Scholars Academic Journal of Biosciences (SAJB) **ISSN 2321-6883 (Online)**
Sch. Acad. J. Biosci., 2014; 2(8): 472-478 **ISSN 2347-9515 (Print)**
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(An International Publisher for Academic and Scientific Resources)
www.saspublishers.com **DOI:** 10.36347/sajb.2014.v02i08.001

Research Article

Enhancing Uptake of Secondary and Micronutrients in Banana Cv. Robusta (AAA) Through Intervention of Fertigation and Consortium of Biofertilizers

M. Senthilkumar[1]*, S. Ganesh, K. Srinivas[2], P. Panneerselvam[2]
[1]Faculty of Agriculture and Animal Husbandry, Gandhigram Rural Institute, Gandhigram-624302, India
[2]Indian Institute of Horticultural Research, Bangalore-89, Karnataka, India

***Corresponding author**
M. Senthilkumar
Email: vanmazhaisenthil@yahoo.com

Abstract: A field experiment was carried out at Indian Institute of Horticultural Research, Bangalore, India in the year 2010 to study the combined effect of fertigation and consortium of biofertilizers on the accumulation of secondary and micronutrients in banana cv Robusta (AAA).The results indicated that the combination of fertigation and consortium of biofertilizers significantly enhanced the secondary and micronutrient accumulation in the leaves, pseudostem and fruits at harvest. In general the fertigation treatments either with or without the combination of consortium of biofertilizers recorded higher secondary and micronutrients in different plant parts as compared to 100% recommended dose of fertilizer applied through soil. Among the treatments, 100% and 75% recommended dose of fertilizers through fertigation with the combination of consortium of biofertilizers, recorded significantly higher secondary and micronutrients in the plant parts analysed. The critical observation on the distribution pattern of secondary and micronutrients indicated that, the calcium and sulphur contents were higher in the pseudostem followed by leaves and fruits whereas, the magnesium content was higher in the pseudo stem followed by fruits and leaves. The iron content was more in the pseudostem followed by leaves and fruits. On contrary, the zinc and manganese contents were higher in the leaves followed by pseudostem and fruits. The secondary nutrient content was in the order of Ca>Mg>S, whereas the micronutrient contents were in the order of Mn>Fe>Zn in the leaves, Fe>Mn>Zn in the psuedostem and Mn>Fe>Zn in the fruits.
Keywords: Banana, fertigation, secondary and micronutrients, Biofertilizers, VAM

INTRODUCTION

Banana is an important commercial fruit crop in the tropical and sub tropical regions of the world. In India, it is grown in different states under different climatic conditions [1]. Presently, it has emerged as the major cash-subsistence crop across all parts of the world [2] as it is a complete fruit-food with delicious taste, necessary energy and health giving elements [3] along with pleasant flavor. On account of these properties, it is a staple food for millions of people all around the world. It is in great demand in fresh as well as processed form all over the world and gained commercial popularity in the international fruit trade [4].

Generally, Banana is a heavy consumer of nutrients and requires large quantities of nutrients for its growth, development and yield [5]. In most of the cases, the nutrient requirement of banana is met by inorganic fertilizers through soil application. Due to its reduced nutrient uptake, the fertigation techniques are being adopted in the recent years. In fertigation, the nutrient use efficiency is as high as 90% compared to 40-60% in conventional methods of fertilizer application [6]. On the other hand, irrespective of the method of fertilizer application, excessive use of inorganic fertilizer often results in extreme situations for the soil, crop and climate involved [7]. The soil has lost its biological dynamics owing to indiscriminate use of chemical fertilizers. Chemical fertilizers have some deleterious effects on fruit quality besides adverse effects on soil, water and environmental conditions [8]. Under these circumstances, incorporation of microbial inoculants not only reduces the requirement of inorganic fertilizers but also has other added advantage of consistent and slow release of nutrients, maintaining ideal C:N ratio, improvement in water holding capacity and microbial biomass of soil profile, without having any adverse residual effects [9]. However, as the demand for horticultural produce is increasing day by day to meet the requirement of the growing population, it becomes imperative to use both the inorganic and organic source of fertilizers in a balanced proportion for realizing higher crop productivity without affecting the soil health. Many research findings well documented that application of either arbuscular mycorrhizal fungi or plant growth-promoting rhizobacteria on banana is highly beneficial in terms of plant development and nutrient uptake [10]. Of-late, the technique of combining two or more microbial inoculants is being tried as a microbial consortium to derive the maximum benefits through single application. The use of beneficial microorganisms as bio-inoculants to increase the availability of native nutrient is a low cost, safe and eco-friendly approach. Besides, it is a well known fact that secondary and micronutrients are critical plant nutrients, and their deficiency, limits crop production, nutritional quality of the produce and also the human health. In this context, it is essential to find out methods to enhance nutrient concentrations in the final produce.

