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Impact of Organic Nutrient Management Practices on Growth Dynamics and Economics of Short-duration Cassava (*Manihot esculenta* Crantz.)

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ABSTRACT

Background: A series of field experiments were conducted at the Tapioca and Castor Research Station (TCRS), Tamil Nadu Agricultural University, Yethapur, Salem from 2022 to 2023. The purpose was to investigate the growth dynamics and economics of short-duration cassava under different nutrient management practices including both integrated and organic approaches.

Methods: Twelve treatments were carried out consisting of various combinations of organic manures, liquid organic foliar sprays, integrated nutrient management treatments and a control treatment (no manures/fertilizers/sprays). The experiments were carried out in a randomized block design (RBD) with three replications at the same location.

Result: The results revealed that the different nutrient management practices had a significant impact on the physiological response throughout the various stages of plant growth. Based on the average data from two experiments, the INM treatment (FYM@ 25 t ha^{-1} + 100% recommended dose of fertilizers andcassava booster spray) showed the highest physiological response during the final phase of growth. This treatment showed superior performance in terms of leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), tuber bulking rate (TBR) and mean TBR. The organic treatment (wood ash @2 t ha^{-1} and 3% panchagavya foliar spray) recorded comparable performance to the INM treatment in major parameters such as LAI, CGR, RGR and NAR. However, it followed the INM treatment in terms of mean TBR. Economic analysis revealed that the INM treatment yielded the highest net income and benefit-cost ratio (BCR), followed by the organic treatment. The control resulted in the least returns. In conclusion, the findings highlight the effectiveness of the INM treatment and the promising performance of the organic treatment which can contribute to sustainable and profitable cassava cultivation.

Key words: Cassava booster, Economics, Growth dynamics, Organic farming, Short-duration cassava.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz.) holds the position of the world's seventh most significant food crop in terms of cultivation area, although it falls behind crops such as wheat, maize, rice, barley, sorghum and millet (Suja and Sreekumar, 2015). 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 ha resulting in a production of 6.94 million t (India-Stat, 2023). This tropical tuber crop plays a vital role in ensuring food and nutritional security in rural areas. Its ability to thrive in marginal lands and the capacity to withstand various climatic conditions contributes to its climate resilience. With the increasing focus on agricultural intensification and multiple cropping systems to enhance productivity, the development of short-duration cassava varieties has become imperative. These varieties which can be harvested within 6-7 months offer potential benefits such as efficient resource utilization for small-scale farmers as well as opportunities for diversifying on-farm enterprises and increasing income (Suja *et al.*, 2011).

Nutrient management plays a crucial role in optimizing cassava productivity. Conventionally, chemical fertilizers,

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organic manures and bio-fertilizers are used to meet the crop nutrient requirements. The adoption of these resources contributes to higher cassava production. However, the rising cost of chemical fertilizers and growing awareness about their negative impact on soil health and sustainability have led to increased interest in alternative nutrient management practices, particularly organic farming and integrated nutrient management. These practices aim to enhance productivity and profitability while reducing reliance on chemical inputs. Despite this, limited information is available regarding the influence of organic cultivation on short-duration cassava (Mhaskar *et al.*, 2013). Therefore, the objective of this study is to assess the growth dynamics and economic outcomes of short-duration cassava under different organic nutrient management practices.

MATERIALS AND METHODS

A series of field experiments were conducted over a span of two years from January 2022 to April 2023 at the Tapioca and Castor Research Station (TCRS) located in Yethapur, Salem, Tamil Nadu. The experimental site is situated in the northwestern region of Tamil Nadu and experiences tropical climatic conditions. Geographically, it lies between 11°37′ North latitude and 78°36′ East longitude with an altitude of 282 meters above mean sea level. The soil at the experimental site is characterized as black soil with a slightly alkaline pH. The soil's nutrient profile revealed low availability of nitrogen, medium availability of phosphorus and high availability of potassium.

