



Effect of nutrient management practices and cropping systems on organic production of crops

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ABSTRACT

A study was carried out during 2022, 2023 and 2024 under All India Coordinated Research Project on Integrated Farming System at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyala, Raipur, Chhattisgarh in strip plot design (SPD) with three replications. The treatment combinations included nutrient management practices, viz. 100%, 50% and 25% nutrients through inorganic and organic sources with combination of *beejamrit*, *ghanjeevamrit*, *jeevamrit*; and four cropping systems, viz. soybean [*Glycine max* (L.) Merr.], sweet corn [*Zea mays* (L.) Saccharata], French bean (*Phaseolus vulgaris* L.), cabbage (*Brassica oleracea* var. *capitata* L.) and tomato (*Solanum lycopersicum* L.). Soybean–tomato recorded the highest total productivity (570.2 q/ha) with NM₆. Application of 100% N through inorganic sources + 5 t FYM resulted greater uptake of available N (26.51 kg/ha) and available P (23.44 kg/ha) along with higher organic carbon (0.79%), whereas available K was higher (415.8 kg/ha) with 25% organic + 25% inorganic sources + Natural farming. Soybean–tomato was more economically feasible system under NM₁ in gross (₹4,32,201/ha) and net (₹3,38,259/ha) returns.

Keywords: Cabbage, French bean, Natural farming, Soybean, Sweet corn, Tomato

Globally, organic agriculture is practiced in 162 countries and 37.00 million hectares of land are managed organically by 1.80 million farming families (Willer *et al.* 2022). The organic food and drink sales in market reached more than 120.6 billion euros in 2020 (Willer *et al.* 2022). The countries with the most organic agricultural land are Australia (12 mha), Argentina (3.80 mha) and the United States (1.90 mha). India has 1.76 mha of organic farming land, 3.62 mha of organic farming land that is being converted and 4.78 mha of wild harvest area, according to the most recent statistics from NPOP India. Sikkim is regarded as the first in India to embrace 100% organic farming. Bhutani *et al.* (2018) attempted in their study to examine organic farming as an alternative agricultural system in the country. Research evidence has proved that RDIS (Rice-Duck Integrated System) enhanced the growth and yield of rice (Mofidian and Sadeghi 2015, Yang *et al.* 2024), improved soil properties (Yan *et al.* 2023) and reduced plant diseases and insect pests (Teng *et al.* 2016, Thavaprakash 2022). Chhattisgarh has 0.0041 mha of

organic farming area in sporadic pockets across the state with a lot of farming area falling under forest fringe and isolated patches and some of the districts have been declared as organic. Organic farming not only support quality and sustainability concerns, but also ensures a profitable livelihood option along with environmental and ecological benefit. The government plans to encourage organic farming by implementing programmes like the Shrianna Yojana, Paramparagat Krishi Vikas Yojana, National Programme for Organic Production and National Project on Organic Farming (NPOF). The PM-PRANAM (PM Programme for Restoration, Awareness Generation, Nourishment, and Amelioration of Mother-Earth) programme was also introduced which offers the states a set of money as compensation in exchange for reducing use of chemical fertilisers. Loaiza *et al.* (2010), Li *et al.* (2012) and Long *et al.* (2013) stated that the productivity of crops in organic farming is lower by 9.2% compared to conventional farming. Panday *et al.* (2012) and Roychowdhury *et al.* (2013) advocated that farmers' apprehension towards India is rooted in the non-availability of inputs and market for organic products, to pay an extra amount by ensuring organic farming (Singh *et al.* 2019). However, it is known that incidence of weeds, insect-pests, nutrients, etc. needs proper attention. Greater yield losses in crops (Thavaprakash *et al.* 2012, Puig-Montserrat *et*

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al. 2017, Kumar *et al.* 2018, Tharun *et al.* 2019) including rice (*Oryza sativa* L.), due to increased weeds (Asai *et al.* 2016, Uno *et al.* 2021), insect-pests (Torok *et al.* 2021), and lack of nutrients (Muthukrishnan *et al.* 2017, Timsina 2018) under organic agriculture were documented earlier. Looking to healthier and safe food demands, incorporation of organic input as nutrition in crop production is a prime focus to reduce pesticide load in soil as well as improving human health. An experiment was conducted to fulfill the objectives of organic food, healthier life and producing environmentally safe products under organic farming.

