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Influence of natural farming in black pepper on soil microbial and nutritional status under areca-based cropping system

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Abstract
An experiment was carried out at Horticultural Research and Extension Centre (HREC), Sirsi, Uttara Kannada district during 2020-2022 to evaluate the influence of natural farming on yield, quality, soil microbial and soil nutritional status in black pepper. The experiment consists of different farming practices, *viz*., natural farming, organic farming, Recommended Package of Practice (RPP) and chemical farming. The results show that natural farming recorded a significantly higher population of bacteria (41.86 cfu × 10^6 g^{-1} soil), fungi (13.70 cfu × 10^3 g^{-1} soil), phosphorous solubilizers (41.60 cfu × 10^4 g^{-1} soil), actinomycetes (16.87 cfu × 10^4 g^{-1} soil) and free-living nitrogen fixers (16.55 cfu × 10^4 g^{-1} soil) in the soil rhizosphere of black pepper under areca based cropping system. While recommended package of practice recorded significantly higher available nitrogen (250.18 kg/ha), phosphorous (19.36 kg/ha) and potassium (304.61 kg/ha) in the soil.

Keywords: Black pepper, natural farming, organic farming, Recommended Package of Practice (RPP) and chemical farming

Introduction
Black pepper (*Piper nigrum* L.) is one of the oldest spices known to mankind and originated in the evergreen forest of the Western Ghats in India. Black pepper has been used for centuries as a seasoning and traditional medicine in various cultures due to its pungent flavour and various health benefits. It contains a compound called piperine, which is responsible for its characteristic taste and aroma and has been shown to have antioxidant, anti-inflammatory and antimicrobial properties (Damanhouri and Ahmad, 2014) [4]. Clean spice is a concept that is catching on and is attained through integrated approaches for pest, disease and nutrient management involving resistant varieties, biocontrol, botanicals and organic farming. The demand for organic spices in the international market shows an upward trend, and premium prices are realized for organic products against conventional products. Natural farming, popularly known as Zero Budget Natural Farming (ZBNF), is an alternative farming approach that promotes the growing of crops in harmony with nature. It emphasizes improving soil fertility through a variety of agroecological principles that include the diversification of crops and nutrient recycling along with increasing beneficial microorganisms in soil rhizosphere and biological interactions. It involves the use of locally available ingredients, *viz.*, cow dung and cow urine, applied in the form of jeevamrutha and beejamrutha, mulching, mixed cropping and other homemade preparations for plant protection (Kumar *et al.*, 2020) [5]. The use of organic supplements helps to exploit the beneficial microorganism in soil, which aid in solubilizing nutrients and supply to plants and improve the soil fertility and quality by promoting the overall health of the plants. It also reduces production costs and, at the same time, can achieve products of high quality produces with reduced or without the usage of inorganic fertilizers and pesticides.

Material and Methods
An experiment was conducted to study the effect of natural farming on growth, yield, quality and soil nutritional and microbial status in black pepper during 2020-2022 for two successive years. The experiment was conducted at Horticulture Research Extension Centre, Sirsi, situated at 14.61°N latitude and 74.84° E longitude at an altitude of 611 m above mean sea level.

