J. Hortic. Sci.
Vol. 20(2), 2025

https://doi.org/10.24154/jhs.v20i2.2819

Original Research Paper

Growth dynamics, yield and quality of short-duration cassava in rice based cropping systems

Suja G.[1*], Sreekumar J.[2], Sunitha S.[3] and John J.[4]

[1,2,3]ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram - 695 017, Kerala
[4]Integrated Farming Systems Research Station, Kerala Agricultural University,
Karamana, Thiruvananthapuram - 695 011, Kerala
[*]Corresponding author Email: sujagin@yahoo.com

ABSTRACT

Crop intensification using short-duration cassava serves as an adaptation strategy promoting climate resilience. A two-year field experiment was carried out to assess the viability of intercropping short-duration cassava with pulse crops in a rice-based system. Rice var. Kanchana was initially planted, followed by short-duration cassava (var. Sree Vijaya and Vellayani Hraswa) intercropped with pulse crops such as green gram, black gram (var. Co-6) and soybean (var. JS-95-60), under two fertility levels. Intercropping Sree Vijaya or Vellayani Hraswa cassava varieties with black gram under reduced fertilizer level produced (25.94 t ha^{-1}; 19.39%) yields similar to sole cassava (32.18 t ha^{-1}). Growth attributes, biomass production and partitioning, crop growth rate and tuber bulking rate of cassava in this treatment matched sole cassava, particularly by the final growth phase. Tuber biochemical constituents remained unaffected. Thus, the combination of rice var. Kanchana followed by short-duration cassava var. Sree Vijaya + black gram var. Co-6 proved productive and feasible, while conserving half of the FYM and N and all P.

Keywords: Cropping system, biomass, growth indices, tuber quality

INTRODUCTION

Cassava, vital for over 800 million people in the world's poorest tropical regions (Lebot, 2019), is considered as a "climate-smart" crop, thriving in challenging conditions. It ranks seventh in cultivated area, following wheat, maize, rice, barley, sorghum, and millets, and serves as a cornerstone of food security for rural households (Howeler, 2014). As a source of calories and carbohydrates in developing nations, cassava excels in marginal environments, withstanding drought and acidic soils (Ceballos et al., 2010).

Farmers in Africa and Asia have embraced cassava-based multiple cropping systems, diversifying cultivation methods (Ravi et al., 2021). These systems optimize land, nutrient, and water use by combining crops with complementary morpho-phenological traits. They enhance total factor productivity and ecosystem services, ensuring sustainable food production, which is particularly crucial under climate change pressures.

Some model cassava-based multiple-cropping systems include intercropping with ephemerals like legumes (cowpea, peanut, soybean, mungbean, pigeonpea, vegetable legumes), cereals, and millets (rice, maize, sorghum), as well as vegetables (okra); intercropping cassava within plantations such as coconut; and relay/sequential cropping involving cassava (Ravi et al., 2021). Delaquis et al. (2018) highlighted several benefits of cassava-based intercropping systems, including pest and disease suppression, efficient land use, and soil and water regulation.

Early-maturing cassava varieties (6-7 months) are preferred as sequential crops with rice, bananas, or vegetables, especially in low lands (Mohankumar & Nair, 1990). Large areas are left fallow after rainfed or irrigated rice cultivation in rice production systems, where water is insufficient for year-round cropping. Short-duration cassava varieties show promise in better resource utilization, diversifying the food basket, and increasing income in such systems (Suja et al., 2010a, 2010b & 2011; Suja & Sreekumar, 2015). Suja & Sreekumar (2015) found that a profitable production system was a sequential cropping of vegetable cowpea followed by short-duration cassava. However, information on intercropping systems involving short-duration cassava in rice-based systems is limited. Thus, the objectives of this investigation were to develop feasible intercropping systems involving short-duration cassava and pulses in rice-based systems and to evaluate the system's growth dynamics, yield, and tuber quality.

MATERIALS AND METHODS

Field experiments were conducted from June to March for two consecutive years (2015-2017) at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India, simulating lowland rice fallow conditions. The site experiences a humid tropical climate, with an average annual rainfall of 1355 mm, maximum and minimum temperatures of 31.74°C and 23.90°C, and mean relative humidity of 79.58%. During crop growth, the total rainfall, maximum temperature, minimum temperature, and relative humidity ranged between 892-1022 mm, 32.30-31.10°C, 23.90-23.50°C, and 78.80-82.10%, respectively. The soil is a well-drained acid Ultisol with pH 5.28, low available nitrogen (115.54 kg ha^{-1}), high available phosphorus (38.08 kg ha^{-1}), medium available potassium (146.56 kg ha^{-1}), and 0.51% organic carbon.

