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Effect of Organic Nutrient Management Practices on Growth and Yield of Short-duration Cassava (*Manihot esculenta* Crantz)

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ABSTRACT

Background: Cassava is an important tropical tuber crop with great potential, particularly for short-duration varieties. Understanding the impact of nutrient management practices on the growth and yield of cassava is crucial for crop intensification and multiple cropping.

Methods: Field experiments were conducted at Tapioca and Castor Research Station, Yethapur, Salem in 2022-2023 to determine the effect of various nutrient management practices on the growth attributes, biomass production, dry matter distribution and yield characteristics of short-duration cassava. The experiment was laid out in a randomized block design with twelve treatments and three replications.

Result: The integrated nutrient management practice of FYM @ 25 t ha^{-1} + 100% RDF + cassava booster spray (T_{10}) resulted in higher crop growth, dry matter production, yield attributes, tuber yield and top yield. This was comparable with the organic practice of Wood ash @ 2 t ha^{-1} + 3% panchagavya foliar spray (T_7) among other organic practices. The control treatment with no manures, fertilizers or foliar sprays recorded lower growth and yield. Also, positive correlations between growth and yield attributes with yield was also observed.

Key words: Biomass, Cassava booster, Organic production, Panchagavya, Tuber yield.

INTRODUCTION

Tropical tuber crops such as cassava, sweet potato, yams, aroids and minor tubers like coleus and arrowroot are important for over 5 billion people globally, providing food, nutrition, employment and social security. They are a good alternative to cereals because they are high in carbohydrates and calories. Some of these crops are now being grown commercially due to their wider use in the industrial sector. Although they are adapted to grow in marginal soils, using manure and fertilizers can improve their yield and quality. To meet the growing demand for tuber crops, there is a need to improve their productivity through better farming practices (Susan John *et al*., 2016).

Among these crops, cassava is a versatile crop that can be used for various purposes, such as animal feed, starch production and also provides food and nutrition for rural communities. It is mainly grown in Kerala, Tamil Nadu andhra Pradesh and Northeastern Himalayan regions. It is highly efficient and can grow in marginal conditions with low external inputs, adverse soil and climatic conditions. This makes it flexible and adaptable to different environments (Anantharaman *et al*., 2020). In recent years, India has gained importance in the global production of cassava achieving high productivity of 37.90 t ha^{-1} over an area of 0.183 million hectares resulting in a production of 6.94 million tons (India-Stat, 2023). The development of short-duration cassava varieties has become increasingly important to intensify agriculture and increase productivity, especially in Southeast Asia where there is a high demand for food production. These varieties can be harvested in 6-7 months instead of the typical 9-24 months. Popular short-duration cassava varieties like Sree Jaya, Sree Vijaya, Sree Prakash, Vellayani Hraswa and Kalpaka have been released by institutions such as ICAR-Central Tuber Crops Research Institute (CTCRI) and Kerala Agricultural University (KAU) is suitable for integration into the existing cropping systems. This provides an opportunity for

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conventional smallholders to diversify and intensify crops to increase on-farm enterprise and income (Suja *et al*., 2010b). However, there is still a need to assess the possibility of saving costly nutrient inputs by formulating suitable nutrient management practices for short-duration cassava.

Moreover, crop diversification and organic farming are crucial for sustainable food production, especially during climate change, as they enable environmentally benign and clean food production. The use of different organic manures and organic liquid formulations promotes soil microorganisms, mobilizes nutrients, increases root growth and improves crop productivity (Rathore *et al*., 2023; Suja *et al*., 2012). Although there is no clear scientific evidence about the impact of organic management on the productivity of cassava, exploring the impact of organic nutrient management on the growth and yield of short-duration cassava is essential. Hence, developing short-duration cassava varieties and implementing organic management practices can enhance productivity, promote sustainability and provide new opportunities for farmers in Southeast Asia (Radhakrishnan *et al*., 2013; Radhakrishnan and Suja, 2017). Therefore, the present investigation was carried out to evaluate the performance of short-duration cassava to various organic nutrient management practices in terms of growth, biomass and yield.

