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Influence of INM treatments on bean yield and quality characters of cocoa (*Theobroma cacao* L.) grown as intercrop in coconut plantations

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Abstract
An field experiment was conducted during 2016 and 2017 to investigate the impact of integrated nutrient management on bean yield and quality characters of cocoa at existing coconut gardens, Horticultural Research Station, Ambajipeta. The study was laid out in randomized block design with ten treatment replicated thrice. The bean characters like wet bean weight of 100 beans (296.39 g), dry bean weight of 100 beans (154.92 g), bean length (2.26 mm), bean width (1.20 mm) and bean thickness (0.58 mm) were recorded highest in the trees treated with 75% RDF + 25% RDN through composted coir pith+ 50g *Azospirillum* + 50g PSB. The highest dry bean yield per tree of 3.57 kg and lowest pod index (15.72) was recorded in same treatment. The bean quality characters like shelling %, nib recovery % and fat % were recorded. The fat % and nib recovery % were highest in trees treated with 75% RDF + 25% RDN through composted coir pith+ 50g *Azospirillum* + 50g PSB with 52.43% and 85.94% respectively. However, the highest shelling % was recorded in control with 22.95%. The combined use of organic manures, bio-fertilizers and chemical fertilizers has been found not only in maintaining higher productivity but also in providing stable crop yields for sustainable crop production through integrated nutrient use. The above results indicated that, for getting higher productivity and quality, application of 75% RDF + 25% RDN through composted coir pith+ 50g *Azospirillum* + 50g PSB is recommended in black alluvial soil of Andhra Pradesh for higher returns.

Keywords: Cocoa, bean, INM treatments, quality, yield

Introduction
Cocoa (*Theobroma cacao* L.) the 'Food of Gods' is a tree originated in South America belong to the family Malvaceae (Alverson *et al*., 1999 and Bayer *et al*., 1999) [1, 3]. In India, it has been growing as intercrop in arecanut, coconut and oilpalm plantations and accounts to an area of 89,000 hectares with a production of 20,000 MT (NHB, 2018-19). In view of increasing the yield potential in cocoa, timely application of nutrient on various crop growth stages *viz*., vegetative, flowering, pod set, pod development and maturity is necessary (Krishnamoorthy and Rajamani, 2013) [13]. Balanced nutrition with different organic and inorganic ensures efficient use of all nutrients by the plant. There is a need for reduced consumption of chemical fertilizers and increased use of organic manures and biofertilizer for increased yields and quality of the beans and to protect the soil fertility. The growth and pod formation of a plant depends on nutrient status of the leaf, hence in the present work was made to find out suitable combination of organic, inorganic manures along with the biofertilizers on quality characters of cocoa beans under INM system.

Material and methods
The experiment was conducted at Horticultural Research Station, Ambajipeta, East Godavari District, Andhra Pradesh. The location falls under Agro-climatic zone-10, humid, East Coast Plain and Hills (Krishna-Godavari zone) with an average rainfall of 900 mm, located at an altitude of 34 m above mean sea level. The cocoa trees of fourteen year old were selected for the present study as intercropped in coconut plantation of thirty year old planted in a spacing of 8 × 8 m. The cocoa plants are intercropped with a spacing of 3 × 3 m in the coconut plantations. The study was laid out in randomized block design with ten treatments. The treatments are 75% RDF + 25% RDN through composted coir pith (T_1), 75% RDF + 25% RDN through composted coir pith+ 50g *Azospirillum* + 50g PSB (T_2), 50% RDF + 50% RDN

through composted coir pith (T_3), 50% RDF + 50% RDN through composted coir pith+ 50g *Azospirillum* + 50g PSB (T_4), 75% RDF + 25% RDN through FYM (T_5), 75% RDF + 25% RDN through FYM + 50g *Azospirillum* + 50g PSB (T_6), 50% RDF + 50% RDN through FYM (T_7), 50% RDF + 50% RDN through FYM+ 50g *Azospirillum* + 50g PSB (T_8), 100% RDF (T_9) and Control (T_{10}). The recommended dosage of N, P and K for cocoa is 100:40:140 g/tree/year. In inorganic fertilizer treatments (50%, 75% and 100% recommended dose of fertilizers) nitrogen, phosphorus and potassium nutrients were applied in the form of urea, single super phosphate and muriate of potash respectively. Nitrogen, Phosphorus and Potash was applied in two equal split doses i.e., first split during August (2016) and second split in November (2016). The *Azospirillum* and PSB @ 50 g/tree was inoculated with the respective organic manures thoroughly and incorporated in the soil. All the treatments were imposed to the cocoa trees timely and maintained. The observations on quality parameters of beans of cocoa were recorded as per standard procedures laid out by Kaushik (2007) [10] and analysis carried out as per Panse and Sukhatme (1978). The weight of 100 wet beans and the average dry weight of 100 beans after fermentation in each treatment was calculated. The average yield of dry beans from tree was calculated from the mean dry weight of the beans per pod and the total number of pods in each treatment. The pod index was calculated from the number of pods required to produce one kg of dry beans in each treatment (Thondaiman *et al.,* 2011). The average length and width of the single bean was calculated by taking the beans randomly from each pod in each treatment by using a standard scale and expressed in centimeters (cm). The average thickness of beans was measured in millimeters using the vernier caliper according to Kaushik *et al*. (2007) [10] in each treatment. The Shelling percentage of the bean was calculated by using the following formula, shell weight/ dry bean weight x 100. The nib recovery percentage of the bean was calculated by using the following formula nib weight/ dry bean weight x 100. The fat content was estimated by petroleum ether extraction method using soxhlet apparatus (Elain apshara *et al*., 2008) by using the formula

