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Combining fertigation and consortium of bio-fertilizers for enhancing growth and yield of banana cv. Robusta (AAA)

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ABSTRACT

The present investigation was carried out to study the effects of combination of fertigation and consortium of bio-fertilizers in enhancing the production of banana cv. Robusta (AAA) and improving the soil biological properties. The results shown that, fertigation with 100% recommended dose of fertilizers (RDF) and 300 g of consortium of bio-fertilizers (CBF) produced significantly higher yield (115 MT ha^{-1}) as compared to other treatments in the main crop. The yield increase was nearly 32 per cent as compared to soil application of fertilizers (78 MT ha^{-1}). However, the yield difference between 100 and 75% RDF with CBF was not significant. Moreover, there was no significant yield difference between 75 and 50% RDF. In the ratoon crop, fertigation with 100% RDF and 100 g of CBF produced significantly higher yield (109 MT ha^{-1}), which was 30 per cent higher as compared to soil application of fertilizers (76 MT ha^{-1}) and 42 per cent higher than the treatment comprising of farm yard manure (FYM) + 300 g of CBF. In the ratoon crop, the yield difference between 100 and 75% RDF with CBF was not significant. Similarly, yield difference between 75 and 50% RDF was not significant. In both the cropping seasons, the soil biological activity in terms microbial population of was enhanced at higher level of consortium of bio-fertilizers.

Key words: Banana, bio-fertilizers, drip irrigation, fertigation.

INTRODUCTION

Banana is one of the important fruit crops in the tropics and India is the largest producer of banana in the world. Banana being a nutrient and water loving crop, the demand for water and nutrient is high (Srinivas *et al.*,14; Robinson and Alberts, 12), thus, it is imperative to maintain high degree of soil fertility to ensure higher productivity. This can be managed effectively by drip-fertigation as this technology has revolutionized the commercial cultivation of banana in recent years. On the other hand, the increase in demand for inorganic fertilizers and their anticipated short supply will be a major threat in the production of horticultural crops in the near future. Therefore, there is a need to reduce the dependency on the usage of organic and inorganic fertilizer by supplementing the nutrients through microbial inoculants. These microbial inoculants are known to increase the soil aggregate formation and improve the soil health. Earlier studies have proved the efficacy of fertigation (Srinivas *et al.*, 14) and bio-fertilizers (Jeeva *et al.*, 8; Tiwary *et al.*, 15) as two different production methodologies, whereas the synergetic effects of these two techniques for realizing maximum benefits have not been worked out for sustainable production of banana. In this back drop, the present study was attempted for maximizing the production of banana cv. Robusta (AAA) through combined application of fertigation and consortium of bio-fertilizers (CBF).

MATERIALS AND METHODS

Present study was conducted at the ICAR-IIHR, Hessarghatta, Bengaluru, situated at 13º 58' N latitude, 78º E longitude and at an altitude of 890 m during 2010-12. The climate of Hessaraghatta is moderately warm with mild summer months. The maximum temperature ranges from 27º to 35ºC with a mean of 29ºC, while the minimum temperature ranges from 10.9º to 21.5ºC with a mean of 17.5ºC. The mean relative humidity is 63.5 per cent and the average rainfall is around 850 mm $annum^{-1}$. Three levels of fertigation, *i.e.*, 100% recommended dose of fertilizer (RDF) @ 200 g N, 110 g P, 200 K g pl^{-1} $crop^{-1}$ (Anon, 1), 75 and 50% RDF and three levels (100, 200, 300 g $pl^{-1}crop^{-1}$) of CBF (*Azospirillum*, phosphate solubilizing bacteria and AM fungi mixed in equal proportion) along with soil application of recommended dose of fertilizers were used. Another treatment was comprising of FYM and 300 g of CBF. These 12 treatment combinations were replicated thrice in a randomized block design using the cv. Robusta (AAA) and a total of 9 plants were used in each treatment. The planting material of banana (*Musa* AAA), Cavendish sub-group cv. Robusta consisted of healthy sword suckers weighing around

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0.80 to 1.0 kg each were planted during the first week of Januray 2010 at a spacing of 1.5 m × 1.5 m (4,444 plants ha^{-1}). The entire quantity of phosphorous as single super phosphate was applied in the pit before planting and 15 days after the CBF was incorporated before the fertigation was started. Nitrogen was applied in the form of calcium ammonium nitrate (CAN) and potassium as muriate of potash (MOP). The fertigation was started from 60^{th} day of planting and continued upto 320 days. For the ratoon crop, it was started after the harvest of the main crop and continued up to 270 days at weekly interval. The fertigation was given at weekly intervals and irrigation was given on daily basis, replenishing 80% of evaporation losses. Any rain, which fell, was deducted from the evaporation but rain in excess of evaporation was disregarded (Hegde and Srinivas, 7). Two emitters were placed for each plant at equal distance of 30 cm from the pseudostem with a discharge rate of 4 l of water/ h. All the suckers were removed periodically until flowering and later one sword sucker per plant was retained for the ratoon crop.

