Medicinal plants as intercrops in cassava (*Manihot esculenta* Crantz)

By

Dayana Samson

(2019-11-144)

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLANIKKARA, THRISSUR – 680656
KERALA, INDIA
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THESIS

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DEPARTMENT OF AGRONOMY
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2021

DECLARATION

I, Dayana Samson (2019-11-144) hereby declare that the thesis entitled **"Medicinal plants as intercrops in cassava (*Manihot esculenta* Crantz)"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other university or society.

Vellanikkara

Date: 25-11-2021

Dayana Samson

2019-11-144

CERTIFICATE

Certified that the thesis entitled **"Medicinal plants as intercrops in cassava (*Manihot esculenta* Crantz)"** is a record of research work done independently by **Mrs. Dayana Samson** (2019-11-144) under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, associate ship or fellowship to her.

Vellanikkara
Date:25-11-2021

Dr. Sindhu P. V.
Assistant Professor
AICRP on MAP & B
COA, Vellanikkara
(Chairperson, Advisory Committee)

CERTIFICATE

We, the undersigned members of the advisory committee of **Mrs. Dayana Samson.** (2019 -11- 144), a candidate for the degree of Master of Science in Agriculture, with major field in Agronomy, agree that this thesis entitled **"Medicinal plants as intercrops in cassava (*Manihot esculenta* Crantz)"** may be submitted by **Mrs. Dayana Samson** (2019 -11- 144) in partial fulfillment of the requirement for the degree.

25.11.2021

Dr. Sindhu P. V.
Assistant Professor
AICRP on MAP & B
College of Agriculture
Vellanikkara

25-11-21

Dr. P Prameela
Professor and Head
Department of Agronomy
College of Agriculture
Vellanikkara

25-11-21

Dr. Meera V. Menon
Professor (Agronomy)
Cashew Research Station
Madakkathara

25/11/21

Dr. Beena C.
Professor (Biochemistry)
AICRP on MAP & B
College of Agriculture
Vellanikkara

"Dedicated to the eternal memory of my loving father

Mr. K.J. Samson"

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Dayana Samson

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1. INTRODUCTION

By 2050, the world population is projected to rise by 33 per cent; from 7.2 billion to 9.6 billion people (UN, 2013). Meeting the demand for sustainable food production and health care systems to support this alarming population under prevailing climate change and land use scenarios will be a challenge to food security and health services. The perceptible rise in population with unplanned urbanization had caused shrinkage in agricultural land. As per reports, Kerala is the State with the lowest per capita land availability in the country, *i.e*., 0.18 hectares (GOI, 2019). In this situation of reduced cultivable land, on-farm crop diversification by intercropping in two dimensions (time and space) is an approach which can amplify not only the farm production but also sustain agriculture from seasonal variability, fluctuating price and uncertain climate (Johnston *et al*., 1995; Njeru, 2013).

Root and tuber crops are capturing significance as climate resilient crops in the vulnerable climate scenario and also, they play an indispensable role in food security, revenue generation and sustainable development. According to reports, in tropical countries, cassava is the third largest source of food energy after rice and maize (FAO, 2013). In India cassava is grown in an area of about 1.72 lakh ha with a production of 49.49 lakh metric tonnes, while in Kerala it is cultivated in an area of 0.54 lakh ha with a production of 17.25 lakh metric tonnes (GOI, 2018). Cassava, a long duration, widely spaced tuber crop with gradual primary growth and development offers cultivable space between the cassava plants in which short duration crops can be integrated, thereby improving the biological efficiency of the system (Mutsaers *et al*., 1993).

Nature has blessed our country with an enormous richness of medicinal plants and therefore, India has often been referred to as the ‘Botanical Garden’ of the world. Past decade has witnessed the resurgence of Medicinal Plants (MPs) in health care services, which has now attained much more importance all over the globe especially during the COVID - 19 pandemic. The pharmaceutical, food, and cosmetics industries are all seeing an increase in demand for medical plant-based goods, and this trend is projected to continue (Lubbe and Verpoorte, 2011; Bernath, 2013). According to the

Task Force report, the global market for medicinal plants is worth about 60 billion dollars per year, and the herbal medication business is growing at a rate of seven to thirty per cent per year (GOI, 2000). The World Health Organization (WHO) predicts that by 2050, the global market for plant-based medicine would be worth five trillion dollars. In India the medicinal and aromatic plants are cultivated in 6.27 lakh ha with production of 7.95 lakh metric tonnes where as in Kerala it is cultivated only in 10 ha (GOI, 2018). There is limited scope of horizontal expansion of medicinal plants but they can be included in existing cropping systems. Numerous tropical medicinal plants thrive in partial shade, moist soil and under high relative humidity (Vyas and Nein, 1999) and hence can be easily integrated in existing cropping systems.

Indigofera tinctoria, a member of the Fabaceae family, and a native to India, is the source of one of the earliest naturally derived colouring agents known to humanity. The whole plant can be used as a thermogenic, laxative, trichogenous expectorant, hepatoprotective, anticancer and antihelminthic and is also used for curing gastropathy, splenomegaly, epilepsy, neuropathy, ulcers, skin diseases and for promoting the growth of hair (Asuntha *et al.*, 2010).

Plectranthus vettiveroides (K. C. Jacob) N. P. Singh & B. D. Sharma (Syn. *Coleus vettiveroides*) is an aromatic herbaceous plant belonging to the family Lamiaceae. *Plectranthus vettiveroides* is a pharmacologically relevant herb that is used as a single medicine or as one of the active ingredients in more than 78 herbal medicines (Nisheeda *et al.*, 2016). In Kerala it is utilized as natural medicine for treating cough and cold in children (Sivarajan and Balachandran, 1986). National Medicinal Plants Board, Government of India, has identified and prioritized this plant as one of the medicinal plant species for its overall development and protection under promotional and commercial scheme.

Sida alnifolia is a species native to India with very high commercial value. The crop is included in the group of high volume traded medicinal plants sourced from waste lands by National Medicinal Plants Board, Government of India. Roots are utilized in a number of Ayurvedic remedies and oils to promote bone, muscle, and joint strength. Due to high market potential, the State Medicinal Plants Board of Kerala has recommended this crop for commercial cultivation.

