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Effect of organic and inorganic sources of nutrients on soil fertility status of arecanut (*Areca catechu*) in north-east India

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ABSTRACT

A study was conducted to assess the effect of three different sources of nutrients on soil fertility status in an adult arecanut (*Areca catechu* L.) plantation at Central Plantation Crops Research Institute, Research Centre, Guwahati, during 2008-09 and 2010-2011 in comparison with the planting time. The results revealed that the available nitrogen content was highest (332.6 and 242.3 kg/ha at 0-30 and 30-60 cm soil depth, respectively) in the soil applied with vermicompost, whereas the soils applied with chemical fertilizer recorded maximum available P and K content. However, the availability of these three major nutrients decreased with soil depth, irrespective of the sources of nutrient. Similar was in the case of organic carbon (OC) content and the soils applied with organics recorded higher value. Water holding capacity of soils was highest in organic plot over control and inorganic. Water holding capacity was significantly and positively correlated with organic carbon content but negatively correlated with bulk density of soil. Organic plots resulted almost 2.5 to 2.9 and 1.6 to 1.8 times higher earthworm population than fertilized plot and control plot respectively. Long-term application of compost improved soil physicochemical properties, available N content and also microbial population except available P and K content in soil which collectively resulted increased kernel yield of arecanut. Highest dry *chali* yield (4 496.9 kg/ha) of arecanut was obtained under vermicompost applied palms and was significantly higher than the *chali* yield of arecanut obtained under common compost and chemical fertilizer applied palms were 4 299.5 kg/ha, and 4 270.7 kg/ha, respectively.

Key words: Arecanut yield, Nutrients, Soil physicochemical properties, Soil organisms

A sustainable crop production system must adopt an ecological approach, using balanced nutrient inputs from inorganic, organic and biological sources. Nutrient inputs may either be from organic sources (i.e. crop residues, green manure, and animal manure) or from inorganic sources (i.e. chemical fertilizers and lime). The decline of crop yields under continuous cultivation has been attributed to factors such as acidification, soil compaction and loss of soil organic matter (Dalal *et al.* 1991, Dalal and Mayer 1986). Thus, application of organic material is needed, not only to replenish soil nutrients but also to improve the physical, chemical, and biological properties of soil. To a large extent, this may be achieved by managing the agro-ecosystem in such a way that nutrient sources are generated, recycled and maintained. Sustainable soil nutrient-enhancing strategies involve the wise use and management of inorganic and organic nutrient sources in ecologically sound production systems. The primary goal of integrated nutrient management (INM) is to combine old and new methods of nutrient management into ecologically sound and economically viable farming systems that utilize available organic and inorganic sources of nutrients in a judicious and efficient way. Integrated nutrient management optimizes all aspects of nutrient cycling. The beneficial effects of organic matter are well known (Brady and Well 2008). Physically, it improves soil structure and increases water holding capacity. Chemically, it increases the capacity of the soil to buffer changes in pH, increases the cation retention capacity (CRC), reduces phosphate fixation, and serves as a reservoir of secondary nutrients and micronutrients. Biologically, organic matter is the energy source for soil fauna and microorganisms, which are the primary agents that manipulate the decomposition and release of mineral nutrients in soil ecosystems.

In north eastern region of India, where arecanut (*Areca catechu* L.) is grown in almost every household and mostly devoid of any external application of fertilizers, the importance of organics is enormous. Keeping the above facts in view, a study was undertaken (i) to assess the changes in soil nutrient status on the application of organic/ inorganic sources of nutrient, (ii) to monitor the changes

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in soil organic matter content and (iii) to gain an idea on the microbial population in soils.