The plant height was measured from ground level to the top of the curve of the bunch stalk. Pseudostem girth was measured at 0.3 m above ground level after flowering. The bunch was weighed and number of hands and fruits were recorded individually. Ten fruits were selected randomly from the middle portion of the bunch and the total soluble solid was recorded using a hand refractometer (ERMA, Japan). The data were analyzed using Web Agri Stat Package version WASP 1.0 developed by the Indian Council of Agricultural Research Complex, Goa. The data were subjected to one way analysis of variance (ANOVA). Treatment difference was evaluated using least significant difference (LSD) at p≥0.05. The data pertaining to population of *Azospirillum* and phosphobacteria were transformed through logarithmic transformation, while the AM fungi spore load and root colonization were transformed through square root transformation and Arc sine transformation respectively for realistic interpretation of the data.

RESULTS AND DISCUSSION

The plant height at harvest did not show any marked variations due to fertigation and consortium of bio-fertilizers (CBF) both in main and ratoon crops, whereas the pseudostem girth and the number of leaves significantly varied (Fig. 1-3). The plants treated with 100% recommended dose of fertilizers (RDF) + 300 g consortium of fertilizers (CBF) recorded maximum pseudostem girth at maturity in both main and ratoon crops and plants received farm yard manure (FYM) with 300 g CBF recorded the lowest

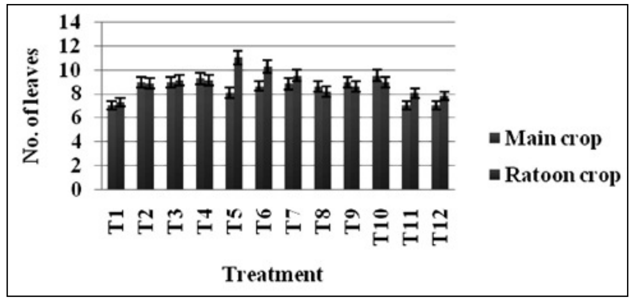

Fig. 1. Effect of fertigation and consortium of biofertilizers on No. of leaves at harvest.

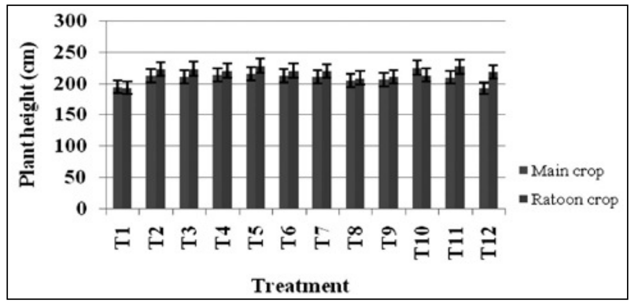

Fig. 2. Effect of fertigation and consortium of biofertilizers on plant height at harvest.

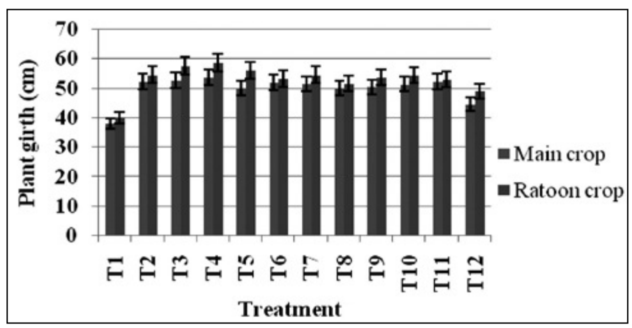

Fig. 3. Effect of fertigation and consortium of biofertilizers on plant girth at harvest.

followed by 100% RDF treatment. The combination of fertigation and CBF resulted in retention of more number of leaves till harvest. In the main crop, application of 50% RDF through fertigation with 300 g of CBF resulted in higher number of leaves per plant (9.5). Whereas, 75% RDF with 100 g of CBF retained more number of leaves in the ratoon crop. It indicates the role of CBF in slow release and mobility of nutrients to the plants even when the fertigation level was reduced to 50 and 75% of recommended dose. Present results are in conformity with the results reported by Niteen *et al*. (11) in banana.