The above three plants are highly valued in medicine and in trade so, their cultivation is to be promoted in available areas. Even though many short duration crops like vegetables, cereals, pulses and oil seeds were recommended as intercrops in cassava, no study has been conducted to assess the feasibility of intercropping with medicinal plants. In this background the present study was proposed to assess the suitability of growing three medicinal plants *Indigofera tinctoria*, *Plectranthus vettiveroides* and *Sida alnifolia* as intercrops in cassava.

2. ***REVIEW OF LITERATURE***

2. REVIEW OF LITERATURE

Medicinal and aromatic plants make up an important part of the vegetation and provide raw materials for use in the pharmaceuticals, cosmetics, and drug industries. The indigenous medical systems in India make use of many medicinal herbs which are underutilized commercially. In the modern era there is global resurgence in traditional and alternative health care systems which have created enhanced market potential for medicinal plants.

Cultivation of medicinal plants on a commercial scale is one of the most profitable ventures for farmers in India. Farmers with land and sufficient knowledge on herb marketing generate high returns with minimal investments. As our nation comprises mostly of small and marginal farmers, scope for commercial cultivation of medicinal plants as pure crop is limited. So, the best alternative to bridge the gap between demand and supply of medicinal plants is intercropping with widely spaced crops like food and commercial crops. Since many of the medicinal plants are shade loving crops, they can be fitted very well in most intercropping systems.

Cassava (*Manihot esculenta* Crantz) is the most important starchy root crop grown in the tropics. The wide spacing adopted together with slow initial growth and development of the crop makes cassava compatible to intercropping with other economically important crops like medicinal plants. In this background a brief review on importance of intercropping, cassava, importance and suitability of cassava for intercropping and its economics is presented below. Literature on medicinal plants *Plectranthus, Indigofera* and *Sida* used for the study has also been documented.

2.1 Importance of intercropping

Intercropping is raising multiple crops simultaneously on the same land which would overlap long enough to include the vegetative stage. Intercropping offers more efficient uses of on-farm resources and enables sustainable crop production. Willey (1979a) reported that this system of cropping gives higher yields with greater stability compared with monoculture and it also offers better income from farm enterprises.

As per Baker (1980) the yield stability of intercropping system is greater than sole cropping. Adelhelm and Kotschi (1985) reported that intercropping could reduce seasonal work peaks, eventually increase output per unit area and particularly with low levels of external inputs and mix of species, make better use of available nutrients and water in the soil. According to Mutsaers *et al*. (1993) intercropping results not only in better utilization of physical resources such as solar radiation, mineral nutrients and water but also provides higher labour productivity with reduced risk as compared with sole cropping.

By growing additional crop farmers can maximise the effective use of available water and minimize soil erosion, which are the demerits of sole culture of a crop (Anon, 1985; Tolera, 2003).

2.2 Cassava

Manihot esculenta belongs to Euphorbiaceae family, sub family crotonoideae tribe manihoteae. Cassava is also called as “the drought, war, and famine crop” because it can be grown in challenging conditions such as dry soils with low fertility and provide a reserve of food in times of adverse condition. Cassava is more climate resilient than other staple food crops

2.2.1 Importance of cassava

The popularization of the crop in the State of Kerala was attributed to the famous king of Travancore State, Sri Visakham Thirunal who introduced popular varieties from Malaya and other places. Cassava saved the people of erstwhile Travancore province from the clutches of famine during World War II (1939-45) when import of rice from Burma (Myanmar) was stopped and the subsequent times of food scarcity (CTCRI, 2006).

The importance of cassava to the livelihoods of many millions of the poor people has made the crop a target for intervention (Anyaegbunam *et al.,* 2010). The potential of the crop is numerous because it offers a cheap source of food calories and the highest yield per unit area. Ceballos *et al.* (2010) reported that cassava has high biological efficiency, flourishes well even under marginal condition, adverse soil and climatic conditions and exhibits greater flexibility to come up in non-congenial situation. Cassava has multiple roles as famine reserve, food and cash crop, industrial raw material and livestock feed (Osipira-Patino and Ezedinma, 2015).

Food security guarantees all human beings physical and economic access to the basic foods needed to lead active and healthy lives. Cassava value chain has the ability to transform a country from poverty state to self-enrichment through employment and income generation, especially at the stages of production, processing and industrial utilization (Anyaegbunam *et al.,* 2010).

In many parts of the world, cassava is consumed fresh, directly after boiling, along with spices and salt, or mixed with several other vegetables. Several food commodities are processed mainly from or substituted with different levels of cassava. These products are either unfermented or fermented foods or drinks, and they vary in their mode of processing (boiled, steamed, fried, roasted, baked, dried, fermented) and the form (liquid or solid) in which they are consumed. Some of these products are localized in some countries while others are available in several regions of the world (Iheke, 2008; Bamiro *et al*., 2012).

2.2.2 Intercropping in cassava

Cassava may be grown in monocultures but is commonly grown in mixture with other crops, especially *Zea mays*, *Dioscorea* spp., *Colocynthis citrullus* and vegetables (Okigbo and Greenland, 1976). Leihner (1980) postulated that cassava with legume combination ensured better soil surface coverage, decreased light penetration and thus suppressed weed growth without other weed control measures. Prabhakar and Pillai (1984) reported the monetary advantage of cassava when intercropped with peanut, cowpea and French beans. Asokan and Sreedharan (1987) suggested the benefits of sequential cropping in casaava.

Bai *et al*. (1992b) demonstrated the paired-row strategy of growing cassava for achieving higher yields of both the main and intercrop, namely groundnut and cowpea. Nair *et al*. (1992) recommended peanut, French bean and vegetable cowpea as the most promising intercrops for cassava in Kerala. In Nigeria, cassava and maize intercrops were highly profitable, and the productivity improved by the inclusion of groundnut (Ikeorgu and Odu-rukwe, 1993). Intercropping cassava with banana was reported by Prasanna *et al*. (1995).

According to Tsay *et al*. (1988) and Fukai and Trenbath (1993), cassava + legume intercropping could be more productive than sole cropping particularly when wide row cassava was intercropped with a short duration plant species, as the associated legume was harvested before competition developed between the two species and cassava had enough time to recover from the adverse effect of competition. According to Melifonwu (1994), for achieving a good crop stand the crop mixtures should be compatible with each other with low inter-plant competition, optimal plant population and spatial arrangements. Melon was proposed as an intercrop in cassava for effective weed control (Okeleye and Salawu, 1999). As per Prameela *et al*. (2012) intercropping of legumes with cassava offer good weed control with a saving of 61 per cent over hand weeding.