In the first season, rice var. Kanchana was grown, followed by short-duration cassava (var. Sree Vijaya and Vellayani Hraswa) intercropped with pulse crops (green gram, black gram, soybean) under two fertility levels: full farmyard manure (FYM) with full nitrogen and potassium but no phosphorus; and half FYM with half nitrogen and full potassium (phosphorus was applied to legume crops). The experimental design was split-plot, with cassava varieties in main plots and combinations of pulse crops and fertility levels in subplots. Sole crops of cassava for both varieties with full FYM and nutrients were included as controls.

Growth parameters such as plant height, stem girth, and leaf production were measured at 2, 4, and 6 months after planting (MAP). Biomass was assessed by uprooting three cassava plants randomly per plot at each stage, separating them into leaves, stems, and tubers, air drying, and then oven drying at 70°C. Dry weights were recorded, and total plant dry weights were computed and expressed as grams per plant. Growth indices, including crop growth rate (CGR), tuber bulking rate (TBR), and harvest index (HI), were computed using Hunt's techniques (1982).

Fresh tuber yield was estimated at harvest in tons per hectare based on data from the net plants. Standard procedures were employed to determine dry matter, starch, total sugar (AOAC, 2005), crude protein (Dubios et al., 1956), and cyanogenic glucoside (Indira & Sinha, 1969) contents of cassava tubers.

Table 1 : Effect of cropping systems and fertility levels on growth attributes of short-duration cassava

Cropping systems and and fertility levels	Plant height (cm)			Stem girth (cm)			Leaf production (number)		
	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP
SV+GG (F1)	120.22	129.70	177.00	12.89	5.47	6.97	184	132	225
SV+GG (F2)	121.78	132.00	173.00	12.69	6.60	6.50	197	174	233
SV+BG (F1)	117.00	135.20	176.60	12.27	6.77	7.33	186	189	178
SV+BG (F2)	123.00	126.10	180.20	13.33	6.37	7.37	175	181	193
SV+SB (F1)	114.87	130.10	190.80	12.23	6.77	7.33	167	151	210
SV+SB (F2)	116.45	134.30	187.30	12.28	6.73	7.43	177	149	215
VH+GG (F1)	109.34	139.10	185.40	12.72	6.60	7.77	168	216	462
VH+GG (F2)	115.34	131.50	186.00	11.98	7.17	7.87	194	211	363
VH+BG (F1)	114.12	141.70	190.30	12.87	7.33	7.83	177	230	468
VH+BG (F2)	103.17	122.10	165.10	11.14	6.63	7.60	160	242	468
VH+SB (F1)	109.34	134.90	178.30	11.95	7.50	8.17	175	252	450
VH+SB (F2)	116.56	122.60	160.80	13.21	6.30	7.67	171	205	395
SV (sole)	114.56	167.90	203.20	12.41	8.13	8.10	160	195	232
VH (sole)	121.89	162.70	183.40	13.14	8.20	7.50	186	305	387
CD (P=0.05) Variety x pulse x fertility level	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control vs treatment	NS	21.478	NS	NS	1.914	NS	NS	77.016	NS

R-Rice, SV-Sree Vijaya, VH-Vellayani Hraswa, GG-Green gram, BG-Black gram, SB-Soybean, F_1-full dose of FYM & N, no P, full K (FYM 12.5 t ha^{-1}, NPK 100:0:100 kg ha^{-1}); F_2-half dose of FYM & N, no P, full K (FYM 6.25 t ha^{-1}, NPK 50:0:100 kg ha^{-1})