Therefore, taking into consideration of the lower fertilizer requirement and higher nutrient use efficiency of the fertigation and the beneficial effects of consortium of microbial inoculants, experiment was conducted by combining the fertigation and a consortium of biofertilizers with different dosages on banana and their effects were studied with respect to accumulation of secondary and micronutrients in different plant parts at harvest.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Indian Institute of Horticultural Research; Bangalore, India situated at 13º 58' N and 78ºE at an altitude of 890 meters. The soil at the experimental site was red sandy loam with low fertility. The soil was acidic in reaction and free from excessive salts. The total available nitrogen, phosphorous and potassium were around160 kg ha^{-1}, 22 kg ha^{-1} and 232 kg ha^{-1} respectively. The field capacity of the experimental plot was in the range of 14.45 to 31.92 percent at different layers up to 120 cm soil depth. The permanent wilting point was low at upper 0-15 cm (6.52 per cent) and gradually increased with the depth and it was maximum (18.64 per cent) at 105-120 cm depth. The bulk density ranged from 1.62 g/cc to 1.55 g/cc in the 0-120 cm soil layer.

Planting material

Healthy suckers of banana cv Robusta (AAA), (Musa sp, Cavendish sub group) weighing 0.80 to 1.0 kg each were planted during the first week of January-2010 at a spacing of 1.5 x1.5 m (4444 plants ha^{-1}).

Treatments

The following 12 treatments were laid out in a randomized block design with 3 replications.

T1= Farm Yard Manure (FYM)-15 kg + 300 g of Consortium of biofertilizers (CBF);T2= 100% Recommended dose of fertilizers through fertigation (RDFTF) + 100 g of CBF;T3= 100% RDFTF + 200 g of CBF;T4= 100% RDFTF + 300 g of CBF;T5= 75% RDFTF + 100 g of CBF;T6= 75% RDFTF + 200 g of CBF;T7= 75% RDFTF + 300 g of CBF;T8= 50% RDFTF + 100 g of CBF;T9= 50% RDFTF + 200 g of CBF;T10= 50% RDFTF + 300 g of CBF;T11= 100% RDFTF;T12= 100% Recommended dose of Fertilizers through soil application (RDFTS).

Specification of treatments

The 100% recommended dose of fertilizers comprised of 200 N, 110P, 200 K g $plant^{-1}crop^{-1}$and the consortium of biofertilizers consisted of *Azospirillum*, phosphate solubilizing bacteria and AM fungi mixed in equal proportions. The nitrogen was applied in the form of calcium ammonium nitrate and the potassium as muriate of potash respectively. The single super phosphate was applied in the pit before planting and the consortium of biofertilizers was incorporated after fifteen days. The fertigation was started on the 60^{th} day of planting and continued upto 320 days at weekly intervals [11]. Irrigation was given on daily basis replenishing 80% of evaporation losses [12]. For each plant, two emitters were placed at equal distance of 30 cm from the pseudostem with a discharge rate of 4 liter of water $emitter^{-1}$ $hour^{-1}$. The suckers were removed from time to time until flowering and one sword sucker was retained $plant^{-1}$ for the ratoon crop.

Analysis of plant parts

Six representative samples of leaf, pseudostem and fruit and samples were collected from each replication at the time of harvest and the secondary and micro nutrients were estimated as detailed below.

Table 1: Estimation of secondary and micronutrients

Nutrient	Method	Reference
Calcium	Atomic absorption spectrophotometer method	Lindsay and Norwell [13]
Magnesium	Atomic absorption spectrophotometer method	Lindsay and Norwell [13]
Sulphur	Turbidimetric method	Verma *et al*. [14]
Iron	Atomic absorption spectrophotometer method	Jackson [15]
Manganese	Atomic absorption spectrophotometer method	Jackson [15]
Zinc	Atomic absorption spectrophotometer method	Jackson [15]

Statistical Analysis

The data were analyzed using Web Agri Stat Package version WASP 1.0. The data were subjected to one way analysis of variance (ANOVA). The treatment difference was evaluated using least significant difference (LSD) at $p \geq 0.05$

RESULTS
Secondary nutrients

The data of the secondary nutrients is presented in table 2.

