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Different Farming Systems Concerning Soil Health and Yield of Arecanut and Black Pepper

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

We conducted two year (2020 and 2021) field experiment in the farmer's field at Hanagal, Sirsi, Karnataka to study the impacts of different farming practices (Recommended package of practice; (RPP), Organic farming, Natural farming and Chemical farming) on rhizosphere microflora, soil nutrient status and yield of arecanut and black pepper. The results revealed that, soil pH and electrical conductivity did not vary significantly due to different farming systems. Whereas, the significantly ($p<0.05$) highest soil organic carbon content was in organic farming (0.74%) which was on par with natural farming (0.66%) and least in chemical farming (0.71%). The highest available nitrogen (258.31 kg ha^{-1}), phosphorus (39.06 kg ha^{-1}) and potassium (205.47 kg ha^{-1}) were in RPP. Whereas the highest secondary nutrients and micronutrients content were in organic and natural faming. The lowest of all these nutrients were recorded in chemical farming at the harvest stage of arecanut. Soil microflora, dehydrogenase and phosphatase activity in the arecanut and black pepper rhizosphere were significantly ($p<0.05$) highest in natural farming and lowest in chemical farming. Concerning yield, the significantly highest arecanut (Chali yield 29.35 q.ha^{-1}) and black pepper (dry yield 12.07 q. ha^{-1}) yield was in RPP and maximum net return also observed in RPP (Rs. 10, 62, 500 ha^{-1}).

Keywords: Arecanut; black pepper; enzyme activity; microflora; nutrients status; soil organic carbon.

1. INTRODUCTION

Agriculture has been the backbone of the Indian economy for centuries. Recently, more than half of the country's population depends on agriculture and allied services for their livelihoods [1]. Over the last few decades there has been a major transformation in the Indian agricultural sector. With the introduction of 'Green Revolution' technologies, agriculture in India has transitioned from subsistence to commercial farming. However, despite the success, the input-intensive 'Green Revolution' has often masked significant externalities, affecting natural resources, human health and agriculture itself. The green revolution increased agricultural output through higher fertilizer and pesticide application, improved irrigation, soil management regimes, crops and significant land conversions. Using chemicals in agriculture resembles giving our soils steroids. It not only depletes the land but also causes the farmer to go into debt. The prevailing agriculture system in India is characterized by high production costs, high-interest rates, volatile market prices for crops, and rising costs for fossil fuel-based inputs and private seeds. As a result, Indian farmers (small holders) increasingly find themselves in debt [2]. The need for an alternative farming system increased significantly. Various forms of alternative low-input farming practices have emerged in different corners of the world, promising reduced input costs and higher yields for farmers. As a result, Natural Farming is the only solution to an ever-increasing challenge (NF). 'Natural farming' is farming in harmony with nature and without the use of chemicals. Subhash Palekar, the ZBNF's discoverer, provided several theories, principles, and methodologies. These principles include mulching, soil protection measures, natural insecticides, and fertilizers that are used by zero-budget farmers. Crop rotation, green manures and compost, biological pest management, and mechanical cultivation are the main inputs of ZBNF. Jeevamrutha, Beejamrutha, Acchadana, and Whapasa are the most well-known ZBNF pillars, and their influence was tested with an organic, recommended package of practice and chemical farming on nutrient-heavy crops. Arecanut and black pepper are the major cropping systems of the Uttara Kannada district cultivated over more than 10,000 hectares. It is the major source of livelihood for small and marginal farmers. An attempt is made here to evaluate the effect of different farming practices (chemical, organic, natural, and recommended package of practices; RPP) on rhizosphere microflora, soil fertility, and yield of arecanut and black pepper.

2. MATERIALS AND METHODS

We carried out a field demonstration on the use of various farming systems during 2020 and 2021 on a silty loam, moderately deep, red soil in arecanut and black pepper mixed cropping system at a farmer's field in Hanagal, Karnataka. The experiment was conducted in the arecanut (var. Mangala) plantation of 12 years and the black pepper vines (var. Panniyur-1) five years. The climate of the experimental area is warm and humid with a mean annual precipitation of 2500 mm and mean minimum and maximum temperature of 19.4° C and 30.3° C, respectively.