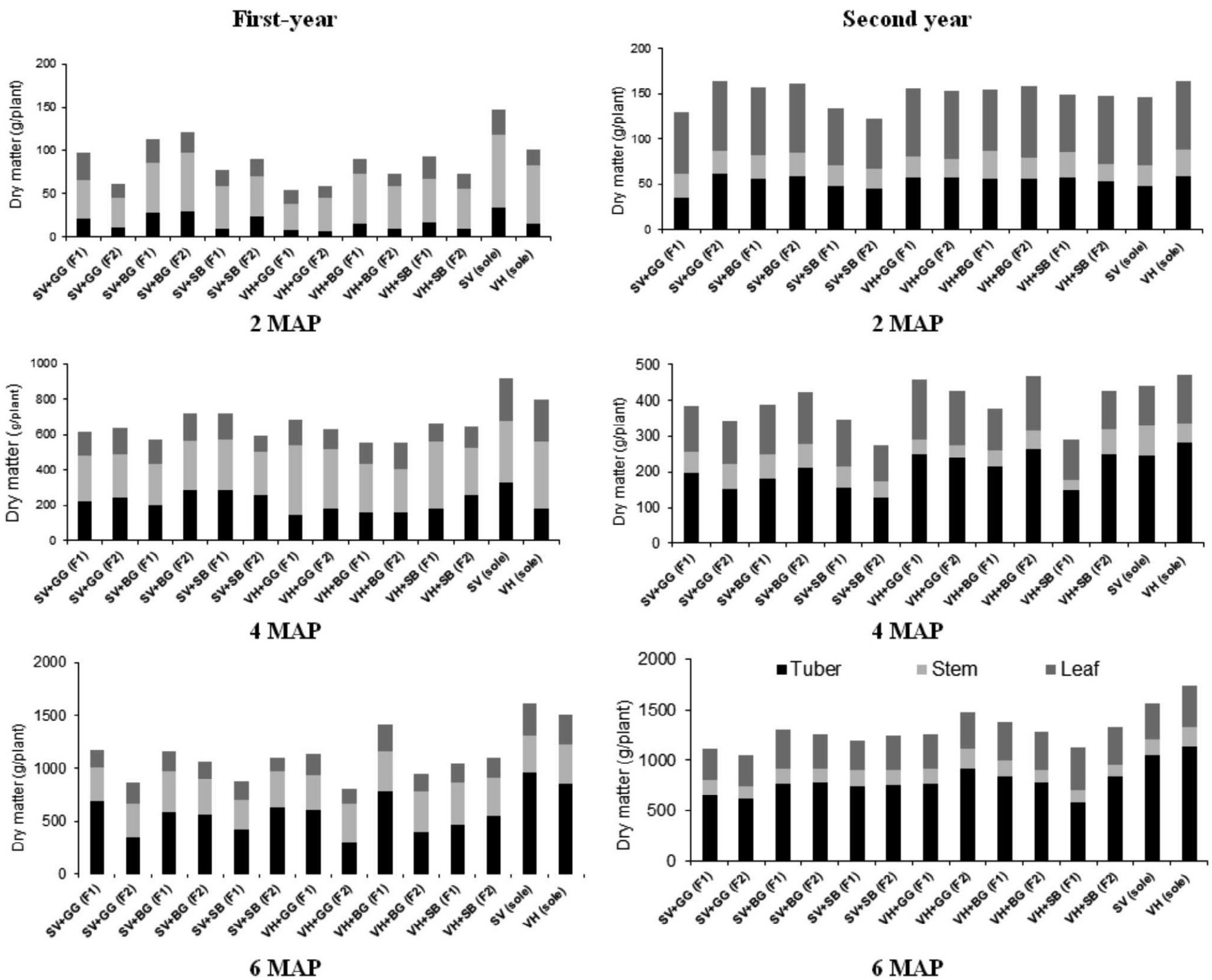

Fig. 1: Interaction effect between pulse crops and fertility levels on biomass production and partitioning at various phases in Cassava

A two-way analysis of variance (ANOVA) for a split-plot design (analyzing data from different years separately) was conducted to compare treatment differences for various plant and soil parameters using SAS statistical software (SAS, 9.3). The critical difference at a significance level of 0.05 was used to compare treatment means.

RESULTS AND DISCUSSION

Growth and biomass

Over the two years, cassava growth parameters such as plant height, stem girth, and leaf production experienced significant reduction by four months after planting (MAP) due to intercrop competition, but recovered post-harvest of the pulse crop, reaching levels comparable to sole cassava (Table 1). The initial 3-4 months of cassava growth are typically slow, making it less competitive with intercropped plants (Suja & Sreekumar, 2015; Silva et al., 2016). Pulse crops, being faster-growing and completing their life cycle within 2-3 months, tend to out compete cassava for available resources in mixed cropping systems (Gou et al., 2016). With their rapid development and extensive rooting system, pulse crops can effectively compete for resources under favorable conditions like adequate moisture and nutrients.

