__Original Research Article__

Effect of different farming systems on soil health and yield of arecanut and black pepper

Abstract

A two year field experiment was conducted in the farmer's field at Hanagal, Sirsi, Karnataka to study the effect 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 pooled data (2020 and 2021) depicted that, soil pH and electrical conductivity did not vary significantly due to different farming system. Whereas, significantly highest soil organic carbon content was found in organic farming (0.74%) which was on par with natural farming (0.66%) and least was noticed 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}) contents in soil were recorded in RPP. Whereas the highest secondary nutrients and micronutrients content in soil was observed in organic and natural faming. The lowest of all these nutrients were recorded in chemical farming at harvest stage of arecanut. Soil microflora, dehydrogenase and phosphatase activity in arecanut and black pepper rhizosphere were significantly highest in natural farming and lowest in chemical farming. With respect to yield, significantly highest arecanut (chali yield 29.35 q ha^{-1}) and black pepper (dry yield 12.07 q ha^{-1}) yield was observed 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, SOC

INTRODUCTION

Agriculture has been the backbone of the Indian economy for centuries. More than half of the country's population at present depends on agriculture and allied services for their livelihoods [17]. 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, in spite of the success, the input intensive 'Green Revolution' in recent decades has often masked significant externalities, affecting natural resources and human health, as well as agriculture itself. The green revolution increased agricultural output through higher fertilizer and pesticide application, improved irrigation, soil management regimes, and crops, as well as significant land conversions. Using chemicals in agriculture is like 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 characterised by high production costs, high interest rates for credit, volatile market prices for crops and rising costs for fossil fuel-based inputs and private seeds. As a result, Indian farmers (especially the small holders) increasingly find themselves in a debt [11]. In this concern, there is a need for an alternative farming system. Various forms of alternative low-input farming practices have emerged in different corners across 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. Mulching, soil protection measures, natural insecticides, and fertilizers 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 is the major cropping system of the Uttara Kannada district cultivated over more than 10,000 hectares. It is grown all over the district and 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) on rhizosphere microflora, soil fertility and yield of arecanut and black pepper.

MATERIALS AND METHODS

A field demonstration on the use of various farming systems was carried out during 2020 and 2021 on a silty loam, moderately deep, red soil in arecanut and black pepper mixed cropping system at farmer's field, Hanagal, Karnataka. The experiment was conducted in the arecanut (var. Mangala) plantation of an approximate age of 12 years and the black pepper vines (var. Panniyur-1) of an approximate age of five years. The climate of experimental area is warm 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. Whereas, 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 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 agar medium and Pikovskayas agar medium, respectively. The estimation of dehydrogenase and phosphatase activity of soil samples were determined by following the procedure described by Casida *et al.* [4] and Evazi and Tabatabai [6], respectively.

The experiment was laid out with the following treatments in a randomised block design with five replications: 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 pre-monsoon period as per the requirement. The quantity of 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 [8].

Soil samples were collected from 0-30 cm depth at harvest stage of arecanut. Five cores collected from each treatment plot were mixed thoroughly and a composite sample was taken. Soil samples were air-dried, ground, and sieved (2 mm) for analysis. The pH of the soil was estimated in 1:2.5 soil: water suspension by using systronic digital pH meter. The electrical conductivity was estimated in supernatant solution of 1:2.5 soil: water suspension using conductivity bridge. Organic C was determined by the wet digestion method of Walkley and Black [19]. Available nitrogen was estimated by distilling soil with 0.5% KMnO4 in a micro-Kjeldhal apparatus [15]. Available phosphorus was extracted with 0.03 N NH_4F + 0.025 N HCl and estimated spectrophotometrically [3]. Available potassium was extracted with neutral 1N NH_4OAC and estimated using flame emission spectroscopy. Available micronutrients (Zn, Fe, Mn and Cu) were extracting with DTPA [10] and estimated by atomic absorption spectrophotometer (Varian spectra AA 20 plus).

