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Short communication

Enhancing growth and yield in banana cv. Robusta (AAA) through fertigation with microbial consortium

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ABSTRACT

Studies were carried out at Indian Institute of Horticultural Research, Bangalore, to test the effect of fertigation with a consortium of biofertilizers for sustainable production in banana cv. Robusta (AAA). The combination of fertigation and consortium of biofertilizers significantly influenced yield and yield-attributing characters in both primary and ratoon crops. Fertigation with 100% recommended dose of fertilizers along with the consortium of biofertilizers recorded significantly higher yield compared to soil application of fertilizer, farm yard manure and consortium of biofertilizers. However, yield difference between 100% and 75% recommended dose of fertilizers was not significant. Likewise, yield difference between 75% and 50% recommended dose of fertilizers (RDF) too did not differ significantly, although yields declined at 50% RDF. Other growth characters such as number of leaves and plant girth were also significantly influenced by the combined application of fertigation and the consortium of biofertilizers in both main and the crops. However, plant height, number of hands per bunch and TSS were not affected by these treatments. Pulp-to-peel ratio significantly differed in both the main plant and ratoon crops, but days to maturity differed significantly in the ratoon crop. Main plant crop yields were higher compared to that in ratoon. N and K accumulation was significantly higher at 100% fertigation with 300g of the consortium of biofertilizers in both the seasons. However, accumulation of phosphorous was higher at 100% fertigation with 300g of the consortium of biofertilizers (CBF) in the plant crop whereas, in the ratoon crop, highest accumulation of P in the stem was observed at 100% RDF+100g CBF, and, in the leaf and fruit, at 100% RDF with 300g and 200g of CBF, respectively.

Key words: Banana, drip irrigation, fertigation, PGPR, Biofertilizers, VAM

Banana requires a large quantity of nutrients and water for growth and development compared to other fruit crops (Ghavami, 1974; Robinson and Alberts, 1986). Demand for water and nutrients can be managed effectively by drip irrigation and fertigation, as, these technologies have revolutionized commercial cultivation of banana in recent years. This technology has resulted in increased fertilizer use efficiency, apart from reducing NO_3 pollution of ground water. However, total dependency on inorganic fertilizers affects sustainability of the crop in the long run. Increase in demand for inorganic fertilizers and anticipated short supply of these are a major threat for optional production in horticultural crops. Therefore, there is a need to reduce dependency on the use of inorganic fertilizers, by supplementing nutrients through microbial inoculants. Earlier studies have proved the efficacy of fertigation (Srinivas *et al*, 2001) and biofertilizers (Jeeva *et al*, 1988; Tiwary *et al*, 1998) when used individually. Therefore, attempts were made to study the effect of fertigation in combination with a consortium of biofertilizers on banana cv. Robusta (AAA) as, synergetic effects of these two techniques have not been worked out so far for maximizing production in banana.

The study was conducted at Indian Institute of Horticultural Research, Bangalore, situated at 13º58' N and 78ºE at an altitude of 890m above MSL. The soil of the experimental site was red sandy loam, with low fertility. The soil was acidic in reaction and free from excessive salts, with organic carbon content of approximately 0.92%. It had total nitrogen content of 160kg ha^{-1}, phosphorus and potassium content of around 22kg ha^{-1} and 232kg ha^{-1}, respectively. Field capacity ranged from 14.45 to 31.92% in different layers up to 120cm soil depth. Permanent wilting point was low in the top 0-15cm (6.52%), and gradually increased with depth. It was 18.64% at 105-120cm depth. Bulk density ranged from 1.62g/cc to 1.55g/cc in the 0-120cm soil layer. The soil was tested for initial level of

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microbial population (*Azospirillum* - 0.18 to 0.22 x 10^4 cfu/g, Phosphate Solublizing Bacteria (PSB) - 0.24 to 0.28 x 10^4 cfu/g, and AM fungi - 4.3 to 5.2 spores g^{-1} of soil)