Enete (2009) opined that in tropics, *Manihot esculenta* and *Lagenaria siceraria* were an excellent combination for intercropping. Gayathri (2010) reported the biological productivity and economic feasibility of alley cropping cassava with fodder cowpea, palisade grass and fodder cowpea.

According to Francesconi *et al.* (2013), in cassava, inclusion of a short duration crop could increase efficiency of the system since it is a long duration, widely spaced crop with retarded growth in its initial growth and development.

Silva *et al.* (2007) encouraged the use of pigeon pea, sunflower and cowpea as potential intercrops in cassava. Tang *et al.* (2015) reported that cassava+ peanut intercropping could improve rhizosphere soil microecological environment and increase soil nutrient contents and the microbial quantity

Ros and Joao (2016) reported that there is an increase in advantages over monoculture when cassava is intercropped with sweet potato. Intercropping is a highly profitable enterprise when maize was grown along with cassava and yam (Egbetokun et al., 2019). Ekwaro et al. (2019) investigated and reported that cassava root yield is highest in sole cassava followed by one row of cassava with one row of maize and least one row of cassava with two rows of maize in cassava maize intercropping system. Although the yields of both cassava and maize under sole cropping were higher than their intercrop counterparts, intercropping was more productive than sole cropping

2.2.3 Effect of intercropping on growth and yield attributes of cassava

Reduction in cassava growth during its initial stages due to intercropping with groundnut was reported by Prabhakar and Nair (1982). Sheela and Kunju (1990) recorded greater plant height and more number of leaves in sole crop than in intercropped cassava. On the contrary, Thamburaj and Muthukrishnan (1991) observed no difference in growth between sole and intercropped cassava after three and half months and after five months after planting.

Light competition between cassava and intercrops was rather intense, leading to cassava etiolation; the magnitude of competition was influenced by the type of intercrop (Wargiono *et al*., 1992). Balakrishnan and Thamburaj (1993) also recorded maximum height of cassava when intercropped with black gram pointing out the influence of intercrop on plant height of cassava.

Increase in plant height after second, third and fourth month after planting in *Manihot esculenta* was observed when intercropped with groundnut (Anilkumar and Sasidhar, 2010). However, when intercropped with cowpea, because of proliferous vegetative growth of cowpea, reduction in plant height of cassava was noticed before the fifth month, after which this effect was decreased. In cassava - groundnut cropping system, maximum height was observed in sole cropped cassava than intercropped cassava.

Akobundu (1980) obtained the highest yield and the lowest weed dry weight with a total plant density of 30,000/ha in maize + cassava intercropping system. According to Olasantan (1988), an increased yield of cassava: cowpea was obtained at 2:2 row arrangements without much reduction in cassava tuber yield. As per Tsay *et al.* (1988), intercropped cassava had lower total dry matter than sole cassava. As an intercrop, lesser yam affected yield of cassava more than maize (Moreno, 1992). According to Zoufa *et al.* (1992), the use of groundnut or cowpea or melon as smother crop in cassava + maize intercropping system with a total plant density of 50,000 plants/ha provided the best weed control and the highest yields.

Olasantan *et al*. (1997) opined that the crucial factor which reduced the yield in a cassava-maize intercropping system was the depression of early cassava growth by the vigorous intercrop component, which decreased the amount of assimilate allocated to cassava roots. They summarised that intercropping cassava with early maturing maize under optimum availability of soil nutrients could give good weed control and maintain high productivity of the system.

When cassava was intercropped with banana, number of tubers was 7.22, whereas it was 8.22 in sole cropped condition (Prasanna *et al*., 1995). They also reported that when cassava was intercropped with banana and cowpea in advanced stages of cassava there was slight increase in number of tubers (8.95).

As per Tscherning *et al*. (1995), the cassava tubers penetrated up to 1 m or even 2.6 m in different field conditions, and to 1.8 m within three months of planting when grown as sole crop. However, as when grown with legumes or grasses, the root penetration was up to 0.5 to 0.75 m.

According to Dung *et al*. (2005), there was no difference in biomass production between monoculture and cassava + groundnut under irrigated conditions. A marginal decrease in tuber yield of cassava intercropped with fodder maize might be due to the competition put up by maize for resources in the early stages and the resultant effect on the growth and yield parameters up to harvest (Amanullah *et al*., 2006).

Hidoto and Loha (2013) reported that cassava tuber yield was higher when intercropped with haricot bean. According to them intercropping cassava with cowpea reduced the cassava yield by 27 per cent, but the land use efficiency was increased by 49 per cent.

2.2.4 Economics of intercropping in cassava

Generally, intercropping is considered as a revenue augmenting measure for cassava. The reports suggest that intercropping could hamper the yield of cassava but the reduction was compensated by total yield from polyculture system and it further increased the net returns to farming community (Mohankumar and Hrishi, 1979).

The economic analysis among different intercropping systems in cassava revealed that the performance of peanut as intercrop was the most profitable one (Anilkumar, 1984; CTCRI, 1988).

The study conducted by Asokan *et al*. (1981) revealed that in cassava + legume intercropping, cowpea was the most remunerative intercrop for high rainfall oxisol of central Kerala. Evengelio and Posas (1983) observed that under intercropping system maximum economic benefits were obtained when root crops and legumes were planted simultaneously. Asokan and Sreedharan (1987) reported the highest returns under cassava + groundnut + red gram (BCR-1.94) followed by cassava + groundnut (BCR-1.86) and cassava + cowpea (BCR-1.83) as compared to monoculture of cassava. According to Gosh *et al*. (1999) the highest net return was obtained from the crop combination of cassava with French bean or cowpea.

When the yield advantage of an association of cassava-cowpea-maize was analysed, the economic advantage of intercropping was only 6-14 per cent (MER monetary equivalent ratio = 1.06 - 1.14). However, in a cassava - bhindi - corn - cowpea combination the total efficiency of the system was 50-62 per cent of the cassava monoculture (Adetiloye and Adekunle, 1989).

Bai *et al*. (1992a) concluded that paired row planting of cassava + cowpea resulted in the maximum net revenue of Rs.11,335/ha, followed by uniform planting of cassava and cowpea (Rs.10,433/ha). In addition, they found that corresponding cost-benefit ratio (BCR) was Rs.1.65 and 1.60, respectively and finalized cassava-cowpea intercropping as the more efficient association than cassava-groundnut association. Intercropping cassava with other crops such as upland rice, maize and legumes elevated the total returns by 33 per cent compared to sole crop of cassava (Wargiono *et al*., 1992).