MATERIALS AND METHODS

Two separate field experiments were conducted in series at the Tapioca and Castor Research Station (TCRS) in Yethapur, Salem from January 2022 to April 2023 to investigate various nutrient management practices on short-duration cassava. The experimental site was located in the northwestern zone of Tamil Nadu, with a tropical climate characterized by hot summers and moderate winters (11°37′N, 78°36′E). The soil at the experimental site was clay loam with low available nitrogen (197.45 kg ha^{-1}), medium available phosphorus (20.26 kg ha^{-1}) and available potassium (224.61 kg ha^{-1}) and had a pH of 8.03. The experiments were laid out in a randomized block design (RBD) with twelve treatments and three replications in the same location. The treatments included T_1- Enriched farm yard manure (EFYM) @ 2 t ha^{-1} + 3% panchagavya foliar spray, T_2 -EFYM @ 2 t ha^{-1} + 3% vermiwash foliar spray, T_3 - EFYM @ 2 t ha^{-1} + 3% banana pseudostem sap foliar spray, T_4- Vermicompost @ 2 t ha^{-1} + 3% panchagavya foliar spray, T_5- Vermicompost @ 2 t ha^{-1} + 3% vermiwash foliar spray, T_6- Vermicompost @ 2 t ha^{-1} + 3% banana pseudostem sap foliar spray, T_7- Wood ash @ 2 t ha^{-1} + 3% panchagavya foliar spray, T_8- Wood ash @ 2 t ha^{-1} + 3% vermiwash foliar spray, T_9- Wood ash @ 2 t ha^{-1} + 3% banana pseudostem sap foliar spray, T_{10}- Farm yard manure (FYM) @ 25 t ha^{-1} + 100% RDF + cassava booster spray, T_{11}- FYM @ 12.5 t ha^{-1} + 50% RDF + cassava booster spray and T_{12}- Control (No manures/fertilizers/sprays). The foliar sprays were given at 30, 60 and 90 days after planting (DAP). Nutrient concentrations of various organic resources were recorded by adopting standard procedures (Table 1).

For this study, the early maturing variety of cassava, Vellayani Hraswa (5-6 months) was selected. This particular variety was selected based on its favourable traits including a compact form, significant branching, abundant yield, reddish-brown tuber skin and a starch content of 27-28% that exhibits excellent cooking properties (KAU, 2016). Disease-free and healthy stems were carefully selected from TCRS and cut into 20 cm setts with uniform thickness. The setts were then planted on ridges with a depth of 10-15 cm, with two nodes below the soil and one above the soil. A spacing of 90 cm × 90 cm with a gross plot size of 5.4 m × 5.4 m was followed. The field was irrigated on a 15 to 20 days interval, depending on the rainfall and soil moisture availability during the study period of January 2022 to April 2023, which received a total annual rainfall of 1244 mm on 70 rainy days during 2022 and 129.6 mm on 7 rainy days till April 2023.

During the study, various organic manures such as FYM, EFYM, Vermicompost and Wood Ash were incorporated into the soil according to the assigned treatments. The recommended dose of fertilizers (90:90:240 kg NPK ha^{-1}) was applied using urea, diammonium phosphate (DAP) and Muriate of Potash (MOP) during planting based on the respective treatments. Basal application of 50% N and K and 100% P was applied and the remaining 50% N and K was top-dressed at 30 DAP. To further optimize the growth and development of the cassava, foliar sprays such as Panchagavya, Vermiwash, Banana pseudostem sap and Cassava Booster (Cassava tonic) were administered at 30, 60 and 90 DAP under the respective treatments. Cassava Booster is a specially-formulated mixture of organic manure, cow dung, neem cake and biocontrol agents, along with inorganic nutrients, to bolster the plant's immunity against cassava mosaic disease (CMD), address nutritional deficiencies and improve tuber yield and starch content (Neelakandan *et al*., 2021). This was procured from TCRS. To ensure optimum plant population and density, gap filling and removal of excess shoots were done at 20 to 30 DAP. The plant was maintained at two shoots per plant in the opposite direction. Hand-weeding was done twice at 30 and 60 DAP and earthing up was also carried out as necessary (CPG-Horticulture, 2020). The field trials were conducted over two separate planting seasons, one in January 2022 and the other in September 2022 and the cassava plants were harvested in July 2022 and April 2023, respectively.