The pH (1:2.5) of the soil (0-30 cm depth) was 5.67, electrical conductivity (EC) 0.17 dSm^{-1}, organic carbon 0.56%. Available nitrogen, phosphorus, potassium and sulphur were 242, 29.99, 195 kg ha^{-1} and 11 mg kg^{-1}, respectively. The exchangeable calcium and magnesium contents were 18.70 and 3.90 cmol (p^{+}) kg^{-1}, respectively. Diethylenetriamine pentaacetatic acid (DTPA) extractable iron, zinc, copper and manganese were 5.51, 0.67, 2.28 and 15.70 mg kg^{-1}, respectively.

Soil samples were collected from the arecanut and black pepper rhizosphere at the harvest stage of arecanut for enumeration of beneficial microflora (P-solubilizers and Free-living N fixers) and enzyme activity (dehydrogenase and phosphatase). Enumeration of N fixers and P solubilizers was carried out by plate technique using Norries N free and Pikovskayas agar, respectively. The dehydrogenase and phosphatase activity of soil samples were determined described by Casida et al. [3] and Evazi and Tabatabai [4].

We designed a randomised block with five replications for the following treatments: T_1: Recommended package of practice, T_2: Organic farming, T_3: Natural farming, and T_4: Chemical farming. Lime ($CaCO_3$) was applied uniformly to all the treatments during the pre-monsoon period as per the requirement. The nutrients used in different farming systems was given in the Table 1 and the average nutrients composition of different organic manures used in the experiment were given in Table 2. Analysis of variance (ANOVA) was carried out using the randomised block design method and Least Significance Difference (LSD) was calculated for treatment means at 5% probability [5].

Soil samples were collected from 0-30 cm depth at the harvest stage of arecanut. The pH of the soil was estimated in 1:2.5 soil: water suspension by using a pH meter. The electrical conductivity was estimated in the supernatant solution of 1:2.5 soil: water suspension using a conductivity bridge. Organic C was determined by the wet digestion method of Walkley and Black [6]. Available nitrogen was estimated by distilling soil with 0.5% KMnO4 in a micro-Kjeldhal apparatus [7]. Available phosphorus was extracted with 0.03 N NH_4F + 0.025 N HCl and estimated spectrophotometrically [8]. Available potassium was extracted with neutral 1N NH_4OAC and estimated using flame photometer. Available micronutrients (Zn, Fe, Mn and Cu) were extracted with DTPA [9] and estimated by atomic absorption spectrophotometer (Varian spectra AA 20 plus).

3. RESULTS AND DISCUSSION

3.1 Effect of Different Crop Production Practices on Soil Fertility Status

3.1.1 Soil pH and Electrical Conductivity (EC)

The results revealed a slight non-significant increase in soil pH and EC in all treatments (Table 3). This might be attributed to the application of lime to all the treatments during the pre- monsoon period. The highest increase in soil pH was in organic farming followed by RPP. Whereas the highest and lowest EC among the treatments were in chemical and organic farming, respectively. The slight increase in soil pH in organic farming and RPP might be attributed to the release of basic cations during the decomposition of farm yard manure (FYM) and vermicompost (VC), which in turn enhances the soil physico-chemical properties and reduces the loss of basic cations through leaching. The lower EC value might be due to the reduction of salt concentration in soil solution and increased water holding capacity with the addition of organic matter. Fan et al. [10] reported that a decrease in soil pH with the use of chemical fertilizers and a decrease in soil pH with continuous application of jeevamrutha was noticed by Ravi et al. [11].

