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Effects of Combined Application of Fertigation and Consortium of Biofertilizers on Biological Properties of Soil Under Banana Cropping System

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A field experiment was conducted during 2010-12 in banana cv. Robusta (AAA) to study the effects of combined application of fertigation and consortium of biofertilizers on some of the biological properties of the soil. The results indicated that the application of fertigation with consortium of biofertilizers significantly enhanced the soil respiration (19 to 83 per cent), dehydrogenese activity (52 to 97 per cent), Glomalin content (21 to 72 per cent) and phosphatase activities (Acid phosphatase from 53 to 92 per cent and alkaline phosphatase from 40 to 82 per cent) as compared to only fertigation treatment. In both main and ratoon crops, the fertigation treatment without consortium of biofertilizers recorded the lowest values for these soil biological properties. This study indicated that the soil biological properties can be significantly enhanced by combining fertigation with consortium of biofertilizers which also substantially reduces the requirement of chemical fertilizers up to 25-50 per cent.

Introduction

Banana (*Musa sp)*, is one of the ancient fruits of the world and also an important food for millions of people all around the world. It is the fourth most important commodity (Mustaffa and Kumar, 2012) after rice, wheat and corn. It is grown in more than 130 countries across the world covering an area of 5.0 million ha with a production of 103.63 million tonnes. The fruits are very delicious, nearly fat free, rich in carbohydrate with a calorific value of 67g $100g^{-1}$. As a diet, it is highly satisfying, easily digestible, and suitable to all the age groups and people of all levels.

Banana requires large quantity of mineral nutrients (Senthilkumar *et al.*, 2016) for rapid growth and development thus readily responds to applied nutrients (Mustaffa and Kumar, 2012). For better growth and yield of banana, optimum levels of nutrients have to be maintained which are partly supplied by the soil (Swennen, 1990) and the remaining is being supplemented through other alternative sources such as organic manure, inorganic fertilizers and bio-inoculants.

The modern agriculture practices with an aim to obtain higher yield has ended in indiscriminate usage of synthetic fertilizers which resulted in pollution of soil and water besides, reduction in the soil fertility and microbial population. Thus in the recent crop management strategy, biofertilizers have emerged as one of the alternatives to inorganic fertilizers due to various advantages of its application such as increased crop yield by 15-30 per cent, replacement of chemical fertilizers by 25 per cent, hastening of flowering and maturity of crops, enhancement of nutrients availability, especially nitrogen and phosphorous and control of soil born diseases.

Microbes are an integral part of soil and contribute to the soil and plant health (Senthilkumar *et al.,* 2016). They have the ability to fix atmospheric nitrogen, solubilize and mobilize phosphorous, produce antibiotics and disease suppressing molecules.

In totality, microbes are considered as biological indicators of soil health as soil health in broad sense is the cumulative effect of the microbial biomass, soil respiration, enzyme activities and microbial diversity (Brussaard *et al.,* 2007).

Worldwide, fertigation is widely adopted in banana cropping system as it reduces the nutrient requirement of the plants considerably due to higher nutrient use efficiency. If fertigation is combined with biofertilizers there is a possibility of further reduction in the input requirement. Inclusion of biofertilizers will help beneficial microbes to proliferate, provide residual effects for subsequent crops besides recycling and decomposition of organic matter. Further, they improve plant growth by releasing vitamins auxins and hormones, aprt from improving the physical, chemical and biological properties of soil (Senthilkumar *et al.*, 2016).

Under this backdrop, there is a need to thoroughly investigate the influence of biofertilizers in enhancing the soil biological properties when biofertilizers is applied along with fertigation as it will help in further refinement of the production technology of Banana so as to improve the production and productivity without any adverse effects on the soil health.

Therefore an experiment was carried out to study the effects of combined application of fertigation and consortium of biofertilizers in enhancing the soil biological properties under banana based cropping system.

Materials and Methods

The present study was conducted during 2010-2012 at the ICAR-Indian Institute of Horticultural Research (IIHR), Hesarghatta, Bengaluru which is situated at 13^0 58' North latitude and 78^0 East longitude with an altitude of 890 meters. Sword suckers of cultivar Robusta (AAA) with uniform size weighing around 0.80-1.00kg were used for planting.

The 100% recommended dose of fertilizer used for banana crop was 200g N, 110g P and 200g K plant^{-1} crop cycle^{-1} (Anon, 2006).