RESULTS AND DISCUSSION

Effect of different crop production practices on soil fertility status

1. Soil pH and electrical conductivity (EC)

Pooled data (2020-2021) indicated that, compared to initial value slight increase in soil pH and EC was observed in all the treatments, but found non-significant among the treatments (Table 3). This might be due application of lime to all the treatments during pre-monsoon period. Among the treatments, highest increase in soil pH was observed in organic farming (5.89) followed by RPP (5.83). Whereas highest (0.26 dS m^{-1}) and lowest (0.20 dS m^{-1}) EC among the treatments was recorded in chemical and organic farming, respectively. The slight increase in soil pH in organic farming and RPP might be attributed to release of basic cations during decomposition of farm yard manure (FYM) and vermicompost, which in turn enhances the soil physico-chemical properties and reduces the loss of basic cations from the soil 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.* [7] reported that decrease in soil pH with use of chemical fertilizers and decrease in soil pH with continuous application of jeevamrutha was noticed by Ravi *et al.* [13].

2. Soil Organic Carbon (SOC)

Compared to initial value increase in soil organic carbon content was observed in RPP, organic and natural farming, whereas it decreased in chemical farming in both the years (2020 and 2021). Pooled data indicated that, the soil organic carbon content was significantly high in organic farming (0.74%) which was on par with natural farming (0.66%) and least was noticed in chemical farming (0.47%) (Table 3). Increased soil organic carbon content might be due to application of organic manures such as farm yard manure and vermicompost to organic treated and ghanajeevamrutha, jeevamrutha and mulching practices in natural farming, resulted in enhanced soil micro flora with 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 also oxidation caused by high temperature and leaching of soluble humic complexes due to coarse textured nature of soil. Other similar findings were Chaithra [5] and Gupta *et al.* [9].

3. Major nutrients (Available nitrogen, phosphorus and potassium)

In the first year of 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 of experiment i.e. 2021 these nutrients were significantly varied among the treatments.

Pooled data (2020 -2021) indicated that, significantly highest available nitrogen (258.31 kg ha^{-1}), phosphorus (39.06 kg ha^{-1}) and potassium (205.47 kg ha^{-1}) contents in soil were recorded in RPP, which was on par with organic and chemical farming and lowest of these nutrients were observed in the natural farming (Table 4). Because of 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 and also release of weak organic acids during decomposition of organic manures dissolve the fixed nutrients and enhances its availability in the soil [16]. Similar results were observed by Bhat and Sujatha [2] and Paul *et al*. [12].

4. Secondary nutrients (Exchangeable calcium and magnesium and available sulphur)

Pooled data (2020 and 2021) indicated that, the highest available sulphur content (12.08 mg kg^{-1}) was recorded in organic farming, which was on par with natural farming (11.67 mg kg^{-1}) and lowest was observed in chemical farming (9.25 mg kg^{-1}).

Exchangeable calcium and magnesium contents in soil did not differ significantly in both the years (2020 and 2021). However highest exchangeable calcium [21.86 cmol (p+) kg^{-1}] and magnesium [4.32 cmol (p+) kg^{-1}] contents in soil was recorded in organic farming, which was followed by natural farming and RPP and lowest of these nutrients were observed in chemical farming [17.12 and 3.38 cmol (p+) kg^{-1}, respectively] (Table 5). Addition of lime along with organic manures reduces the loss of basic cations and increased the secondary nutrients content in soil [14]. The consistently declining trend of secondary nutrients with the chemical farming warrants the supplementation of NPK fertilizers with calcium and magnesium for the maintenance of soil health and sustainable crop production.

