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IMPACT OF NATURAL FARMING AND INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON SOIL FERTILITY AND CROP YIELD IN ARECANUT WITH BLACK PEPPER CROPPING SYSTEM

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ABSTRACT

Maintaining soil fertility is essential for sustaining the long-term productivity of arecanut gardens, particularly in multi-tier cropping systems involving black pepper. As a perennial crop, arecanut requires a continuous and balanced nutrient supply, making effective nutrient management crucial for ensuring soil health and crop performance. An experiment was conducted during 2022-2023 to study the effect of natural farming and integrated nutrient management practice on soil fertility status in arecanut with black pepper cropping system at Horticulture Research and Extension Center, Sirsi, Karnataka. The experiment was laid out in RCBD with four treatments: (1) Integrated nutrient management, (2) Organic farming practice, (3) Natural farming practice and (4) Chemical farming practice. The study revealed that, the soil organic carbon (1.09%) was observed highest under organic farming practice. Higher values of available primary and secondary nutrients were found in integrated nutrient management practice compared to other nutrient management practices. Similarly, the DTPA extractable micronutrient such as Fe and Mn content was recorded higher in organic farming practice. Whereas, Zn and Cu was higher in INM practice. Higher yield of arecanut and black pepper (3083.06 and 322.36 kg ha^{-1}, respectively) was recorded in INM treatment as compared to other treatments. It was observed from the present study that the soil fertility status of arecanut and black pepper was recorded higher in INM and organic farming practice compared to other nutrient management practice. Therefore, adopting sustainable nutrient management practices like organic farming and integrated nutrient management can play a crucial role in ensuring the long term productivity and health of arecanut and black pepper garden soils.
***Keywords*:** Integrated nutrient management, Soil fertility, Productivity, Organic farming, Arecanut, Black pepper.

Introduction

Arecanut (*Areca catechu* Linn.) is one of the important plantation crops, and about 90 per cent of total arecanut production in India is mainly contributed by Karnataka, Kerala and Assam. Black pepper (*Piper nigrum* L.) is raised exclusively as mixed crop in homestead gardens in Kerala and Karnataka, wherein, vines are trained on coconut and arecanut trunks. Arecanut is predominantly cultivated in laterite soils, which have inherent constraints like P fixation, rapid hydraulic conductivity, faster infiltration rate, leaching of basic cations and low CEC (3–15 cmol kg^{-1}). Thus, this perennial palm requires large quantity of nutrients to support its growth and yield. Soil fertility plays a pivotal role in determining the growth, yield, and quality of arecanut and its intercrops. However, intensive cultivation, unbalanced fertilizer use, and declining organic matter levels have led to the gradual depletion of soil nutrients in many plantation areas. This degradation affects not only crop yields but also long-term soil health and ecosystem stability. Hence, the adoption of sustainable nutrient management strategies has become increasingly important.

An ecological approach through the utilization of both organic and inorganic nutrient inputs will help in sustainable yield production of the crops. Nutrient input enhancing and recycling on existing crop land is required for intensifying food production for food security. Crop yields are highly affected mainly due to compaction of soils, acidification and decrease in organic matter of soils (Dalal *et al*., 1991). Organic matter application to the soil will help in replenish soil nutrients and also improve soil physical, biological and chemical properties.

Organic farming, integrated nutrient management practices and natural farming have expanded rapidly in recent years as viable alternatives to chemical-based agricultural systems. Overuse of fertilizers not only reduces fertilizer efficiency, but also causes environmental degradation through nutrient runoff and biodiversity loss (Li *et al.,* 2015 and Zhang *et al.,* 2012). Organic farming aims to enable the soil to provide the crop with all the nutrients it needs for healthy growth and development. Organic farming is a special agriculture approach that promote and enhances agro-ecosystem health such as soil biological activity, biological cycles and biodiversity. Adoption of integrated nutrient management (INM) practices is a practical way to improve the soil fertility status by increasing soil organic matter in the surface soil layer that ultimately will minimize soil erosion and boosts the soil biological and also chemical attributes (Ghosh, 2010). 'Natural farming' is a natural agriculture alternative which promotes lower production costs and is able to achieve products of high quality and yield without usage of chemical fertilizers. These various nutrient management techniques have an influence on soil nutrient holding capacity, organic carbon status in soil and subsequently productivity. Therefore, a thorough understanding of the dynamics of soil nutrients as impacted by different nutrient management strategies may be beneficial for establishing soil fertility management approaches to protect soil health for sustainable agriculture. The main objective of this study is to assess the effect of natural farming and integrated nutrient management practice on soil fertility status in arecanut with black pepper cropping system