Planting material of banana *Musa* AAA, Cavendish sub-group cv. Robusta, consisting of healthy suckers weighing about 0.8 to 1.0kg each were planted during the first week of January 2010 at a spacing of 1.5x1.5m (4444 plants ha^{-1}), and its ratoon crop was taken in the year 2011. Single super phosphate as per the treatment was applied to the pit before planting. Fifteen days later, the consortium of biofertilizers was incorporated. Three levels of fertigation: 100% Recommended Dose of Fertilizer (RDF) (200:110:200 NPKg $plant^{-1}crop^{-1}$), 75% RDF and 50% RDF, and three levels (100, 200, 300g $plant^{-1}crop^{-1}$) of the consortium of biofertilizers (CBF) (*Azospirillum*, phosphate solubilizing bacteria and AM fungi) were combined with soil application of recommended dose of fertilizers. Besides these, there was one treatment with 15kg Farm Yard Manure and 300g consortium of biofertilizers $plant^{-1}$. These 12 treatment combinations were replicated thrice in Randomized Block Design. There were nine plants in each treatment. Nitrogen was applied in the form of calcium ammonium nitrate and potassium as muriate of potash. Fertigation was applied from the 60^{th} day of planting at weekly intervals, up to 320 days as per Reddy *et al*, (2002). Irrigation was done on daily basis, replenishing 80% of the evaporation loss (Hegde and Srinivas, 1991). Rain, if any fell, was deducted from evaporation; but, rain in excess of evaporation was disregarded. Two emitters were placed for each plant at equal distance of 30cm from the pseudostem, with a total discharge rate of 8 litres of water/hour. Suckers were removed periodically until flowering, and one sword sucker was retained per plant for the ratoon crop.

Plant height was measured from ground level to the top of the curve of the bunch-stalk. Pseudostem girth was measured 0.3m above ground level after flowering. Fruit bunch was weighed and the number of hands and fruits per bunch were recorded. Ten fruits were selected at random from the middle part of the bunch for recording fruit weight and pulp–peel ratio. Total Soluble Solids were recorded in the randomly-selected ripe fruits using a hand-held refractometer (ERMA, Japan).

Data were analyzed using Web Agri Stat Package, version WASP 1.0. The data were subjected to one way Aanalysis of Variance (ANOVA). Treatment difference was evaluated using Least Significant Difference (LSD) at pe≥ 0.05.

Data on various growth characters is presented in Table 1 and shows that plant height showed no marked variation due to fertigation and the consortium of biofertilizers, both in the plant and ratoon crops. However, pseudostem girth and number of leaves differed significantly with treatments. Combined effect of fertigaton and the consortium of biofertilizers was seen, with retention of more number of leaves untill maturity. In the plant crop, application of 50% fertigation with 300g consortium of biofertilizers resulted in significantly higher number of (9.5) leaves per plant than in 100% RDF through fertigation, 100% RDF through soil application or FYM and consortium of biofertilizers. In the ratoon crop, 75% RDF with 100g consortium of biofertilizers resulted in more number of leaves (11.0), indicating the role of the consortium of biofertilizers

Table 1. Effect of fertigation with a consortium of biofertilizers on growth characters in banana cv. Robusta