Intercropping crops like green gram, cowpea, black gram or groundnut gave an additional income without negatively affecting the yield of main crop and also gave higher returns than sole cassava (Varughese, 2006).

2.3 Medicinal plants

2.3.1 *Plectranthus vettiveroides*

Plectranthus vettiveroides (K. C. Jacob) N. P. Singh & B. D. Sharma (Syn. *Coleus vettiveroides*) is an aromatic herbaceous plant. The genus *Plectranthus* is also called as spur flowers. It belongs to the family Lamiaceae, subfamily Nepetoideae, tribe Ocimeae and sub tribe Plectranthinae (Retief, 2000). In Kerala it is locally known as *Iruveli.* National Medicinal Plants Board (NMPB), Government of India, has identified and prioritized this plant as one of the medicinal plant species for its overall development and protection under promotional and commercial scheme.

Habitat

The genus *Plectranthus* prefers tropical climate and grows well in warm temperate climatic zones (Mabberley, 2008). This herb is native to Sri Lanka. According to Lukhoba *et al*. (2006), commercial cultivation of *Iruveli* is limited to tropical India. In Kerala, as reported by Nair *et al*. (1986), the cultivation of *Iruveli* is confined to herbal gardens of Arya Vaidya Sala, Kottakal, Medicinal Plants Gardens of Kerala Agricultural University, and to close vicinity of the clinics of many Ayurveda and Siddha physician. The latter is sold and used by the physicians themselves.

Extinction of *Plectranthus* occurred in the wild natural habitat, because of unavailability of water, light and other growth factors (Shivananda *et al*., 2007). Saraswathy and Lavanya (2013) reported that during early 20th century *Plectranthus* has been cultivated in a few districts of Tamil Nadu namely, North Arcot, Coimbatore, Madurai, Thanjavur, Tirunelveli and Chengalpattu.

Morphology

Plectranthus vettiveroides is a small profusely branching pubescent succulent herb. The plant grows up to 1 m height. Lateral spread is around 60-80 cm in both east-west and north-south directions. On an average, a plant produces 20-22 branches per plant and 20-22 leaves per branch. Fresh roots are straw colored, fibrous, 30-90 cm long and form a tuft, very thin and fragile, but strongly aromatic. Color of the roots changes to dark brown on drying. Stem is slightly quadrangular, light brown or purple. Leaves are simple, opposite, decussate, estipulate, petiolate. Petioles are 2-10 cm long, sub-succulent, slightly hairy with a central groove. Leaves are sub-fleshy to leathery and with dense white minute hairs on either surface. Leaf lamina is sub-orbicular to oval shaped with 6-8 pairs of lateral veins which are less prominent above but prominent below. Size of the leaves is 5-7 × 5-9 cm. Base and apex of leaves is almost rounded. Leaf margin is serrated with triangular teeth (Jacob, 1941; Shivananda *et al*., 2007).

Shivananda *et al*. (2007) studied the rooting pattern of *Plectranthus vettiveroides* and according to them, root characters varied based on the texture of soil. If they are grown on sandy soil with ambient water source, there will be profuse long slender tufted tertiary roots, whereas in loamy soil the primary and secondary roots will be more prominent. Being a member of Lamiaceae family, *Plectranthus vettiveroides* have blue colored, bilabiate flowers with corolla arranged in whorls and the fruits are small nutlets (Saraswathy and Lavanya, 2013).

Phytochemical constituents

As per Waldia *et al.* (2011) the major chemical constituents in *Plectranthus vettiveroides* includes essential oils, diterpenoids, triterpenoids, flavones and fatty acids. According to them the essential oil is highly viscous, brightly coloured (orange red) and with a pleasant odour.

High-performance thin- layer chromatography (HPTLC) studies done by Beesha and Padmaja (2013) in *Plectranthus vettiveroides* using various extracts specified the occurrence of carbohydrates, steroids, proteins, amino acids, phenolic compounds, tannins and alkaloids. In addition to this, phytochemical screening by Gopalakrishnan and Dhanapal (2014) of methanolic extracts figured out the presence of triterpenoids, phenolic compound, proteins, flavonoids, alkaloids and tannins. Rohini and Padmini (2016) reported the presence of mono, di and sesqui tepenoides and phenolics in the roots of *Plectranthus vettiveroides.*

As stated by Abdel-Mogib *et al.* (2002) the amount of essential oil in *Plectranthus* genus is greater than 0.5 per cent. Saraswathy and Lavanya (2013) cross checked the constituents of essential oil in *Plectranthus vettiveroides* root using the gas chromatography - mass spectrometry (GC-MS) analysis and identified 36 compounds. The oil was rich not only in oxygenated hydrocarbons, but also saturated hydrocarbons, like aldehydes, ketones and hydroxy groups. The major plant constituents identified were mostly as androstan-17-one, 3-ethyl-3- hydroxy-, (5α) - (25 per cent) and -(-) spathulenol (9 per cent). Apart from this, other compounds were α- bisabolol (7 per cent), Z-valerenyl acetate (7 per cent), 8(Z)-triene (6 per cent), 1H-cycloprop(E)azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene (5 per cent), myrtenol (2 per cent), 1-naphthalenol (2 per cent), caryophyllene oxide (2 per cent), abieta-9(11),8(14),12- trien-12-ol (2 per cent). All other minor compounds accounted less than 2 per cent.

Medicinal uses and economic importance

In Kerala, *Plectranthus* is utilized as natural medicine for treating cough and cold in children (Sivarajan and Balachandran, 1986). Joy *et al*. (2001) reported the use of *Plectranthus* against leprosy and other dermal diseases. According to Mondal and Kolhapure (2004), distillates of *Plectranthus* have been used in hand sanitizer preparation. The alcoholic extract of this plant can be used as adulticidals for mosquito control (Beenarani *et al*., 2008). Chopda and Mahajan (2009) reported it to be a traditional wound healing plant used in Maharashtra. *Plectranthus* is also reported to be effective in hair growth (Dharmapalan *et al.*, 2011). Safeer *et al.* (2013) reported various medicinal uses of *Plectranthus* such as antibacterial, deodorant, cooling agent, against eye burning, head ache and fever. According to them many house hold items like bathing soap and agarbathi can be made from *Plectranthus*.