Effect of the plants applied with the combination of fertigation and CBF recorded significantly higher yield over control. The fruit number was highest with 100% RDF and 100 g CBF in main as well as ratoon crops (98 and 106). However, it was lower in treatment of FYM + 300 g CBF (62 and 77) and 100% RDF given through soil (79 and 87). It was also observed that the treatment of 100% RDF + 300 CBF recorded 33.65 and 26.76% higher fruit weight in the main and ratoon crops as compared to FYM + 300 g CBF treatment. It was evident that banana yield increased significantly through combined application of fertigation and CBF. In the main crop, application of 100% RDF with 300 g of CBF produced higher yield (115 MT ha^{-1}), which was 32% higher than the treatment 100% RDF applied through soil. However in the ratoon crop, 100% RDF with 100 g of CBF resulted in higher yield (109 MT ha^{-1}), which was 30 and 43% higher than the treatment of 100% RDF applied through soil and FYM + 300 g CBF (Table 1). The better growth and yield components might be attributed to reduced nutrient losses by deep percolation and leaching and also timely application of nutrients directly to the root zone of plants improving fertilizer use efficiency (Srinivas *et al*., 14). It was also observed that highest levels of fertigation resulted in heaviest bunches in both main and ratoon crops. Similar results were obtained by Mahalakshmi *et al*. (9) in banana.

In both main and ratoon crops, the yield difference between 100 and 75% RDF combined with CBF was not statistically significant. Likewise, the yield difference between 75% and 50% RDF was also not significant. The non-significant difference in yield observed with the 75 and 50% RDF might be attributed to the nutrient supplementation among the inoculated organisms, which might have mutually enhanced their efficiencies of N_2 fixation by *Azospirillum* and phosphorus solubilization by PSB (Rudresh *et al*., 13). Further, *Azospirillum* is known to produce bioactive substances having similar effect as that of the growth regulators besides N_2 fixation. Therefore, the enhanced uptake of nutrients such as N and auxins due to *Azospirillum*, could have diverted the photo-assimilates to the developing flower buds and helped in conversion of flowers to more femaleness to produce higher number of fingers which in turn increased the bunch yield (Dhanapal *et al*., 5). This improved growth parameters in turn resulted in higher bunch weight, number of fingers per hand. Besides, the increase in the growth parameters due to microorganisms may also be due to the direct role of *Azospirillum* spp. in nitrogen fixation (Jeeva *et al*., 8), phosphorus solubilization by PSB and production of plant growth substances by AM, which are known to mobilize more nutrients and make them available to the plants (Eswarappa *et al*., 6). Furthermore, the yield increase in treatments having combination of recommended dose of fertilizers and consortium of bio-fertilizers might be due to improvement in yield contributing attributes like increased number of fingers, fruit and bunch weight (Meena and Somasundram, 10).

The yield difference between 50% RDF + CBF and 75% RDF + CBF was not marked. This was largely due to the beneficial synthesis of hormones by the AM in increasing the cell division and cell

Table 1. Effect of fertigation and consortium of bio-fertilizers on the yield characters and TSS of banana.

Treatment	No. of fruits		Fruit wt. (g)		Bunch yield (kg)		Yield/ ha (MT)		TSS (°Brix)	
	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop
1. FYM + 300 g CBF	62.00	76.80	195.16	196.74	12.10	15.71	53.77	62.79	18.25	18.50
2. 100% RDF + 100 g CBF	98.69	106.23	249.06	228.94	24.58	24.64	109.23	109.50	19.07	20.00
3. 100% RDF + 200 g CBF	97.54	98.13	250.89	243.59	24.93	24.10	110.92	107.10	19.68	20.50
4. 100% RDF + 300 g CBF	97.54	95.85	260.84	249.39	25.93	24.00	115.23	106.66	20.85	21.00
5. 75% RDF + 100 g CBF	95.92	96.67	249.00	238.85	23.87	23.09	106.08	102.61	20.35	20.75
6. 75% RDF + 200 g CBF	93.36	92.63	249.90	241.15	24.25	22.43	107.77	99.68	21.00	21.00
7. 75% RDF + 300 g CBF	94.63	94.78	257.75	232.12	24.86	22.00	111.89	97.77	21.55	21.55
8. 50% RDF + 100 g CBF	90.04	83.20	222.12	240.00	20.72	20.10	92.07	89.32	19.03	19.25
9. 50% RDF + 200 g CBF	91.40	88.00	227.27	232.00	21.15	20.50	93.99	91.10	19.07	19.50
10. 50% RDF + 300 g CBF	91.82	85.60	230.13	241.50	21.45	20.80	94.54	92.44	19.75	19.00
11. 100% RDF (fertigation)	93.60	90.50	246.00	209.25	23.00	19.00	101.06	84.44	20.06	21.00
12. 100% RDF (soil application)	78.90	86.83	230.64	198.00	17.50	17.17	77.77	76.30	18.85	18.85
CD at 5%	12.56	12.95	33.94	31.98	3.10	2.97	13.84	13.10	NS	NS