3.1.2 Soil Organic Carbon (SOC)

An increase in soil organic carbon content was in RPP, organic and natural farming, whereas it decreased in chemical farming in both the years (2020 and 2021). The soil organic carbon content was significantly ($p<0.05$) high in organic farming which was on par with natural farming and the least was in chemical farming (Table 3). Increased soil organic carbon content might be due to the application of organic manures such as FYM and VC to organic treated and ghanajeevamrutha, jeevamrutha and mulching practices in natural farming, resulting in enhanced soil micro flora with a drastic increase in different soil enzymes which in turn contributes more organic carbon to the soil. The decrease in soil organic carbon content in chemical farming might be due to less humus formation and oxidation caused by high temperature and leaching of soluble humic complexes due to the coarse textured nature of the soil. Similar findings were from Chaithra [12] and Gupta et al. [13].

3.1.3 Major nutrients (Available nitrogen, phosphorus and potassium)

In the first year of the experiment i.e. 2020, the available nitrogen, phosphorus, and potassium contents in soil did not vary significantly among the treatments. But in the second year i.e. 2021 these nutrients were significantly ($p<0.05$) varied among the treatments.

The significantly highest available nitrogen, phosphorus and potassium contents in soil were recorded in RPP, which was on par with organic, and chemical farming, and the lowest were in natural farming (Table 4). The combined application of chemical fertilizers and organic manures in RPP treatment 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 [14]. Similar results were observed by Bhat and Sujatha [15] and Paul et al. [16].

3.1.4 Secondary nutrients (Exchangeable calcium and magnesium and available sulphur)

The highest available sulphur content was in organic farming, which was on par with natural farming, and the lowest was in chemical farming. Exchangeable calcium and magnesium contents in soil did not differ significantly in both the years (2020 and 2021). However, the highest exchangeable calcium and magnesium contents in soil were in organic farming, which was followed by natural farming and RPP, and the lowest were in chemical farming (Table 5). The addition of lime along with organic manures reduces the loss of basic cations and increased the secondary nutrients content in soil [17]. The consistently declining trend of secondary nutrients with chemical farming warrants the supplementation of NPK fertilizers with calcium and magnesium for the maintenance of soil health and sustainable crop production.

3.1.5 Micronutrients (DTPA extractable iron, zinc and manganese)

DTPA extractable zinc, copper, iron, and manganese contents in soil were non-significant among the treatments. A slight increase in these micronutrients was in RPP, organic, and natural farming practices, whereas a slight decrease was in chemical farming practices (Table 6). Among the treatments, the highest DTPA extractable zinc was in RPP, which was followed by organic and natural farming. This might be due to the application of zinc sulphate to the RPP treatment at the time of the pre-monsoon period. Whereas the highest copper was in natural farming and iron and manganese contents in organic farming and the lowest of Zn, Cu, Fe, and Mn, were in chemical farming. These results are in agreement with those of Verma and Mathur [18] and Zhang et al. [19].

3.1.6 Effect of different crop production practices on soil microbial population and enzyme activity

The significantly ($p<0.05$) highest population of free nitrogen fixers, phosphorus solubilizing microbes, dehydrogenase and phosphatase (6.80 µg pnp released g^{-1} soil h^{-1}) activity were in natural farming, which was on par with organic farming, and the lowest were in chemical farming (Fig 1 and 2). The application of jeevamrutha at frequent intervals help to increase the soil biological activity in the soil [20,11].

3.1.7 Effect of different crop production practices on yield and net returns from arecanut and black pepper

Chali yield of arecanut and dry pepper yield was recorded as maximum in RPP, which was on par with organic and chemical farming. The minimum values were in the natural farming system.

The maximum net return was in RPP (Fig. 3). The judicious application of recommended dosages of fertilizers and plant protection chemicals influenced to obtain optimum yield under the recommended package of practice. A net returns of Rs. 8,43,918 per ha was gained from natural framing practice which is lower among all the treatments without the premium price.