The hydro alcoholic extract of *Plectranthus* exhibited apparently higher phytotoxicity, antioxidant and anticancerous properties even at very low concentration (Ganapathy *et al*., 2015). *Plectranthus vettiveroides* is a pharmacologically relevant herb that is used as single or one of the active ingredients in more than 78 herbal medicines (Nisheeda *et al.*, 2016). Use of whole plant extract of *Plectranthus vettiveroides* for treating leucoderma was reported by Chandrasekar *et al.* (2016).

Studies revealed that the methanol extract of *Plectranthus vettiveroides* reduced the blood glucose level and thus held anti diabetic activity (Gopalakrishnan and Dhanapal, 2014). As per Priya *et al.* (2017) the herbal drug preparation with *Plectranthus* can effectively control diabetics by inhibiting the growth of bacteria *Candida albiscans* which assimilate the glucose in intestine. The whole plant extract of *Plectranthus* had been used in south India in formulations for management of dengue fever (Singh and Rawat, 2017).

Anbarasu *et al.* (2011) reported the antipyretic anti inflamatory and analgesic properties of *Nilavembukudineerchoornam*, a classical siddha medicine used in the treatment of Chikunguniya where *Plectranthus* is an important component. Ramanathan *et al*. (2019) also evaluated *Nilavembukudineer* tablet and reported its antipyretic property.

2.3.2 *Sida alnifolia*

The genus *Sida,* also called as fanpetals, belongs to mallow family Malvaceae, sub family Malvoideae and tribe Malveae. *Sida alnifolia* is a species broadly used as raw material for preparation of various plant-based formulations in *Ayurveda*. The genus has nearly 200 species in tropical and subtropical region (Paul and Nair, 1988) and about 20 species in India (Sivarajan and Pradeep, 1996). The plant is locally known as *Kurunthotti*, in Malayalam and as *Bala* in Sanskrit. Roots are the economic part and are used as ingredient in many Ayurvedic formulations, mainly for treating rheumatic complaints.

According to Sivarajan and Balachandran (1994), in northern parts of India *Sida cordifolia* is widely used as source of bala whereas physicians of Kerala prefer *Sida alnifolia*.

Habitat

The ability to grow from sea level to higher altitude makes *Sida acuta* and *Sida cordifolia* pan tropical in its distribution. Conversely *Sida alnifolia* is confined to hills and basins of southern peninsular India and is seen along road sides, wastelands and in secondary growth in forest cleared lateritic hilly slopes and also as weed in upland cultivation (Sivarajan and Pradeep, 1996). Globally this plant is distributed in regions of China, India, Malaysia and Srilanka.

As per NMPB, Sida is the 3rd most consumed drug in herbal pharmaceutical business and is largely taken from the wild (Ved and Goraya, 2008).

Morphology

Sida alnifolia is a woody herb or shrub grown either as annual or perennial, up to a height two meters. Stems are erect to sprawling and profusely branched. Branches are prostrate or ascending with green or purplish grey colour and are glabrescent.

Diamond shaped dark green leaves have 4-8 cm long and are arranged alternately with petioles less than one third length of leaves. The leaf blades are 0.5-5 × 0.5-4 cm, usually lobed or unlobed and with serrated edges. Lower leaves are obovate with retuse or emarginated apex, rarely truncate. But upper leaves are obovate to elliptical - lanceolate with the rounded or acute apex (Sivarajan and Pradeep, 1996).

Flowers are axillary, solitary consisting of 5 hairy sepals and 5 petals of yellow color. Stamens are many in number and a style 7-10 and white in its appearance. The fruit is a schizocarp up to two centimeters long, containing a black colored seed (Assam *et al*., 2010).

Sasidharan and Ansari (2017) reported that roots of *Sida alnifolia* were 8-10 mm in diameter and cylindrical in shape, and lateral roots were long, slender and wavy with a large number of tertiary roots. The yellowish-brown roots possess a pleasant aroma.Neethu and Sajeev (2019) reported two important morphometric forms of *Sida alnifolia,* namely white *Sida* and black *Sida* commonly known as *vellakurunthotti* and *karimkurunthotti* respectively which show difference in their phenotypic characters like stem and leaf colour, leaf shape, branching pattern etc.

Phytochemical constituents

Various classes of chemical constituents like alkaloids, phytosterols, carbohydrates, flavanoids, fatty acids, amino acids and other minor components including long chain hydrocarbons, alcohol, coumarins, phenolic acids etc. were identified from the genus *Sida*. Dinda *et al*. (2015) reported presence of 142 chemical constituents in *Sida* spp. of which alkaloids, flavonoids and ecdysteroids were the predominant chemicals responsible for the therapeutic value of the plant.

Prakash *et al*. (1981) reported the phytochemical constituents of *Sida* as a) phenethyl amine bases i) ß- phenethylamine ii) ephedrine iii) Ψephedrine b) quinazoline i) vasicine ii) vasicinol iii) vasicinone c) choline d) betaine e) hypaphorine f) hypaphorine methyl ester g) cryptolepine h) gossypol i) S-(+)-Nb methyl trptophan methyl ester j) S-(+)- Nb,Nb dimethyl tryptophan methyl ester.

Alkaloids being the major class of phytochemicals, Khatoon *et al*. (2005) conducted HPTLC studies and reported ephedrine as the chief alkaloid compound present in *Sida alnifolia* roots imparting therapeutic potential. According to Khare *et al*. (2002), roots of *Sida* comprised alkaloids such as betaphenethylamine, ephedrine, siephedrine, vasicinol, vasicinone, vasicine, choline, hypaphorine, methyl ester, betaine, phytosterols, α-amyrin, starch and ecdysterone.

Medicinal uses and economic importance

Sida is a predominant and popular herbal drug in India mainly used as a single drug or as an ingredient in many of the Ayurveda formulations. Roots are used in different Ayurvedic medicines and oils to improve strength of bones, muscles and joints. Nadkarni (1982) reported *Sida alnifolia* as a very effective drug for curing of gonorrhea, piles, gout and rheumatism and as nutritive tonic, diuretic and aphrodisiac. Traditionally it is used against diarrhoea, dysentery, skin diseases, asthma and other chest ailments, snakebite, etc.

Kritikar and Basu (2008) reported that in Ayurveda, the root, leaf and fruit destroys *kapha and vata* and cures ulcers, biliousness and leprosy, and are useful in urinary discharges. They also act as astringent and has cooling effect.