Material and Methods

Description of the study site

The present investigation was carried out at Horticulture Research and Extension Center, Sirsi. Geographically Sirsi is located in the agro-climatic Zone 9 (Hilly zone) of Karnataka. The study area lies between 14°37' North latitude and 74° 85' East longitudes. The altitude of the study area is 590 m above mean sea level. The soil of the experimental site was sandy loam to sandy clay loam in texture.

Experimental Details

The experiment was conducted in > 30 years old arecanut with black pepper plantation. The experiment was laid out a randomized block design (RBD) with four treatments and five replications. The treatments included (1) Integrated nutrient management practices, (2) Organic farming practices, (3) Natural farming practice, (4) Chemical farming practices. Recommended fertilizer dose for arecanut and black pepper is 100:40:140 g N/P/K per palm per year. The recommended dose of N, P, and K fertilizers together with micronutrient fertilizers and organic sources like vermicompost, FYM and biofertilizers were applied per palm per year as per UHS, Bagalkot package of practice. Additionally, 1kg of lime/palm/year was applied uniformly to all the treatments during the pre-monsoon period as per the recommendation. Ganajeevamrutha was applied at the rate of 400 kg/acre in split doses during the pre-monsoon (200 kg/acre) and post-monsoon (200 kg/acre) period. Jeevamrutha was sprinkled on soil (200 l/acre) at 15-day intervals. 1% Bordeaux mixture is also sprayed during the monsoon period.

Soil Sample Preparation and Analysis

Soil samples were collected at three depths of 0–20, 20–40 and 40-60cm in root zone at 60 cm from the tree trunk. The air-dried soil samples were ground to pass through a 2.0-mm sieve and kept in labeled plastic bags for further analysis. Soil samples were analyzed, pH (soil: water 1:2.5) was measured with the help of pH meter (Jackson, 1973); organic carbon by Walkley and Black (1934) chromic acid digestion method. Available nitrogen in soil was determined by using Kel-plus nitrogen distillation unit (Subbiah and Asija, 1956). The available phosphorus was determined following the procedure described by Bray and Kurtz (1945) and potassium was determined flame photometrically by neutral normal ammonium acetate extraction method (Jackson, 1973). Calcium and magnesium was determined by complexometric titration method (Page *et al.,* 1982). Available sulphur content is by turbidometry method (Hesse, 1994). The concentration of micronutrients was estimated in MPAES using diethylenetriaminepentaacetic acid (DTPA) extract (Lindsay and Norvell, 1978).

Statistical analysis

Data obtained during the investigation was subjected for two factorial RCBD. By taking nutrient management practices and soil depth as factors. Statistical analysis was performed at a 5 % level of significance using OPSTAT software.

Results and Discussion

Soil pH and electrical conductivity (EC)

The soil pH and EC did not vary among different nutrient management practices and depth. The pH and EC of the soil was slightly higher in the subsurface soils of chemical farming practice as compared to other treatments (Table 1). The variation of soil pH and EC in areca fields is due to the application of inorganic fertilizers, organic manures, straw mulching and frequent irrigations might have slightly altered these soil properties. Increased microbial activity in the soil leads to a fall in pH when organic matter is added to the soil (Mohana Rao *et al.*, 2013). Similar observations on pH and EC alterations with the use of fertilizers are reported by Saha *et al*., 2008 and Kumari *et al.,* 2019.