The entire quantity of phosphorous as single super phosphate (16 per cent P) was applied (Senthilkumar *et al.*, 2016) in the pit before planting and after fifteen days, the consortium of biofertilizers comprised *of Azospirillum* and phosphate solubilizing bacterial strain (*Bacillus aryabhattai),* and Arbuscular Mychorrizhal (AM) fungi in equal proportions was incorporated.

The fertigation was started at 60^{th} day of planting and continued up to 320 days at weekly interval (Senthilkumar *et al.,* 2013). Nitrogen as Calcium Ammonium Nitrate (25 per cent N and 15 per cent Ca) and potassium as Muriate of Potash (60 per cent K) were flushed into drip irrigation system through fertilizer injector.

The experiment was laid out in a Randomised block design with three replications and twelve treatments viz., T_1- Farmyard manure+300 g of Consortium of biofertilizers (CBF),T_2-100% Recommended dose of Fertilizer through fertigation (RDFTF)+ 100g of CBF,T_3-100 % RDFTF+ 200g of CBF,T_4-100 % RDFTF + 300g of CBF,T_5-75% RDFTF + 100g of CBF,T_6-75% RDFTF + 200g of CBF,T_7-75% RDFTF + 300g of CBF,T_8-50% RDFTF + 100 g of CBF,T_9-50% RDFTF + 200 g of CBF,T_{10}-50% RDFTF + 300 g of CBF,T_{11}-100% RDFTF,T_{12}-100%

Recommended dose of fertilizer through soil (RDFTS)-Control. Irrigation was scheduled on a daily basis to replenish 80 per cent of the evaporation losses (Senthilkumar *et al.,* 2016).Three uniformly grown plants were selected for observation in each treatment.

The rhizosphere soil samples and plant roots of banana at 15-30cm depth which were collected at 180 days after planting and at harvest were used for estimation of soil respiration. For estimating Dehydrogenase activity, glomalin content and the phosphatise activities, the rhizosphere soil samples collected at harvest were used.

Assay of soil dehydrogenase activity in soil

Dehydrogenase activity (DHA) was determined following the method of Casida *et al.,* (1964) was expressed as μg TPF g^{-1} dry soil h^{-1}.

Soil respiration

The soil respiration was carried as per the procedure suggested by Isermayer (1952).

Phosphatase activity in soil

The estimation of Acid and Alkaline phsophatase was carried out in triplicate as per the protocol elucidated by Eivazi and Tabatabai (1977).

Estimation of Glomalin

The glomalin content of the soil samples was analyzed using the Bradford protein assay as modified by Wright and Upadhyaya (1996).

The data were analyzed using Web Agri. Stat Package version WASP 1.0 developed by the ICAR- Central Coastal Agricultural Research Institute, Goa and subjected to one way analysis of variance (ANOVA). Treatment difference was evaluated using least significant difference (LSD) at $p \geq 0.05$.

Results and Discussion

Soil respiration

Application of consortium of biofertilizers significantly influenced the soil respiration at different growth stages. Soil respiration was higher at 180 days after planting and there was a gradual decline in the soil respiration in the main crop at harvest indicating the reduction in the microbial population and necessity of applying the biofertilizers for the next crop. Consequent to the application of consortium of biofertilizers the soil respiration again increased in the ratoon crop and gradually decreased at harvest.

Critical observation revealed that the soil respiration was higher at reduced fertigation levels with higher doses of consortium of biofertilizers. The fertilizer dose of 75% through fertigation with consortium of biofertilizers consistently resulted in higher soil respiration. Especially, 75% recommended dose of fertilizer through fertigation with 300g of consortium of biofertilizers recorded significantly higher respiration rate in both main and ratoon crops with a value of 9.10 and 10.03 mg kg^{-1} soil hr^{-1} respectively.

This indicated that the microbial population will not adversely be affected at reduced rates of fertilizer dose. It also indicated that higher doses of inorganic fertilizers, though economical in terms of yield, they are not very conducive for better microbial growth and their beneficial activities in the rhizosphere soil (Senthilkumar *et al.,* 2016). Further, the soil respiration at 100% recommended dose of fertilizers applied through soil and 100% recommended dose of fertilizers through fertigation (both were without consortium of biofertilizers) recorded less soil respiration as compared to inoculated treatments. The 100% recommended dose of fertilizer applied through soil recorded the lowest rate of soil respiration with a value of 5.19 and 5.22 mg kg^{-1} soil hr^{-1} respectively at harvest. This might be due to the fact that only inorganic fertilizers application was not conducive for the growth of native microbes in the rhizosphere of banana which resulted in low soil respiration.