$$\text{Percentage of fat content on moisture free basis} = \frac{(W_2 - W_1)}{\text{Weight of the sample X } (100 - M)} \text{ X } 100$$

Where,

W_1 – weight of the receiver (bottom flask)

W_2 – weight of the flask + ether extractives

M – Moisture content of the sample

Results and discussion

The results varied significantly among the treatments. The highest wet weight of 100 beans (296.39 g) was recorded in T_2 and lowest wet weight of 100 beans (153.59 g) was recorded in T_{10} (Table 1). The increase in fresh weight of beans might be on account of incorporation of composted coir pith and biofertilizers. This might also be due to proper supply of nutrients and induction of growth hormones which stimulated cell division, cell elongation leads to increase in number and weight of beans. The results were also reported by Baviskar *et al*. (2011) [2] and Dwivedi (2013) [7]. The highest dry weight of 100 beans (154.92 g) was recorded in T_2, while lowest dry weight of 100 beans (110.65 g) was recorded in T_{10}. This increase in dry weight of beans is due to integration of inorganic and organic sources of nutrient maximized supply of nutrients during entire period of pod growth, ultimately resulting in accumulation of more photosynthates leading dry weight and yield. Fawazi *et al*. (2010) in pear and Kumar (2010) in litchi also reported similar the results. The highest dry bean yield per tree of 3.57 kg was recorded in T_2 and the lowest dry bean yield per tree (0.97 kg) was recorded in T_{10}. Yield is a complex trait and is a product of several other yield attributing characters. The increase in dry bean yield per tree could be attributed to increased rate of photosynthesis which could have further led to the better partitioning of assimilates. Higher values observed for these traits might be due to higher fertilizer use efficiency and higher uptake of macro and micronutrients. These findings are in agreement with that of Kaur *et al* (2007) [11] and Kundu *et al*. (2011) [14]. The highest pod index of 26.78 was recorded in T_{10} and the lowest pod index (15.72) was recorded in T_2 (Table 1). Lower pod index is preferred to have higher bean yield which was also reported by Karthik kumar, 2014, Murali and suresh, 2015 [21]. The highest bean length of 2.26 mm was recorded in T_2 and the lowest bean length (1.94 mm) was recorded in T_{10}. The bean width varied significantly among different treatments. The highest bean width of 1.20 mm was recorded in T_2 and the lowest bean length (0.97 mm) was recorded in T_{10}. The bean thickness varied significantly among different treatments, the highest bean thickness of 0.58 mm was recorded in T_2 and the lowest bean thickness (0.46 mm) was recorded in T_{10} (Table 1). The increase in length, width and thickness of the bean is due to better filling of bean and their growth with increased uptake of nutrients from soil which had produced enough carbohydrates in the leaf for translocation to the sink for better filling of the beans.. This was also reported by Dalal *et al*. (2004) [4], Madhavi *et al*. (2008) [17].

The shelling percentage varied significantly among different treatments, the highest shelling percentage (22.95%) was recorded in T_{10} (control), while the lowest shelling percentage (14.06%) was recorded in with T_2. Highest shelling percentage was reported in control due to limited nutrients supply to the pods from the plant. The highest nib recovery percentage was recorded in T_2 (85.94%), while the lowest nib recovery percentage (77.04%) was recorded in T_{10} (Table 2). The highest fat percentage of (52.43%) was recorded in T_2 and the lowest fat percentage (46.44%) was recorded in T_{10} (Table 2). Improvement in pod quality (nib recovery % and fat %) is by continuous supply of nutrients, higher concentration of soil enzymes, soil microorganism, more friable and pours soils made by composted coir pith may be attributed to better vegetative growth of the treated plants and which resulted in higher quantities of photosynthates (starch, carbohydrates, etc.) and the translocation to the pod, thus increasing the various contents of pod hence quality improvement reflected in pod chemical character. Similar findings were also reported by Shukla *et al*. (2009) [28], Yadav *et al*. (2011) [30] and Dhaval and Naik (2010) [6].

