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Effect of organic, integrated and conventional management on growth, yield and soil health in cassava (*Manihot esculenta*) - vegetable intercropping systems

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Abstract

The experiment was conducted to evaluate the effects of organic, chemical, and integrated management methods on growth, yield, dry-matter production, and soil physical and chemical parameters of cassava (*Manihot esculenta* Crantz) -vegetable intercropping at ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Sreekariyam, Thiruvananthapuram, Kerala, India, during 2021. The split plot design consisted of three vegetables, amaranthus (*Amaranthus* spp.), okra [*Abelmoschus esculentus* (L.) Moench] and vegetable cowpea [*Vigna unguiculata* (L.) Walp] in main plots and four management options, 100% organic, 75% organic + innovative practices, integrated and package of practices (POP) in subplots. The 75% organic + innovative practices exhibited significantly higher harvest index and tuber dry matter production at 9 MAP, tuber yield, tuber dry matter% and mean tuber bulking rate. Highest tuber equivalent yield was observed in cassava-okra intercropping system under 75% organic + innovative practices. Soil organic C, available N and available Zn were significantly higher in 100% organic practices, and exchangeable Ca in 75% organic + innovative practices. Thus, organic management imparted significant effect on soil chemical properties, which was reflected in higher yields.

Key words: Cassava-Vegetable system, Intercropping, Organic farming, Tuber equivalent yield

Cassava (*Manihot esculenta* Crantz) is a drought-tolerant, staple food crop that is grown in tropical and subtropical areas that plays a vital role in global food security. High calorific value and environmental adaptability are the major factors that make cassava a staple food in areas affected by chronic food shortages, where conventional staples are insufficient (Bayata 2019). Cassava-based multi-cropping systems have long been practised by smallholder farmers in tropical regions across Africa and Asia to enhance agroecosystem resilience and household food security (Ravi *et al.*, 2021; Nedunchezhiyan *et al.*, 2022; Suja *et al.,* 2025). As the demand for organic vegetables has risen in recent years globally, the integration of short-duration vegetable crops like amaranthus (*Amaranthus* spp.), okra [*Abelmoschus esculentus* (L.) Moench] and cowpea [*Vigna unguiculata* (L.) Walp], as intercrops in organically managed cassava systems can offer nutritional enrichment and agroecological benefits.

The effect of organic management on crop productivity, produce quality and soil health in tropical tuber crops is well documented (Suja *et al*., 2012; Suja and Sreekumar, 2014; Suja *et al.*, 2017; Seena Radhakrishnan *et al.*, 2022). Intercropping, however, involves complex plant-to-plant and plant-to-soil interactions that differ significantly from monocropping due to resource competition and complementarity in terms of light, water, and nutrients (Willey, 1979; Lithourgidis *et al.*, 2011; Brooker *et al.*, 2015). Despite the long-standing practice of cassava-based intercropping among smallholder farmers in tropical regions (Ravi *et al.*, 2021; Nedunchezhiyan *et al.*, 2022), there is limited systematic research evaluating the performance of short-duration vegetables under organically managed cassava systems.

Most comparative nutrient management studies have been conducted either in monocropped cassava or in cereal-legume systems (Velten *et al.*, 2015; Ravisankar *et al.,* 2021), with limited emphasis on tropical tuber crop-vegetable intercropping systems. Addressing these research gaps is essential for developing scientifically validated technologies that enhance productivity, soil health, and nutritional diversification in sustainable cassava-based organic farming systems. The present study aims to develop technologies for organic production of short-duration vegetables like amaranthus, okra and cowpea in association with cassava and to evaluate the effect of organic, integrated and chemical management options on growth, yield and soil properties, in cassava + vegetable intercropping system.

MATERIALS AND METHODS

Field experiments were conducted during January-October in 2021 at ICAR-CTCRI (8° 29' N, 76°57'E, 52 m altitude), Thiruvananthapuram, Kerala, India. Chemical inputs were not used for six years before taking up the

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current research. The soil of experimental site was acidic in reaction (pH: 4.34), with low available N (132.71 kg/ha), and organic C (0.48), high available P (101.52 kg/ha) and high available K (334.95 kg/ha). The site experiences a typical humid tropical climate. During the experimental period, total rainfall received was 1544.61 mm, maximum and minimum temperatures were 31.79 and 24.77°C respectively, and mean relative humidity was 81.40%.