Deydrogenase activity

Soil enzymes play an important role in various biochemical functions in the soil such as organic matter decomposition, catalyzing several reactions which are necessary for the life processes of microorganisms in soil, stabilization of soil structure, decomposition of organic wastes, organic matter formation, and nutrient cycling (Ebersberger *et al.*, 2003). Particularly, dehydrogenase activity is an indication of the activeness of the microbial population in the rhizosphere soil. The soil samples of different treatments, analyzed at harvest of the main crop significantly differed in the dehydrogenase activity. In general, the treatments with the combination of consortium of biofertilizers resulted in significantly higher dehydrogenase activity than the un-inoculated treatments. At harvest of the main crop, the dehydrogenase activity was higher at the lower doses of fertigation with higher levels of consortium of biofertilizers. This was evident from the fact that dehydrogenase activity recorded at 100% recommended dose of fertilizers with the combination of consortium of biofertilizers was less than the 50% recommended dose of fertilizers through fertigation with the combination of consortium of biofertilizers. Similar trend was noticed in the ratoon crop also

Among the treatments, the highest values (85.80 and 88.8 µg TPF g^{-1} soil hr^{-1}) were recorded at 75% recommended dose of fertilizer through fertigation with 300g of consortium of biofertilizers which was significantly higher than the 100% recommended dose of fertilizer through soil application (48.4 and 51.8 µg TPF g^{-1} soil hr^{-1}) and the treatment with 100% recommended dose of fertilizer through fertigation (42.80 and 45.8 µg TPF g^{-1} soil hr^{-1}).

The pooled data at harvest, indicated that dehydrogenase activity ranged from 44.30 µg TPF g^{-1} soil hr^{-1} (100% recommended dose of fertilizer through fertigation) to 87.30 µg TPF g^{-1} soil hr^{-1} (75% recommended dose of fertilizer through fertigation with 300g of consortium of biofertilizers).

Glomalin production

Soil aggregation is a complex process which is mainly dependent upon secretion of microbial polysaccharides or gummy substances that hold soil particles together. Among the many soil microbes, Arbuscular Mycorrhizal (AM) fungi are considered to be primary soil aggregators. Recent evidence suggests that glomalin a glycoprotein is known to be secreted only by AM fungi in the taxon Glomales, including fungi of the genera Acaulospora, Entrophospora, Gigaspora, Glomus, and Scutellospora which have a cementing capacity to maintain soil particles together (Singh, 2012). Thus, the AM fungi enhances the water holding capacity of the soil there by improve the plant water relations, potentially contributing to increased crop drought resistance (Auge, 2003) which can cut short total water requirement of banana as it is a water and nutrient exhaustive crop considerably. AM Fungi and their product glomalin affect the carbon (C) dynamics in agro ecosystems (Singh, 16) apart from their key role in the soil aggregation.

The rhizosphere soil samples collected from all the treatments were analysed for total glomalin. Though the initial soil samples analyzed did not show any marked difference in the glomalin content among the treatments, the soil samples collected at harvest shown significant difference among the treatments. It was significantly highest at the treatments applied with consortium of biofertilizers as compared to un-inoculated control in both the cropping season.

The treatment of 75% recommended dose of fertilizer through fertigation with consortium of biofertilizers recorded 63 and 81 per cent higher glomalin content as compared to the treatment with 100% recommended dose of fertilizers through fertigation. The pooled data of two years also revealed higher glomalin content (71 per cent) compared to the un inoculated fertigation treatment. Similarly, Panneerselvam *et al.,* (2012) reported that application of AM fungi along with *Pseudomonas putida* increased total glomalin content by 40 per cent compared to the un-inoculated control, whereas *G. mosseae* alone increased it by 22 per cent.

Phosphatase activities

Phosphorus is an essential nutrient for plant growth and crop yield, however a large portion is immobilized because of intrinsic characteristics of soils such as pH that affects the availability of nutrients and the activity of enzymes, altering the equilibrium of the soil solid phase (Dick *et al.,* 2000). Soil microorganisms play a key role on phosphate solubilisation with the release of low molecular weight organic acids (Sundara *et al.,*2002) and production of extracellular enzymes as phosphatases. Phosphatases are a group of enzymes that catalyze hydrolysis of esters and anhydrides of phosphoric acid. Its activity depends on extracellular enzymes, which can be free in the soil water phase or stabilized in the humic fraction or clay soil content (Sundara *et al.,* 2002). In soil, phosphomonoesterases have been the most studied enzymes probably because they have activity both under acidic and alkaline conditions, according to its optimal pH, and because they act on low molecular P-compounds including nucleotides, sugar phosphates and polyphosphates (Makoi and Ndakidemi, 2008); thus they can be used as soil quality indicators as the acid and alkaline phosphate of the rhizosphere soil is directly proportional to the microbial population.