5. Micronutrients (DTPA extractable iron, zinc and manganese)

Pooled data (2020 and 2021) indicated that, DTPA extractable zinc, copper, iron and manganese contents in soil were found non-significant among the treatments. However compared to initial value slight increase in these micronutrients was observed in RPP, organic and natural farming practices, whereas slight decrease was noticed in chemical farming practice (Table 6). Among the treatments, the highest DTPA extractable zinc was observed in

RPP (0.79 mg kg^{-1}), which was followed by organic and natural farming. This might be due to application of zinc sulphate to the RPP treatment at the time of pre-monsoon period. Whereas highest copper (3.26 mg kg^{-1}) was recorded in natural farming and iron (6.79 mg kg^{-1}) and manganese (16.68 mg kg^{-1}) contents in organic farming and lowest of these micronutrients (0.53, 1.62, 5.28 and 14.09 mg kg^{-1} Zn, Cu, Fe and Mn, respectively) were observed in chemical farming. These results are in agreement with the findings of Verma and Mathur [18] and Zhang *et al.* [20].

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

Pooled data (2020 and 2021) indicated that, significantly highest population of free nitrogen fixers (8.60 ×10^{4} cfu g^{-1} of soil), phosphorus solubilizing microbes (7.69×10^{4} cfu g^{-1} of soil), dehydrogenase (9.55 µg TPF formed g^{-1} soil d^{-1}) and phosphatase (6.80 µg pnp released g^{-1} soil h^{-1}) activity were recorded in natural farming, which was on par with organic farming and lowest were recorded in chemical farming (Fig 1 and 2). The application of jeevamrutha at frequent intervals help to increase the soil biological activity in the soil [1, 13].

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

Chali yield of arecanut (29.35 q ha^{-1}) and dry pepper yield (12.07 q ha^{-1}) was recorded maximum in RPP, which was on par with organic and chemical farming however, minimum values were recorded in natural farming system (22.72 and 4.92 q ha^{-1}, respectively).

The maximum net return was observed in RPP of around Rs. 10,62,500 per ha (Fig 3). The judicious application of recommended dosage of fertilizers and plant protection chemicals influenced to obtain optimum yield under recommended package of practice. The net returns of Rs. 8,43,918 per ha was gained from natural framing practice which is lower among all the treatments without premium price.

Conclusion

The current analysis amply demonstrated that there was improvement in the 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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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)	Nutrient were supplied equivalent to recommended dose of fertilizer through FYM and vermicompost	Ganajeevamrutha @ 500 kg/ha 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 status 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 status 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 status 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 farming