The experiment was laid out in a split plot design with cassava variety, Sree Reksha, intercropped with amaranthus (Arun), okra (Anjitha) and vegetable cowpea (bush type) (Anaswara) in main plots and four management options, 100% organic, 75% organic + innovative practices, integrated (50% organic +50% inorganic) and package of practices in sub plots (Table 1). The gross plot size was 5.4 m × 5.4 m, accommodating 16 net plants. Observations on total biomass production and partitioning to leaf, stem and tuber of cassava were made 3, 6 and 9 months after planting (MAP). Based on these, growth indices, viz. leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), harvest index (HI), tuber bulking rate (TBR) and mean TBR of cassava were computed using growth analysis techniques of Hunt (1982). Fresh tuber yield of cassava and yield of vegetables were collected from the net plants and expressed in tonnes/ha. Tuber equivalent yield was calculated based on yields of component crops (Devasenapathy *et al.*, 2009).

Physical characters of soil such as bulk density, particle density, water-holding capacity and porosity

Table 1: Description of management options

Management	Inputs and quantity			
	Cassava	**Amaranthus**	**Okra**	**Vegetable cowpea**
100% organic	FYM @ 12.5 t/ha *in situ* green manuring @10 t/ha PGPR mix 1@ 250 kg/ha crop residue @ 3 t/ha	FYM @ 25 t/ha poultry manure @ 12 t/ha vermicompost @ 3.35 t/ha neem cake @ 1.675 t/ha ground nut cake@ 350 kg/ha and P_2O_5 @ 15 kg/ha as Mussoorie phosphate @ 75 kg/ha	FYM @ 12 t/ha poultry manure @ 4.2 t/ha vermicompost @ 3.35 t/ha neem cake @ 1.675 t/ha groundnut cake @ 350 kg/ha	FYM @ 10 t/ha poultry manure @ 4.2 t/ha vermicompost @ 660 kg/ha neem cake @ 660 kg/ha
75% organic + innovative practices	FYM @ 12.5 t/ha *in situ* green manuring @ 10 t/ha PGPR mix 1 @ 250 kg/ha *Panchagavya*, Vermiwash, Cow urine, *Jeevamrit*	FYM @ 18.75 t/ha poultry manure @ 9 t/ha vermicompost @ 2.5 t/ha neem cake @ 1.26 t/ha Groundnut cake @ 265 kg/ha P_2O_5 @ 11.25 kg/ha as Mussoorie phosphate @ 56.25 kg/ha *Panchagavya*, vermiwash, Cow urine, *Jeevamrit*	FYM @ 9 t/ha poultry manure @ 3.15 t/ha vermicompost @ 2.5 t/ha neem cake @ 1.26 t/ha groundnut cake @ 265 kg/ha *Panchagavya*, vermiwash, Cow urine, *Jeevamrit*	FYM @ 7.5 t/ha poultry manure @ 3.15 t/ha vermicompost @ 500 kg/ha Neem cake @ 500 kg/ha *Panchagavya*, vermiwash/ Cow urine, *Jeevamrit*
Integrated (50% Organic + 50% Inorganic)	FYM @ 12.5 t/ha PGPR mix 1 @ 250 kg/ha NPK @ 80:37.5:75 kg/ha	FYM @ 12.5 t/ha poultry manure @ 3.5 t/ha Vermicompost @ 1.675 t/ha neem cake @ 0.850 t/ha groundnut cake @ 175 kg /ha PGPR mix 1 @ 250 kg/ha NPK @ 175:75:125 kg /ha	FYM @ 15 t/ha poultry manure @ 0.850 t /ha PGPR mix 1 @ 250 kg/ha NPK @ 105:35:75 kg/ha	FYM @ 10 t/ha PGPR mix 1 @ 250 kg/ha NPK @ 60:35:45 kg/ha
Package of Practices (POP)	FYM @ 12.5 t/ha NPK @ 100:50:100 kg/ha	FYM @ 50 t/ha NPK @ 100:50:50 kg/ha	FYM @ 20 t/ha NPK @ 110:35:70 kg/ha	FYM @ 20 t/ha NPK @ 20:30:10 kg/ha

were estimated as per the methods of Gupta and Dakshinamoorthy (1980). The pH, organic C, available N, P, K, Ca, Mg, Fe, Zn and Cu status of soil were estimated by standard analytical methods (Page *et al.,* 1982). Data were analyzed by ANOVA for split-plot design with three replications, with intercropping systems in whole plots and management options in subplots. The main plot factor was tested against whole plot error and the subplot factor and interaction against subplot error. Treatment means were compared using the critical difference at 0.05 significance level, utilizing SAS statistical software (Version 9.3).