The experiment was laid out in Randomized Complete Block Design with four treatments/blocks (T1, T2, T3, T4) and each treatment was replicated five times. The treatments include T1: natural farming (Jeevamrutha at 200 l/acre, applied at fortnightly intervals once in 15 days, followed by Ghanajeevamrutha applied at 200 kg/acre during pre and post-monsoon), T2: organic farming (Biocontrol agents *viz*., Trichoderma (10g), pseudomonas (30g), PSB (30g) were mixed with FYM, neem cake and vermicompost applied at 20kg per vine), T3: Recommended Package of Practice (RPP) NPK at 100:40:140 g/vine and FYM/green manure/compost at 10 kg/vine) and T4: chemical farming (NPK at 100:40:140 g/vine). Observations on soil parameters *viz*., pH, EC, organic carbon, major nutrients (N, P, K) and soil biological parameters. The representative soil samples from each treatment were drawn from the rhizosphere soil to the depth of 0 – 15 cm, while the nutrient status of the soil was estimated by taking the soil samples from a depth of 0-30 cm. Soil chemical properties and nutritional status were assessed using established protocols outlined by Jackson (1973), Walkley and Black (1934) [8], and Subbaiah and Asija (1956). The total microbial count was determined through serial dilution and the standard plate count method. Soil microbial populations were assessed by mixing ten grams of homogenized soil (treatment-wise) with 90 ml of sterile water blank to yield a 10^{-1} dilution. Subsequent dilutions up to 10^{-6} were made by serially transferring 1 ml of the dilution to 9 ml sterile water blanks. The populations of fungi, bacteria, actinomycetes, N-fixers, and phosphorous solubilizers were estimated by transferring 1 ml of 10^6 (for bacteria), 10^3 (for fungi), and 10^4 (for actinomycetes, N-fixers, and phosphorous solubilizers) respectively.

Result and Discussion

Microbial population

Different farming systems significantly influenced the microbial population in the black pepper rhizosphere. Significantly higher bacterial population was recorded by natural farming (51.68 and 41.86 cfu × 10^6 g^{-1} soil) followed by organic farming (46.10 and 37.41 cfu × 10^6 g^{-1} soil) while, chemical farming (35.83 and 26.86 cfu × 10^6 g^{-1} soil) recorded the lowest population of bacterial in soil rhizosphere of black pepper during flowering and harvesting stage, respectively (Table 1). The highest bacterial population under natural farming may be owing to the large amount of microbial load found in jeevamrutha, which increases soil bio-mass upon application to soil even at a very low rate since it functions as a tonic to the soil in addition to enhancing soil health.

Natural farming recorded a significantly higher fungi population (13.82 and 13.70 cfu × 10^3 g^{-1} soil) followed by organic farming (12.41 and 12.51 cfu × 10^3 g^{-1} soil) whereas, the lowest fungi population in soil rhizosphere was recorded under chemical farming (10.29 and 10.12 cfu × 10^3 g^{-1} soil) during flowering and harvesting period of black pepper, respectively. In comparison to RPP, natural farming and organic farming recorded higher fungi populations in soil (Table 1). The increase in the microbial population in soil may be linked to readily available micronutrients and organic manures as sources of organic carbon for microbial population growth. It could also be ascribed to favourable excretions of root exudates such as sugars, organic acids, amino acids, and many growth-promoting substances which serve as a food substrate for bacteria in the soil rhizosphere. These findings are in conformity with those of Choudary *et al.* (2022) [3] in pomegranate.

Actinomycetes population was found to be significantly higher under natural farming practices (44.16 and 41.85 cfu × 10^4 g^{-1} soil) followed by organic farming (35.28 and 35.54 cfu × 10^4 g^{-1} soil), while the lowest actinomycetes population was recorded by chemical farming (31.22 and 27.48 cfu × 10^4 g^{-1} soil) in soil rhizosphere of black pepper during flowering and harvesting stage, respectively (Table 1). Natural farming had the highest actinomycetes population, followed by organic farming, which may be attributed to the fact that the majority of soil microorganisms are chemo heterotrophs, which require an organic carbon source as food and obtain energy through the oxidation of organic substances present in the soil. The farming practice involves organic sources such as vermicompost, FYM and jeevamrutha to improve the microbial activity in the soil rhizosphere through root exudates and other enzyme activities that provide organic matter for microorganisms that increase the number of actinomycetes in soil. Similar observations were made by Thakur *et al.* (2022) [7] and Choudhary *et al.* (2022) [3].