MATERIALS AND METHODS

The study was carried out during 2022, 2023 and 2024 under All India Coordinated Research Project at Integrated Farming System at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyala, Raipur (21.23°N, 81.63°E; at an elevation of 314 m amsl), Chattisgarh. Raipur has sub-tropical humid climate. The monsoon starts from 2nd week of June receiving average 1077 mm rainfall during *kharif* season. However, experimental site received 1250.80 mm rainfall. The soil was clayey in texture (Vertisols) locally known as *kanhar* which is characterised by neutral in pH (7.4), medium in organic carbon (0.70%), low in available nitrogen (240 kg/ha), medium in available phosphorus (19 kg/ha) and available potassium (374 kg/ha). The electrical conductivity of soil was 0.28 dS/m.

The treatment combinations of nutrient management practices and cropping systems were respectively laid out into strip plot design (SPD) as in cropping system strip with three replications. The treatments were NM₁, 100% Organic sources; NM₂, Supply of only 50% nutrients through organic sources + seed/seedling treated with *beejamrit* (200 mL/kg of seeds) + application of *ghanjeevamrit* @1,000 kg/ha (10 q/ha), *jeevamrit* @1,500 L/ha applied every 15 days through irrigation till flowering; NM₃, 50% N through organic sources + 50% N through inorganic sources (fertilisers); NM₄, 25% nutrients through organic (FYM) + 25% nutrients through inorganic sources + seed/seedling treated with *beejamrit* (200 mL/kg of seeds) + application of *ghanjeevamrit* @1,000 kg/ha (10 q/ha), *jeevamrit* @1,500 L/ha applied every 15 days through irrigation till flowering; NM₅, 100% N through inorganic sources; NM₆, 100% N through inorganic sources + 5 t FYM; CS₁, Soybean var. JS-9752–Sweet corn var. Sugar 75; CS₂, Soybean–French bean var. Amar; CS₃, Soybean–Cabbage var. *Pusa Mukta*; and CS₄, Soybean–Tomato var. *Abhilash*. The sources of organic inputs were used according to treatments as given below for supplying nutrients to the crops. Soybean (var. JS-97-52), Sweetcorn (var. Sugar-75), French bean (var. *Amar*), Cabbage (var. *Pusa Mukta*) and Tomato (var. *Abhilash*) were sown on second fortnight of November in all the years at spacing of 30 cm × 10 cm, 40 cm × 20 cm, 50 cm × 10 cm, 60 cm × 30 cm and 60 cm × 30 cm, respectively. Nutrient supply sources have been given in detail in Supplementary Table 1. Harvesting was done

once for soybean, sweet corn, French bean and cabbage, whereas tomato was picked up six times. Organic carbon (%), bulk density (mg/cm³) and particle density (mg/cm³) were analysed as per Walkley and Black's rapid titration method (Black 1965), Soil core method (Black 1965) and Gupta and Dakshinamurti (1981), respectively. Available N (kg/ha), available P (kg/ha) and available K (kg/ha) were analysed using alkaline permanganate method (Subbiah and Asija 1956), Olsen's method (Olsen *et al.* 1959) and Flame photometer method (Muhr *et al.* 1965), respectively. Data were subjected to the Fisher's analysis of variance technique (Steel *et al.* 1997) using Statistix 8.1 (Analytical software, Statistix; Tallahassee, FL, USA, 1985-2003).

RESULTS AND DISCUSSION

Kharif crops (Soybean): Plant morphological traits and yield components of soybean varied significantly under different nutrient management practices and cropping systems in three years (Table 1). Among the nutrient treatments, the combination of 100% inorganic sources with 5t FYM (NM₆) resulted the highest plant population at harvest, followed by NM₁ (100% organic sources) and NM₅ (100% inorganic), both were performed comparable to NM₆. The maximum number of nodules at 60 DAS was recorded under NM₁, which remained superior to the rest of treatments except NM₅ and NM₆. A similar pattern was observed for number of branches, where NM₆ produced more branches, closely followed by NM₁. Pods/plant also showed higher values under NM₆, NM₁ was next in the order. The number of seeds/pod increased significantly with NM₆ and did not differ statistically from NM₁. Although differences in 100-seed weight due to treatments was not significant. However, NM₆ still recorded significantly higher value, while NM₃ (50% organic + 50% inorganic) registered the lowest 100-seed weight.