Table 1. Nutrients management under different crop production practices

Particulars	Recommended Package of Practices (RPP)	Organic farming (OF)	Natural Farming (NF)	Chemical Farming (CF)
Arecanut + Black pepper	FYM: 20 kg/palm/year 100:40:140 g N: P_2O_5: K_2O /palm/year (same dose to black pepper also)	Nutrients were supplied equivalent to the recommended dose of fertilizer through FYM and vermicompost	Ganajeevamrutha- (500 kg/ha) during premonsoon and (500 kg/ha) post-monsoon Jeevamrutha - sprinkled on soil (500 l/ha) at 15 days interval	Required quantities of NPK supplied through chemical fertilizers (Urea, DAP, and MOP)

Table 2. Average nutrients composition of different organic manures used in the experiment

Manure type	pH	EC	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu
		dS/m	-------------------------------------%-----------------------------------									
Desi cow dung	7.82	1.78	0.53	0.17	0.23	0.37	0.12	0.40	0.02	0.61	0.06	0.12
Desi cow urine	7.54	2.16	1.09	0.097	0.31	0.28	0.16	0.21	0.07	0.53	0.04	0.05
Beejamrutha	8.12	1.15	1.03	0.17	0.25	0.13	0.08	0.25	0.012	0.12	0.02	0.06
Jeevamruta	4.51	1.98	1.10	0.25	0.38	0.25	0.18	0.10	0.05	0.45	0.07	0.03
Ghana jeevamruta	7.95	1.72	1.62	0.52	0.75	4.90	2.95	0.55	0.02	0.36	0.53	0.04
FYM	7.85	2.26	0.53	0.22	0.50	2.82	0.25	0.35	0.05	0.23	0.06	0.07
Vermicompost	7.96	1.26	1.65	0.45	0.61	1.05	0.86	0.52	0.015	0.04	0.27	0.06

Table 3. Effect of different crop production practices on soil chemical properties in arecanut + black pepper mixed cropping system

Treatment	Soil pH (1: 2.5)			Electrical Conductivity (dS m^{-1})			Organic Carbon (%)		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1: RPP	5.80	5.87	5.83	0.21	0.24	0.23	0.60	0.62	0.61
T_2: OF	5.85	5.93	5.89	0.19	0.21	0.20	0.71	0.78	0.74
T_3: NF	5.78	5.83	5.80	0.22	0.25	0.24	0.63	0.69	0.66
T_4: CF	5.73	5.79	5.76	0.24	0.28	0.26	0.50	0.45	0.47
S. Em ±	0.13	0.04	0.13	0.03	0.03	0.04	0.04	0.04	0.05
CD at 5 %	NS	NS	NS	NS	NS	NS	0.12	0.13	0.16

Note: RPP: Recommended package of practice, OF: Organic farming, NF: Natural farming, CF: Chemical farming

Table 4. Effect of different crop production practices on major nutrients of soil in arecanut + black pepper mixed cropping system

Treatment	Avail. N (kg ha^{-1})			Avail. P_2O_5 (kg ha^{-1})			Avail. K_2O (kg ha^{-1})		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1: RPP	257.05	259.57	258.31	36.69	41.42	39.06	201.95	208.99	205.47
T_2: OF	243.90	250.26	247.08	34.44	37.07	35.76	192.92	203.37	198.15
T_3: NF	235.29	241.50	238.39	28.40	31.40	29.90	180.35	186.52	183.44
T_4: CF	240.00	244.98	242.49	26.11	31.87	28.99	186.32	192.07	189.20
S. Em ±	4.21	3.40	3.67	4.22	3.24	3.68	4.95	5.75	5.35
CD at 5 %	12.96	10.48	11.31	NS	NS	NS	15.27	17.73	NS

Note: RPP: Recommended package of practice, OF: Organic farming, NF: Natural farming, CF: Chemical farming

Table 5. Effect of different crop production practices on secondary nutrients of soil in arecanut + black pepper mixed cropping system