Ayurvedic medicines such as Baladikwath, Baladyaghirt, Baladyarista, Chandanbalalakshaditaila, Sudarshanchurna and Kukuvadichurna are prepared by *Sida alnifolia* and *Sida cordifolia* which are used to alleviate pain and swelling in rheumatic disorders, muscular weakness, tuberculosis, heart diseases, bronchitis, wounds in urinary tract and neurological problems (Khare *et al*., 2002).

Ethnopharmacological properties of *Sida* spp. included analgesic, anti - inflammatory, antidiabetic, antiobesity, antioxidant, antimicrobial, anxiolytic, cardioprotective, cytotoxic, hepatoprotective and nephroprotective (Abat *et al*., 2017).

2.3.3 *Indigofera tinctoria*

Indigofera tinctoria also called as true indigo belongs to family Leguminosae, subfamily Papilionoideae, tribe Indigoferea and subtribe Galegeae. *Indigofera* originally comes from “indigo” (since it was thought to have originated in India) and the latin word “ferre”, means bear, and “tinctoria”, which corresponds to tinctorius, which means dyes or related to dyes (Marafioti, 1970; Simon *et al.*, 1984).

Habitat

According to Leake (1975) there are around 350 species of *Indigofera* distributed throughout tropical and warmer subtropical nations across the globe. As per Thomas *et al*. (2000), Indian indigo grows well in both lowlands and hilly areas, and the ideal soil is sandy loam. *Indigofera tinctoria* prefers a mean annual precipitation of 146 mm, a mean annual temperature of 22.50°C, and a soil pH of 6.5 as a farmed crop (Dukes, 1982).

Morphology

Indigofera tinctoria is an annual herb or small bushy perennial shrub having 60 to 120 cm height. The leaves are alternate, compound imparipinnate, with 4-6 pairs of leaflets. The leaflets are opposite, obovate to elliptical. The young branches, petiole and rachis are covered with hairs. The flowers are axillary sessile racemes, 3 to 6 cm long. The fruits are linear pods, 20 to 35 mm long and 2 mm wide and contain 7 to 12 seeds (Bernard, 1979).

Phytochemicals

Phytochemical screening of *Indigofera tinctoria* disclosed the presence of several bioactive chemicals such as tannins, saponins, phenols, flavonoids, terpenoids, alkaloids, and steroids, and minerals such as calcium, phosphorus, potassium, iron, zinc, magnesium, selenium, sodium, copper, manganese, cobalt and molybdenum. This also contains vitamins and fatty acids (Chakrabarti *et al*., 2006; Yinusa *et al*., 2007; Bueno *et al*., 2013).

Bioactive chemical investigation with methanol and hydromethanol extracts of *Indigofera tinctoria* by Alagbe (2020) unveiled the occurrence of pharmacologically potent plant extract such as flavonoids, saponins, glycosides, steroids, tannins and phenols. It was summarized that *Indigofera tinctoria* leaves, stem, bark and roots contain nutrients, vitamins and amino acid (leaves > roots > stem bark).

Plant extracts of *Indigofera tinctoria* contain the glycoside Indican and about 2.5 per cent alkaloids (Choudhri, 1996). Galactomannan composed of galactose and mannose in the molar ratio of 1:1.52 was isolated from seeds of *Indigofera tinctoria* (Chopra *et al.*, 1956).

Various species of *Indigofera* showed the presence of terpenes, alkaloids, β - sitosterol and flavanoids (Varier and Vaidyanathan, 1996). Presence of flavanoid compounds glabretephrin, semiglabrin, pseudosemiglabrin and flavonol glycoside was reported by Subramaniam and Ayarivan (2014).

Medicinal uses and economic importance

Indigofera tinctoria has been used as a cover crop in plantations of coffee and as a green manure crop for in rice, maize, cotton, and sugarcane, as well as an occasional fodder crop (Dukes, 1982; Lemmens and Soetjipto, 1991). In addition to this they have also reported that the leaves were used as prophylactic against hydrophobia epilepsy, nervous disorders, bronchitis and as an ointment for sores, old ulcers, hemorrhoids, scorpion bites and other urinary complaints.

Macfadyen (1837) reported the use of *Indigofera* leaves as blue dye by the ancient painters. *Indigofera* possesses glycosides, which could lower the blood pressure (Nyarko and Addy, 1990). Just *et al.* (1998) reported that saponins present in leaves are responsible for hemolytic and anti-inflammatory ability. In Madagascar, the leaves of *Indigofera* were used in herbal tea preparation (Puy *et al*., 2002). Steroids present in leaves of *Indigofera* are reported to have antibacterial activity (Epand *et al.*, 2007).

The whole plant of *Indigofera tinctoria* can be used as a thermogenic, laxative, trichogenous expectorant, hepatoprotective, anticancer, antihelminthic and also in curing gastropathy, splenomegaly, cephalalgia, cardiopathy, epilepsy, neuropathy, ulcers, skin diseases and diuretic and are useful for promoting the growth of hair (Asuntha *et al.,* 2010). Anti-cancer capacity of *Indigofera tinctoria* was reported by Yadav and Agarwala (2011). Tiwari *et al. (*2011) reported the antidiarrhoeal activity as it increases intestinal absorption of sodium ions and water.

Phytochemical constituents perform several pharmacological effects in animals such as antibacterial, antifungal, antiviral, anti-inflammatory, hypolipidemic, neuroprotective, anti-allergic, hepato-protective, antipasmodic and antioxidant effects (Prakash *et al*., 2007; Oluwafemi *et al*., 2020). In ancient time the plants parts such as leaf, stem, bark and roots had been used for the treatment of toothache, abdominal pain, waist pain, piles, epistaxis rheumatism, stroke and sexually transmitted diseases (Esimon *et al*., 1999; Abubakar *et al*., 2006).

2.4 Suitability of medicinal plants as intercrops

Jessykutty and Jayachandran (2009) reported the suitability of intercropping lesser galangal (*Alpinia calcarata* Rosc.) under various canopy shade conditions. Furthermore, the plant lesser galangal grew and yielded better in the shade of oil palms ranging in age from five to fifteen years, providing additional significantly higher income

Intercropping possibility of *Coleus forskohlii* with teak was reported by Pujar *et al*. (2007). According to them when intercropped with teak, herbage yield of *Coleus forskohlii* increased by 12.93 per cent. The interaction of *Coleus forskohlii* with red gram productivity was investigated by Thakur *et al.* (2008) who recorded a significantly higher plant height (52.67 cm) in the sole crop. Effect of intercropping *Coleus forskohlii* with castor on its productivity was studied by Shrivastava *et al.* (2009) and it was found that the root yield of *Coleus forskohlii* was significantly higher under sole crop. Roopa (2017) reported the feasibility of intercropping *Coleus forskohlii* with leafy vegetables. Malek *et al.* (2020) analysed the biometric characters of *Coleus aromaticus* under different combinations of sapota - jatropha plantation and they reported that under sapota - jatropha intercropping number of branches and leaves were higher than in sole crop of coleus.