Treatment	No. of leaves at maturity$plant^{-1}$		Plant height at maturity(cm)		Plant girth at maturity(cm)		Days taken for maturity		TSS°brix	
	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop
FYM+CBF	7.0	7.3	194.3	192.9	38.0	40.0	410	361	18.3	18.5
100% RDF+100g CBF	9.0	8.9	212.6	223.1	52.3	54.6	360	291	19.1	20.0
100% RDF+ 200g CBF	9.0	9.2	211.2	224.0	52.8	57.7	366	285	19.7	20.5
100% RDF+ 300g CBF	9.3	9.2	214.1	221.2	53.9	58.7	372	280	20.9	21.0
75% RDF+100g CBF	8.1	11.0	215.3	228.3	50.0	56.2	368	288	20.4	20.8
75% RDF+ 200g CBF	8.7	10.3	212.1	220.6	51.9	53.3	371	284	21.0	21.0
75% RDF+ 300g CBF	8.8	9.5	210.7	219.8	51.5	54.6	361	284	21.6	21.6
50% RDF+ 100g CBF	8.6	8.2	204.8	208.9	50.0	51.6	366	300	19.0	19.3
50% RDF+ 200g CBF	9.0	8.6	206.1	210.6	50.5	53.8	366	299	19.1	19.5
50% RDF+ 300g CBF	9.5	9.0	225.0	213.4	51.4	54.5	364	302	19.8	19.0
100% RDF (fertigation)	7.1	8.0	210.0	227.5	52.2	53.0	365	300	20.1	21.0
100% RDF (soil application)	7.0	7.8	192.5	219.0	44.7	49.1	371	330	18.9	18.9
CD (*P e≥0.05*)	1.17	1.24	NS	NS	6.94	7.43	NS	43.51	NS	NS

Table 2. Effect of fertigation and a consortium of biofertilizers on yield characters in banana cv. Robusta

Treatment	No. of hands bunch^{-1}		No. of fruits plant^{-1}		Fruit weight (g)		Bunch yield plant^{-1} (kg)		Yield ha^{-1}		Pulp:peel ratio	
	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop
FYM+CBF	6.6	5.7	62.0	76.8	195.2	196.7	12.1	15.7	53.8	62.8	2.1	2.4
100 % RDF + 100g CBF	7.0	6.5	98.7	106.2	249.1	228.9	24.6	24.6	109.2	109.5	3.2	3.2
100% RDF + 200g CBF	7.0	6.6	97.5	98.1	250.9	243.6	24.9	24.1	110.9	107.1	3.8	3.3
100% RDF + 300g CBF	7.2	6.4	97.5	95.9	260.8	249.4	25.9	24.0	115.2	106.7	3.3	3.3
75% RDF + 100g CBF	6.6	6.6	95.9	96.7	249.0	238.9	23.9	23.1	106.1	102.6	3.5	3.8
75% RDF + 200g CBF	6.7	6.5	93.4	92.6	249.9	241.2	24.3	22.4	107.8	99.7	3.5	3.3
75% RDF + 300g CBF	6.9	6.4	94.6	94.8	257.8	232.1	24.9	22.0	111.9	97.8	3.3	3.3
50% RDF + 100g CBF	6.3	6.3	90.0	83.2	222.1	240.0	20.7	20.1	92.1	89.3	3.1	2.8
50% RDF + 200g CBF	6.7	6.4	91.4	88.0	227.3	232.0	21.2	20.5	94.0	91.1	3.6	3.0
50% RDF + 300g CBF	6.9	6.4	91.8	85.6	230.1	241.5	21.5	20.8	94.5	92.4	3.7	3.2
100% RDF (fertigation)	6.6	6.3	93.6	90.5	246.0	209.3	23.0	19.0	101.1	84.4	3.2	3.2
100% RDF (soil application)	6.5	6.0	78.9	86.8	230.6	198.0	17.5	17.1	77.8	76.0	2.5	2.5
CD (*Pe≥0.05*)	NS	NS	12.56	12.95	33.94	31.98	3.10	2.94	13.85	13.10	0.45	0.43

in slow release and mobility of nutrients to the plant even with reduced fertigation level.