For the study, a short-duration variety of cassava called Vellayani hraswa with a growth cycle of 5-6 months was chosen. The experiment was laid out in a randomized block design (RBD) with twelve treatments, each replicated three times. The treatments applied were as follows:

T_1: EFYM @2 t ha^{-1} + 3% panchagavya foliar spray at 30, 60 and 90 DAP.

T_2: EFYM @2 t ha^{-1} + 3% vermiwash foliar spray at 30, 60 and 90 DAP.

T_3: EFYM @2 t ha^{-1} + 3% banana pseudostem sap foliar spray at 30, 60 and 90 DAP.

T_4: Vermicompost @2 t ha^{-1} + 3% panchagavya foliar spray at 30, 60 and 90 DAP.

T_5: Vermicompost @2 t ha^{-1} + 3% vermiwash foliar spray at 30, 60 and 90 DAP.

T_6: Vermicompost @2 t ha^{-1} + 3% banana pseudostem sap foliar spray at 30, 60 and 90 DAP.

T_7: Wood ash @2 t ha^{-1} + 3% panchagavya foliar spray at 30, 60 and 90 DAP.

T_8: Wood ash @2 t ha^{-1} + 3% vermiwash foliar spray at 30, 60 and 90 DAP.

T_9: Wood ash @2 t ha^{-1} + 3% banana pseudostem sap foliar spray at 30, 60 and 90 DAP.

T_{10}: FYM @25 t ha^{-1} + 100% RDF + cassava booster spray at 30, 60 and 90 DAP.

T_{11}: FYM @12.5 t ha^{-1} + 50% RDF + cassava booster spray at 30, 60 and 90 DAP.

T_{12}: Control (No manures/fertilizers/sprays).

[EFYM- Enriched farm yard manure; FYM- Farm yard manure; DAP-Days after planting; RDF- Recommended dose of fertilizer (90: 90: 240 kg NPK ha^{-1})].

Planting and agronomic practices were followed as per the recommended guidelines for cassava cultivation (CPG-Horticulture, 2020). Cassava setts of uniform size (20-30 cm in length) were planted on ridges with a spacing of 90 x 90 cm. Organic manures like EFYM, vermicompost, FYM and wood ash were applied at planting depending on the treatment. For the INM treatment, specific combinations of FYM, Urea, DAP and MOP were used. P_2O_5 and half of the N and K_2O doses were applied during planting and the remaining quantities of N and K_2O applied after one month along with weeding and earthing up operations. Harvesting took place six months after planting in both experiments. To assess growth dynamics, the dry weight of plants was recorded by uprooting three random plants per plot at 60, 120 DAP and at harvest. The uprooted plants were air dried and then oven-dried with their weights measured in grams per plant. Growth indices were computed using the collected dry weight values including leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), tuber bulking rate (TBR) and mean TBR. LAI, CGR and TBR were calculated for three crop growth phases: 0-60 DAP (Phase 1), 60-120 DAP (Phase 2) and 120-180 DAP (Phase 3). RGR and NAR were computed for Phases 2 and 3. Mean TBR was determined by averaging TBR values from all phases across the two experiments.

The growth indices were calculated by the following formulas:

$$\text{LAI} = \frac{\text{Leaf area per plant}}{\text{Land area occupied by plant}}$$

(Watson, 1947)

$$\text{CGR (g/m}^2\text{/day)} = \frac{(W_2-W_1)}{(t_2-t_1)]\ (1/A)}$$

(Watson, 1956)

$$\text{RGR (mg/g/day)} = \frac{(\log_e W_2-\log_e W_1)}{(t_2-t_1)}$$

(Williams, 1946)

$$\text{NAR (mg/cm}^2\text{/day)} = \frac{(W_2/W_1)}{(t_2-t_1)\ \tfrac{3}{2}\ [\ln(L_2)-\ln(L_1]/(L_2-L_1)}$$

(Williams, 1946)

$$\text{TBR (g/day)} = \frac{(W_2-W_1)}{(t_2-t_1)}$$

Where

W_1= Plant dry weight.