Natural farming recorded significantly higher phosphate solubilizers (16.56 and 16.87 cfu ×10^4 g^{-1} soil) followed by organic farming (13.70 and 14.22 cfu × 10^4 g^{-1} soil), whereas the lowest fungi population in the soil rhizosphere was recorded under chemical farming (11.66 and 11.99 cfu × 10^4 g^{-1} soil) during the flowering and harvesting period of black pepper, respectively (Table 1). The increased phosphate solubilizers in soil under natural farming and organic farming may be due to the fact that jeevamrutha serves as a good source of beneficial microorganisms in soil and increases the microbial load in the soil rhizosphere, and the addition of organic manures has improved microbial activity and increased nutrient availability in the soil. Aher *et al*. (2018) [1] found that enhanced microbial population under organic manure application was mostly related to more organic carbon, particularly the biologically active phase of carbon, which worked as a source of energy for bacteria proliferating in soil.

Natural farming practice recorded significantly higher free living N_2 fixers (15.31 and 16.65 cfu × 10^4 g^{-1} soil) followed by organic farming (13.31 and 14.10 cfu × 10^4 g^{-1} soil), whereas the lowest free living N_2 fixers population was recorded by chemical farming (11.43 and 11.86 cfu × 10^4 g^{-1} soil) in soil rhizosphere during flowering and harvesting period of black pepper, respectively (Table 1). Jeevamrutha has a huge microbial load that multiplies in the soil and serves as a tonic to boost microbial activity there. Higher nitrogen fixers in soil treated with organic manures and jeevamrutha may be attributed to the organic matter in the soil acting as a source of carbon and energy for microorganisms. Additionally, the application of jeevamrutha ensures proper aeration, moisture content, and nutrient levels in the soil, leading to the proliferation of microorganisms. In contrast, the reduced microbial count of free-living nitrogen-fixing organisms in chemical farming may result from the limited availability of substrates necessary to sustain microbial biomass. Similar findings were reported by Boraiah *et al.* (2017) [2] that significantly higher nitrogen fixers were recorded in the soil rhizosphere due to the application of jeevamrutha.

Soil properties

The soil pH and soil EC did not show any significant difference during the flowering and harvesting stages of black pepper among the treatments (Table 2). The pooled data showed that organic farming recorded significantly higher organic carbon content in soil (0.97% and 1.27%), followed by natural farming (0.84% and 0.90%) during the flowering and harvesting stage of black pepper, respectively, while the lowest organic carbon in soil was recorded by chemical farming (0.64%) during the flowering stage and RPP during harvesting stage (0.71%) of black pepper.

The treatment involving recommended package of practice recorded higher available nitrogen in the soil (243.09 kg ha^{-1} and 250.18 kg ha^{-1}) followed by organic farming (212.72 kg ha^{-1} and 218.07 kg ha^{-1}) during the flowering and harvesting period of black pepper, respectively. At the same time, the lowest available nitrogen in the soil was observed in natural farming practices (191.94 kg ha^{-1}) during the flowering stage and chemical farming (196.06 kg ha^{-1}) during the harvesting stage of black pepper (Table 2). The use of both chemical fertilizers and organic manures in the soil, which aided in the breakdown of organic matter and increased nitrogen levels in the RPP treatment, could have contributed to the augmentation of available nitrogen. The incorporation of inorganic sources and nitrogen-rich organic manures into the soil might be responsible for the increase in the amount of nitrogen that is readily available.

Available phosphorus in soil varied significantly among different treatments during the flowering and harvesting stage of black pepper. RPP recorded significantly higher available phosphorus (17.50 and 19.36 kg ha^{-1}) followed by organic farming (16.18 and 18.24 kg ha^{-1}) during the flowering and harvesting stages of black pepper, respectively (Table 2). At the same time, natural farming (12.74 kg ha^{-1}) recorded the lowest available P in the soil during the flowering period and chemical farming (16.43 kg ha^{-1}) during the harvesting stage of black pepper. The significant increase in the amount of soil-available phosphorus caused by the addition of organic manure and FYM may be due to the complexing of cations like Ca2+ and Mg2+, which are primarily responsible for the fixation of phosphorus in soil.