Table 2: Effect of fertigation and consortium of biofertilizer on secondary nutrients in leaf, pseudostem and fruit of Banana

	Ca (%)			Mg (%)			S (%)		
Treatments	**Leaf**	**Pseudo Stem**	**Fruit**	**Leaf**	**Pseudo Stem**	**Fruit**	**Leaf**	**Pseudo Stem**	**Fruit**
FYM&300 g CBF	0.90	1.01	0.12	0.10	0.98	0.13	0.06	0.03	0.04
100 % RDFTF & 100 g CBF	1.95	2.01	0.23	0.15	1.23	0.26	0.09	0.12	0.06
100% RDFTF & 200 g CBF	1.87	2.14	0.39	0.16	1.38	0.31	0.09	0.09	0.08
100% RDFTF & 300 g CBF	1.79	2.21	0.48	0.16	1.49	0.45	0.11	0.10	0.09
75% RDFTF & 100 g CBF	2.00	1.98	0.29	0.14	1.21	0.33	0.10	0.14	0.05
75% RDFTF & 200 g CBF	1.91	2.06	0.27	0.14	1.33	0.42	0.09	0.10	0.08
75% RDFTF & 300 g CBF	1.93	2.19	0.45	0.15	1.58	0.47	0.08	0.09	0.08
50% RDFTF & 100 g CBF	1.71	1.68	0.19	0.13	1.14	0.17	0.07	0.06	0.05
50% RDFTF & 200 g CBF	1.74	1.77	0.16	0.12	1.13	0.20	0.08	0.08	0.05
50% RDFTF & 300 g CBF	1.68	1.92	0.21	0.12	1.18	0.27	0.09	0.08	0.06
100% RDFTF	1.31	1.89	0.19	0.12	1.18	0.24	0.08	0.09	0.06
100% RDFTS	1.01	1.31	0.16	0.11	1.12	0.15	0.07	0.06	0.05
Mean	1.65	1.85	0.26	0.13	1.25	0.28	0.08	0.09	0.06
SEM±	0.08	0.09	0.02	0.01	0.06	0.02	0.004	0.004	0.003
C.D at 5%	0.23	0.26	0.045	0.02	0.19	0.04	0.01	0.01	0.01

Calcium content

The fertigation treatments with the combination of consortium of biofertilizers significantly increased the calcium content in leaves, pseudostem and fruits than the 100% recommended dose of fertilizer applied through soil. Among the fertigation treatments 100% and 75% recommended dose of fertilizer through fertigation with consortium of biofertilizers resulted in higher calcium content than the rest of the treatments. The calcium content of leaf was significantly higher (2.00 per cent) at 75% RDFTF with 100 g of CBF as against 1.01 per cent recorded at 100% RDFTS. The highest calcium content (2.21 per cent) in the pseudostem was recorded at 100% RDFTF with 300 g of CBF. The treatment of 100% RDFTF with 300 g of CBF recorded the highest (0.48 per cent) calcium content in the fruit which was 200 per cent higher than the 100% RDFTS. In all these plant parts, the lowest calcium content was recorded at the combination of FYM with 300 g of consortium of biofertilizers.

Magnesium content

The magnesium content in the leaves, pseudo stem and fruits were marked at 100% and 75% recommended dose of fertilizers through fertigation with the combination of consortium of biofertilizers. The highest magnesium content in the leaf (0.16 per cent) was recorded at 100% RDFTF with 200 and 300 g of CBF which was 45 per cent higher than the 100% RDFTS. Significantly higher magnesium content (1.58 per cent) in the pseudostem as compared to 100% RDFTS was obtained at 75% RDFTF with 300 g of CBF. In the fruits also, 75% RDFTF with 300 g of CBF resulted in significantly higher magnesium content (0.47 per cent).

Sulphur content

The fertigation treatments either with or without the combination of consortium of biofertilizers recorded significantly higher sulphur content as compared to 100% RDFTS. Among the treatments, 100% RDFTF with 300 g of CBF, recorded the highest sulphur content of 0.11 per cent as compared to 0.05 per cent recorded at 100%RDFTS. Whereas in the pseudostem the highest sulphur content of 0.14 per cent was recorded at 75% RDFTF with 100 g of CBF. Similarly, the sulphur content in the fruits was significantly higher at 100% and 75 % RDFTF with 200 and 300 g of CBF as compared to 100% RDFTS. Among the treatments, 100% RDFTF with 300 g of CBF recorded the highest (0.09 per cent) sulphur content which was 80 per cent higher than the 100% RDFTS and the lowest (0.04 per cent) was found in FYM with 300 g of CBF.