L_1= Leaf area at time t_1.

W_2= Plant dry weight.

L_2= Leaf area at time t_2.

A= Land area occupied by the plants.

For TBR calculation, W_1 and W_2 were considered as the tuberous root dry weight at time t_1 and t_2, respectively.

To evaluate the economic aspects of the study, the total cost of cultivation and gross returns were calculated based on the average input cost and market price of the cassava produce throughout the investigation period. Furthermore, the net return and benefit-cost ratio (B:C ratio) were computed to assess the profitability of the different treatments. Statistical analysis of the experimental data was done using the R studio package Grapes Agri1 (Gopinath *et al.*, 2021). The technique of analysis of variance (ANOVA) was applied as described by Gomez and Gomez (1984). In instances where a significant difference between treatment means was observed through ANOVA, a critical difference (CD) at 5% level of significance was used to compare the means.

RESULTS AND DISCUSSION

Growth indices

Leaf area index (LAI)

The leaf area index (LAI) was a parameter strongly affected by the various nutrient management practices throughout all phases of plant growth (Table 1). Notably, the LAI exhibited an increasing trend across all phases with rapid growth observed from phase 1 to phase 2 followed by a slight increase towards the harvest period. In terms of LAI, the INM treatment (FYM @25 t ha^{-1}+ 100% RDF + cassava booster spray) (T_{10}) established higher values during the initial two phases compared to other treatments (0.99 and 3.88, respectively). Following closely was the organic treatment utilizing wood ash @2 t ha^{-1}+ 3% panchagavya foliar spray (T_7) with LAI of 0.86 and 3.50, respectively. However, as the crop progressed to phase 3, both the INM (T_{10}) and organic treatment (T_7) show cased comparable and significantly higher LAI values (4.36 and 4.06, respectively). The INM treatment incorporating organic and mineral inputs exhibited an early advantage in LAI during the initial growth stages. Nevertheless, the organic treatment relying on wood ash and panchagavya foliar spray registered similar LAI levels in the later phases emphasizing its effectiveness in sustaining leaf area expansion.This was similar to the findings of Radhakrishnan *et al.* (2013); Mhaskar *et al.* (2013); Sreelakshmi and Menon (2019); Velmurugan *et al.* (2020); Pooja and Swadija (2020); Babu and Isaac (2023) and also by Hensh *et al.* (2020) on potatoes.

Crop growth rate (CGR)

The crop growth rate (CGR) of cassava was significantly influenced by the different nutrient management practices implemented throughout the crop growth cycle (Table 1). Initially, during the early phase, CGR exhibited a relatively slow rate across all treatments, ranging from 1.32 g m^{-2} day^{-1} to 1.87 g m^{-2} day^{-1} with low substantial differences observed. As the crop progressed, CGR experienced a rapid increase reaching its peak during the second phase followed by a gradual decline towards the harvest period for all treatments.

Remarkably, at harvest, the INM treatment (T_{10}) registered significantly higher CGR values (10.23 g m^{-2} day^{-1}) which were on par with the organic practice (T_9) recording CGR of 9.46 g m^{-2} day^{-1}. Notably, this organic practice confirmed comparable CGR with the treatment (T_7) with a CGR of 9.14 g m^{-2} day^{-1}. The INM treatment proved its ability to enhance CGR indicating its potential in facilitating accelerated crop growth. Similarly, the organic practices combiningwood ash and foliar sprays exhibited comparable performance emphasizing their viability as sustainable alternatives for promoting cassava growth. The timely application of nutrients might have helped in meeting crop nutrient demand leading to higher dry matter production and crop growth rate. These findings were in similarity to Suja *et al.* (2010); Radhakrishnan *et al.* (2013); Sunitha *et al.* (2014) and also by Hensh *et al.* (2020) on potatoes.

Table 1: Effect of organic nutrient management on LAI and CGR of short-duration cassava (mean value of two experiments).