Across both years, cropping system treatments (variety x pulse x fertility level) showed no significant impact on total biomass production or distribution to leaf, stem, or tuber during various growth stages. This suggests a consistent pattern of biomass distribution regardless of cassava variety, pulse intercrop, or fertility level. In the first year, no significant difference was observed between sole cassava and cropping system treatments in terms of tuber dry matter at

Table 2 : Effect of cropping systems and fertility levels on CGR and TBR of short-duration cassava

Cropping systems and fertility levels	CGR (g m^{-2} day^{-1})			TBR (g day^{-1})		
	0-2 MAP	2-4 MAP	4-6 MAP	0-2 MAP	2-4 MAP	4-6 MAP
SV+GG (F1)	2.33	7.92	13.28	0.47	3.03	7.67
SV+GG (F2)	2.32	7.74	10.32	0.60	2.68	4.74
SV+BG (F1)	2.78	7.09	16.40	0.71	2.47	8.12
SV+BG (F2)	2.91	8.84	12.87	0.73	3.42	7.07
SV+SB (F1)	2.16	8.80	10.32	0.47	3.22	5.97
SV+SB (F2)	2.20	6.78	15.58	0.57	2.65	8.30
VH+GG (F1)	2.17	9.63	14.77	0.55	2.72	8.14
VH+GG (F2)	2.19	8.65	14.40	0.53	3.01	6.61
VH+BG (F1)	2.52	7.01	19.19	0.59	2.51	10.40
VH+BG (F2)	2.38	8.12	13.14	0.55	2.98	6.26
VH+SB (F1)	2.49	7.38	12.70	0.62	2.11	6.00
VH+SB (F2)	2.28	8.76	16.74	0.53	3.72	7.32
SV (sole)	3.02	10.95	20.15	0.68	4.13	11.87
VH (sole)	2.72	10.32	23.48	0.62	3.23	12.72
CD (P=0.05) Variety x pulse x fertility level	0.356	NS	NS	0.032	NS	NS
Control vs treatment	0.714	2.563	7.053	NS	NS	5.264

R-Rice, SV-Sree Vijaya, VH-Vellayani Hraswa, GG-Green gram, BG-Black gram, SB-Soybean, F_1-full dose of FYM & N, no P, full K (FYM 12.5 t ha^{-1}, NPK 100:0:100 kg ha^{-1}); F_2-half dose of FYM & N, no P, full K (FYM 6.25 t ha^{-1}, NPK 50:0:100 kg ha^{-1})

2 and 4 MAP. However, at these stages, total dry matter under sole cassava cultivation was comparable to cassava (var. Sree Vijaya) grown with reduced fertility and intercropped with black gram.

By harvest, total and tuber biomass under sole cropping was on par with cassava (var. Vellayani Hraswa) intercropped with black gram at full fertility level (Fig. 1). In the following year, control versus treatment at 2 and 4 MAP did not significantly influence dry matter distribution. However, at 6 MAP, total biomass and tuber partitioning were higher under sole cropping, similar to most cropping system treatments, except for Sree Vijaya intercropped with green gram at full or half fertility levels and Vellayani Hraswa intercropped with soybean at full fertility level (Fig. 1). This suggests similar efficiency of most of the cropping system treatments to that of sole cropping.

Pulse crops, highly compatible with cassava, share similar growth patterns, canopy development, shorter crop duration (3 months), and nutrient demands. They primarily require phosphorus and can fulfill some nitrogen requirements through biological nitrogen fixation (Giller, 2001), while cassava relies on potassium for storage root formation and nitrogen for leaf production (Howeler, 2002; Carsky & Toukourou, 2005). Thus, pulse intercropping can enhance biomass production without compromising cassava yield.