Micro nutrients

The data of the micronutrients is presented in table 3.

Table 3: Effect of fertigation and consortium of biofertilizer on micronutrients in leaf, pseudostem and fruit of Banana

	Iron (ppm)			Mn (ppm)			Zn (ppm)		
Treatments	**Leaf**	**Pseudo Stem**	**Fruit**	**Leaf**	**Pseudo Stem**	**Fruit**	**Leaf**	**Pseudo Stem**	**Fruit**
FYM &300 g CBF	70	208	14	109	73	16	31	12	10
100 % RDFTF & 100 g CBF	91	249	30	202	225	41	40	19	16
100% RDFTF & 200 g CBF	97	236	29	188	217	36	43	19	17
100% RDFTF & 300 g CBF	105	251	33	199	224	39	48	20	23
75% RDFTF & 100 g CBF	99	334	31	207	243	45	36	17	15
75% RDFTF & 200 g CBF	90	372	29	211	231	33	38	19	20
75% RDFTF & 300 g CBF	84	425	31	240	237	38	38	21	22
50% RDFTF & 100 g CBF	79	307	21	121	111	29	32	16	14
50% RDFTF & 200 g CBF	81	249	26	133	119	22	31	16	14
50% RDFTF & 300 g CBF	84	372	23	145	154	21	34	18	18
100% RDFTF	89	252	24	151	101	24	34	15	13
100% RDFTS	80	233	19	130	86	22	38	14	13
Mean	87	291	26	170	168	31	31	17	16
SEM±	4.13	16.35	1.25	8.74	8.68	1.52	1.78	0.85	0.82
C.D at 5%	12.14	47.94	3.66	25.64	25.45	4.47	5.22	2.49	2.39

Iron content

The combined application of fertigation and consortium of biofertilizers significantly influenced the accumulation of iron in the leaves, pseudostem and fruits. In the leaves, significantly higher iron (105 ppm) content was recorded at 100% RDFTF with 300 g of CBF as compared to 100% RDFTS (80 ppm).The iron content of the pseudostem was significantly higher (425 ppm) at 75% RDFTF with 300 g of CBF compared to 233 ppm recorded at 100% RDFTS. In the fruits, 100% RDFTF with 300 g of CBF resulted in higher iron content (33 ppm) whereas, it was merely 19 ppm at 100% RDFTS. Similarly, the lowest iron content in leaves, pseudo stem and fruits was observed at the treatment of FYM with the combination of 300 g of CBF

Manganese content

Combined application of 100% and 75% RDFTF with consortium of biofertilizers resulted in higher manganese content in the leaves, pseudostem and fruits. Among the treatments, 75% RDFTF with 300 g of CBF recorded the highest manganese content (240 ppm) in the leaves as compared to 100% RDFTS

(130 ppm). Similarly, highest manganese content in the pseudostem was recorded at 75% RDFTF with 100 g of CBF. (243 ppm) while the lowest (73 ppm) was observed at the combination of FYM with 300 g of CBF. In the fruits also, 75% RDFTF with the combination of 100 g of CBF recorded significantly higher (45 ppm) manganese content as compared to 22 ppm obtained at100%RDFTS.

Zinc content

The Zinc content in the leaves, psuedostem and fruits was considerably increased as a result of combined application of fertigation with consortium of biofertilizers. In leaves, 100% RDFTF with 300 g of CBF recorded the highest Zn content (48ppm) as compared to 31ppm recorded at 100 % RDFTS. Whereas,75% RDFTF with 300 g of CBF resulted in higher Zn content of 21ppm and 22ppm in the pseudostem and fruits respectively as against 31ppm and 13ppm recorded at 100% RDFTS. The treatment combination of FYM with 300 g of CBF recorded lesser Zn content in leaves, psuedostem and fruits

DISCUSSION

The PGPR inoculation changes many root and shoot parameters. These changes are directly attributed to positive bacterial effects on mineral uptake by the plant. Enhancement in uptake of NO_3^-, NH_4^+, HPO_4^{2-}, K^+, Rb^+ and Fe^{2+} by *Azospirillum* [16-18] was proposed to cause an increase in foliar dry matter and accumulation of minerals in stems and leaves as observed from the results. Rai and Hunt [19] observed the occurrence of associative N_2-fixation and higher mineral nutrient uptake (P, K, Ca, Mg) and growth in maize, when inoculated with *Azospirillum* spp. in both sterilized and non sterilized saline calcarious soils. Mixed inoculation of four different PGPR strains changed the total accumulation, concentration and/or distribution of the macro-and micronutrients in *Vicia faba* L. [20].