Similarly, plants treated with 100% RDF+300g CBF recorded higher pseudostem girth at maturity in both the plant and ratoon crops; plants with FYM + 300g CBF recorded the lowest value for this parameter, followed by application of 100% RDF through soil. Days taken to maturity were higher in FYM+CBF application and soil application, but lower in fertigation treatments. Earliness was observed in plants supplied with a combination of fertigation and consortium of biofertilizers, in both the plant and ratoon crops. Even though days taken to maturity did not differ significantly in the plant crop, this parameter differed significantly in the ratoon crop supplied with fertigation and the consortium of biofertilizers. Application of FYM and the consortium of biofertilizers resulted in late maturity (361 days), followed by that in 100% fertilizer applied through soil (330 days); whereas, plants treated with 100% RDF with 300g of consortium of biofertilizers matured early (280 days). This may be due to a continuous availability of nutrients through fertigation, which facilitates timely application of nutrients directly to the root zone, reducing leaching losses and improving fertilizer use efficiency (Srinivas *et al*, 2001) and hastening maturity.

Fruit number was higher (99 and 106 in plant and ratoon crops, respectively) with 100% RDF and 100g CBF (Table 2). This value was lower in FYM (Farm Yard Manure) and CBF (Consortium of Bio-fertilizers) (62 and 77) as well as 100% RDF applied to soil (79 and 87). Fruit weight was higher in 100% RDF+300g CBF both in the plant (260.8g fruit^{-1}) and the ratoon crop (249.4g fruit^{-1}) compared to FYM+300g CBF which resulted in lower fruit weight (195.2 and 196.7g fruit^{-1}). Banana yield increased significantly with combined application of fertigation and the consortium of biofertilizers. In the plant crop, application of 100%RDF with 300g of consortium of biofertilizers produced higher yield (115MT ha^{-1}), which was nearly 32% higher than 100% RDF applied through soil. However, in the ratoon crop, 100% RDF with 100g of the consortium of biofertilizers resulted in higher yield (109MT ha^{-1}), which was 30% and 43% higher, respectively, than the 100% RDF applied through soil, FYM and 300g consortium of biofertilizers. This increase in growth and yield components could be due to reduced nutrient loss by deep-percolation and leaching and, also, by timely application of nutrients directly to the root zone of the plant, thus improving fertilizer use efficiency (Srinivas *et al*, 2001). Similar results were reported by Mahalakshmi *et al* (2003) in banana.

In both the plant and ratoon crops, yield difference between 100% and 75% RDF combined with biofertilizers consortium was found not significant. Likewise, yield differences between 75% and 50% RDF were also not significant. This indicates that the performance of microbial inoculants was better at the reduced rate of inorganic fertilizers which might have enhanced their efficiencies to fix more Nitrogen by *Azospirillum* and solubilization of phosphates by PSB (Rudresh *et al*, 2005).

Further, *Azospirillum* is known to produce bioactive substances having an effect similar to that of growth regulators, besides its ability to fix N fixation. Therefore, enhanced uptake of nutrients such as N, and auxins, due to *Azospirillum*, may have diverted photoassimilates to the

developing flower buds and helped convert flowers to femaleness to produce a higher number of fingers. This, in turn, would have increased bunch yield (Dhanapal *et al*, 1978). This improved growth parameter perhaps resulted in higher bunch weight and greater number of fingers per hand. Besides, the increase in growth parameters could be due to growth substances produced by VAM which are known to mobilize nutrients and make them available to the plant (Eswarappa *et al*, 2002). Yield increase can also be attributed to increased number of fingers, increased individual-fruit weight and, thereby, bunch weight (Meena and Somasundram, 2004).

Treatments that received 50% RDF + CBF also yielded on par with plants receiving 75% RDF + CBF. This indicates synthesis of beneficial hormones due to VAM (*Glomus fasciculatam*) by increased cell division and cell multiplication (Azcon and Bago, 1994). Tiwary *et al* (1998) also reported that inoculation with biofertilizers in various combinations increased yield in banana by 18-84% over the Control, and the response was more pronounced when N dose was reduced to half.