RESULTS AND DISCUSSION

During initial and mid growth phases, management options did not influence leaf biomass, but 100% organic plots tended to produce higher leaf biomass during both phases (60.62 and 314.87 g/plant respectively). At harvesting, organically raised plants produced higher leaf biomass (431.47 g/plant) on a par with conventional plants. Stem biomass production was not significantly influenced by the management options throughout the growth phases. However, organically grown plants produced numerically more stem biomass compared to conventional plants during first and final stages (10.96 and 315.50 g/plant respectively).

During initial stage, management options did not vary significantly in tuber biomass production, but 75% organic + innovative practices appeared to have higher tuber biomass (38.81 g/plant). Tuber biomass was significantly influenced by management options during second and third growth phases. In mid growth phase, 50% organic + 50% inorganic practice increased tuber biomass on a par with 75% organic + innovative practices and 100% organic practice (700.26, 657.32 and 610.29 g/plant respectively). At harvesting, 75% organic + innovative practices produced significantly highest tuber dry matter (955.82 g/plant). Significantly highest tuber dry matter percentage was observed in 75% organic + innovative practices (25.38%). There was no significant difference in total dry matter production among management options.

However, both 100% organic and 75% organic + innovative practices produced relatively more total plant biomass compared to conventional plants during initial and final growth phases. At harvesting, 75% organic + innovative practices showed comparatively higher values, followed by 100% organic resulted in higher total dry matter production (1570.15 and 1457.35 g/plant respectively). Thus organically managed plots showed a favourable trend in phasic course of biomass production and its partitioning to various plant parts. The greater contribution of major, secondary and micronutrients from the organic resources such as green manure cowpea, vermicompost, neem cake, groundnut cake and poultry manure in comparison to other practices might have contributed to the increased biomass accumulation under organic management. This confirms studies of Suja *et al.* (2012), Suja *et al.* (2017) and Seena Radhakrishnan *et al.* (2022).

Leaf Area Index (LAI) peaked at the mid growth phase and decreased slightly towards final phase. The management options did not significantly influence LAI, however 100% organic practice resulted in slightly higher LAI by first and final stages (1.76 and 2.96 respectively), while in mid stage, 50% organic + 50% inorganic practices resulted in relatively higher LAI values, followed by 100% organic practice (4.38 and 3.91 respectively). These findings are consistent with those of Almunqedhi *et al.* (2025). Seena Radhakrishnan *et al.* (2022) also observed similar results in cassava.

Both organically managed practices showed numerically higher Crop Growth Rate (CGR) values at the initial growth stage with 100% organic, resulting in marginally higher CGR followed by 75% organic + innovative practices (1.50 and 1.49 respectively). At the mid growth phase, 50% organic + 50% inorganic plants showed a trend towards higher values, followed by 100% organic (13.40 and 12.69 respectively) and by harvest 75% organic + innovative practices resulted in slightly higher CGR (8.43) compared to POP. Though not significant, CGR was favoured by organic treatments reflecting the impact of organic management practices during the critical growth period. Kumar *et al.* (2024) found that the crop growth rate of stevia showed an upward trend under organic manures, with increasing quantity of farmyard manure and vermicompost applied.

Relative Growth Rate (RGR) showed a tendency to decrease with crop age (Fig. 1). It was higher during second phase (3-6 MAP) than third phase (6-9 MAP). The treatments did not affect RGR significantly, though integrated practice (50% organic + 50% inorganic) produced relatively higher RGR at second phase, followed by 100% organic (26.24 and 24.94 respectively). Ahirwar *et al.* (2025) reported similar results in wheat. The RGR showed slight increase under 75% organic + innovative practices (5.45) compared to the other management options during the last phase. An increase of RGR was observed in all treatments from the first to the second growth period and a steep decrease was found from the second to the final growth stage. The trend in relative growth rate can be viewed as normal, as biomass production efficiency may decline