Cropping systems had a noticeable influence on soybean growth attributes. CS₂ (Soybean–French bean) produced more nodules, branches, pods, seeds/pod and higher seed weight than the other systems except CS₄ (Soybean–tomato), which showed a higher value but no advantage in seed weight. Yields responded to the nutrient management and cropping systems under organic and inorganic treatments (Table 1). The significantly higher average seed yield was obtained in NM₁, followed by NM₅ and NM₆, being statistically at par with NM₁ in consecutive 3 years. Whereas stover yield and harvest index were more under NM₆. Among cropping systems, CS₂ produced the highest mean seed yield, stover yield and harvest index which were statistically similar to CS₁. Improvement in soil organic carbon was seen under organic nutrient sources, which is supported by earlier findings of Loaiza *et al.* (2010).

Rabi crops: Maize (sweet corn), French bean, tomato and cabbage grown during *rabi* under soybean-based cropping systems were significantly influenced by nutrient management practices (Table 2). Sweet corn recorded significantly superior cob weight, grains/cob and green cob yield under NM₆, followed by NM₁. Changes in cob

Table 1 Effect of organic, inorganic and integrated nutrient management practices on growth, yield parameters and yield of soybean (pooled mean of 3 years)

Treatments	Yield attributes						Yield (q/ha)		
	Plant population/ m ² at harvest	No. of nodules/ plant at 60 DAS	No. of branches/ plant at harvest	No. of pods/plant	No. of seeds/pod	100-seed weight (g)	Seed	Stover	Harvest index (%)
Nutrient management									
NM ₁	13.39	157.9	5.78	122.95	3.15	12.08	22.01	34.37	35.37
NM ₂	12.73	152.75	4.66	95.45	2.83	11.74	11.80	26.31	27.31
NM ₃	12.68	155.42	5.29	109.79	2.91	11.27	17.22	29.90	30.90
NM ₄	12.65	149.75	5.00	101.61	2.86	11.44	13.95	27.40	28.40
NM ₅	13.36	153.78	5.49	116.11	2.95	11.73	20.36	30.63	31.63
NM ₆	13.42	155.67	6.10	132.19	3.23	12.32	21.89	37.75	38.75
SEM±	0.24	3.29	0.04	1.20	0.09	0.14	0.82	0.73	0.73
CD (p=0.05)	1.26	14.25	0.13	3.78	0.30	0.46	2.58	2.29	2.29
Cropping system									
CS ₁	13.08	155.56	5.4	113.32	3.02	11.84	18.60	33.80	34.83
CS ₂	12.92	158.19	5.44	114.04	3.13	11.85	19.77	36.09	37.13
CS ₃	13.01	153.78	5.38	112.47	2.91	11.73	17.71	30.46	31.49
CS ₄	13.12	149.32	5.34	112.23	2.89	11.63	17.62	27.74	28.77
SEM±	0.05	2.26	0.11	1.76	0.04	0.05	0.54	1.74	1.74
CD (p=0.05)	0.20	8.62	0.43	6.73	0.16	0.20	1.62	5.25	5.25

Treatment details are given under Materials and Methods.

Table 2 Effect of organic, inorganic and integrated nutrient management practices on yield attributing characters and yield of succeeding *rabi* crops in soybean based cropping system (pooled mean of 3 years)

Nutrient management	Maize (Sweet corn)				French bean			Cabbage		Tomato		
	Wt./cob (g)	Grains/cob	Green cob yield (q/ha)	% change	No. of pods/plant	Green pod weight (g/pod)	% change	Yield (q/ha)	% change	Fruit weight (g)	Fruit yield (q/ha)	% change
NM ₁	321.65	484.23	148.15	10.70	20.79	6.05	5.92	373.99	9.20	67.35	440.36	3.80
NM ₂	262.25	346.04	92.53	-30.14	20.17	5.51	-13.05	306.82	-8.45	62.54	406.24	-3.40
NM ₃	282.86	429.66	119.99	-9.98	19.4	5.46	-20.55	335.06	-1.03	58.98	360.71	-13.01
NM ₄	275.07	388.39	99.73	-24.86	18.64	5.33	-23.23	328.29	-2.81	57.91	329.09	-19.67
NM ₅	299.79	455.6	133.57	-	20.38	5.86	-	338.98	-	66.01	422.36	-
NM ₆	337.51	529.41	161.84	20.76	22.13	6.41	15.61	395.72	14.91	71.45	471.18	10.30
SEM±	9.71	11.48	9.40		0.45	0.12		16.57	5.88	2.32	17.46	3.74
CD (p=0.05)	30.8	36.17	29.62		1.40	0.38		52.20	18.44	7.31	55.06	11.94