Basavaraju (2010) reported that when medicinal plants were intercropped in coconut garden, the andrographolide content in kalmegh (4.40 to 3.20 per cent), rutin alkaloids in garden rue (1.68 to 1.40 per cent) and oil content in lepidium (19.60 to 17.23 per cent) were significantly lowered compared to mono crop. However, the forskohlin content in coleus (0.43 to 0.61 per cent) and essential oil content in ambrette (0.24 to 0.29 per cent) were increased by intercropping.

Buchanan *et al*. (1977) reported the suitability of intercropping prickly sida (*Sida alnifolia*) with *Gossypiyum hirsutum.* Priyadarsini *et al.* (2020) reported that higher total alkaloid content (3.13 per cent) was observed in plants grown under open condition whereas in 50 per cent shaded condition it was 2.18 per cent.

Garrity and Flinn (1988) studied the intercropping of *Indigofera tinctoria* with dry season upland crops. According to them, *Indigofera* is a drought tolerant crop suitable for rainfed rice fields and fixes 62-122 kg N/ha to the succeeding rice crop, depending on soil, climate, and cropping conditions *Indigofera* was used as a green manure crop by farmers and cultivated widely in the north western region of Luzon (Garrity *et al*., 1989). According to Mann (1990), a classic system of green manuring has been developed using *Indigofera tinctoria* as intercrop in legume. Suitability of intercropping *Indigofera* in coconut plantations was reported by Sarada and Reghunath (2009).

Khoshnam *et al.* (2020) assessed the effect of intercropping system with *Indigofera tinctoria* and *Hibiscus sabdariffa* on various aspects of biodiversity, weed population and crop yield. The maximum yield of *Hibiscus sabdariffa* (1114.2 kg/ha) and leaf dry weight (3016.7 kg/ha) of *Indigofera tinctoria* was obtained in I_{100}: H_{100} ratio. The Land Equivalent Ratio (LER) in all of intercropping treatments was greater than unity and the highest LER belonged to H_{100}: I_{100} treatment, indicating that intercropping system outperforms the sole crop in terms of crop productivity.

2.5 Competition indices in intercropping

The LER greater than one implies the advantage of intercropping over the sole culture with reference to use of external resources available to the crop growth and development (Mead and Willey, 1980). On the flip side, Nassab *et al*. (2011) and Zhang *et al*. (2011) opined that high value of LER is obtained because of greater interspecific interaction or complementarity than competition in intercropping. Mbah and Ogidi (2012) reported that total land equivalent ratio (LER) of cassava and soybean in the intercropping system ranged from 1.53 to 1.99 which indicated that higher productivity per unit area was attained in intercropping than monoculture. LER greater than unity in cassava + *Lagenaria siceraria* intercropping system reflects the additional benefit of intercropping system over pure culture (Doubi *et al.,* 2016).

A positive value of aggressivity indicates the dominance and negative value indicates subjugation (Mc Gilchrist, 1965). Ennin *et al*. (2001) reported that aggresivity values of cassava were all positive when cassava was intercropped with maize, soyabean and cowpea which proves that cassava is a strong competitor in the crop mixture. On the contrary, Gayathri (2010) obtained negative value for cassava when intercropped with fodder grasses and fodder cowpea which indicated that latter crops are more competitive than cassava.

Doubi *et al*. (2016) observed higher Relative Crowding Coefficient (RCC) for cassava compared to *Lagenaria siceraria*, in cassava + *Lagenaria siceraria* intercropping system. Competitive ratio (CR) is used as a gauge to measure the competitive ability of component species in intercropping (Weigelt and Jolliffe, 2003; Uddin *et al*., 2014). CR value greater than unity denotes that the species is more competitive than the other in the crop combination. As per Gayathri (2010) highest cassava equivalent yield was obtained in sole crop of cassava than in cassava intercropped with fodder cowpea and fodder grasses.

2.6 Economics of medicinal plants intercropping

According to Maheshwari *et al.* (1985), monoculture of *Rauvolfia serpentina* yielded a greater number of roots than intercropped condition, but an added income was obtained when intercropped with soybean, garlic and onion. As per Thakare and Khode (1992), introduction of medicinal plants periwinkle in cropping systems resulted in better profit than conventional crops.

Maheshwari *et al*. (1997) suggested intercropping vetiver with medium duration pigeon pea. According to them vetiver + pigeon pea intercropping system gave an additional income of Rs. 6876/ha over sole crop of vetiver. Singh *et al.* (1998) reported increased land use efficiency by 47 per cent and profit by Rs. 12500/ha by intercropping of palmarosa with pigeonpea over a single crop of palmarosa.

Dutt and Thakur (2004) studied the monetary status of cropping systems by combining medicinal and aromatic herbs with commercial timber species. Four herbal crops namely *Ocimim sanctum*, *Spilanthes acmella*, *Tagetes minuta* and *Withania somnifera* were intercropped for two consecutive years with six year old plantation of Populus hybrid (G-48) and income improvement was observed on including medicinal plants to the system. A significantly higher net return of Rs. 33,520 and B:C ratio of 3.05 were recorded in 2:4 row proportion of pigeon pea and ashwagandha as compared to 2:1 (Rs. 22, 403/ha and 2:47 respectively) row proportion (Koppalkar, 2007). Ghosh *et al*. (2007) reported the highest total return from coconut + arrowroot (Rs. 51,500/ha) intercropping system, whereas the highest net profit was from coconut+ brahmi (Rs. 27,600/ha) intercropping system.

While intercropping medicinal plants in arecanut plantation, Sujatha *et al*. (2009) recorded the highest net return from *Asparagus racemosus* (Rs. 80,000/ha) followed by *Nilagirianthus ciliatus* (Rs. 42,000/ha), *Bacopa monnieri* (Rs. 39,380/ha) and *Chrysopogon zizanoides* (Rs. 31,000/ha). Chandranath and Pujari (2011) concluded that intercropping sunflower with ashwagandha was beneficial over sole cropping. Among the row ratios, 1:6 sunflower: ashwagandha recorded the highest net profit of Rs. 3, 17,000/ha.