MATERIALS AND METHODS

The experiment was conducted in arecanut plantation spaced at 2.7m x 2.7m distance at Central Plantation Crops Research Institute, Research Centre, Kahikuchi, Guwahati, Asom, located in sub-humid area at 20^0 18´N latitude and 91° 78´E longitude. Kahikuchi receives an average annual precipitation of 2500–3000 mm. The mean maximum temperature ranges between 15^0C and 34^0C and mean minimum temperature varies from 8^0C to 22^0C. The relative humidity ranges between 67 to 96%. The soil of the experimental site was clay loam in nature. Arecanut seedlings were planted in 2000 and the experiment was initiated in 2003. The different treatments were: T_0: no application of nutrient, (control); T_1: vermicompost application @ 10 kg/palm/year, T_2: common compost application @ 15 kg/palm/year and T_3: recommended chemical fertilizer (100:40:140 NPK/palm/year). The treatments were applied as two equal split doses during April-May and October-November. Each treatment had nine (9) palms replicated four times. Vermicompost was produced from arecanut leaf by using earthworm species *Eudrilus euginae* and it contains 1.2% N, 0.47% P and 0.52% K content, whereas common compost was produced by a mixture of common weeds, whole banana plant, arecanut leaf sheath, citrus leaf, nutmeg leaf etc. in a pit by spraying water to undergo decomposition and contains 0.72% N, 0.40% P and 0.45% K.

Pre-experimental soil analysis showed that the soil had a pH 5.02, CEC 8.34 cmol (+) kg, bulk density 1.38 Mg/m^3, maximum water holding capacity 40.2% and organic carbon 1.14% at 0-30 cm of soil depth and 5.07, 7.42 cmol(+) kg, 1.48 Mg/m^{-3}, 37.8% and 0.72% at 30-60 cm soil depth, respectively. N, P and K content were 239.4, 48.3, 162.3 kg/ha at 1st depth and 203.3, 24.1, 97.2 kg/ha at second depth, respectively. Before the application of treatments, soil samples were collected during 2008-09 (8th year of planting) and 2010-11 (10th year of planting) at a distance of 75 cm from the arecanut base at 0-30 cm and 30-60 cm depth during the month of April. Representative composite soil samples were dried in shade, ground and sieved through 2 mm sieve for analysis.

The soil pH was measured in 1:2.5 soil: water suspension. Soil organic carbon was estimated following Walkley and Black's method. CEC was estimated by using standard procedures as described by Jackson (1973) and bulk density and maximum water holding capacity (Max. WHC) by the procedures described by Baruah and Barthakur (1993). Available N was measured by using Kel-plus nitrogen distillation unit (Subbiah and Asija 1956). Available P (Bray and Kurtz 1945) and available K were determined by Neutral Normal Ammonium Acetate Extraction Method. Microbial population (Bacteria, actinomycetes and fungi) was also taken into account by counting colony forming unit (cfu/g) through serial dilution plate technique (Pramer and Schmidt 1956). Earthworm population was counted by digging soil in 1 m^2 area under two different depths (0-30 and 30-60 cm) separately and it was converted into earth count per hectare. The data were subjected to statistical analysis by following the technique of ANOVA applicable to Randomised Block Design by using Agricultural statistical package new (AGDATA and AGRES) and SPSS.

RESULTS AND DISCUSSION

Physico-chemical properties of soil

Changes in soil physicochemical properties as influenced by different treatments are presented in Table 1. Current investigation showed that upper layer of soils (0-30 cm depth) of fertilizer treated plot recorded lowest pH (4.82) and control plot recorded highest pH (5.36). The pH was lower in 8th year of application than 10th year under organics applied plots, where it was opposite under fertilizer applied plot and control plot. As soil pH depends upon type of parent material, climatic factors and input materials, continuous application of chemical fertilizer causes a gradual decrease in soil pH and which might be attributed to rapid leaching of bases through comparatively high rainfall in north eastern states. Soil pH increased down the profile might be due to leaching of basic elements from upper depth to the lower depth of soil. Continuous application of nutrient revealed that chemical fertilizer application not only decreases soil pH, it tends to soil pH to strongly acidic. Similar findings reported by Gopalasundaram and Yusuf (April 1989) in red loam soils of coconut plantation that continuous application of chemical fertilizer resulted in reduction in soil pH.