Table 1: Soil reaction (pH) and electrical conductivity (EC) in acid soils as influenced by different nutrient management practices in arecanut with black pepper cropping system

Treatments	pH				EC (dS m^{-1})			
	Soil depth (cm)				Soil depth (cm)			
	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean
T_1	5.81	6.01	6.11	5.98	0.18	0.16	0.19	0.18
T_2	5.82	5.70	5.90	5.81	0.14	0.18	0.15	0.16
T_3	5.45	5.84	5.75	5.68	0.13	0.15	0.16	0.14
T_4	6.20	6.02	6.25	6.15	0.19	0.17	0.21	0.19
Mean	5.82	5.89	6.00		0.16	0.17	0.18	
Interaction	M	D	M x D		M	D	M x D	
S. Em.±	0.13	0.11	0.22		0.03	0.02	0.04	
CD at 5%	NS	NS	NS		NS	NS	NS	

*T_1- Integrated nutrient management, T_2- Organic farming practice, T_3- Natural farming practice and T_4- Chemical farming practice
M- Nutrient management practice, D- Depth, M x D- Interaction between nutrient management practice and depth, NS- non-significant

Soil organic carbon

Soil organic matter is a source of essential plant nutrients and acts as a source of food for soil microorganisms. The SOC content differed among the nutrient management practices it ranged from 0.30% to 1.25%. The higher (1.09%) SOC content was recorded under organic farming practice and natural farming system (1.02%) as compared to INM practice (0.64%) and the least was (0.43%) in chemical farming practice (Table 2). Increased soil organic carbon content might be due to the application of organic manures such as FYM and VC to organic treated and ganajeevamrutha, jeevamrutha and mulching practices in natural farming, resulting in enhanced soil microflora with a drastic increase in different soil enzymes which in turn contributes more organic carbon to the soil. The results were in agreement with the findings of Hongal *et al.,* 2023, Dutta *et al.*, 2022 and Sujatha and Bhat, 2012. organic carbon content of surface soil was higher (0.97%) than that of the subsurface soil layer (0.60%) which was due to the various carbon input distributions in terms of root biomass, root exudates, rhizospheric deposition, followed by slow decomposition due to poor oxygenic conditions for microbial oxidation at deeper soil layers. The results are consistent with the findings of Padbhushan *et al.* (2016) and Mahanta *et al.* (2013).

Major nutrients (Available Nitrogen, Phosphorus and Potassium)

In perennial crops like arecanut and black pepper, sustained nutrient availability is critical as the crops have long-term nutrient demands. Maintaining optimal levels of NPK ensures continuous productivity and supports root development, foliage health, and fruiting. Different nutrient management approaches such as natural farming and integrated nutrient management (INM) have varied effects on nutrient cycling, microbial activity, and organic matter dynamics, which in turn influence primary nutrient availability. The soil available nitrogen, phosphorus and potassium content significantly differed with nutrient management practices and depth. Among the nutrient management practices, the available nitrogen, phosphorus and potassium content was significantly higher (242.28 kg ha^{-1}, 21.71 kg ha^{-1} and 265.23 kg ha^{-1}, respectively) in soils under INM practice as compared to other nutrient management treatments.

Table 2: Soil organic carbon status in acid soils as influenced by different nutrient management practices in arecanut with black pepper cropping system

Treatments	**Soil organic carbon (%)**			
	Soil depth (cm)			
	0-20	**20-40**	**40-60**	**Mean**
T_1	2.13	1.48	1.14	1.60
T_2	2.98	2.88	2.15	2.67
T_3	3.02	2.89	2.06	2.66
T_4	1.41	1.21	0.84	1.15
Mean	2.38	2.11	1.56	
Interaction	M	D	M x D	
S. Em.±	0.05	0.04	0.09	
CD at 5%	0.15	0.13	NS	

*T_1- Integrated nutrient management, T_2- Organic farming practice, T_3- Natural farming practice and T_4- Chemical farming practice
M- Nutrient management practice, D- Depth, M x D- Interaction between nutrient management practice and depth, NS- non-significant