Treatment	Available sulphur (mg kg^{-1})			Exchangeable calcium [cmol (p+) kg^{-1}]			Exchangeable magnesium [cmol (p+) kg^{-1}]		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1: RPP	11.01	11.31	11.16	18.20	19.77	18.98	3.90	3.94	3.92
T_2: OF	12.04	12.11	12.08	19.98	23.34	21.86	4.19	4.45	4.32
T_3: NF	11.53	11.80	11.67	18.70	20.10	19.40	3.92	3.95	3.93
T_4: CF	9.44	9.06	9.25	17.74	16.49	17.12	3.47	3.29	3.38
S. Em ±	0.74	0.89	0.75	0.74	1.16	1.46	0.17	0.31	0.24
CD at 5 %	NS	NS	NS	NS	3.58	NS	NS	NS	NS

Note: RPP: Recommended package of practice, OF: Organic farming, NF: Natural farming, CF: Chemical farming

Table 6. Effect of different crop production practices on micro nutrients of soil in arecanut + black pepper mixed cropping system

Treatment	Zinc (mg kg^{-1})			Copper (mg kg^{-1})			Iron (mg kg^{-1})			Manganese (mg kg^{-1})		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1: RPP	0.75	0.84	0.79	2.72	2.82	2.77	5.45	5.87	5.66	15.19	15.19	15.19
T_2: OF	0.69	0.72	0.70	2.95	3.16	3.05	6.28	7.30	6.79	16.53	16.83	16.68
T_3: NF	0.65	0.66	0.65	3.26	3.27	3.26	5.60	6.12	5.86	15.74	15.64	15.69
T_4: CF	0.55	0.51	0.53	1.85	1.40	1.62	5.30	5.27	5.28	14.75	13.43	14.09
S. Em ±	0.05	0.07	0.06	0.39	0.48	0.42	0.29	0.49	0.38	0.47	0.77	0.62
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: RPP: Recommended package of practice, OF: Organic farming, NF: Natural farming, CF: Chemical farmin