Treatment details are given under Materials and Methods.

yield ranged from -9.98% to +20.76% compared to 100% inorganic sources. Yield attributes of French bean also varied significantly with nutrient treatments. NM₆ recorded more pods/plant, higher green pod weight which turned into greater pod yield and positive percentage change over inorganic

sources. Cabbage yield was considerably higher under NM₆, while NM₂ recorded the lowest yield. The improvement in cabbage yield over inorganic fertilisation was greater under NM₆ (14.91%), whereas NM₁ and NM₅ showed moderate gains. Although, in 3 years of experimentation NM₆ had

instant nutrient supply and fortified with 5 t FYM reflected as higher yield (Hijbeek *et al.* 2018) being the highest fruit weight and yield of tomato when treated with NM₆ which was statistically comparable to NM₁ and the greatest positive change over organic nutrient management, whereas minimum tomato yield was observed in NM₄.

Cropping system analysis: Integrated nutrient management had a strong influence on total system productivity (Supplementary Fig. 1). During *kharif*, the soybean–French bean system produced the higher productivity with NM₆ and NM₁ whereas in *rabi* season, soybean–tomato recorded the maximum total productivity under same nutrition. Soybean equivalent yield (SEY) was also recorded highest in soybean–tomato.

Production efficiency was highest with soybean–French bean, followed by soybean–maize and soybean–tomato which were significantly similar. Relative productivity efficiency peaked in soybean–tomato under NM₄, while relative economic efficiency was the highest under soybean–French bean. In terms of profitability, soybean–French

bean performed better during *kharif*, whereas vegetable-based systems increased total output but did not produce the highest economic returns under organic nutrient management. These multiple indicators including *kharif* and *rabi* yield, SEY, total productivity, production and economic efficiency did not follow a normal distribution pattern because of the diverse functional roles in integrated systems (Fig. 1 and 2). Economic efficiency is fully driven by fluctuation in market price throughout growing period which reflected vegetable sequences with organic amendments (Asai *et al.* 2016)

Nutrient uptake: Nutrient uptake by soybean was strongly affected by nutrient management practices and cropping systems (Table 3). NM₆ showed the highest uptake of N, P and K, being statistically similar to NM₁ and NM₅. Among cropping systems, CS₂ was found maximum uptake of all 3 nutrients, although phosphorus and potassium uptake did not differ in CS₁, but nitrogen uptake was comparable to CS₄. Finding of Mohan *et al.* (2016) is closer conformity in nutrient uptake.

The uptake of nutrients did not vary significantly due to the interaction between nutrient treatments and cropping sequences. Increased availability of K may be related to reduced fixation and release of K through organic matter interaction (Hijbeek *et al.* 2018). Enhanced phosphorus availability in combined organic and inorganic nutrient sources might be due to the complex of cations responsible for P fixation (Mohan Rao *et al.* 2016, Barbieri *et al.* 2017).

Soil fertility status: Soil nutrient status under soybean-based cropping systems improved significantly by integrated nutrient management. NM₆ recorded higher organic carbon (0.79%), availability nitrogen (269.51 kg/ha) and phosphorus (23.44 kg/ha). Potassium enrichment was highest under NM₄ and superior to remaining treatments. NM₁ exhibited comparable to NM₆ for organic carbon, nitrogen and phosphorus, while potassium availability under NM₃ was statistically similar with NM₄. The increase in soil organic matter and improvement in aggregate stability attributed to organic inputs is supported by the findings of Bajgai *et al.* (2015). Cropping systems did not showed major differences in soil nutrient levels. Continuous and excessive use of chemical fertilisers is known to degrade soil quality (Bajwa *et al.* 2015).