Plant growth promoting rhizobacteria (PGPR) inoculation has been reported to improve mineral uptake in several cereal species [21, 22]. In our study, PGPR inoculation led to enhancement of Zn, Fe content in the plant parts indicating its role in improving the translocation and mobilization of micronutrients. PGPR play an important role in solubilization of nutrients from soil and enhancing their availability to plants [23]. Enhancement in the uptake of micronutrients by the bacterial inoculants is supported by the data on PGPR [24]. In terms of micronutrients (Fe, Zn, Mn), application of all the bacterial strains resulted in enhancement of micronutrient concentrations as compared with those of the un- inoculated treatments.

The distribution of secondary and micronutrients was observed to be un-even among the plant parts analysed as some of the nutrients were high in the leaves and others were high in the pseudostem and fruits. Calcium is generally considered immobile as compared to magnesium as it is distributed moderately in banana. Further, the calcium content in the leaf was around ten times as compared to magnesium concentration. The sulphur contents distributed in the leaves, psuedostem and fruits were very less as compared to calcium and magnesium. This is due to the fact that, in banana the sulphur uptake is reduced after shooting and the sulphur needed for further growth is derived from the leaves and pseudostem [25].

The distribution pattern of secondary nutrients indicated that the pseudostem is the major repository of calcium and sulphur followed by leaves and fruits. Whereas, the magnesium content was higher in the pseudostem followed by fruits and leaves. These facts corroborate with the findings of Ragupathi *et al*., [26]. Similarly, the distribution of micronutrients indicated that, the iron, manganese and zinc contents were significantly higher in the fertigation treatments with the combination of consortium of biofertilizers. The un-inoculated treatment and soil application of 100% recommended dose of inorganic fertilizers resulted in lower micronutrient contents in the leaves, pseudo stem and fruits. The iron was readily redistributed in the plant [27] and the major share of iron was found in the stem and the mean value indicated that the movement of iron from stem to leaf and fruit was least. Similarly, the manganese concentration was high in the leaves as it is a special character of banana [28]. The manganese concentration in plant is mainly governed by oxidation and reduction process in the soil and hence, wide variation was noticed in manganese concentration in the plant. Higher iron contents was recorded in pseudostem followed by leaves and fruits. On contrary, manganese and zinc contents were higher in the leaves followed by pseudo stem and fruits. Similar findings were obtained by Ragupathi *et al*. [26].

CONCLUSION

The present investigation clearly proved that, with a special reference to accumulation of secondary and micronutrients in the fruits, application of 100% RDFTF with 300 g of CBF recorded 200 per cent higher Ca and 80 per cent higher Sulphur contents as compared to 100% RDFTS. Similarly, application of 75 % RDFTF with 300 g CBF recorded 213 per cent higher Mg. Among the micronutrients, 73 per cent higher Fe and 76 per cent higher Zn contents as compared to 100% RDFTS was recorded through the application of 100% RDFTF with 300 g of CBF. Whereas, 75 % RDFTF with 300 g CBF recorded 104 per cent higher Mn than the soil application of 100% recommended dose of fertilizers. It is also worth to note that, higher secondary and micronutrients were recorded even at reduced rate of 50% RDFTF when combined with the consortium of biofertilizers vis-à-vis soil application of inorganic fertilizers. These findings positively indicated that the mineral nutrients content in banana fruits can be improved through intervention of biofertilizers consortium with fertigation. This kind of technique may also be used as one of the ways for supplementing micronutrients in human nutrition to manage micronutreint deficiency related problems in particular, also help to solve malnutrition problem in our country in general. The present investigation also revealed that application of CBF along with fertigation (T_4 and T_7) significantly enhanced the secondary and micronutrients uptake as compared to un inoculated control (T_{11}) and soil application of fertilizers(T_{12}). Besides, sufficient micronutrient content in the plants reported to reduce the severity of diseases and improves plant resistance [29-33] to various diseases. The essential micronutrients are involved in many metabolic processes that affect the response of plants to pathogens [34]. *The present investigation had given some lead that the plant nutrient uptake could be increased through microbial intervention with fertigation in banana cultivation.*

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