Across years, cropping system treatments (variety x pulse x fertility level) did not significantly affect various growth indices at different growth stages, except at the first phase, wherein Sree Vijaya intercropped with black gram at full or half fertility levels significantly enhanced CGR and TBR (Table 2). However, control versus treatment had a significant impact on CGR at all stages and TBR at the final stage. CGR and TBR were higher for sole cassava but comparable to several intercropping treatments, Sree Vijaya intercropped with black gram at full or half fertility levels or Vellayani Hraswa intercropped with

Table 3 : Effect of cropping systems and fertility levels on yield and yield attributes of short-duration cassava

Cropping systems and fertility levels	Tuber yield (t ha^{-1})	No. of tubers	Mean tuber weight (kg)	Tuber length (cm)	Tuber girth (cm)
SV+GG (F1)	23.19	7	0.274	22.12	14.72
SV+GG (F2)	22.09	7	0.250	26.05	15.44
SV+BG (F1)	24.18	8	0.271	24.95	16.01
SV+BG (F2)	26.67	7	0.304	27.33	15.27
SV+SB (F1)	23.83	8	0.244	24.06	14.98
SV+SB (F2)	24.01	7	0.283	23.20	15.79
VH+GG (F1)	23.53	7	0.249	24.13	15.13
VH+GG (F2)	22.76	6	0.297	27.03	15.26
VH+BG (F1)	24.89	7	0.288	26.34	16.18
VH+BG (F2)	25.21	6	0.286	26.94	14.60
VH+SB (F1)	21.46	5	0.294	24.58	15.72
VH+SB (F2)	23.70	7	0.261	28.15	14.75
SV (sole)	30.76	10	0.276	22.55	14.66
VH (sole)	33.59	8	0.372	26.36	15.82
CD (P=0.05) Variety x pulse x fertility level	NS	NS	NS	NS	NS
Control vs treatment	6.393	2.621	0.114	NS	0.812

R-Rice, SV-Sree Vijaya, VH-Vellayani Hraswa, GG-Green gram, BG-Black gram, SB-Soybean, F_1-full dose of FYM & N, no P, full K (FYM 12.5 t ha^{-1}, NPK 100:0:100 kg ha^{-1}); F_2-half dose of FYM & N, no P, full K (FYM 6.25 t ha^{-1}, NPK 50:0:100 kg ha^{-1})

Table 4 : Effect of cropping systems and fertility levels on biochemical composition of tubers of short-duration cassava

Cropping systems and fertility levels	Dry matter (%)	Starch (% FW basis)	Total sugar (% FW basis)	Crude protein (% FW basis)	Cyanogenic glucoside (µg g^{-1})
SV+GG (F1)	36.27	22.12	1.12	1.52	21.10
SV+GG (F2)	36.18	22.19	1.73	1.27	22.63
SV+BG (F1)	37.47	22.54	1.79	1.60	24.60
SV+BG (F2)	36.25	23.50	1.64	1.55	23.83
SV+SB (F1)	37.74	21.29	1.66	1.65	26.98
SV+SB (F2)	38.42	21.13	1.31	1.91	29.84
VH+GG (F1)	39.39	23.08	1.2	1.92	13.68
VH+GG (F2)	38.29	23.32	1.23	1.78	20.31
VH+BG (F1)	41.23	24.40	1.26	2.05	20.56
VH+BG (F2)	39.35	23.95	1.31	2.02	17.30
VH+SB (F1)	39.68	25.40	1.07	2.04	17.31
VH+SB (F2)	38.67	26.07	1.32	1.96	26.34
SV (sole)	40.91	22.54	1.54	1.59	17.67
VH (sole)	38.96	22.57	1.15	1.86	19.34
CD (P=0.05) Variety x pulse x fertility level	NS	NS	NS	NS	NS
Control vs treatment	0.92	NS	NS	NS	8.255

R-Rice, SV-Sree Vijaya, VH-Vellayani Hraswa, GG-Green gram, BG-Black gram, SB-Soybean, F_1-full dose of FYM & N, no P, full K (FYM 12.5 t ha^{-1}, NPK 100:0:100 kg ha^{-1}); F_2-half dose of FYM & N, no P, full K (FYM 6.25 t ha^{-1}, NPK 50:0:100 kg ha^{-1})

black gram at full fertility level. This indicates that short-duration cassava regained growth due to recovery from competition after the harvest of pulse intercrops, as reported earlier by Suja & Sreekumar (2015). The harvest index remained unaffected in both years.

Yield, yield attributes and tuber biochemical constituents

Cropping system treatments (variety x pulse x fertility level) did not significantly affect yield, yield attributes, or tuber biochemical composition. Control versus treatment significantly impacted tuber yield, number of tubers, mean tuber weight, tuber girth, tuber dry matter and cyanogenic glucoside content (Tables 3 & 4).