Observations on the growth attributes of cassava, such as plant height and the total number of leaves plant^{-1} at harvest were recorded. Additionally, biomass production and partitioning to the top portion and tubers by randomly uprooting three plants per plot at 60 DAP, 120 DAP and at harvest were analyzed. The plants were separated into tubers and tops (stems and leaves), air-dried and oven-dried at 70°C until reaching a constant weight. The dry

weight was expressed in grams plant^{-1}. Various yield characters, including the mean weight of tuber (g), number of tubers plant^{-1}, mean weight of tubers plant^{-1} (kg), tuber yield (t ha^{-1}), top yield (t ha^{-1}) and harvest index (HI) were recorded. The fresh weight of the harvested tubers from each net plot was recorded and the yield was expressed in tons hectare^{-1}.

After collecting the data, it was analyzed by performing an analysis of variance (ANOVA) followed by conducting a least significant difference (LSD) test to compare the treatment means at 5% level of significance as described by (Gomez and Gomez, 1984). To obtain accurate results, the statistical analysis was carried out by using the R software package: GrapesAgri1, Version 1.0.0 (Gopinath *et al*., 2021).

RESULTS AND DISCUSSION

Growth attributes

The growth of short-duration cassava including plant height and total number of leaves plant^{-1} at harvest was significantly impacted by various nutrient management practices (Table 2). Based on the average data, plants grown under integrated nutrient management with the application of FYM at 25 t ha^{-1}+ 100% RDF+ cassava booster spray significantly recorded taller plants but it was on par with the organic practice of wood ash at 2 t ha^{-1}+ 3% panchagavya foliar spray (136.47 cm and 126.82 cm, respectively). In the case of total leaf production plant^{-1}, maximum leaf production was significantly recorded in the same treatments (92.77 and 91.40, respectively) compared to other nutrient management practices. The control treatment registered the lowest plant height (79.55 cm) and the minimum number of leaf production plant^{-1} (60.67).

The rapid release and availability of essential nutrients from integrated or organic sources led to increased plant height and leaf production. Organic nutrient application may have resulted in a steady release of nutrients throughout the entire crop growth period. Additionally, micronutrients present in liquid organic fertilizers and their foliar application could have contributed to enhanced cassava growth. These results are consistent with previous studies by Susan John *et al.* (2005); Susan John and Suja (2006); Amanullah *et al.* (2007); Ojeniyi *et al.* (2009); Suja *et al.* (2009); Suja *et al.* (2010a); Suja *et al.* (2017) and Pooja and Swadija (2020), also by Channakeshava *et al.* (2017) on potato.

Table 1: Average nutrient concentration of organic inputs.

Organic inputs	N (%)	P (%)	K (%)
Farmyard manure	0.42	0.16	0.33
Vermicompost	1.30	0.40	1.60
Wood ash	1.10	0.35	3.60
Enriched FYM	0.74	1.02	0.66
Panchagavya	0.02	0.02	0.03
Vermiwash	0.01	0.57	0.003
Banana pseudostem sap	0.07	0.02	0.17
Cassava booster spray	0.12	0.06	0.07

Biomass production and dry matter distribution

The various nutrient management practices significantly affected the total biomass production (Table 2) and its distribution of dry matter in the top and root portions. The integrated treatment of FYM at 25 t ha^{-1}+ 100% RDF+ cassava booster spray significantly favoured higher total plant biomass (16.22 t ha^{-1}) and tuber biomass production (11.39 t ha^{-1}) at harvest. The next best performing practices were the application of Wood ash @ 2 t ha^{-1} + 3% panchagavya foliar spray (14.53 t ha^{-1} and 10.09 t ha^{-1}, respectively) and the application of Wood ash @ 2 t ha^{-1} + 3% Banana pseudostem sap foliar spray (14.19 t ha^{-1} and

Table 2: Effect of various organic nutrient management practices on growth attributes and dry matter production of short-duration cassava at harvest (Mean value of two experiments).

Treatments	Growth attributes		Total dry matter production	Root dry matter production	Harvest
	Plant height (cm)	Number of leaves plant^{-1} (cm)	(TDMP) (t ha^{-1})	(RDMP)(t ha^{-1})	index (HI)
T_1	108.30	80.58	11.19	7.67	0.69
T_2	84.12	62.45	6.16	4.25	0.69
T_3	84.84	67.67	7.09	4.77	0.67
T_4	106.30	76.77	10.07	6.77	0.67
T_5	87.98	68.00	7.89	5.35	0.68
T_6	89.08	69.24	8.55	5.81	0.68
T_7	126.82	91.40	14.53	10.09	0.70
T_8	103.99	74.80	8.67	5.88	0.68
T_9	122.84	89.59	14.19	9.95	0.70
T_{10}	136.47	92.77	16.22	11.39	0.70
T_{11}	107.92	78.47	10.94	7.48	0.69
T_{12}	79.55	60.67	4.97	3.43	0.69
SEd	6.40	4.64	0.65	0.45	0.04
CD (0.05)	13.27	9.63	1.35	0.93	NS

9.95 t ha^{-1}, respectively). However, the harvest index was not significantly affected by the different nutrient practices since the treatments that recorded higher root biomass also recorded higher total biomass production at harvest, as indicated in Table 1.