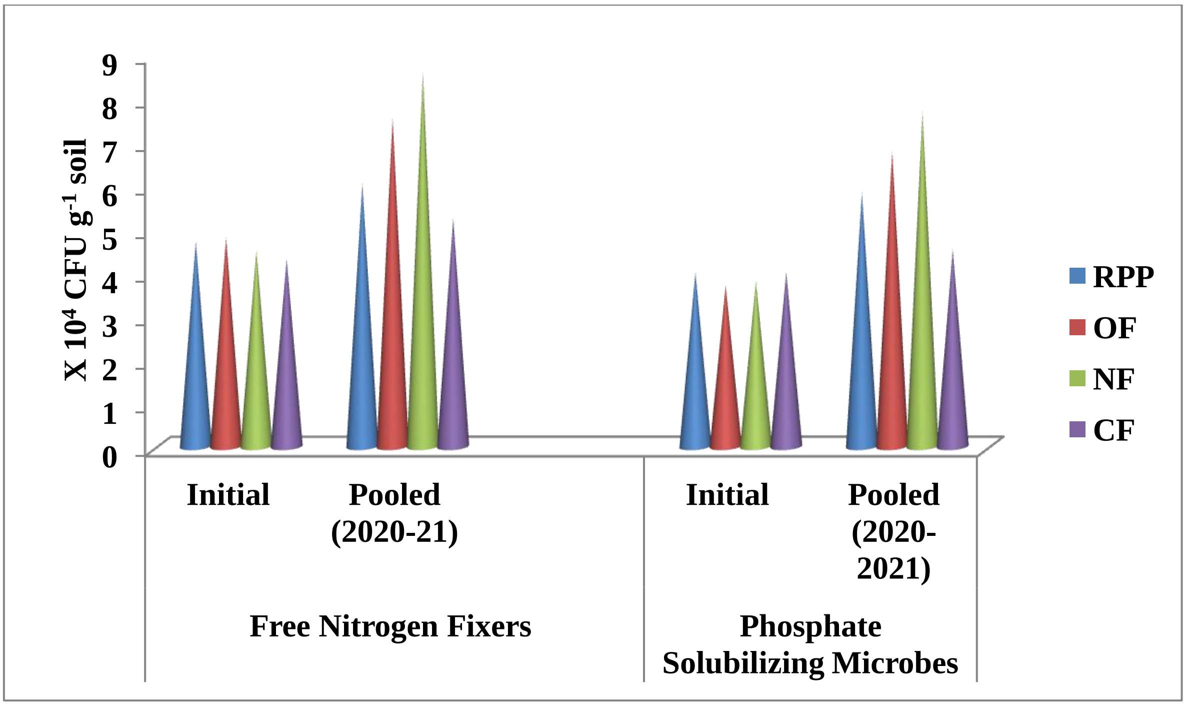

Fig. 1. Effect of different crop production practices on free nitrogen fixers and phosphate solubilizing microbes in arecanut and pepper rhizosphere

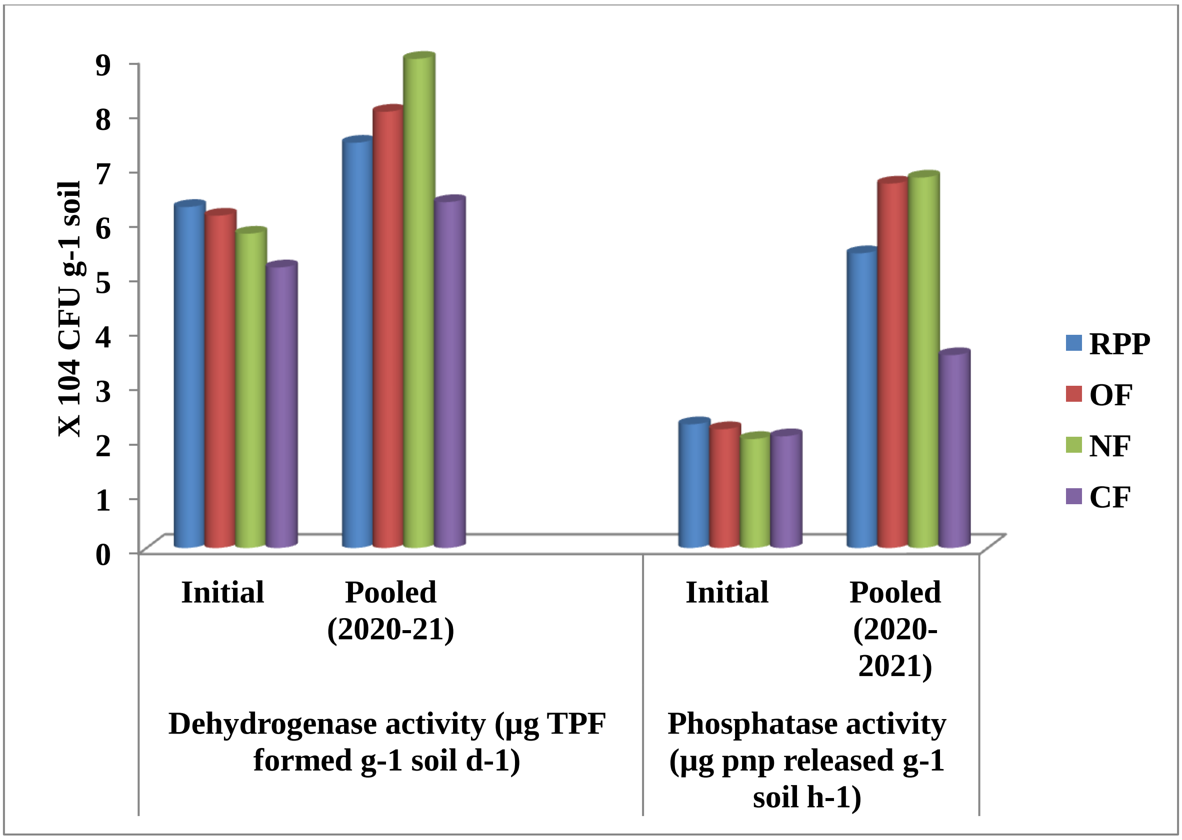

Fig 2. Effect of different crop production practices on dehydrogenase and phosphatase enzyme activity in arecanut and pepper rhizosphere