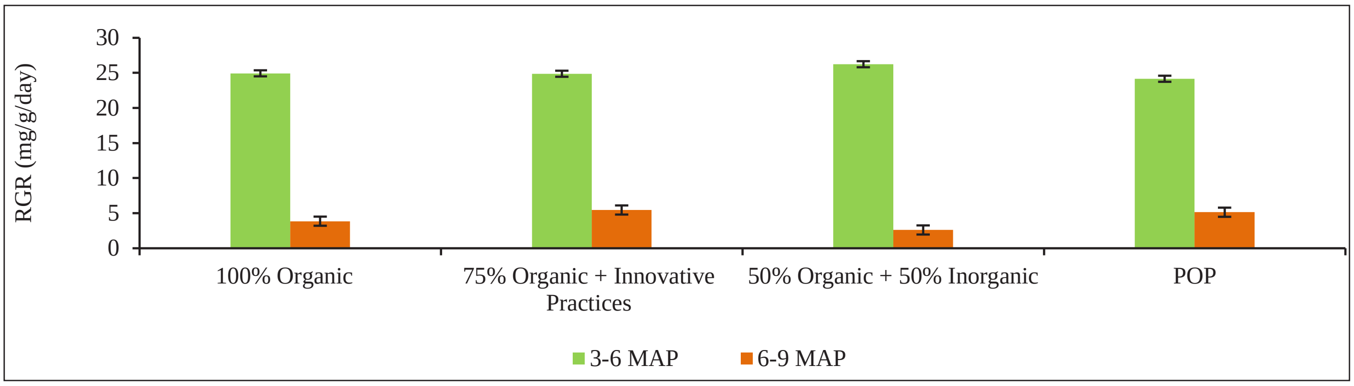

Fig. 1: Relative growth rate as affected by management options

over time due to plant senescence (Kumar *et al.,* 2024).

Tuber Bulking Rate (TBR) did not vary significantly, but during the initial and final phase, 75% organic + innovative practice showed comparatively higher TBR values (0.43 and 4.01 g/day respectively), while 50% organic +50% inorganic practices tended to be higher in mid phase (7.36 g/day). Among management options, 75% organic + innovative practices (3.54 g/day) resulted in significantly highest mean TBR. The higher TBR in first and final phases and the greater mean TBR might have contributed to a higher tuber yield in 75% organic + innovative practices. Similar trend of tuber bulking rate was documented by Seena Radhakrishnan *et al.* (2015). The higher LAI and CGR under organic management also led to efficient translocation of biomass to tuber resulting in higher TBR.

Harvest Index (HI) did not vary among the treatments at the initial stage, but 50% organic + 50% inorganic practices had slightly higher HI, followed by 75% organic + innovative practice (0.37 and 0.35 respectively). Management options varied significantly in HI at the last two phases of crop growth. 75% organic + innovative practices resulted in higher HI on a par with 50% organic + 50% inorganic practices at the mid growth phase (0.65 and 0.64 respectively). The harvest index (HI) at 9 MAP (0.61) was significantly highest in 75% organic + innovative practices (Fig. 2), which might have resulted in highest tuber yield in this management option. Farhad *et al.* (2009) noticed that applying poultry manure at varying levels in spring maize had a significant influence on the harvest index indicating that proper nutrient management through organic means can enhance crop performance.

The tuber yield was significantly highest in 75% organic + innovative practice (46.62 t/ha). This was followed by the 100% organic practices (41.37 t/ha) (Table 2). The mean weight of tubers, length and girth of tubers were also numerically higher under organic management options. The yield increase in 75% organic + innovative practices demonstrates effectiveness of integrating solid and liquid organic manures. Seena Radhakrishnan *et al.* (2022) reported significantly higher cassava yields under organic management practices compared to conventional systems. It has been conclusively proved that organic farming resulted in 10-20% higher yield over conventional farming in tropical tuber crops like elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson), yams (*Dioscorea* spp.) and Chinese potato (*Plectranthus rotundifolius* (Poir.) Spreng) (Suja *et al.,* 2012; Suja and Sreekumar, 2014; Suja *et al.,* 2021). Mali *et al.* (2018) found that application of vermicompost along with biofertilizers resulted in higher growth and yield parameters. Joddar *et al.* (2025) noticed that combined application of vermicompost and