multiplication (Azcon and Bago, 2) at reduced levels of inorganic fertilizers. Tiwary *et al*. (15) also reported that inoculation with bio-fertilizers in various combinations increased the yield of banana by 18-84% over the control and the response was more pronounced when the N dose was reduced to half.

In ratoon crop, there was a decrease in the bunch weight in all the treatments except 100% RDF with 100 g CBF and FYM with CBF. The yield reduction in the ratoon crop might be basically due to reduced fruit weight as compared to the main crop. Though there was an increase in the fruit weight at 50% RDF with all the three levels of CBF. The bunch weight was also less as compared to main crop due to reduction in the number of fruits in the ratoon crop. Whereas, plants applied with FYM + 300 g of CBF resulted in higher number of fruits, fruit weight and bunch yield in the ratoon crop. This increase of yield might be due to enhanced root growth, which absorbed more nutrients and consequently accumulated higher nutrients (Baset Mia *et al*., 3).

The highest total soluble solids (TSS) was observed at the treatment combination of 100% RDF through fertigation with CBF. The TSS marginally reduced at lower doses (50% RDF fertigation + CBF), but the differences were not marked among the treatments in both main and ratoon crops. The increase in TSS at lower level of fertigation might be due to steady accumulation of nutrients especially K, all through the cropping season which resulted in higher level of sugars in the pulp. This finding corroborates with the report of Baset Mia *et al*. (3), which reveals that plant growth promoting rhizobacteria (PGPR) might improve the efficiency of absorbing applied mineral nutrients by helping the plant, scavenge limiting nutrients.

The initial population of *Azospirillum*, PSB and AM did not differ significantly in the samples, which indicated the overall uniformity of the microbial load that existed prior to planting. However, the application of CBF considerably increased the microbial population in the rhizosphere soil (Table 2). Twelve months after the application, the microbial population was significantly higher in the rhizosphere soil applied with CBF. The rhizosphere colonization of *Azospirillum* was higher (4.48×10^4 cfu g^{-1} soil) at 75% RDF + 300 g CBF in the main crop and 4.61×10^4 cfu g^{-1} soil at 75% RDF + 200 g CBF in the ratoon crop. The bacterial population was higher at 75% RDF + 300 g CBF in both main and ratoon crops with 4.76×10^4 cfug^{-1} soil 4.77×10^4 cfu g^{-1} soil, respectively. Among the treatments 75% RDF + 300 g CBF recorded significantly higher microbial load in terms of AM spore density in plant (3.14 g^{-1} of dry soil) in the main and ratoon crops. AM root colonization was also higher at 75% RDF through fertigation with 300 g CBF in main and ratoon crops with a value of 56.06 and 59.03 per cent, respectively. Higher level of fertigation (100% RDF) with the combination of CBF could result in lesser microbial population compared to the 75 and 50% levels of fertigation in both the crop cycles. This indicated that the microbes would have a better association and colonization when the inorganic fertilizer level was reduced. In a similar experiment, plant growth promoting strains inoculated with minimal N fertilizer supply were found to be more effective as a bio-enhancer and bio-fertilizer to fix N_2 and increase plant growth, nutrient uptake, yield and fruit quality of banana (Baset Mia *et al*., 4). In both the crop cycles, the treatments without the combination of CBF recorded less microbial population.

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 bio-fertilizers. It was noted that even a dosage of 50% RDF when combined with the consortium of bio-fertilizers could result in 18 to 23 and 17 to 21% higher yield in the main and the ratoon crop, respectively when compared to 100% RDF applied to soil. It is also an indication that, through combined application of fertigation and consortium of bio-fertilizers, the inorganic fertilizers can be saved from 25-50%. The microbial population being the biological indicators of the soil health found higher at 75% recommended dose of fertilizer through fertigation combined with consortium of bio-fertilizers.