However, the lowest (165.33 kg ha^{-1}, 17.81 kg ha^{-1} and 169.74 kg ha^{-1}, respectively) was recorded in natural farming practices (Table 2). The availability of major nutrients in sub surface soil was found to be lesser compared to surface soil. The higher available nitrogen, phosphorous and potassium in INM treatment may be due to the conjoint application of inorganic fertilizers, organic manures (FYM and vermicompost), liquid organic manures (jeemanrutha and ganajeevamruta), biofertilizers and organic mulching enhances the mineralization of nutrients and reduces the loss of nutrients through leaching, denitrification and volatilization.

The release of weak organic acids during the decomposition of organic manures dissolves the fixed nutrients and enhances their availability in the soil (Paul *et al.,* 2020). Such observation on the increase in value of available major nutrients was recorded in plots where the combined application of fertilizers and organic manures was done as compared to only chemically fertilized plots are in conformity with the findings of Kumar *et al.,* 2019 and Gupta *et al.,* 2018.

Secondary nutrients (Exchangeable Calcium and Magnesium and available Sulphur)

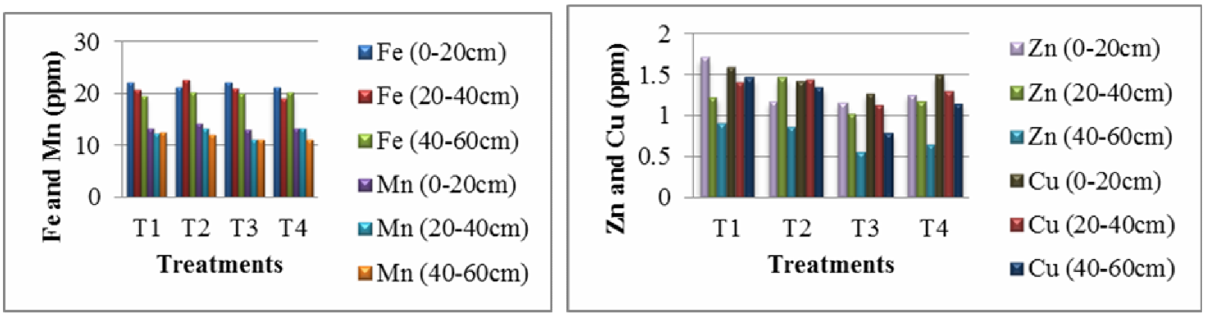
In long-term cropping systems like arecanut and black pepper, continuous nutrient uptake without adequate replenishment can lead to gradual depletion of secondary nutrients, impacting yield and plant health. Secondary nutrients Calcium (Ca), Magnesium (Mg), and Sulphur (S) are vital for physiological and biochemical functions in plants. Though required in lesser amounts than primary nutrients, their role is critical in maintaining soil structure, chlorophyll synthesis, and protein formation. Calcium is essential for cell wall strength and improves soil aggregation, aiding water infiltration and root penetration. Magnesium is a central component of chlorophyll, crucial for photosynthesis. Sulphur is important for enzyme activation and synthesis of amino acids and vitamins. Exchangeable Ca^{2+}, Mg^{2+} and available sulphur content in soils differed significantly with depth and nutrient management practices. The values of exchangeable Ca^{2+}, Mg^{2+} and sulphur content of surface soils (0-20cm) in INM treatment plots were significantly higher (5.89 cmol (p^+) kg^{-1}, 2.22 cmol (p^+) kg^{-1} and 23.31 ppm, respectively) than that of organic farming practice and chemical farming practice and the least (4.00 cmol (p^+) kg^{-1}, 1.47 cmol (p^+) kg^{-1} and 18.34 ppm respectively) was noticed in natural farming practice as depicted (Table 3). All the surface soils recorded the highest calcium, magnesium and sulphur content than subsurface soils.