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Table 1 Effect of different INM treatments on bean characters of cocoa (*Theobroma cacao* L.)

Treatments	Weight of the pod (g)	Total beans per pod	Wet weight of 100 beans (g)	Dry weight of 100 beans (g)	Bean length (mm)	Bean width (mm)	Bean thickness (mm)	Pod index	Total dry bean yield/tree (kg)
T_1: 75% RDF + 25% RDN through CCP	448.91	42.28	284.21	147.47	2.21	1.19	0.57	17.01	3.03
T_2: 75% RDF + 25% RDN through CCP + 50g *Azospirillum*+ 50g PSB	485.26	42.41	296.39	154.92	2.26	1.20	0.58	15.72	3.57
T_3: 50% RDF + 50% RDN through CCP	438.03	41.89	257.36	144.64	2.19	1.18	0.56	17.50	2.48
T_4: 50% RDF + 50% RDN through CCP + 50g *Azospirillum* + 50g PSB	398.90	36.96	274.93	138.65	2.04	1.16	0.51	20.80	2.13
T_5: 75% RDF + 25% RDN through FYM	398.49	40.78	229.43	133.81	2.18	1.08	0.48	19.24	2.26
T_6: 75% RDF + 25% RDN through FYM + 50g *Azospirillum* + 50g PSB	410.00	37.34	256.43	137.77	2.11	1.14	0.53	19.49	2.34
T_7: 50% RDF + 50% RDN through FYM	401.91	42.08	226.42	141.58	2.12	1.13	0.52	17.89	2.48
T_8: 50% RDF + 50% RDN through FYM + 50g *Azospirillum* + 50g PSB	410.36	39.36	225.51	140.94	2.16	1.13	0.55	19.12	2.25
T_9: 100% RDF	390.56	41.91	228.41	140.07	2.07	1.08	0.50	17.98	2.26
T_{10}: Control	329.50	36.34	153.59	110.65	1.94	0.97	0.46	26.78	0.97
SE m ±	21.52	0.05	12.97	3.56	0.05	0.03	0.01	0.61	0.11
CD (P=0.05)	64.44	0.16	38.83	10.68	0.15	0.09	0.04	1.84	0.34
CV (%)	9.06	1.48	9.23	4.44	4.25	4.81	5.32	5.57	8.26

RDF- Recommended dose of fertilizers RDN-Recommended dose of nitrogen CCP- Composted coir pith
FYM- Farm yard manure PSB-Phosphate solubilizing bacteria

Table 2: Effect of different INM treatments on bean quality parameters of cocoa (*Theobroma cacao* L.)

Treatments	Shelling %	Nib recovery%	Fat (%)
T_1: 75% RDF + 25% RDN through CCP	15.23(22.96)	84.76(67.00)	51.63(45.91)
T_2: 75% RDF + 25% RDN through CCP + 50g *Azospirillum*+ 50g PSB	14.06(21.98)	85.94(67.98)	52.43(46.37)
T_3: 50% RDF + 50% RDN through CCP	14.14(22.07)	85.86(67.89)	50.55(45.29)
T_4: 50% RDF + 50% RDN through CCP + 50g *Azospirillum* + 50g PSB	14.47(22.33)	85.53(67.62)	50.55(45.29)
T_5: 75% RDF + 25% RDN through FYM	14.61(22.46)	85.39(67.50)	50.31(45.16)
T_6: 75% RDF + 25% RDN through FYM + 50g*Azospirillum* + 50g PSB	14.36(22.25)	85.64(67.70)	49.51(44.70)
T_7: 50% RDF + 50% RDN through FYM	14.79(22.60)	85.21(67.35)	49.69(44.80)
T_8: 50% RDF + 50% RDN through FYM + 50g *Azospirillum* + 50g PSB	14.20(22.12)	85.79(67.83)	49.43(44.65)
T_9: 100% RDF	14.15(22.08)	85.84(67.87)	49.41(44.64)
T_{10}: Control	22.95(28.60)	77.04(61.36)	46.44(42.94)
SE m ±	0.50	0.50	0.48
CD (P=0.05)	1.52	1.52	1.44
CV (%)	3.83	1.31	1.85

RDF- Recommended dose of fertilizers RDN-Recommended dose of nitrogen CCP- Composted coir pith
FYM- Farm yard manure PSB-Phosphate solubilizing bacteria
Figures in the parenthesis indicates arc sine transformed values

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