Significantly higher available potassium in soil was observed in the treatment T3 receiving the recommended package of practice (298.94 kg ha^{-1} and 304.61 kg ha^{-1}) followed by chemical farming (269.91 kg ha^{-1} and 282.51 kg ha^{-1}), whereas natural farming (229.72 kg ha^{-1} and 234.97 kg ha^{-1}) recorded the lowest available potassium in the soil during flowering and harvesting stage of black pepper, respectively (Table 2). The use of both organic manures (FYM) and chemical fertilizers in the soil resulted in higher levels of soil potassium in RPP. This effect may be attributed to the decomposition of organic matter, which includes diverse organic acids, leading to the liberation of non-exchangeable potassium in soluble forms, thereby augmenting the availability of potassium in the soil.

Table 1: Influence of farming systems on total microbial population in the rhizosphere of black pepper under areca-based mixed cropping system

Treatments	Flowering stage					Harvesting stage				
	Bacteria (cfu × 10^6 g^{-1} soil)	Fungi (cfu × 10^3 g^{-1} soil)	Actinomycetes (cfu × 10^4 g^{-1} soil)	Phosphate solubilizers (cfu × 10^4 g^{-1} soil)	Free living N_2 fixers (cfu × 10^4 g^{-1} soil)	Bacteria (cfu × 10^6 g^{-1} soil)	Fungi (cfu × 10^3 g^{-1} soil)	Actinomycetes (cfu × 10^4 g^{-1} soil)	Phosphate solubilizers (cfu × 10^4 g^{-1} soil)	Free living N_2 fixers (cfu × 10^4 g^{-1} soil)
T_1	51.68	13.82	44.16	16.56	15.31	41.86	13.70	41.60	16.87	16.65
T_2	46.10	12.41	35.28	13.70	13.31	37.41	12.51	35.54	14.22	14.10
T_3	36.16	11.04	33.05	12.44	11.68	27.39	10.81	30.11	12.46	12.13
T_4	35.83	10.29	31.22	11.66	11.43	26.86	10.12	27.41	11.99	11.86
S.Em ±	0.88	0.56	0.63	0.59	0.50	0.61	0.40	1.30	0.73	0.72
CD at 5%	2.71	1.72	1.95	1.81	1.53	1.87	1.23	4.00	2.26	2.21

NS: Non Significant

T_1: Natural farming (NF), T_2: organic farming (organic treatment), T_3: Recommended Package of Practice (RDF with INM) T_4: Chemical farming – without FYM (control)

Table 2: Influence of farming systems on chemical properties and nutritional status in the soil of black pepper under areca-based mixed cropping system

Treatments	Flowering stage						Harvesting stage					
	pH	EC (dS m^{-1})	OC (%)	N (Kg ha^{-1})	P (Kg ha^{-1})	K (Kg ha^{-1})	pH	EC (dS m^{-1})	OC (%)	N (Kg ha^{-1})	P (Kg ha^{-1})	K (Kg ha^{-1})
T_1	6.45	0.09	0.84	191.94	12.74	229.72	6.20	0.10	0.90	208.44	17.23	234.97
T_2	6.44	0.08	0.97	212.72	16.18	248.03	6.38	0.09	1.27	218.07	18.24	262.16
T_3	6.54	0.1	0.74	243.09	17.50	298.94	6.24	0.12	0.71	250.18	19.36	304.61
T_4	6.42	0.1	0.64	210.95	14.60	269.97	6.27	0.10	0.84	196.06	16.43	282.51
S.Em ±	0.04	0.01	0.05	6.32	0.50	8.76	0.12	0.02	0.08	7.79	0.36	12.91
CD at 5%	NS	NS	0.15	19.48	1.54	26.98	NS	NS	0.24	23.99	1.10	39.77

NS: Non Significant

T_1: Natural farming (NF), T_2: organic farming (organic treatment), T_3: Recommended Package of Practice (RDF with INM) T_4: Chemical farming – without FYM (control)

Conclusion

The natural farming practices greatly influenced the soil biological properties in terms of microbial population and enhanced the diversity of microbes in the soil rhizosphere, which in turn enhanced the nutrient availability and maintained the soil nutrient status in the long run.

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