Organic carbon content (Table 1) was high in the soils applied with both form of compost in the 1st layer, but vermicompost applied plot contain highest value (1.29 and 1.32% at 8th and 10th year, respectively) as vermicompost bears more humus than the other form of compost (Shukla *et al.* 2009). Although, chemical fertilizer applied plot and control plot contain high OC at 0-30 cm depth of soil but that might be due to growth of grasses at the base of arecanut palm and decomposition of arecanut leaves *in-situ* under sub-humid climate. Bhat and Mahapatra (1989) reported that there was no significant difference between soil organic carbon content of plots receiving organic manures, inorganic fertilizers and those did not receive under arecanut cultivation due to luxuriant weed growth, under favoured condition of light and moisture inside the plot, which was cut and allowed to undergo incorporated to the plot. A non-significant but slow increase in organic carbon content found between 8th year and 10th year of planting under organically treated soils but it significantly decreased under chemical fertilizer treated soils and no treated (control) soil. As a result of continuous application of compost, it may be opined that there is a slow build-up of organic carbon pool in soil. But it was reverse under fertilizer applied plot and no nutrient applied plot as resulted

Table 1 Physicochemical properties of soil under study

Treatment	pH (1:2.5)				OC (%)				CEC [cmol(+)/kg]				Bulk density (Mg/m^3)				Max WHC (%)			
	8th	10th	Mean	% increase over initial	8th	10th	Mean	% increase over initial	8th	10th	Mean	% increase over control	8th	10th	Mean	% increase over control	8th	10th	Mean	% increase over control
0-30 cm soil depth																				
Vermicompost applied plot	5.10	5.15	5.13	1.0	1.29	1.32	1.31	2.3	12.48	12.55	12.52	0.6	1.33	1.31	1.32		42.6	42.7	42.6	0.2
Compost applied plot	4.98	5.05	5.02	1.4	1.25	1.27	1.26	1.6	11.86	12.04	11.95	1.5	1.35	1.34	1.34		42.7	42.8	42.8	0.2
Fertilizer applied plot	4.82	4.80	4.81		1.11	1.07	1.09		11.56	11.58	11.57	0.2	1.52	1.55	1.54	2.0	38.8	38.7	38.8	
Control plot	5.36	5.35	5.35		0.98	0.93	0.96		10.65	10.55	10.60		1.56	1.57 (0.6)	1.56		37.3	37.2	37.2	
Factors		*P=0.05*				*P=0.05*				*P=0.05*				*P=0.05*				*P=0.05*		
Treatment (T)		0.022				0.019				0.29				0.023				0.4		
Year (Y)		0.016				0.013				0.20				0.017				0.3		
T × Y		0.031				0.026				0.41				0.033				0.5		
30-60 cm soil depth																				
Vermicompost applied plot	5.16	5.18	5.17	0.4	0.82	0.88	0.85	7.3	8.56	8.60	8.58	0.5	1.42	1.42	1.42		38.14	38.16 (0.1)	38.15	0.1
Compost applied plot	5.02	5.04	5.03	0.4	0.94	0.95	0.95	1.1	8.78	8.80	8.79	0.2	1.47	1.47	1.47		37.88	37.93 (0.1)	37.91	0.1
Fertilizer applied plot	6.72	6.70	6.71		0.70	0.69	0.70		9.45	9.40	9.43		1.60	1.61	1.61	0.6	35.32	35.21	35.26	
Control plot	5.42	5.42	5.42		0.66	0.64	0.65		8.33	8.25	8.29		1.65	1.66	1.66	0.6	34.48	34.27	34.38	
Factors		*P=0.05*				*P=0.05*				*P=0.05*				*P=0.05*				*P=0.05*		
Treatment (T)		0.015				0.017				0.20				0.019				0.21		
Year (Y)		0.011				0.012				0.14				0.014				0.15		
T × Y		0.021				0.025				0.28				0.027				0.30		

after 10th year of planting, which clearly express while comparing it with initial value (1.14% at 0-30 cm depth). Down the profile organic carbon content decreased irrespective of the different treatments. Increase in organic carbon content due to application of compost was also reported by Ramesh *et al.* (2008) and Babhulkar *et al.* (2000).