Economics: Economic evaluation

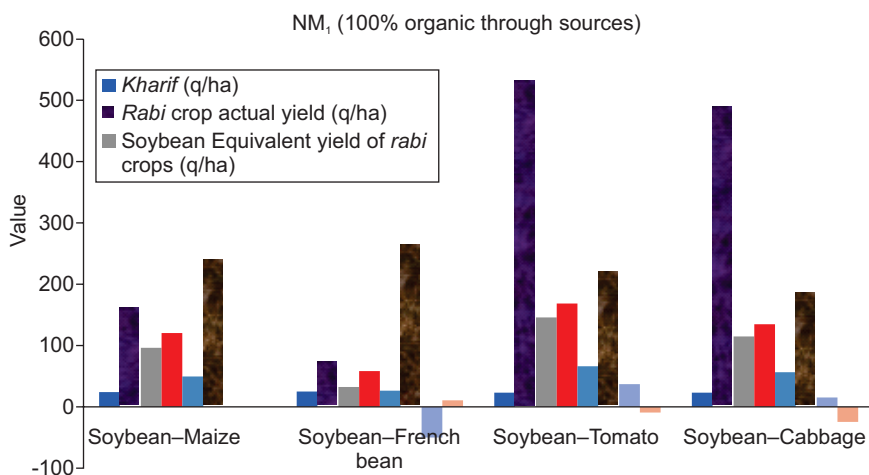


Fig. 1 Response of 100% organic to different yield and cropping parameters under 100% organic through different sources.

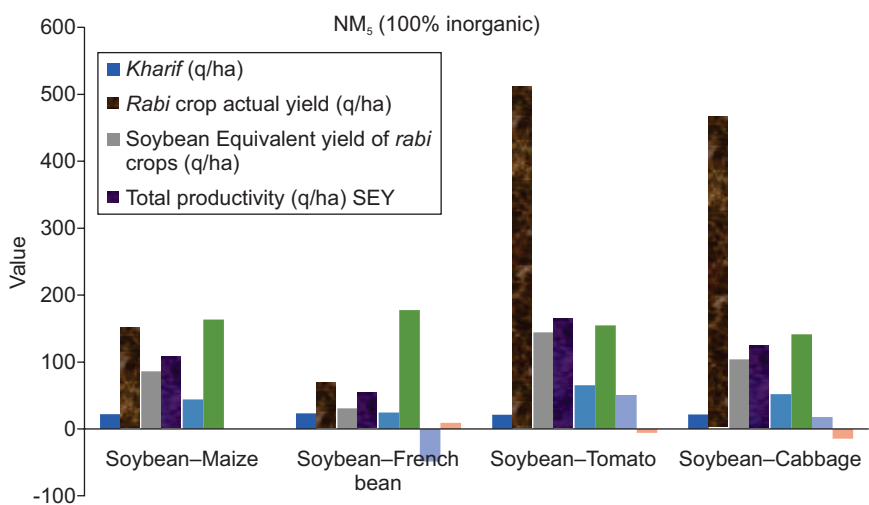


Fig. 2 Response of 100% organic to different yield and cropping parameters under 100% inorganic sources.

Table 3 Effect of organic, inorganic and integrated nutrient management practices on nutrient uptake by soybean (pooled mean of 3 years)

Nutrient management	Total uptake of nutrients by soybean (kg/ha)			Soil fertility status (kg/ha) after sequence			
	N	P	K	OC (%)	N	P	K
NM ₁	291.24	32.12	149.42	0.76	266.68	22.86	406.19
NM ₂	144.96	17.06	79.87	0.73	263.31	21.97	409.50
NM ₃	192.71	24.44	116.22	0.72	258.85	20.86	411.84
NM ₄	141.75	19.13	93.89	0.69	258.48	20.84	415.80
NM ₅	267.74	29.77	137.84	0.74	265.96	22.57	407.43
NM ₆	293.45	32.68	149.12	0.79	269.51	23.44	400.67
SEM±	13.23	1.21	5.55	0.01	2.71	0.26	2.51
CD (<i>p</i> =0.05)	41.70	3.81	17.50	0.03	6.21	0.82	7.93
Cropping system							
CS ₁	219.35	25.98	122.22	0.73	249.73	21.26	383.35
CS ₂	235.20	27.71	129.81	0.75	249.96	20.71	387.35
CS ₃	212.41	24.97	116.60	0.76	248.88	20.60	385.20
CS ₄	220.94	24.81	115.62	0.75	246.02	20.71	384.52
SEM±	7.42	0.72	3.50	0.01	2.22	0.20	2.03
CD (<i>p</i> =0.05)	22.38	2.19	10.52	NS	NS	NS	NS

Treatment details are given under Materials and Methods.