Averaging over two years, rice produced 3.45 t ha^{-1} of grain yield and 5.89 t ha^{-1} of straw yield. Over two years, intercropping Sree Vijaya or Vellayani Hraswa cassava with black gram under reduced fertilizer level produced similar cassava tuber yields (25.94 t ha^{-1}; -19.39%) compared to sole cassava (32.18 t ha^{-1}). Sree Vijaya exhibited better tolerance to competitive stress from intercropping, with a lower yield reduction of 22% compared to Vellayani Hraswa (-30%). These yield reductions in cassava may be attributed to its poor competitive ability during early growth stages when intercropped with pulse crops, consistent with observations by Nwokoro et al. (2021) in cassava-maize intercropping systems. A yield reduction of up to 20.36% over sole cropping was previously reported by Suja & Sreekumar (2015) in cassava-cowpea intercropping systems.

While cassava is a food security crop, its nutritional value may be limited by low root protein content, with the roots having the lowest protein-to-energy ratio among staple crops. Consumption of cassava alone has been linked to protein deficiency disorders like kwashiorkor (Ravi et al., 2021). Therefore, integrating grain legumes such as pulses into cassava-based cropping systems may offer a feasible approach to enhancing protein intake and nutritional security (Ogola et al., 2013).

The mean tuber weight of sole cassava matched almost all intercropping treatments, except Sree Vijaya intercropped with soybean/green gram at full fertility level. Girth of tubers from almost all Sree Vijaya cassava intercropping treatments outperformed or was on par with sole Sree Vijaya. Sole Vellayani Hraswa cassava exhibited higher tuber girth, similar to all intercropping treatments, except that intercropped with black gram/soybean at half fertility level.

However, the dry matter content of tubers was significantly higher in all the intercropping treatments involving Vellayani Hraswa, except that intercropped with green gram at the reduced fertility level, over sole Vellayani Hraswa. Among these, Vellayani Hraswa intercropped with black gram at full fertility level resulted in highest tuber dry matter content (41.23%). Cyanogenic glucoside content varied significantly among treatments, with Vellayani Hraswa intercropped with green gram at full fertility level showing the lowest content (13.68%). Most of the cropping system treatments resulted in comparably low cyanogenic glucoside contents similar to sole cassava, except that under soybean intercropping. The starch, total sugar, and crude protein content of tubers remained unaffected (Table 4). The study conclusively demonstrates that early competition effects from intercropping do not compromise tuber quality.

Intercropping short-duration cassava with short-duration pulses presents an opportunity, as the reduction in cassava yield (26% average over two years) could be offset by additional yield and soil health benefits from the legume. In contrast to Suja & Sreekumar's (2015) findings, the present study shows that the short-duration cassava variety Sree Vijaya exhibited better tolerance to competitive stress (yield reduction of 22%) and greater compatibility than Vellayani Hraswa (yield reduction of 30%). Therefore, developing a feasible rice-based cropping system incorporating short-duration cassava and pulses could diversify our food sources, promote self-sufficiency, and enhance resilience to climate change.

ACKNOWLEDGEMENT

The authors are thankful to the Director, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India, for providing the facilities to carry out the research work and Dr. Saravanan Raju, Principal Scientist, Division of Crop Production for the critical editing of the manuscript.

REFERENCES

AOAC. (2005). In: *Official Methods of Analysis.* (Horwitz, W. and G.W. Latimer Eds.). 8th Ed. Association of official agricultural chemists (AOAC) International, Gaithersburg, Maryland, USA.

Carsky, R. J., & Toukourou, M. A. (2005). Identification of nutrients limiting cassava yield maintenance on a sedimentary soil in southern Benin, West Africa. *Nutrient Cycling in Agroecosystem*, *71*, 151–162. doi: 10.1007/s10705-004-1803-9

Ceballos, H., Okogbenin, E., Perez, J. C., Lopez-Valle, L. A. B., & Debouck, D. (2010). Cassava. In: *Root and Tuber Crop, Handbook of Plant Breeding*. (Bradshaw J.E. Eds.). pp. 53-54, Springer Science Business Media. doi: https://doi.org/10.1007/978-0-387-92765-7_2

Delaquis, E. S. de Haan, & Wyckhuys, K. A. G. (2018). On-farm diversity offsets environmental pressures in tropical agro-ecosystems: a synthetic review for cassava-based systems. *Agriculture Ecosystems and Environment*, *251*, 226–235. https://doi.org/10.1016/j.agee.2017.09.037

Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*, *28*, 350-356. https://doi.org/10.1016/j.agee.2017.09.037

Giller, K. E. (2001). *Nitrogen Fixation in Tropical Cropping Systems*, 2nd Ed. CAB International, Wallingford.