In the ratoon crop, there was a decrease in bunch weight in all the treatments, except 100% RDF with 100g consortium of biofertilizers, and, FYM with consortium of biofertilizers. Thus, yield reduction in the ratoon crop could be basically due to reduced fruit weight as compared to that in the plant crop. Though there was an increase in fruit weight at 50% RDF with all the three levels of consortium of biofertilizers, bunch weight was low compared to that in the plant crop, as, there was a reduced number of fruits in the ratoon crop; whereas, plants supplied with FYM and 300g of consortium of biofertilizers resulted in higher number of fruits, fruit weight and bunch yield in the ratoon crop. This increase in yield may have been due to the inoculation process which would have assisted the plants absorb nutrients (Baset Mia *et al*, 2009).

Treatment with 100% fertigation and the consortium of biofertilizers recorded higher TSS, although the differences were not marked among treatments in both the plant and the ratoon crops. This might be due to a steady accumulation of nutrients especially, K, all through the cropping season thereby resulting in higher levels of sugars in the pulp. TSS decreased gradually at lower doses (50% fertigation and the consortium of biofertilizers). This trend was observed in the ratoon crop too which corroborates the report of Baset Mia *et al* (2009), that, Plant Growth Promoting Rhizobacteria (PGPR) improve efficiency of absorption of the applied mineral nutrients by helping the plant scavenge the limiting nutrients.

Pulp-to-peel ratio significantly differed among treatments in both the plant and ratoon crops. Fruits in the combined application of fertigation and consortium of biofertilizers treatment recorded higher pulp:peel ratio. Plants that received 100% RDF along with 300g consortium of biofertilizers recorded higher pulp-to-peel ratio (3.8) in the main crop. In ratoon, the treatment 75% RDF with 100g consortium of biofertilizers recorded highest pulp-to-peel ratio (3.8). In general, ratoon crop resulted in reduced pulp-to-peel ratio in all the plants compared to the main crop, except in the treatment 75% RDF with 100g of biofertilizers. Similar results were obtained by Hegde and Srinivas (1991) in banana for ratoon crop. Plants supplied with FYM+ biofertilizers and 100% RDF through soil recorded lowest pulp:peel ratio in both the seasons.

Table 3. Effect of fertigation with a consortium of biofertilizers on nitrogen content at harvest in banana cv. Robusta

Treatment	Nitrogen (%)					
	Plant crop			Ratoon crop		
	Stem	Leaf	Fruit	Stem	Leaf	Fruit
FYM+300g CBF	0.63	0.95	0.63	0.68	0.98	0.73
100 % RDF + 100g CBF	0.97	1.80	1.42	0.98	1.82	1.41
100% RDF + 200g CBF	1.06	1.85	1.51	1.00	1.85	1.48
100% RDF + 300g CBF	1.15	1.87	1.59	1.11	1.89	1.53
75% RDF + 100g CBF	0.95	1.64	1.38	1.00	1.70	1.38
75% RDF + 200g CBF	0.97	1.76	1.35	1.01	1.75	1.34
75% RDF + 300g CBF	1.12	1.80	1.47	1.10	1.78	1.43
50% RDF + 100g CBF	0.86	1.51	1.19	0.83	1.54	1.13
50% RDF + 200g CBF	0.84	1.54	1.20	0.90	1.53	1.18
50% RDF + 300g CBF	0.90	1.52	1.16	0.94	1.49	1.16
100% RDF (fertigation)	0.79	1.54	0.83	0.77	1.52	0.80
100% RDF (soil application)	0.74	1.28	0.79	0.72	1.18	0.79
CD (*Pe≥0.05*)	0.23	0.23	0.18	0.13	0.23	0.18

Table 4. Effect of fertigation with a consortium of biofertilizers on phosphorus content at harvest in banana cv. Robusta