T.no	Leaf area index			Crop growth rate (gm^{-2} day^{-1})		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
T_1	0.79	2.96	3.33	1.64	10.62	6.39
T_2	0.52	1.73	2.20	1.33	5.69	3.25
T_3	0.58	1.85	2.37	1.36	6.16	4.30
T_4	0.73	2.57	3.12	1.54	9.34	5.91
T_5	0.61	2.04	2.49	1.46	6.52	5.16
T_6	0.64	2.14	2.55	1.52	7.30	5.43
T_7	0.86	3.50	4.06	1.76	13.32	9.14
T_8	0.68	2.43	2.97	1.54	9.08	3.83
T_9	0.83	3.27	3.93	1.72	12.48	9.46
T_{10}	0.99	3.88	4.36	1.87	14.95	10.23
T_{11}	0.76	2.76	3.22	1.62	10.08	6.54
T_{12}	0.46	1.46	2.05	1.32	4.76	2.21
SEd	0.04	0.16	0.19	0.09	0.61	0.39
CD	0.09	0.34	0.40	0.19	1.26	0.81

Relative growth rate (RGR)

Relative growth rate (RGR) of cassava shown significant variation as a result of different nutrient management practices. Notably, RGR was higher during the second phase (60-120 DAP) compared to the third phase (120-180 DAP) indicating a decreasing trend with crop age (Table 2). The various nutrient treatments had a significant impact on RGR. Specifically, the INM treatment (T_{10}) resulted in the highest RGR (36.68 mg g^{-1} day^{-1}) during the second phase. This was comparable to other treatments including T_7, T_9, T_1 and T_{11} which recorded RGR values of 35.82, 35.24, 33.57 and 32.96 mg g^{-1} day^{-1}, respectively. In contrast, the control treatment which did not receive any manures, fertilizers or sprays exhibited the lowest RGR during both phases with values of 25.46 mg g^{-1} day^{-1} and 4.87 mg g^{-1} day^{-1}, respectively.The INM treatment recorded the highest RGR during the critical growth phase 2. Other treatments incorporating specific nutrient combinations also demonstrated comparable RGR values indicating their effectiveness in promoting crop growth. Conversely, the control treatment lacking essential nutrients exhibited the lowest RGR suggesting the importance of appropriate nutrient management for achieving optimal growth rates in cassava. This result was under the findings of Suja *et al.* (2010) and Radhakrishnan *et al.* (2013).

Net assimilation rate (NAR)

Net assimilation rate (NAR) of cassava showed consistent pattern to crop age, showing an increase as the crop matured reaching its peak during the second phase and followed by a sharp decline in the third phase regardless of the treatments applied (Table 2). Among the various nutrient management practices, treatments T_{10}, T_7 and T_9 consistently recorded significantly higher NAR values during the second phase (0.71, 0.71 and 0.70 mg cm^{-2} day^{-1}, respectively). During the third phase, the same treatments namely T_9, T_{10} and T_7 maintained their superiority in terms of NAR with values of 0.26, 0.25 and 0.24 mg cm^{-2} day^{-1}, respectively. These treatments confirmed comparable NAR levels among each other.Irrespective of the treatments, the crop exhibited a similar pattern of NAR increase as it aged, reaching its peak during the second growth phase and subsequently declining in the third phase.Treatments T_{10}, T_7 and T_9 consistently promoted higher NAR values which might be due to their effectiveness in facilitating efficient assimilation and utilization of nutrients during the crucial growth stages.These results show similarity with the findings of Radhakrishnan *et al.* (2014) and Sawatraksa *et al.* (2019).

Tuberous root bulking rate (TBR) and mean TBR

Tuberous root bulking rate (TBR) and mean TBR of cassava were influenced by the age of the crop with a progressive increase observed during the initial and mid phases, reaching peak values at harvest for most treatments. However, a slight decline was noted in a few treatments during the final phase (Fig 1). The TBR of cassava was significantly affected by various nutrient management practices. The INM treatment (T_{10}) consistently resulted in significantly higher TBR throughout all phases of crop growth. Notably, during the initialphase, the INM treatment (T_{10}) recorded statistically on par TBR values to the organic practice (T_7) of 0.49 g day^{-1} and 0.46 g day^{-1}, respectively. During the second phase, the INM (T_{10}) outperformed the other organic nutrient treatments recording a TBR of 7.38 g day^{-1}. However, in the final phase, the maximum TBR (7.46 g day^{-1}) was registered in INM treatment (T_{10}) which was comparable to the treatment (T_9) with TBR value of 7.13 g day^{-1}.