In general, the soils showed low cation exchange capacity (CEC) irrespective of soil depth under different treatments. However, the CEC was found (Table 1) to be decreased in the lower soil depth. Treatment imposed soils showed higher CEC content [range: 11.56 to 12.55 and 8.56 to 9.45 cmol(+)/kg in both soil depth respectively] than the control plot, which might be due to continuous addition of organic substances that having very high negative charge sites in upper soil surface under organic applied soil and phosphate anions and illuviation of phosphates at 30-60 cm depth under chemical fertilizer used plot. Ghosh and Paul (2009) reported that application of phosphatic fertilizer to the soil increases net negative charge in soil which contribute to the increase in CEC content in soil. Continuous application of organic substances produces organic acids which resulted in higher but non-significantly increase in CEC content of soils at 10th year than the 8th year of its application. A significant and positive correlation between CEC and organic carbon ($r = 0.92^*$) of soil was observed.

Bulk density showed a highest value in control soil and soil applied with recommended dose of chemical fertilizer significantly differed (Table 1) to the soils applied with organic. Application of vermicompost and general compost into the soil resulted to formation of soil aggregate as organic substances works as a good cementing agent between particles (Brady and Well 2008) and that might be the reason in lower bulk density of soil at both depth comparable to the non-organic plots. Soils of 8th year and 10th year of planting resulted to slight decreased but non-significant in bulk density in soil applied with organics,whereas non-significant and increasing phenomenon appeared in the chemical fertilizer applied plot and control plot. The increase in bulk density at the 2nd depth (30-60 cm) attributed to the more soil compactness and less organic matter content. Non-availability of organic substances in soils of perennial crop resulted to decrease in soil porosity that influences the bulk density to a higher value at lower depth. Maximum water holding capacity of soil was estimated (Table 1) in the soils of both vermicompost applied plot (mean value of two years: 42.6%) and general compost applied plot (mean value of two years: 42.8%) which were higher than the other treatments. A significant increase in maximum water holding capacity was observed after a long period (on both 8th year and 10th year of nutrient application) of experiment among organic substances applied plots and chemical fertilizer applied plot

Table 2 Changes of nutrient content in soils under study

Treatment	Available N (kg/ha)				Available P (kg/ha)				Available K (kg/ha)			
	8th	10th	Mean	% increase over initial	8th	10th	Mean	% increase over initial	8th	10th	Mean	% increase over initial
					0-30 cm soil depth							
Vermicompost applied plot	332.6	337.3	334.9	1.4	47.7	47.7	47.7		158.7	158.4	158.5	
Compost applied plot	271.0	272.6	271.8	0.6	41.8	40.9	40.4		156.9	155.8	156.3	
Fertilizer applied plot	253.4	249.5	251.4		63.5	64.2	63.9	1.1	187.3	188.1	187.7	0.4
Control plot	187.9	184.8	184.8		19.7	19.3	19.5		124.8	121.4	123.1	
Factors		*P=0.05*				*P=0.05*				*P=0.05*		
Treatment (T)		3.4				2.8				3.0		
Year (Y)		2.4				2.0				2.1		
T × Y		4.9				4.0				4.3		
					30-60 cm soil depth							
Vermicompost applied plot	242.3	244.9	243.6	1.1	23.7	23.6	23.6		103.7	102.3	103.0	
Compost applied plot	234.1	235.6	234.9	0.6	21.6	21.1	21.3		101.4	99.9	100.6	
Fertilizer applied plot	192.3	189.4	190.9		32.2	32.8	32.5	1.7	111.6	114.3	112.9	2.4
Control plot	178.6	175.6	177.1		16.9	16.8	16.8		87.3	86.3	86.7	
Factors		*P=0.05*				*P=0.05*				*P=0.05*		
Treatment (T)		1.5				0.5				3.0		
Year (Y)		1.0				0.4				2.1		
T × Y		2.1				0.7				4.3		

but soils applied with two different kinds of organic substances remained at par. And soils of both organic and chemical sources of nutrients resulted significantly improvement in this character over control plot at both depth. Similar finding was also coined by Kannan *et al.* (2005). The water holding capacity observed to decrease at 2nd depth of soil. It is highly and significantly correlated with organic carbon content (r = 0.94**) of the soil. As a result of continuous application of compost, it was found that organic carbon content increased in its subsequent year which can by described as the reason for increasing water holding capacity of soil at the 10th year of planting. A negative but significant correlation (r = -0.94**) appeared between maximum water holding capacity and bulk density of the soil.