The distribution of dry matter showed a significant increase with the progression of plant age under different nutrient management practices as illustrated in Fig 1. At 2 months after planting, higher root, aerial and total plant dry weight was significantly recorded in INM, FYM at 25 t ha^{-1} + 100% RDF+ cassava booster spray (29.39, 61.12 and 90.50 g plant^{-1}, respectively) which was statistically on par with the application of Wood ash @ 2 t ha^{-1} + 3% panchagavya foliar spray (27.29, 58.15 and 85.43 g day^{-1}, respectively). During the mid stage, the aforementioned INM showed superior performance in producing dry matter partitioning (472.28, 344.67 and 816.95 g plant^{-1}, respectively). The same trend was followed at harvest where the INM treatment (T_{10}) continued its dominance in recording higher root, aerial and total plant dry matter (919.55, 394.35 and 1313.90 g plant^{-1}, respectively). This was followed by T_7 and T_9 which recorded 821.68 and 812.10 g plant^{-1} of root dry matter, 354.89 and 337.29 g plant^{-1} of aerial dry matter respectively. Initially, photosynthates primarily accumulated in the vegetative parts, but later shifted towards the tuberous roots. Leaves and stem acted as the main storage for nutrients initially, while the tuberous roots became dominant after 4 months. With maturity, the competition for