The mean TBR also exhibited significant variation among different nutrient management practices (Table 2). On average, the INM practice (T_{10}) resulted in the highest mean TBR (5.11 g day^{-1}). This was followed by the treatment

Table 2: Effect of organic nutrient management on RGR, NAR and mean TBR of short-duration cassava (mean value of two experiments).

T. No	Relative growth rate (mg g^{-1} day^{-1})		Net assimilation rate (g m^{-2} day^{-1})		Mean tuberous root bulking rate (g day^{-1})
	Phase 2	Phase 3	Phase 2	Phase 3	
T_1	33.57	7.01	6.48	2.03	3.49
T_2	27.78	6.36	5.67	1.68	1.90
T_3	28.55	7.50	5.65	2.08	2.20
T_4	32.56	7.26	6.40	2.09	3.10
T_5	28.29	8.37	5.52	2.32	2.43
T_6	29.36	8.06	5.88	2.35	2.63
T_7	35.82	7.90	7.09	2.41	4.57
T_8	32.23	5.17	6.62	1.42	2.66
T_9	35.24	8.53	7.04	2.64	4.51
T_{10}	36.68	7.94	7.08	2.50	5.11
T_{11}	32.96	7.42	6.52	2.19	3.42
T_{12}	25.46	4.87	5.56	1.25	1.53
SEd	1.91	0.42	0.38	0.12	0.20
CD	3.96	0.86	0.79	0.25	0.42

(T_7) and (T_9) with values of 4.57 g day^{-1} and 4.51 g day^{-1}, respectively. The lowest mean TBR (1.53 g day^{-1}) was observed in the control treatment (T_{12}).

The impact of nutrient management practices on tuberous root bulking rate (TBR) and mean TBR is significant. The INM treatment consistently promotes robust tuber growth in all crop development phases. Organic practices, such as wood ash with foliar sprays also show promising results, serving as sustainable alternatives for enhancing TBR in cassava cultivation. The improved physiological growth and efficient translocation of photosynthates contribute to higher TBR and mean TBR. Organic nutrient sources further enhance nutrient supply, supporting increased tuber development throughout the growing season.These results were similar to the findings of Suja *et al.* (2010); Radhakrishnan *et al.* (2013), Radhakrishnan *et al.* (2014); Suja *et al.* (2021) and also by Meena *et al.* (2016) on potatoes.

Economics

The different nutrient management practices greatly influenced the economics of short-duration cassava (Table 3). Based on the mean data of two experiments, the INM with the application of FYM @25 t ha^{-1}, 100% RDF and cassava booster spray (T_{10}) generated the highest net income (` 126497 ha$^{-1}$) with a higher tuber yield of 33.27 t ha$^{-1}$. This was closely followed by organic practices, the application of wood ash @2 t ha$^{-1}$ + 3% panchagavya foliar spray ($T_7$) and wood ash @2 t ha$^{-1}$ + 3% banana pseudostem sap foliar spray ($T_9$) with a net income of ` 114300 and 107670 ha^{-1}, respectively. The maximum B:C ratio (2.73) was obtained in INM practice (T_{10}), followed by organic practice (T_7) with B:C ratio of 2.66. Next to this, the organic treatment (T_9) recorded a B: C ratio of 2.58. The control treatment (no manures/fertilizers/sprays) recorded negative net income (` 1280 ha^{-1}) with a B:C ratio of 0.98 and also the lowest tuber yield (8.67 t ha^{-1}). It is to be noted that economic analysis was carried out without considering the premium price of the produce. The inclusion of the premium price of the organic produce may outweigh the conventionally produced productsin terms of the monetary benefits in addition to devising techniques to lower the costs of organic production (Suja *et al.*, 2020).