Available nutrient status

Long-term experiment in arecanut garden revealed that available N content increased with time when the garden was maintained with application of organic sources of nutrients. But reverse phenomenon was observed in case of chemical fertilizer applied plot and no nutrient applied plot, i.e. control. Average available N content was recorded (Table 2) highest (335.0 kg/ha) under the soils of vermicompost applied plot, which was 40% increase over initial available N content of soil. All the treatments were significantly differed with each other in available N content at both 8th and 10th year of planting under both depth of soil. The order of available nitrogen status at both 8th year and 10th year of planting was similar to vermicompost applied plot > compost applied plot > chemical fertilizer applied plot > control plot. Down the soil profile available N content was decreased with increasing depth of soil irrespective of the treatments imposed. Similar observation was also reported by Kannan *et al.* (2005). It was really noticeable that application of nutrients in the form of organic builds up a carbon pool in the soil when compared with initial soil carbon status. The available N content was found to be correlated with the organic carbon content (r = 0.84) of the soil.

Available P and K content were highest (Table 2) only in soils applied with chemical fertilizer in both depth of soil as compared to the other treatments in both 8th (P: 63.9 and 32.2; K: 187.3 and 111.6 kg/ha) and 10th (P: 64.2 and 32.8; K: 188.1 and 114.3 kg/ha) years of planting and these were much more higher than the initial P (48.3 kg/ha) and K (162.3 kg/ha) content in 0-30 cm depth of soil. It may be due to continuous application of phosphatic and potassic fertilizer in the surface soil. As vermicompost and general compost were applied in the field on the basis of recommended dose of N and these compost contain little quantity of P and K and the rest amount of phosphorus and potash were not supplemented by other sources. Therefore, a little quantity of available P and K deficit has been created in each spell of fertilizer application for both type of compost applied plot since long period. There was no significant increase or decrease in available P and K

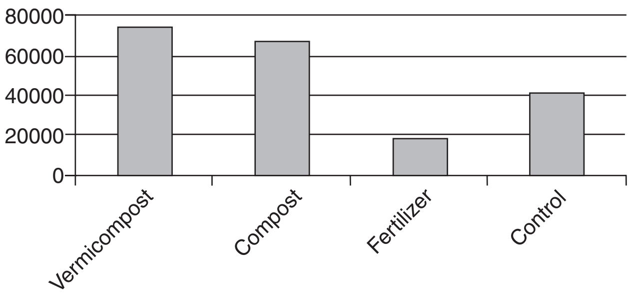

Fig 1 Earthworm count in numbers per hectare

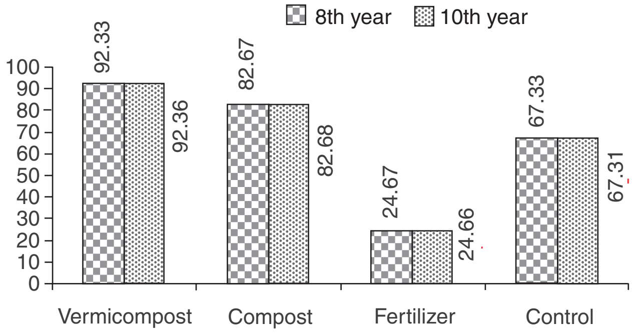

Fig 2 Bacteria population in (× 10^5)

content in soil between 8th and 10th years of planting and both kinds of organic treatments were at par but significantly differed results found among organic treated plot, fertilizer treated plot and control plot after a long period study. Khan *et al.* (1996) found in coconut plantation that continuous application of phosphatic and potassic fertilizer resulted in building up of available phosphorus and potash pool (Fig 2) in soil. Similar findings also reported by Gopalasundaram and Yusuf (1989).