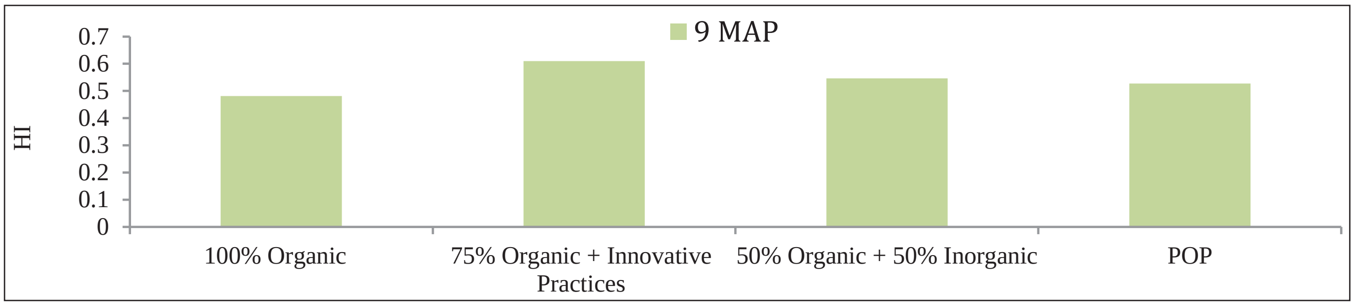

Fig. 2. Harvest index at 9 MAP as affected by management options

panchagavya facilitated higher grain yield in aromatic rice. These findings highlight the potential of organic inputs to boost crop output compared to conventional agricultural systems.

Table 2. Yield of cassava as influenced by management options

Management	Tuber yield (kg/plant)	Tuber yield (t/ha)
100% organic	3.35	41.37
75% organic + Innovative Practices	3.78	46.62
50% organic + 50% inorganic	3.32	41.01
package of practices	3.30	40.77
CD (0.05)	0.372	4.587

The yield of vegetables varied significantly among management options with 50% organic + 50% inorganic practice producing highest vegetable production (4.62 t/ha), followed by 100% organic and package of practices (4.61 and 4.16 respectively), which were on a par (Table 3). Among vegetables, okra produced highest yield. The combining vermicompost with synthetic fertilizers can enhance yield as integrated nutrient management balances nutrient availability with crop demand (Magar *et al.,* 2023). Management options did not impart significant variations in TEY, while 75% organic + innovative practices showed relatively higher system productivity. The vegetables x management options interactions indicated that highest tuber equivalent yield (TEY) was obtained in cassava intercropped with okra under 75% organic + innovative practices (63.92 t/ha), on a par with cassava + okra under 100% organic treatment (59.28 t/ha) (Table 4). The synergy of solid manure that offer slow-release nutrients and liquid manure that supplies quick-release nutrients together fulfill both immediate and long-term nutrient demands (Joddar *et al.*, 2025). This in turn leads to more balanced and sustained nutrient release throughout the crop cycle, resulting in higher yields, and greater overall system efficiency.

Table 3. System productivity under various management options

Management	Vegetable yield (t/ha)	Tuber equivalent yield (t/ha)
100% organic	4.61	48.30
75% organic + Innovative Practices	3.41	51.77
50% organic + 50% inorganic	4.62	48.32
package of practices	4.16	47.02
CD (0.05)	0.656	NS

Table 4. Interaction effect of vegetable intercrops and management options on vegetable yield and system productivity

Vegetables x management		Vegetable yield (t/ha)	TEY (t/ha)
	100% organic	2.69	41.82
Amaranthus	75% organic + inorganic practices	2.00	51.02
	50% organic + 50% inorganic	4.20	40.17
	package of practices	2.80	38.61
Okra	100% prganic	8.60	59.28
	75% oganic + innovative practices	6.24	63.92
	50% organic + 50% inorganic	7.26	56.54
	package of practices	7.77	48.73
Vegetable cowpea	100% organic	2.55	43.79
	75% organic + innovative practices	1.98	40.37
	50% organic + 50% inorganic	2.41	48.24
	package of practices	1.91	53.72
	CD (0.05)	1.560	6.529

The physical properties of soil, bulk density, particle density, water holding capacity and porosity were unaffected by various management options.