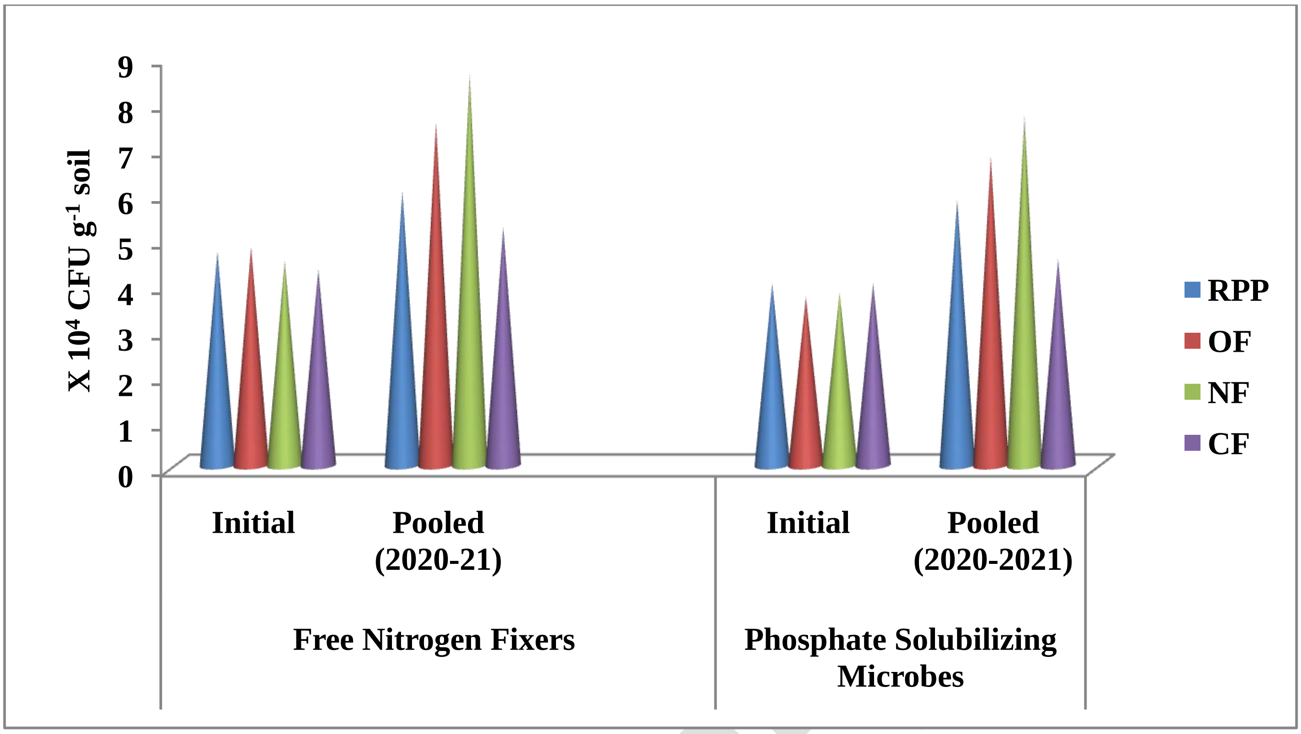

Fig. 1: Effect of different crop production practices on free nitrogen fixers and phosphate solubilizing microbes in arecanut and pepper rhizosphere