In this study the acid and alkaline phosphatase activity was higher at 75% recommended dose of fertilizer through fertigation with consortium of biofertilizers followed by 50% recommended dose of fertilizers through fertigation with consortium of biofertilizers. Comparatively, the 100% recommended dose of fertilizers through fertigation with consortium of biofertilizers resulted in lower acid and alkaline phosphatase activity indicating the inhibitory effect of higher doses of inorganic fertilizer on the microbial growth in the rhizosphere soil (Table 1–3).

Table.1 Effect of fertigation and consortium of biofertilizers on soil respiration (mg kg^{-1} soil hr^{-1})

Treatments		Main crop		Ratoon crop		Pooled	
	Initial	**180 DAP**	**At harvest**	**180 DAP**	**At harvest**	**180 DAP**	**At harvest**
1. FYM&300 g CBF	5.30	6.84	6.15	7.69	6.27	7.26	6.21
2. 100 % RDFTF&100 g CBF	5.32	7.54	6.48	7.82	6.53	7.68	6.51
3. 100% RDFTF& 200 g CBF	6.13	9.13	7.61	10.13	8.23	9.63	7.92
4. 100% RDFTF& 300 g CBF	5.41	7.93	6.74	8.26	6.67	8.10	6.71
5. 75% RDFTF&100 g CBF	6.28	8.98	7.94	9.72	8.09	9.35	8.02
6. 75% RDFTF& 200 g CBF	5.31	9.78	8.73	10.01	8.89	9.90	8.81
7. 75% RDFTF& 300 g CBF	5.63	10.31	9.10	11.33	10.03	10.82	9.56
8. 50% RDFTF& 100 g CBF	6.01	7.10	6.19	7.36	6.69	7.23	6.44
9. 50% RDFTF& 200 g CBF	5.58	7.43	6.26	7.63	6.73	7.53	6.49
10. 50% RDFTF& 300 g CBF	5.49	8.16	6.86	8.29	7.13	8.23	7.00
11. 100% RDFTF	5.39	5.89	5.07	6.13	5.38	6.01	5.22
12. 100% RDFTS	5.28	6.03	5.19	6.26	5.22	6.15	5.20
S.Em±	**-**	**0.41**	**0.35**	**0.44**	**0.38**	**0.43**	**0.37**
C.D at 5%	**NS**	**1.20**	**1.04**	**1.30**	**1.11**	**1.25**	**1.07**

FYM- Farmyard manure, RDFTF- Recommended dose of fertilizers through fertigation, RDFTS- Recommended dose of fertilizers through soil, CBF- Consortium of biofertilizers.

Table.2 Effect of fertigation and consortium of biofertilizers on Dehydrogenase activity and glomalin production at harvest

Treatments	Dehydrogenase activity (µg TPF g^{-1} soil h^{-1})				Glomalin production (mg g^{-1} soil)			
	Initial	**Main crop**	**Ratoon crop**	**Pooled**	**Initial**	**Main crop**	**Ratoon crop**	**Pooled**
1. FYM&300 g CBF	29.80	68.90	71.30	70.10	3.38	5.78	5.83	5.81
2. 100 % RDFTF&100 g CBF	31.40	67.50	66.85	67.18	3.76	5.21	5.68	5.45
3. 100% RDFTF& 200 g CBF	30.70	72.30	74.70	73.50	3.33	6.48	6.92	6.70
4. 100% RDFTF& 300 g CBF	28.80	69.80	70.50	70.15	4.01	6.08	6.78	6.43
5. 75% RDFTF&100 g CBF	29.50	81.70	82.60	82.15	3.33	6.39	7.09	6.74
6. 75% RDFTF& 200 g CBF	31.30	84.20	84.60	84.40	3.67	6.89	7.38	7.14
7. 75% RDFTF& 300 g CBF	30.03	85.80	88.80	87.30	4.03	7.66	7.82	7.74
8. 50% RDFTF& 100 g CBF	27.81	70.20	71.60	70.90	3.43	6.09	6.52	6.31
9. 50% RDFTF& 200 g CBF	32.24	73.40	74.86	74.13	3.39	6.27	6.77	6.52
10. 50% RDFTF& 300 g CBF	33.10	76.70	79.30	78.00	3.44	6.83	7.23	7.03
11. 100% RDFTF	29.40	42.80	45.80	44.30	3.59	4.68	4.34	4.51
12. 100% RDFTS	30.33	48.40	51.80	50.10	3.69	4.73	4.31	4.52
S.Em±	**-**	**3.48**	**3.59**	**3.54**	**-**	**0.31**	**0.32**	**0.31**
C.D at 5%	**NS**	**10.21**	**10.55**	**10.38**	**NS**	**0.90**	**0.93**	**0.92**