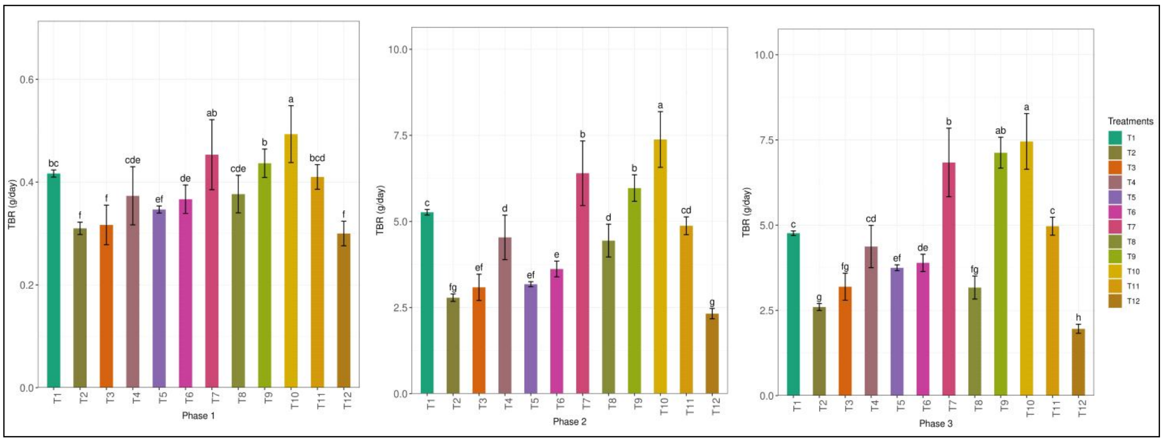

Fig 1: Effect of nutrient management practices on TBR of short-duration cassava (mean value of two experiments).

Table 3: Effect of organic nutrient management on economics of short-duration cassava (mean value of two experiments).

T. no	Tuber yield (t ha^{-1})	Cost of cultivation (` ha^{-1})	Gross income (` ha^{-1})	Net income (` ha^{-1})	B:-C ratio
T_1	24.63	62628	147780	85152	2.36
T_2	11.36	61818	68160	6342	1.10
T_3	14.01	61818	84060	22242	1.36
T_4	22.28	83060	133680	50620	1.61
T_5	15.56	82250	93360	11110	1.14
T_6	17.04	82250	102240	19990	1.24
T_7	30.56	69060	183360	114300	2.66
T_8	18.40	69150	110400	41250	1.60
T_9	29.32	68250	175920	107670	2.58
T_{10}	33.27	73123	199620	126497	2.73
T_{11}	23.70	67787	142200	74414	2.10
T_{12}	8.67	53300	52020	-1280	0.98

(Price of tuber= ` 6/kg).

CONCLUSION

Based on the findings of the study, it can be concluded that the integrated application of FYM @ 25 t ha^{-1}, 100% RDF and cassava booster spray (T_{10}) resulted in a significantly higher physiological growth response of short-duration cassava. Furthermore, this treatment proved to be economic profitable as indicated by the maximum net income and Benefit-Cost ratio. Comparatively, the organic practice of using wood ash @ 2 t ha^{-1} along with a 3% panchagavya foliar spray yielded similar results to the INM treatment. Additionally, the application of wood ash @ 2 t ha^{-1} combined with a 3% banana pseudostem sap foliar spray showed comparable effectiveness to the aforementioned organic practice. The study highlights the effectiveness of INM treatment and organic practices in promoting short-duration cassava growth. These approaches offer sustainable and profitable alternatives for cultivation. Integrated nutrient management and organic methods are crucial for enhancing cassava production while ensuring economic viability and long-term sustainability.

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Conflict of interest

The authors declare that there is no competing interest.

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