Various management options imparted significant effect on chemical properties of soil (Table 5). Among management options, 100% organic exhibited higher soil pH (4.45), on a par with POP (4.32) and 75% organic + innovative practices (4.16). Long-term experiments on organic farming undertaken at ICAR-CTCRI, Thiruvananthapuram (Suja *et al.*, 2012; Suja and Sreekumar, 2014; Suja *et al.*, 2017) strongly supports significant pH increase under organic management. The increase in pH can be attributed to the addition of green manure and other manures that plays a critical role in providing the soil surface with extra cations from deeper soil layers following the decomposition of nutrients. The electrical conductivity indicated no significant difference among treatments but organic managements showed a marginally higher value with 75% organic + innovative practices resulting in highest value, followed by 100% organic (0.39 and 0.35 respectively).

Soil organic C was significantly highest in 100% organic (1.78%). The incorporation of green manure cowpea along with effect of nutrient rich solid organic manures might have played a great role in increasing the organic carbon content. Ravisankar *et al.* (2016) found that inclusion of legumes in farming systems resulted in an average increase of 9.3% in soil organic carbon, improving from 0.75% to 0.82%. An increase in soil organic carbon after green manure incorporation, compost and organic matter addition were noticed in previous studies (Melero

Table 5. Major chemical properties of soil as influenced by management options

Management	pH	Elecrical conductivity (dS/m)	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
100% organic	4.45	0.35	1.78	308.82	82.94	392.28
75% organic + innovative practices	4.16	0.39	1.53	226.97	77.83	368.85
50% organic + 50% Inorganic	3.94	0.34	1.40	202.07	58.34	335.09
package of practices	4.31	0.33	1.51	218.61	65.34	315.79
CD (0.05)	0.347	NS	0.192	24.567	7.200	NS

Table 6. Secondary and micronutrient status of soil as influenced by management options

Management	Exchangeable Ca (cmol/kg)	Exchangeable Mg (cmol/kg)	Available Fe (ppm)	Available Zn (ppm)	Available Cu (ppm)
100% organic	3.11	1.48	29.52	3.73	2.07
75% organic+ innovative practices	3.78	1.28	29.16	2.98	2.17
50% organic+ 50% inorganic	2.60	1.02	30.07	2.78	1.50
POP	2.47	1.03	30.87	2.17	1.51
CD (0.05)	0.208	0.236	NS	0.378	0.271

et al., 2008; Gurudivya *et al.*, 2025). Higher organic C status of organic plots might be attributed to addition of green manure cowpea along with poultry manure and vermicompost.

Among management options, 100% organic treatment resulted in significantly highest soil available N (308.82 kg/ha). Higher available N status may be due to higher N content in the organic manures particularly poultry manure, and green manure. Gurudivya *et al.* (2025) observed increase in available nitrogen and phosphorus content through green manuring. Available P content was highest in 100% organic management (82.94 kg/ha) on a par with 75% organic + innovative practices (77.83 kg/ha). The increase in P can be due to the application of vermicompost that can significantly increase phosphorous-use efficiency and further enhance the ability of soil to recycle essential micronutrients (Nieto-Cantero *et al.* 2025). Though available K content was not influenced significantly, it was tended to be higher under 75% organic + innovative practice (368.85 kg/ha).

Significantly higher exchangeable Ca (3.78 cmol/kg) was in 75% organic + innovative practices. Higher levels of exchangeable Mg were in 100% organic practices (1.48 cmol/kg) on par with 75% organic + innovative practices (1.28 cmol/kg) (Table 6). The Fe content was not significantly affected by the various management options. 100% organic management resulted in significantly higher values of available Zn (3.73 ppm). Available Cu was higher in 75% organic + innovative practices (2.17 ppm) on a par with 100% organic treatment (2.07 ppm). Studies by Kwiatkowski and Harasim (2020) also observed comparable increase in pH, organic C, available N, Mg and Zn content in the organically managed soil compared to the conventional system. According to the study by Melero *et al.* (2008) soils under organic fertilization showed improvement in soil fertility. The sustained use of organic amendments play a critical role in boosting the soil properties in the long term and increase its plant available micronutrient contents (Zhang *et al.,* 2015).

CONCLUSIONS

Intercropping cassava with vegetables can help improve nutritional yield per hectare. By enhancing soil health while maintaining yield levels, intercropping under organic management could provide a basis for sustainable agricultural policy, contribute to climate resilience planning, nutrition-sensitive agriculture and food security in tropical regions.

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