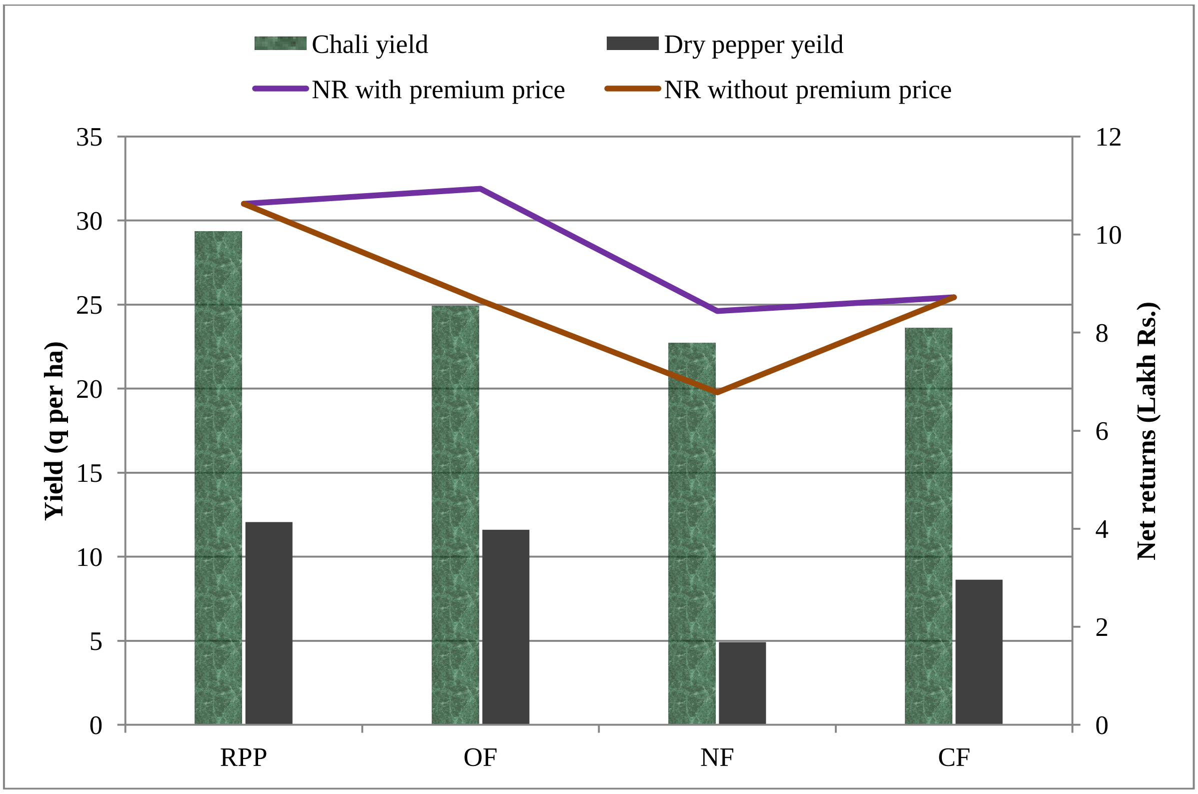

Fig. 3. Effect of different crop production practices on yield and net returns from arecanut and black pepper

4. CONCLUSION

An improvement in soil health with natural and organic farming and there was no appreciable difference between various crop production practices in terms of arecanut and black pepper yield. Hence, reducing the input of chemical fertilizers and application of natural fertilizers such as organic manure *viz.,* jeevamrutha, ghanajeevamrutha, FYM, vermicompost, crop residues, green manure and compost could sustain the soil health by keeping good growth and yield of arecanut and black pepper. Though the application of natural fertilizers may yield less when compare with chemical farming concerning soil health and nutrient status it plays a significant role and the reduction in arecanut and black pepper yield should be compensated by premium pricing of organic produce.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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