The higher Ca and Mg content in INM areca garden soil may be attributed to application of agricultural lime ($CaCO_3$) and dolomite ($CaCO_3$ $MgCO_3$). The addition of lime along with organic manures reduces the loss of basic cations and increased the secondary nutrients content in soil and also because of addition of organic manures, which leads to Ca^{2+} and Mg^{2+} binding to aggregates through decomposition (Sujatha and Bhat, 2012). Ananthanarayan and Ravi, 1997 and Paul *et al.,* 2015 observed similar results. The reason for higher available sulphur content in soil under INM may be due to applications of S-containing fertilizers (single super phosphate or ammonium sulphate) and $CuSO_4$ (through Bordeaux mixture) responsible for higher S in that system. Similar results on higher S availability were observed by (Shivakumar *et al.,* 2010 and Nichitha *et al.,* 2023).

Micronutrients (DTPA extractable Iron, Zinc, Copper and Manganese)

Crops like arecanut and black pepper, grown in perennial, high-input systems, are often sensitive to micronutrient imbalances, especially under continuous cultivation and monocropping conditions. Micronutrients like Fe, Mn, Cu, and Zn, though required in small quantities, are critical for enzyme activation, photosynthesis, respiration, and hormone regulation in plants. Their deficiency can impair vital physiological functions and reduce crop productivity. The amount of DTPA extractable micronutrients Fe and Mn were found higher in organic farming practices compared to other treatments. Similarly, the concentration of Zn and Cu micronutrients was higher under INM practice soils than in organic farming and natural farming practices (Figure 1). In general; DTPA extractable Fe, Mn, Zn and Cu content were higher in surface soils than sub surface soils.

Sufficiency level of available copper and zinc in INM practice might be attributed to spraying Bordeaux mixture, Zn and Cu-fungicides to control fruit rot (koleroga) disease, besides the application of zinc sulphate to areca (Jayaprakash *et al.*, 2022 and Choudary *et al.*, 2022). It was observed that all soils recorded available iron above the critical limit. This was attributed to the soils being derived from granite and tanzanite parent rocks with hot humid climatic conditions resulting in the development of lateritic type soils which are rich in iron and aluminium hydroxide. The sufficiency of manganese might be attributed to chelation by organic compounds released during the decomposition of organic matter (Sharan *et al.*, 2020). These results are in accordance with the findings of Verma *et al.,* 2005.



NOTE: T_1- Integrated nutrient management, T_2- Organic farming practice, T_3- Natural farming practice and T_4- Chemical farming practice

Fig. 1 : Micronutrients (DTPA extractable iron, zinc, copper and manganese) influenced by different nutrient management practices in arecanut with black pepper cropping

Yield of arecanut and Black pepper

The higher yield of arecanut and black pepper was obtained in INM treatments (3083.06 and 322.36 kg ha^{-1}, respectively). In contrast, the lower yield of arecanut and black pepper was recorded under natural farming treatment (1603.04 and 89.86 kg ha^{-1}, respectively). Whereas, moderate yield was recorded in organic farming (2255.00 and 150.74 kg ha^{-1} respectively) and chemical farming treatments (2074.08 and 145.24 kg ha^{-1}, respectively). The differences in yield could be attributed due to variations in soil nutrient availability as determined by nutrient applications (Jayachandran *et al.*, 1991). The addition of organic manures is essential for restoring soil quality and sustaining production. However, the application of organic manures alone improves soil health, whereas, the nut yield in organic systems was reduced by 22-45% over inorganic systems (Lawande *et al.*, 2009). The higher application of N, P and K fertilizers might have contributed to increased arecanut and pepper yield as in the case of the integrated nutrient management practices. These results were in conformity with Nair and Verma, 1970. The yield differences between organic farming practices and natural farming practices could be attributed to variations in the use of organic manures. These are in conformity with results obtained by Kambar *et al.*, 2025 that higher yields were obtained with moderate fertilizers and high FYM applications and lesser yields in high fertilizer applied fields.