Earthworm and microbial population

A study was conducted at 0–30 cm depth of soil on the population of earthworm in different treatments plot. In both years (8th and 10th years of planting) of soil accounted almost similar result in this point of view which has been presented by Fig 1 considering mean value of both. It was observed in the soils applied with chemical fertilizer accounted less number of earthworms (19 150 no's/ha) than the soils devoid of fertilizer application, i.e. control (41 360). However, soils applied with vermicompost and general compost resulted in highest earthworm count which was almost 1.8 and 1.6 times higher than the control plot and 2.9 and 2.5 times higher than the fertilized plot, respectively. This indicates that application of organic substances in soil increases the population of earthworm which helps in maintaining soil respiration and soil fertilty. With the application of compost (*amrit pani*) earthworm population increased to more than 2 times in comparison to normal soil which was observed by Acharya *et al.* (2008). Similar report also coined by Brady and Well (2008). At lower depth of the soil, earthworm counted was nil which might be due to compactness and low organic matter content.

The study on microbial population under different treatment plots in both the years indicated that the bacterial population in soils of 0-30 cm depth treated with vermicompost resulted highest to 92.33 × 10^5 and 92.36 × 10^5 cfu/g, respectively, which was presented by Fig 2. But actinomycetes (38.67 × 10^4, 38.7 × 10^4 cfu/g) and fungi (12.33 × 10^4, 12.34 × 10^4 cfu/g) population were highest (Fig 3 and 4) in common compost treated plot in 0-30 cm depth of soil. Soils treated with chemical fertilizer resulted lowest population of bacteria and fungi and actinomycetes. Bopaiah and Bhat (1981) suggested that increase in microbial population could be attributed to the increase in organic carbon in soil and the decline of bacteria and actinomycetes population in soils receiving inorganic fertilizer could be attributed to decreased soil pH and low organic matter level in soil. This finding also corroborated with Kannan *et al.* (2005). Under long-term study in arecanut plantation, it may be suggested by seeing the results of the population of bacteria, fungi and actinomycetes during 8^{th} year and 10^{th} year of planting that there was an increasing phenomenon of population in soils under the vermicompost treated plot and common compost treated plot. Very less number of these populations was found in 30-60 cm depth in all the treatments which could be due to less organic carbon, soil compactness influencing less soil aeration. Similar results also reported by Bopaiah and Bhat (1981) in arecanut rhizosphere where cultivations practiced.

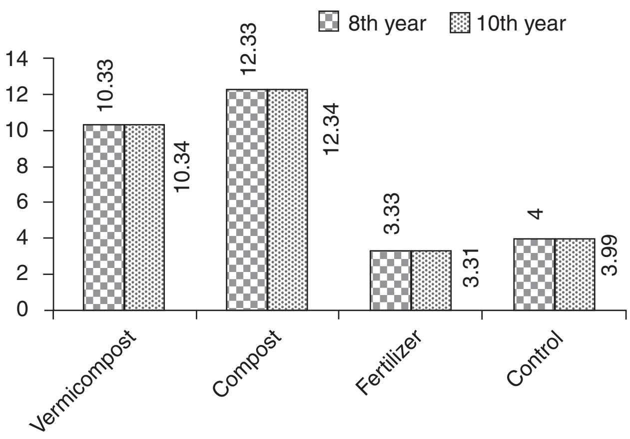

Fig 3 Fungi population in (× 10^4)

