaf mineral content expressed as percentages of nitrogen, phosphorus and potassium increased significantly by the combined treatments of RDF and biofertilizers. The highest significant effects over the control and the remaining treatments in both seasons were due to triple combination biofertilizer (Fig. 5 and 6). Application of 100% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB leads to increase the leaf nutrient content of banana. Total N (3.18%), P (0.48%) and K (4.01%) were recorded maximum with same treatment. While, it was recorded minimum with treatment 100% RDF only. Total P was remains at par with treatments 75% RDF + soil application of PSB (0.42%), 75% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB (0.44%) and 100% RDF + soil application of PSB (0.45%).

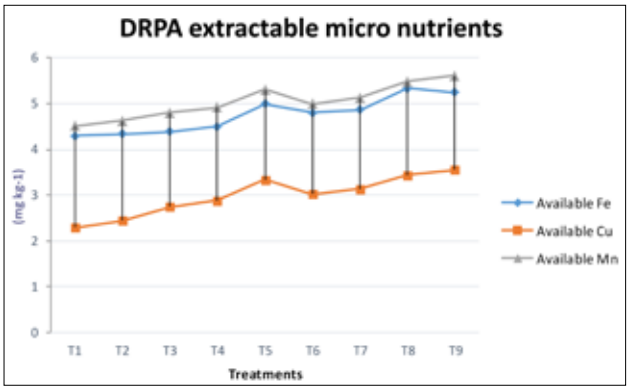

Fig. 4: Effect of bioagents on available micronutrients (mg kg^{-1}) of banana growing soil before harvest.

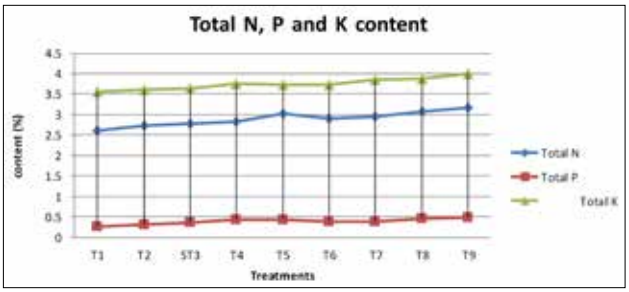

Fig. 5: Effect of bioagents on total N, P and K content (%) of banana leaves after harvest.

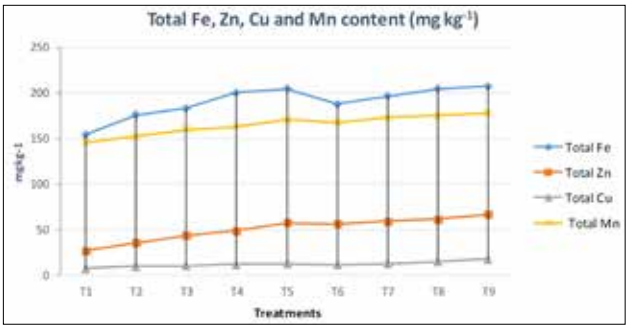

Fig. 6: Effect of bioagents on total Fe, Zn, Cu and Mn content (mgkg^{-1}) of banana leaves after harvest.

This pronounced effect of organic manures on leaf mineral content is due to their high content of N, P and K beside other nutrients. In addition, the marked effect of these organic fertilizers in reducing soil pH may be responsible for facilitating the availability of most nutrients (Smith *et al.,* 18). These results are in harmony with those obtained by Umesh *et al.* (21). They indicated that, nitrogen, phosphorus and potassium increased when banana plants were inoculated with biofertilizers.

Maximum and minimum total Fe (207.60 and 154.84 mgkg^{-1}), Zn (66.68 and 27.25 mgkg^{-1}) , Cu (17.77 and 7.67 mgkg^{-1}) and Mn (178.47 mgkg^{-1}) were noted with 100% RDF + soil application of *Trichoderma harzianum* + *Azospirillum* + PSB and 100% RDF only, respectively. The increased availability of macro and micronutrients in the pomegranate leaves with the addition of biofertilizers and RDF might be due to acceleration of microbial

N-fixation, improved physical condition of soil, root development by mycellial network of mycorrhizal fungi, more moisture retention and thus increased absorption of water and nutrients. Significantly higher amount of other nutrients *viz;* Cu, Fe, Zn and Mn might be due to the production of nutrient solubilizing enzymes by microorganisms and ability of AM fungal hyphae towards uptake of immobile ions, besides increasing the surface area of roots by tapping larger soil volume (Kholer *et al.,* 6).

Growth characters, yield, soil organic carbon, available macro and micro nutrients as well as leaf nutrient content of banana were greatly influenced by combined application of bioagents along with chemical fertilizers in banana. Among the treatments, 100% RDF + Soil application of *Trichoderma harzianum* @ 25 g plant^{-1} + *Azospirillum* @ 25 g plant^{-1} + PSB @ 25 g plant^{-1} recorded the maximum soil organic carbon, available macro and micro nutrients as well as leaf nutrient content. Hence, the integrated nutrient management practice in banana crop has been found to be an ideal option to sustain soil fertility and uptake of nutrients.

AUTHORS' CONTRIBUTIONS

Investigation data recording and writing original draft (BRG, RK); Review editing, supervision (RNK, SVD); Research administration (SZ, SS).

DECLARATION

The authors declare that there are no conflicts of interest regarding this article.

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