Conclusion

The study reveals that integrated nutrient management, organic farming and natural farming practices have a substantial and positive impact on the soil fertility status within arecanut and black pepper cropping systems. Integrated nutrient management enhances crop productivity and soil health through a balanced combination of organic and inorganic inputs, while organic and natural farming practices promote sustainability, biodiversity, and improved soil microbial activity. The choice of the most appropriate practice should be context-specific, with a focus on ensuring long-term soil fertility and productivity in these important cropping systems. Overall, the findings suggest that INM offers the most effective strategy for achieving higher yields while also maintaining soil fertility, making it a suitable and balanced approach for sustainable arecanut–black pepper production systems.

Table 2: Major nutrients (Available nitrogen, phosphorus and potassium) status in acid soils as influenced by different nutrient management practices in arecanut with black pepper cropping system

Treatments	Available nitrogen (kg ha^{-1})				Available phosphorous (kg ha^{-1})				Available potassium(kg ha^{-1})			
	Soil depth (cm)				Soil depth (cm)				Soil depth (cm)			
	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean
T_1	300.53	239.93	186.37	242.28	34.86	23.01	19.76	25.88	284.68	262.06	248.95	265.23
T_2	232.69	210.76	158.97	200.81	21.66	16.83	14.95	17.81	203.17	182.29	169.6	185.02
T_3	215.13	141.02	139.83	165.33	17.42	19.09	13.09	16.53	191.74	169.43	148.04	169.74
T_4	282.87	194.37	167.83	215.02	24.52	22.21	18.41	21.71	219.17	262.71	190.24	224.04
Mean	257.81	196.52	163.25		24.62	20.29	16.55		224.69	219.12	189.21	
Interaction	M	D	M x D		M	D	M x D		M	D	M x D	
S. Em.±	7.46	6.61	13.23		1.82	1.58	3.16		12.57	10.89	21.77	
CD at 5%	21.77	18.86	37.72		5.20	4.50	NS		35.83	31.03	NS	

Table 3: Secondary nutrients (Exchangeable calcium and magnesium and available sulphur) status in acid soils as influenced by different nutrient management practices in arecanut with black pepper cropping system

Treatments	Exchangeable calcium (c mol p^{+} kg^{-1})				Exchangeable magnesium (c mol p^{+} kg^{-1})				Available sulphur (ppm)			
	Soil depth (cm)				Soil depth (cm)				Soil depth (cm)			
	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean
T_1	5.89	5.37	4.04	5.10	2.33	2.27	2.06	2.22	24.53	22.52	22.87	23.31
T_2	5.28	4.65	3.87	4.60	2.13	1.76	1.64	1.84	22.65	19.76	17.76	20.06
T_3	4.00	4.71	3.02	3.91	1.73	1.48	1.21	1.47	20.26	18.76	16	18.34
T_4	5.12	4.51	3.46	4.36	1.88	1.55	1.32	1.58	23.59	21.12	14.21	19.64
Mean	5.07	4.81	3.55		2.02	1.77	1.56		22.79	20.80	16.25	
Interaction	M	D	M x D		M	D	M x D		M	D	M x D	
S. Em.±	0.23	0.20	0.34		0.17	0.14	0.29		0.83	0.72	1.44	
CD at 5%	0.65	0.75	NS		0.48	0.41	NS		2.38	2.06	NS	

NOTE: T_1- Integrated nutrient management, T_2- Organic farming practice, T_3- Natural farming practice and T_4- Chemical farming practice M- Nutrient management practice, D- Depth, M x D- Interaction between nutrient management practice and depth, NS- non-significant

Table 4: Yield of arecanut and black pepper influenced by different nutrient management practices

Treatments	Yield (kg ha^{-1})	
	Arecanut	Black pepper
T1: INM practice	3083.06	322.36
T2: Organic farming practice	2255.00	150.74
T3: Natural farming practice	1603.04	89.86
T4: Chemical farming practice	2074.08	145.24
Mean	2253.80	177.05
S. Em.±	117.29	8.81
CD at 5%	365.41	27.46

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