Gou, F., van Ittersum, M. K., Wang, G., van der Putten, P. E. L., & van der Werf, W. (2016). Yield and yield components of wheat and maize in wheat-maize intercropping in the Netherlands. *European Journal of Agronomy*, *76*, 17–27. https://doi.org/10.1016/j.eja.2016.01.005

Howeler, R. (2014). *Sustainable Soil and Crop Management of Cassava in Asia-a Reference Manual*. 280 pp. Centro Internacional de Agricultura Tropical (CIAT), Cali, Columbia.

Howeler, R. (2002). Cassava mineral nutrition and fertilization. In: *Cassava: Biology, Production and Utilization*. (Hillocks, R.J., Thresh, J.M. and Bellotti, A.C. Eds.). pp. 115-147, CAB International, Wallingford. https://doi.org/10.1079/9780851995243.0115

Hunt, R. (1982). *Plant Growth Curves: The Functional Approach to Plant Growth Analysis*. Arnold Publishers, London.

Indira, P., & Sinha, S. K. (1969). Colorimetric method for the determination of HCN in tuber and leaves of cassava (*Manihot esculenta* Crantz). *Indian Journal of Agricultural Sciences*, *39*(11), 1021-1023.

Lebot, V. (2019). *Tropical Root and Tuber Crops: Cassava, Sweetpotato, Yams and Aroids*. 2nd Ed. 544 pp. Crop Production Science in Horticulture Series, CABI International, United Kingdom.

Mohankumar, C. R., & Nair, P. G. (1990). Production potential and economics of tuber crop-based cropping system for low lands. *Indian Journal of Agronomy*, *35*(1&2), 44-49.

Nwokoro, C. C., Kreye, C., Necpalova, M., Adeyemi, O., Busari, M., Tariku, M., Tokula, M., Olowokere, F., Pypers, P., Hauser, S., & Six, J. (2021). Developing recommendations for increased productivity in cassava-maize intercropping systems in Southern Nigeria. *Field Crops Research*, *272*,108283. doi: 10.1016/j.fcr.2021.108283

Ogola, J. B. O., Mathews, C., & Magongwa, S. M. (2013). The productivity of cassava legume intercropping system in a dry environment in Nelspruit, South Africa. *African Crop Science Conference Proceedings*, *11*, 61–65.

Ravi, V., Suja, G., Saravanan, R., & Sanket J. More. (2021). Advances in cassava-based multiple-cropping systems. In: *Horticultural Reviews*. (Warrington I. Ed.). pp. 153-232, Volume 48, 1st Ed. John Wiley & Sons, Inc. https://doi.org/10.1002/9781119750802.ch3

Silva, D. V., Ferreira, E. A., Oliveira, M. C., Pereira, G. A. M., Braga, R. R., dos Santos, J. B., Aspiazu, I., & Souza, M. F. (2016). Productivity of cassava and other crops in an intercropping system. *Ciencia e Investigacion Agraria*, *34*, 159-166.

Suja, G., & Sreekumar, J. (2015). Crop diversification with short-duration cassava (*Manihot esculenta*) in the humid tropics for agronomic and economic benefits. *Indian Journal of Agricultural Sciences*, *85*(12), 1619-1625. https://doi.org/10.56093/ijas.v85i12.54320

Suja, G., Susan John, K. Sreekumar, J., & Srinivas, T. (2010a). Short-duration cassava genotypes for crop diversification in the humid tropics: growth dynamics, biomass, yield and quality. *Journal of the Science of Food and Agriculture*, *90*, 188-198. doi:10.1002/jsfa.3781

Suja, G., Susan John, K., & Sreekumar, J. (2010b). Soil test based nutrient management for short-duration cassava (*Manihot esculenta*). analysis of growth, biomass, yield, quality, nutrient uptake and soil nutrient status. *Indian Journal of Agronomy*, *55*, 66-72.

Suja, G., Susan John, K., & Sreekumar, J. (2011). Impact of nutrient management based on soil test data on biomass production and partitioning and growth indices of short-duration cassava (*Manihot esculenta* Crantz). *Indian Journal of Agricultural Sciences*, *81*, 247-251.

(Received : 16.4.2024; Revised : 25.8.2025; Accepted : 30.8.2025)