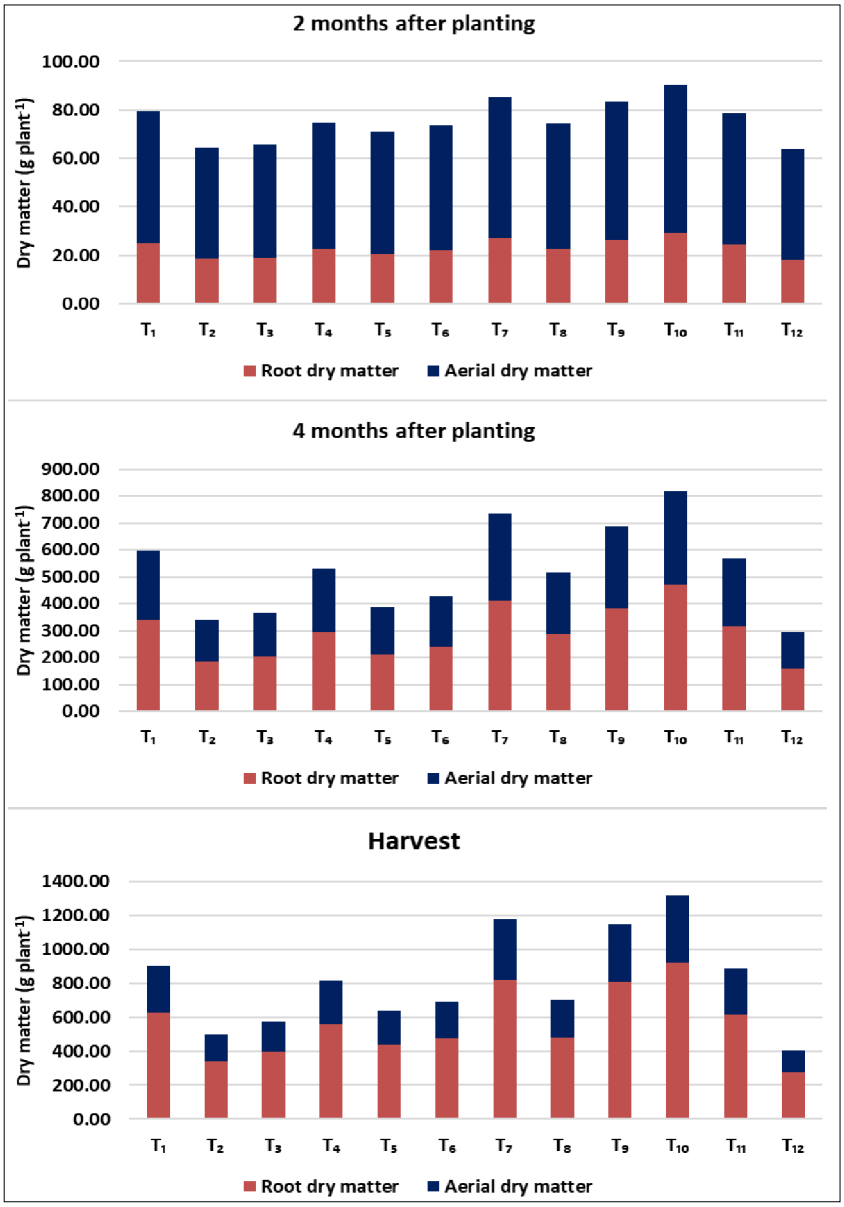


Fig 1: Effect of organic nutrient management practices on total dry matter and dry matter distribution of short-duration Cassava (Mean value of two experiments).

assimilates between leaves/stem and tubers decreased, leading to higher tuber biomass in the harvest. Both chemical fertilizers and organic sources aided efficient distribution of assimilates. Organic manures and foliar application of organics with macro/micronutrients and growth regulators likely promoted greater biomass production. These findings are consistent with previous studies by Suja *et al.* (2009); Suja *et al.* (2010a); Suja *et al.* (2017) and also by Champaneri *et al.* (2021) on Indian beans and Rathore *et al.* (2023) on brinjal.

Yield attributes

The different nutrient management practices had a positive impact on the yield attributes of cassava, including the mean weight of tuber, the number of tubers plant^{-1} and the mean weight of tubers plant^{-1} (Table 3). Application of FYM @ 25 t ha^{-1} + 100% RDF + cassava booster spray was found to be the most effective in producing a significantly higher mean weight of tuber (337.93 g), number of tubers plant^{-1} (7.98) and mean weight of tubers plant^{-1} (2.70 kg). The application of Wood ash @ 2 t ha^{-1} + 3% panchagavya foliar spray showed similar results and it was on par with the above treatment in producing significant yield attributes *viz*., number of tubers plant^{-1} (7.77) and mean weight of tubers plant^{-1} (2.48 kg). The control group had the minimum number of tubers plant^{-1} (5.15), lower mean tuber weight (135.56 g) and mean weight of tubers plant^{-1} (0.71 kg). It should be noted that the genetic makeup of the variety played a significant role in the number of tubers plant^{-1} and the mean weight of the tuber, which had a positive correlation with tuber yield (Jayakumar *et al*., 2019; Kanthaswamy *et al*., 2021; Singh *et al*., 2016). Similar findings were reported by Champaneri *et al.* (2021) in Indian beans, where the foliar application of nutrients increased the uptake of nutrients and water, leading to the allocation of photosynthates towards the economic parts.

Yield

The tuber and top yield of cassava were significantly influenced by the application of various nutrient management practices (Table 3). The integrated application of FYM @ 25 t ha^{-1} + 100% RDF + cassava booster spray resulted in a significantly higher tuber yield (33.27 t ha^{-1}) and was comparable to the organic treatment of Wood ash @ 2 t ha^{-1} + 3% panchagavya foliar spray (30.56 t ha^{-1}) which resulted in a percentage decrease of 8.1% in tuber yield compared to the integrated treatment. In case of top yield, the nutrient management practices *viz*., FYM @ 25 t ha^{-1} + 100% RDF + cassava booster spray, Wood ash @ 2 t ha^{-1} + 3% panchagavya foliar spray and Wood ash @ 2 t ha^{-1} + 3% banana pseudostem sap foliar spray significantly recorded higher top yield (9.82, 9.17 and 9.05 t ha^{-1} respectively). The control treatment registered the lowest tuber (8.67 t ha^{-1}) and top yield (5.34 t ha^{-1}).