Table 4 Effect of organic, inorganic and integrated nutrient management on economics of soybean based cropping system (pooled mean of 3 years)

Treatment	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
CS ₁ NM ₁	77,389	3,09,061	2,31,673	2.24
CS ₂ NM ₁	38,363	1,49,737	1,11,374	2.19
CS ₄ NM ₁	93,942	4,32,201	3,38,259	2.58
CS ₃ NM ₁	72,416	3,45,732	2,73,316	2.68
CS ₁ NM ₂	96,591	1,98,691	1,02,101	1.16
CS ₂ NM ₂	43,359	1,03,226	59,867	1.34
CS ₄ NM ₂	87,433	3,00,622	2,13,189	1.93
CS ₃ NM ₂	65,907	2,69,713	203,806	2.29
CS ₁ NM ₃	66,704	2,07,995	1,41,291	1.75
CS ₂ NM ₃	36,069	92,022	55,953	1.43
CS ₄ NM ₃	81,542	3,08,967	2,27,425	2.13
CS ₃ NM ₃	59,808	2,46,528	1,86,720	2.31
CS ₁ NM ₄	68,289	1,73,013	1,04,724	1.42
CS ₂ NM ₄	42,197	82,077	39,881	1.10
CS ₄ NM ₄	81,224	2,84,665	2,03,442	1.96
CS ₃ NM ₄	59,594	2,34,143	1,74,550	2.20
CS ₁ NM ₅	56,011	2,21,819	1,65,808	2.22
CS ₂ NM ₅	33,757	1,10,446	76,688	1.84
CS ₄ NM ₅	69,129	3,40,042	2,70,913	2.76
CS ₃ NM ₅	47,188	2,54,113	2,06,925	3.02
CS ₁ NM ₆	57,132	2,96,032	2,38,901	2.91
CS ₂ NM ₆	34,877	1,28,197	93,320	2.06
CS ₄ NM ₆	70,250	3,52,262	2,82,012	2.81
CS ₃ NM ₆	48,309	2,91,361	2,43,053	3.38

Treatment details are given under Materials and Methods.

of soybean-based cropping systems showed strong variation among nutrient management treatments (Table 4). The cost of cultivation was highest (₹96,591/ha) in soybean–maize in NM₂, while the lowest cost (₹33,757/ha) was recorded in soybean–French bean under NM₅. The highest gross and net returns were achieved by soybean–tomato under NM₁ (₹4,32,201 and ₹3,38,259), whereas soybean–French bean under NM₄ recorded the lowest returns (₹39,881). A maximum B:C ratio of 3.38 was obtained under soybean–cabbage with NM₆, which was in line with the results reported by Krishnaprabu (2019) and closely followed by soybean–cabbage cropping with B:C (3.02) in NM₅. Continued supply of instant nutrients helped much to the cropping sequence for better performance.

The present study assessed the nutrient management practices (100%, 50% and 25% nutrients) through inorganic and organic sources with combination of *beejamrit*, *ghanjeevamrit*, *jeevamrit* and four cropping systems, viz. CS₁ (Soybean–Maize), CS₂ (Soybean–French bean), CS₃ (Soybean–Cabbage) and CS₄ (Soybean–Tomato). Soybean–tomato recorded the highest total productivity (570.2 q/ha) with application of NM₆ (100% inorganic + 5t FYM) and also economically feasible in obtaining gross (₹4,32,201/ha) and net (₹3,38,259/ha) returns. Application of 100% N through inorganic sources + 5 t FYM resulted greater uptake of available nitrogen (26.51 kg/ha) and available phosphorus (23.44 kg/ha) along with higher organic carbon (0.79%).

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