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Table 2. Effect of fertigation and consortium of bio-fertilizers on the microbial population.

Treatment	*Azospirillum* (10^4cfu g^{-1} dry soil)			Phospobacteria (10^4cfu g^{-1} dry soil)			AM spore load (No. g^{-1} dry soil)			AM fungal root colonization (%)	
	Main crop		Ratoon crop	Main crop		Ratoon crop	Main crop		Ratoon crop	Main crop	Ratoon crop
	Initial	12th month	12th month	Initial	12th month	12th month	Initial	12th month	12th month	12th month	12th month
1. FYM + 300 g CBF	0.198 (3.29)	1.16 (4.06)	1.13 (4.05)	0.243 (3.38)	2.72 (4.43)	2.77 (4.41)	4.74 (2.17)	6.56 (2.56)	6.62 (2.57)	45.11 (42.17)	52.46 (46.42)
2. 100% RDF + 100 g CBF	0.211 (3.32)	1.21 (4.08)	2.01 (4.30)	0.251 (3.40)	2.36 (4.37)	2.14 (4.32)	4.30 (2.07)	6.65 (2.58)	7.13 (2.67)	49.32 (44.61)	58.77 (50.06)
3. 100% RDF + 200 g CBF	0.223 (3.35)	2.03 (4.31)	2.51 (4.40)	0.273 (3.43)	3.62 (4.55)	3.27 (4.51)	4.48 (2.11)	7.88 (2.80)	8.00 (2.82)	50.83 (45.60)	60.06 (50.87)
4. 100% RDF + 300 g CBF	0.193 (3.29)	1.24 (4.09)	2.38 (4.38)	0.227 (3.36)	2.84 (4.45)	2.91 (4.46)	5.01 (2.24)	6.91 (2.63)	6.89 (2.62)	57.01 (49.03)	62.16 (52.04)
5. 75% RDF + 100 g CBF	0.199 (3.30)	2.31 (4.36)	2.81 (4.45)	0.230 (3.36)	3.72 (4.57)	3.90 (4.59)	5.12 (2.26)	8.14 (2.85)	8.28 (2.88)	56.28 (48.61)	66.89 (54.88)
6. 75% RDF + 200 g CBF	0.212 (3.33)	2.77 (4.44)	4.03 (4.61)	0.263 (3.41)	4.98 (4.70)	5.05 (4.70)	4.97 (2.23)	8.83 (2.97)	8.92 (2.99)	58.15 (49.70)	68.05 (55.61)
7. 75% RDF + 300 g CBF	0.182 (3.25)	3.01 (4.48)	3.75 (4.57)	0.247 (3.39)	5.83 (4.76)	5.96 (4.77)	4.88 (2.21)	9.92 (3.14)	9.86 (3.14)	68.57 (56.06)	73.11 (59.03)
8. 50% RDF + 100 g CBF	0.204 (3.32)	1.19 (4.08)	1.64 (4.21)	0.271 (3.43)	2.49 (4.40)	2.62 (4.42)	4.77 (2.18)	7.40 (2.72)	7.52 (2.74)	51.42 (45.81)	54.48 (47.57)
9. 50% RDF + 200 g CBF	0.192 (3.29)	1.32 (4.12)	1.59 (4.20)	0.282 (3.45)	2.76 (4.44)	2.80 (4.45)	5.21 (2.28)	7.61 (2.76)	7.73 (2.78)	52.62 (46.50)	55.35 (48.07)
10. 50% RDF + 300 g CBF	0.201 (3.30)	1.57 (4.20)	1.89 (4.28)	0.264 (3.43)	3.59 (4.56)	3.73 (4.57)	5.18 (2.28)	8.60 (2.93)	8.71 (2.95)	58.34 (46.91)	58.66 (49.99)
11. 100% RDF (fertigation)	0.213 (3.33)	0.89 (3.95)	0.68 (3.83)	0.252 (3.40)	1.59 (4.20)	1.31 (4.12)	5.00 (2.24)	5.23 (2.29)	5.37 (2.32)	38.83 (38.54)	42.61 (40.75)
12. 100% RDF (soil application)	0.188 (3.29)	0.57 (3.75)	0.52 (3.71)	0.239 (3.38)	1.41 (4.14)	1.69 (4.23)	4.81 (2.19)	5.43 (2.33)	5.42 (2.33)	32.16 (34.52)	38.29 (38.21)
CD at 5%	NA	0.06	0.06	NA	0.06	0.06	NA	0.20	0.20	4.45	5.20

Figures given in the parenthesis are transformed values

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