The short-duration variety exhibited higher crop growth, biomass and yield attributes (Suja *et al*., 2010a). The use of a cassava booster with potassium reduced CMD incidence and positively influenced yield (Neelakandan *et al*., 2021). Wood ash application improved plant growth and yield by reducing soil acidity and providing calcium (Suja *et al*., 2009). Organic inputs released nutrients synchronously, enhancing performance compared to other treatments (Suja *et al*., 2014; Suja *et al*., 2020). Combining chemical fertilizers with organic manures increased tuber and top yield (Mhaskar *et al*., 2013; Pooja *et al*., 2018). Foliar application of nutrients improved yield attributes and tuber yield as observed in potato studies Channakeshava *et al.* (2017).

Correlation of growth and yield attributes with tuber and top yield

The correlation matrix of various growth and yield attributes with tuberous root and top yield of cassava was presented in Table 4. The results of the Pearson correlation analysis

Table 3: Effect of various organic nutrient management practices on yield attributes and yield of short-duration cassava (Mean value of two experiments).

Treatments	Yield attributes			Tuber yield	Top yield
	Mean tuber weight (g)	No. of tubers plant^{-1}	Weight of tuber plant^{-1} (kg)	(t ha^{-1})	(t ha^{-1})
T_1	273.23	7.31	2.00	24.63	8.05
T_2	160.77	5.72	0.92	11.36	6.10
T_3	184.71	6.13	1.14	14.01	6.76
T_4	264.42	6.83	1.81	22.28	7.84
T_5	198.00	6.36	1.26	15.56	6.94
T_6	211.80	6.52	1.38	17.04	7.12
T_7	319.14	7.77	2.48	30.56	9.17
T_8	227.61	6.55	1.49	18.40	7.29
T_9	316.01	7.53	2.38	29.32	9.05
T_{10}	337.93	7.98	2.70	33.27	9.82
T_{11}	270.99	7.09	1.92	23.70	7.89
T_{12}	135.56	5.15	0.71	8.67	5.34
SEd	15.22	0.41	0.11	1.36	0.47
CD (0.05)	31.57	0.84	0.23	2.82	0.97

Table 4: Correlation of growth and yield attributes with yields of short-duration cassava.

Growth and yield attributes (at harvest)	Correlation coefficient with	
	Tuber yield	Top yield
Plant height (cm)	0.966***	0.973***
Total leaf production plant $^{-1}$	0.962***	0.984***
The mean weight of tuber (g)	0.995***	0.982***
Number of tubers plant $^{-1}$	0.942***	0.983***
The mean weight of tubers plant $^{-1}$ (kg)	1***	0.974***
Tuber yield (t ha^{-1})	1	0.974***
Top yield (t ha^{-1})	0.974***	1
Total dry matter production (t ha^{-1})	0.994***	0.976***
Root dry matter production (t ha^{-1})	0.99***	0.971***
The total dry matter (g plant^{-1})	0.994***	0.976***
Total root dry matter (g plant^{-1})	0.992***	0.973***
Harvest index	0.31	0.472**

***Correlation is significant at 0.001 level (Two-tailed).

**Correlation is significant at 0.01 level (Two-tailed).

indicate that tuber and top yield have a strong positive correlation with crop growth and yield attributes. The positive correlation coefficients suggest a positive relationship between all growth and yield attributes with both types of yield. The mean weight of tubers plant^{-1} had a perfect positive correlation with tuber yield, while total leaf production at harvest had a strong positive correlation with top yield. This could be due to the slow release of nutrients from manures and the release of enzymes by microbes in liquid formulations, resulting in higher yields. The harvest index at harvest had a moderate positive correlation with top yield, but a weak positive correlation with tuber yield. The study found that the mean weight of the tuber, number of tubers plant^{-1}, total dry matter production and total dry matter at harvest have the highest correlation coefficients with both types of yield. These findings were consistent with the studies conducted by Suja *et al.* (2010b); Kanthaswamy *et al.* (2021); Neelakandan *et al.* (2021) and Rathore *et al.* (2023).

CONCLUSION

From the study, it can be concluded that the integrated application of FYM @ 25 t ha^{-1} + 100% RDF + cassava booster spray registered maximum yield and it was comparable with the organic practice of Wood ash @ 2 t ha^{-1} + 3% panchagavya foliar spray with only a slight reduction in yield (8.1%). However, Wood ash @ 2 t ha^{-1} + 3% banana pseudostem sap foliar spray was also similarly effective and on par with the above organic practice. Based on the availability of local organic inputs, the above practices can be suggested for an effective cropping system with cassava for sustainable crop production.

Conflict of interest

All authors declare that they have no conflict of interest.

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