Treatment	Phosphorus (%)					
	Plant crop			Ratoon crop		
	Stem	Leaf	Fruit	Stem	Leaf	Fruit
FYM+300g CBF	0.11	0.08	0.11	0.11	0.09	0.13
100 % RDF +100g CBF	0.17	0.14	0.21	0.19	0.13	0.20
100% RDF + 200g CBF	0.17	0.16	0.20	0.18	0.16	0.21
100% RDF + 300g CBF	0.18	0.18	0.21	0.18	0.17	0.20
75% RDF +100g CBF	0.17	0.13	0.19	0.17	0.13	0.18
75% RDF + 200g CBF	0.16	0.13	0.20	0.16	0.13	0.19
75% RDF + 300g CBF	0.17	0.14	0.20	0.17	0.13	0.20
50% RDF + 100g CBF	0.14	0.11	0.18	0.15	0.11	0.18
50% RDF + 200g CBF	0.16	0.11	0.17	0.15	0.12	0.19
50% RDF + 300g CBF	0.17	0.12	0.19	0.16	0.12	0.18
100% RDF (fertigation)	0.16	0.13	0.15	0.13	0.11	0.15
100% RDF (soil application)	0.13	0.11	0.14	0.13	0.11	0.13
CD (*Pe≥0.05*)	0.02	0.02	0.03	0.02	0.02	0.03

Table 5. Effect of fertigation with a consortium of biofertilizers on potassium content at harvest in banana cv. Robusta

Treatment	Potassium (%)					
	Plant crop			Ratoon		
	Stem	Leaf	Fruit	Stem	Leaf	Fruit
FYM+300g CBF	1.12	1.18	1.81	1.15	1.13	1.80
100% RDF+100g CBF	3.00	3.88	4.05	3.00	3.83	4.06
100% RDF+ 200g CBF	3.08	3.91	4.08	3.10	3.85	4.10
100% RDF+ 300g CBF	3.10	3.93	4.11	3.12	3.90	4.15
75% RDF+100g CBF	2.95	3.70	3.96	3.00	3.70	3.98
75% RDF+ 200g CBF	2.80	3.75	3.98	3.00	3.65	4.00
75% RDF+ 300g CBF	3.00	3.84	3.93	3.11	3.71	4.01
50% RDF+ 100g CBF	2.35	3.01	3.22	2.48	3.11	3.34
50% RDF+ 200g CBF	2.38	3.15	3.33	2.40	3.18	3.38
50% RDF+ 300g CBF	2.40	3.30	3.38	2.44	3.21	3.40
100% RDF (fertigation)	2.95	2.95	3.37	2.55	2.90	3.41
100% RDF (soil application)	1.73	2.50	2.73	1.78	2.60	2.78
CD (*Pe≥0.05*)	0.37	0.64	0.50	0.37	0.46	0.50

Leaf, stem and fruit sample analysed at harvest revealed that nitrogen accumulation was higher in the leaf, whereas, phosphorus and potassium accumulation was higher in fruits (Tables 3-5). Similar results were obtained by Srinivas *et al* (2001) also in banana. In both the cropping seasons, nutrient uptake was higher in plants receiving a combined application of fertigation and the consortium of biofertilizers. N and K accumulation was significantly higher at 100% fertigation with 300g consortium of biofertilizers in both the seasons. However, accumulation of phosphorus was higher at 100% fertigation with 300g consortium of biofertilizers in the plant crop, whereas, in the ratoon crop, highest accumulation of P in the stem was observed at 100% RDF+100g CBF. In the leaf and fruit, this was seen at 100% RDF with 300g and 200g of CBF, respectively. The combination of FYM + consortium of biofertilizers recorded lowest nutrient uptake in both the crop cycles. Higher accumulation of K in fruits indicates that a major portion of K is diverted to the fruit at its late developmental stage, which is associated with sweetness and higher TSS.

In conclusion, it may be stated that growth and yield of banana can be significantly enhanced with 100% RDF, followed by 75% RDF through fertigation with a combination of a consortium of biofertilizers. It was noted that even a dosage of 50% RDF, combined with the consortium of biofertilizers, gave significantly higher yield than 100% RDF applied to soil.

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