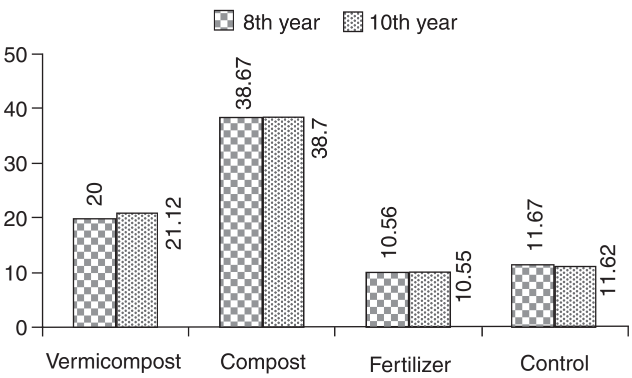

Fig 4 Actinomycetes population in (× 10^4)

Table 3 Some important characteristics of arecanut

Treatment	Fresh nut yield (kg/ha)	Chali weight (kg/ha)	Weight of a healthy nut(g)	Dry husk: chali ratio
Vermicompost	22484.4 (37.1)*	4496.9 (44.4)	44.2 (11.1)	0.91
Compost	21497.3 (31.1)	4299.5 (38.0)	43.6 (9.5)	0.91
Fertilizer	20336.5 (24.0)	4270.7 (37.1)	43.8 (10.1)	0.85
Control	16394.9	3115.0	39.8	0.89
P = 0.05	205.8	42.0	0.7	0.03

* Figure in the parenthesis indicates per cent increase value over control treatment.

Yield

Application of nutrients of any kind enhanced fresh nut yield and fresh nut weight as well as dry *chali* yield (Table 3). Among the different sources of organics, vermicompost had most effective role in producing nut yield and nut weight. The yield increase in the palms applied with vermicompost, FYM and fertilizer suggested external application of fertilizer is of greater importance of achieving optimum yield in arecanut. The magnitude of increase (44%) in vermicompost applied plot for dry *chali* yield was higher than the magnitude of increase in case fresh nut yield over control which suggested that vermicompost helped in increase of kernel weight. Fresh nut weight was maximum (44.2 g) under vermicompost applied palm followed by chemical fertilizer (43.8 g), general compost (43.6 g) and non-application of nutrient (39.8 g) of healthy fruit. There was no significant difference among the nutrient applied treatments for fresh nut weight but were significant different from control. Highest dry husk: *chali* ratio (0.91) was estimated under organic applied palms followed by chemical fertilizer applied palms (0.85) and were significant different. Dry husk:*chali* ratio under organic sources, chemical sources and control treatments were significantly different.

Table 4 Contribution of soil characteristics on prediction of yield

Multiple regression equations	$R^2 \times 100$
$Y = 7567.95 + 53.13X_1$	90.5
$Y = 11122.36 + 35.55X_1 + 2251.97X_2$	99.3
$Y = -6044.23 + 38.77X_1 + 1441.96X_2 + 18.63X_3$	99.6
$Y = 26701.51 + 10.28X_1 + 120.69X_2 + 65.21X_3 + 12421.87X_4$	99.9
$Y = 28764.15 + 9.02X_1 + 68.64X_3 + 13076.15X_4$	99.9
$Y = 43058.15 - 4.68X_1 + 23.33X_3 + 18374.99X_4 + 79.65X_5$	100

X_1 = Available N, X_2 = CEC, X_3 = available K, X_4 = bulk density, X_5 = available P.

Relationship between yield and soil test parameters

Regression equations were computed to assess the contribution of soil parameters on fresh and dry yield of arecanut was presented in Table 4. Stepwise regression analysis revealed that total fresh nut yield/ha was the result of combined effect of available N, CEC, available K, bulk density and available P content of soil. Available N alone found to contribute 90% variation in the total fresh nut yield. But available N and cation exchange capacity (CEC) combined can explain 99% variation in the total fresh nut yield. Available N, CEC, available K and bulk density combinedly can explain about 100% variation in the total fresh nut yield. Besides available N, available K, bulk density and available P can explain 100% influence on the total fresh nut yield when CEC was excluded.

From the study above, it can be concluded that application of nutrients in the form of compost, there would be improvement of soil physico-chemical characteristics, soil macro and microorganisms leading to increase in arecanut yield and vermicompost would be showing most efficient activity.

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