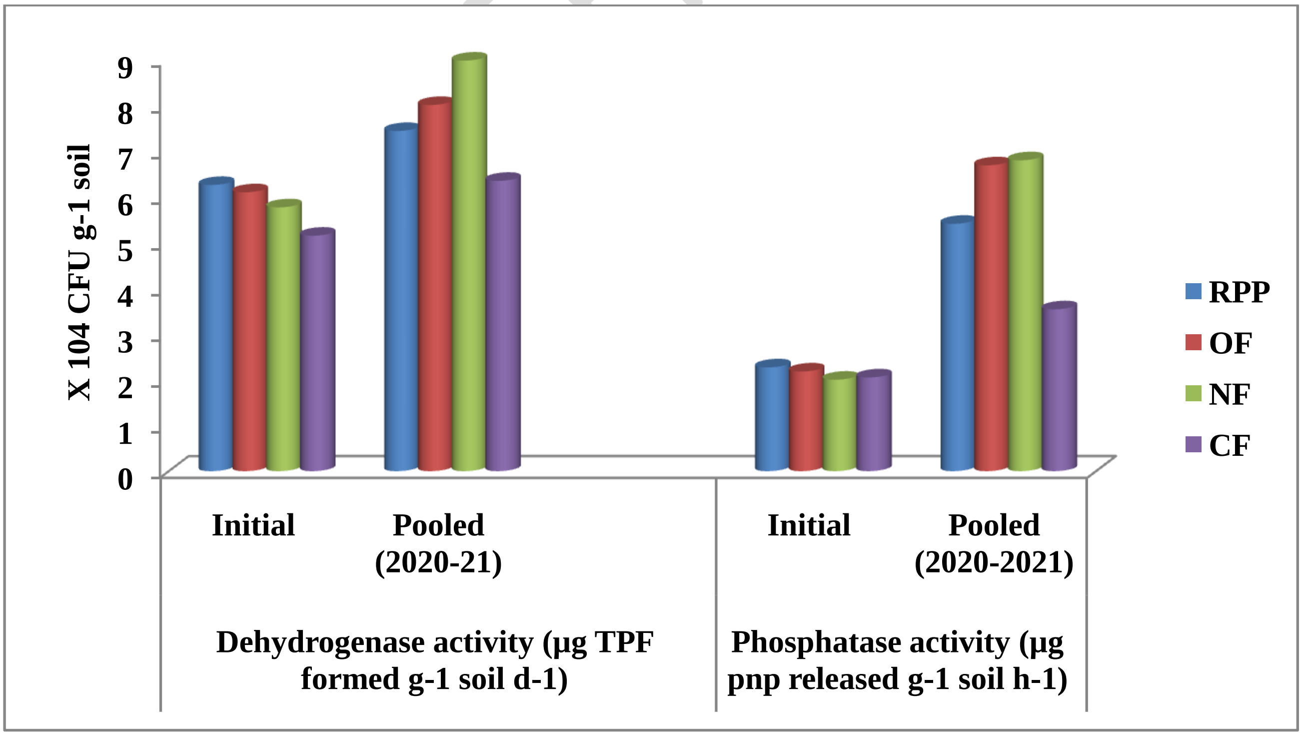

Fig 2: Effect of different crop production practices on dehydrognase and phosphatase enzyme activity in arecanut and pepper rhizosphere

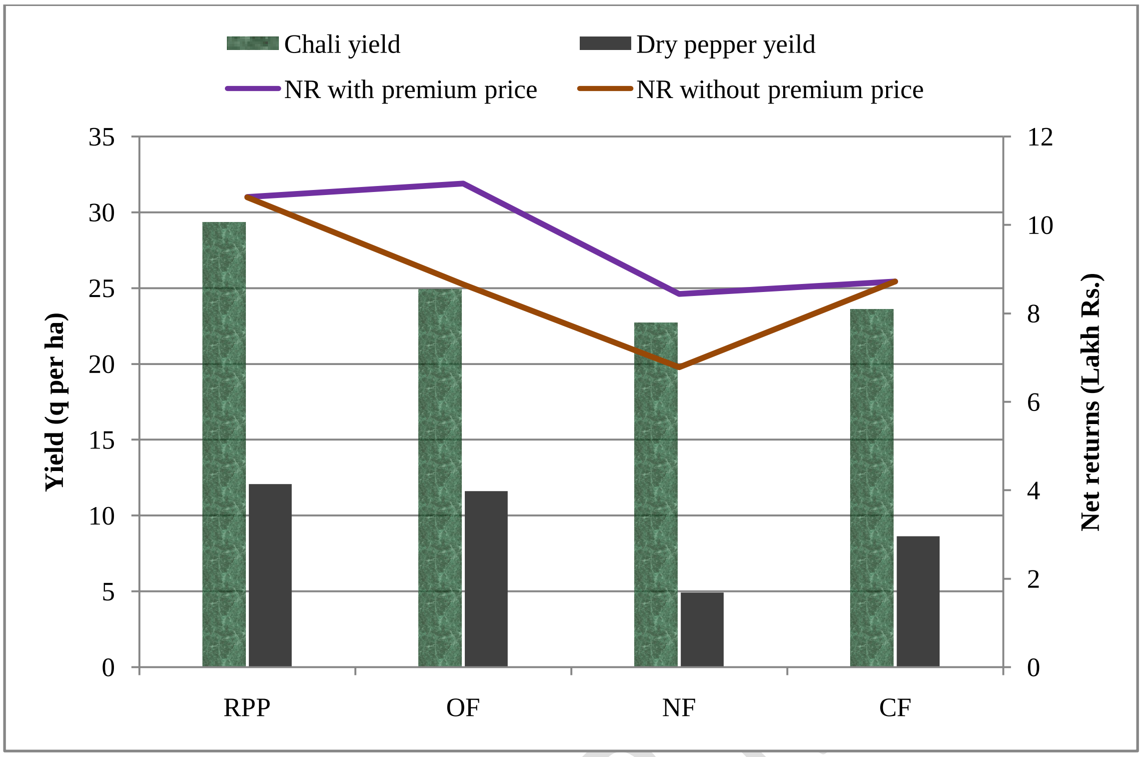

Fig 3: Effect of different crop production practices on yield and net returns from arecanut and black pepper