Table.3 Effect of fertigation and consortium of biofertilizers on phosphomonoesterase activity in soil

Treatments	Acid Phosphatase activity (µg PNP g^{-1} soil hr^{-1})				Alkaline phosphatase activity (µg PNP g^{-1} soil hr^{-1})			
	Initial	**Main crop**	**Ratoon crop**	**Pooled**	**Initial**	**Main crop**	**Ratoon crop**	**Pooled**
1. FYM&300 g CBF	36.61	68.90	70.90	69.90	5.30	75.80	84.30	80.05
2. 100 % RDFTF&100 g CBF	35.53	66.70	68.03	67.37	5.32	73.30	79.50	76.40
3. 100% RDFTF& 200 g CBF	37.45	69.30	71.17	70.24	6.13	79.40	82.80	81.10
4. 100% RDFTF& 300 g CBF	35.78	67.40	69.43	68.42	5.41	78.10	81.90	80.00
5. 75% RDFTF&100 g CBF	37.13	78.60	81.31	79.96	6.28	95.10	96.75	95.93
6. 75% RDFTF& 200 g CBF	36.86	82.30	85.10	83.70	5.31	96.20	102.90	99.55
7. 75% RDFTF& 300 g CBF	37.21	83.90	85.31	84.61	5.63	87.96	99.80	93.88
8. 50% RDFTF& 100 g CBF	36.66	72.70	74.50	73.60	6.01	87.20	87.60	87.40
9. 50% RDFTF& 200 g CBF	35.99	73.90	74.70	74.30	5.58	87.90	88.90	88.40
10. 50% RDFTF& 300 g CBF	38.48	76.60	78.30	77.45	5.49	91.10	93.70	92.40
11. 100% RDFTF	35.01	43.90	44.20	44.05	5.39	53.20	56.30	54.75
12. 100% RDFTS	36.16	53.80	54.90	54.35	5.28	60.70	69.60	65.15
S.Em±	**-**	**3.45**	**3.53**	**3.49**	**-**	**3.85**	**4.18**	**4.01**
C.D at 5%	**NS**	**10.12**	**10.35**	**10.24**	**NS**	**11.28**	**12.27**	**11.77**

FYM- Farmyard manure, RDFTF- Recommended dose of fertilizers through fertigation, RDFTS- Recommended dose of fertilizers through soil, CBF- Consortium of biofertilizers.

This could be reconfirmed by the lowest acid and alkaline phosphatase activity recorded at 100% recommended dose of fertilizers through fertigation without consortium of biofertilizers.

Phosphatase activity in rhizosphere soil is related to AM fungal activity of plants (Chethan Kumar *et a1*., 2008). AM fungal colonization is known to alter the inherent phosphorus supply by increasing phosphatase activity in the plant rhizosphere (Allen *et al.*, 1995) and in confirmation Sumana (1998) reported an increase in acid phosphatase activity with increased colonization by AM fungi. Thus, it could be inferred that the application of consortium of biofertilizers which had AM fungi as one of the components could have resulted in significantly higher acid and alkaline phosphatase activity in all the inoculated treatments as compared to un-inoculated control.

Phosphatases secreted in hyphae catalyse the hydrolysis of both organic P esters and anhydrate of phosphoric acid into inorganic P. Higher activities of acid and alkaline phosphatase in the rhizosphere soil of banana are indicative of better phosphorus utilization by plants inoculated with consortium of biofertilizers with AM fungi. Earlier investigation by Lynch *et al.*, (1991) revealed a positive relationship between P absorption and plant growth as they reported a strong connection between P absorption activity and dry matter production.

Hence concluded in this study the combined application of fertigation with consortium of biofertilizer resulted in higher rate of soil respiration, dehydrogenic and phospatase activities which is an indication of the presence of higher population of microbes in the rhizosphere soil which are considered as biological indicators of soil health. It was noted that the lesser levels of fertigation and higher levels of consortium of biofertilizers resulted in more soil respiration, dehydrogenic and phospatase activities. Among the treatments 75% recommended dose of fertilizers through fertigation combined with the consortium of fertilizers found to be the ideal combination followed by 50% recommended dose of fertilizers through fertigation with the consortium of fertilizers in up-keeping the soil health in a long run.

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