3. ***MATERIALS AND METHODS***

3. MATERIALS AND METHODS

The present investigation entitled "Medicinal plants as intercrops in cassava (*Manihot esculenta* Crantz)" was conducted from September 2020 to April 2021 at the Agronomy Farm, Department of Agronomy, College of Agriculture, Vellanikkara. The technicalities of the materials used and methods adopted for experimentation are presented in this chapter.

3.1. Details of experimental site

a) Location

The study was conducted at the Agronomy Farm, Department of Agronomy, College of Agriculture, Vellanikkara, Thrissur, Kerala. Topographically the field is situated at 13° 32'N latitude and 76° 26'E longitude, at an altitude of 40 m above mean sea level.

b) Soil

The plot was sandy clay loam in texture and acidic in its reaction with a pH of 4.45. The physical and chemical properties of soil are present in Table 1.

c) Weather

The experiment was carried out during the period from September 2020 to April 2021.

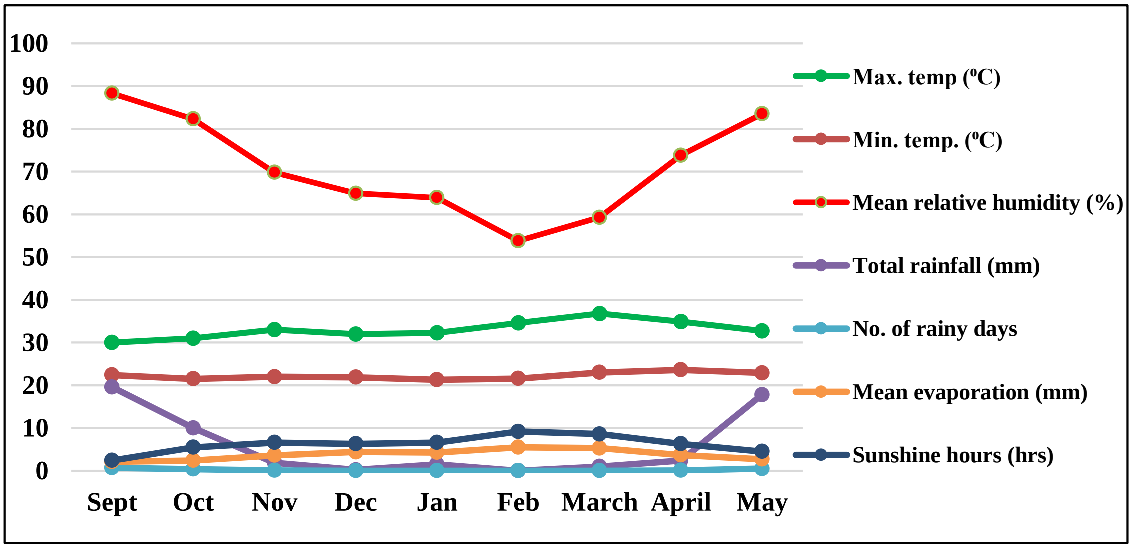


Fig. 1. Monthly mean of meteorological data during experimental period

Table 1. Soil physico-chemical properties

Particulars	Value	Method adopted
1. Physical properties Particle size composition		
Coarse sand (%)	31.90	Robinson international pipette method (Piper, 1942)
Fine sand (%)	27.30	
Silt (%)	18.64	
Clay (%)	22.16	
2. Chemical properties		
pH	4.55	1: 2.5 soil water suspension (Jackson, 1958)
Organic carbon (%)	0.58	Walkley and Black method (Jackson, 1958)
Available N (kg/ha)	336.00	Alkaline Permanganate Method (Subbaiah and Asija, 1956)
Available P (kg/ha)	25.00	Ascorbic acid reduced molybdo phosphoric acid blue colour method (Bray and Kurtz, 1945; Watanabe and Olsen, 1965)
Available K (kg/ha)	217.00	Neutral normal ammonium acetate extraction and estimation using flame photometry (Jackson, 1958)

d) Cropping history of the experimental site

The experimental area was under stevia cultivation during the previous year.

3.2 Experimental details

The period of study was from September 2020 to April 2021. The experiment was laid out in Randomized Block Design (RBD) with 10 treatments and three replications. The plot size of main crop *i*.e., cassava was 5 m x 5 m with plant spacing of 1m x 1m. The details of the cropping system including the crop, spacing and plant population per hectare adopted in the study are given in the Table 2 and layout is given in Fig. 2. The treatment details are given in Table 3.

Crop and variety

Study was conducted using a locally available high yielding cassava cultivar with erect growth habit having duration of seven months, which was intercropped with three medicinal plants namely *Indigofera tinctoria*, *Plectranthus vettiveroides* and *Sida alnifolia.* Planting material of medicinal intercrops, *Indigofera tinctoria*, *Plectranthus vettiveroides* and *Sida alnifolia* were collected from AICRP on Medicinal, Aromatic plants and Betelvine, College of Agriculture, Vellanikkara.

Table 2. Details of crops in the intercropping systems

Scientific name	Common name	Spacing	Date of Planting	Date of harvest	Plant population per hectare		
					Sole	Single row	Double row
Manihot esculenta	Cassava	1 m x 1m	28.09. 2020	18.04.2021	10000	10000	10000
Indigofera tinctoria	Neelamari	40 cm x 30 cm	01.10. 2020	1. 13.11.2021 2. 11.12.2021 3. 10.01.2021 4. 13.02.2021 5. 28.03.2021	83333	27200	54400
Plectranthus vettiveroides	Iruveli	40 cm x 40 cm	01.10. 2020	02.01.2021	62500	20800	41600
Sida alnifolia	Kurumthotti	40 cm x 30 cm	01.10. 2020	03.03.2021	83333	27200	54400

Table 3. Details of treatments in the experiment

T_1	Sole crop of cassava
T_2	Inter cropping cassava with *Indigofera tinctoria* (single row)
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)
T_4	Intercropping cassava with *Sida alnifolia* (single row)
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)
T_7	Intercropping cassava with *Sida alnifolia* (double row)
T_8	Sole crop of *Indigofera tinctoria*
T_9	Sole crop of *Plectranthus vettiveroides*
T_{10}	Sole crop of *Sida alnifolia*

Layout

N

R1	R2	R3
T_2	T_8	T_{10}
T_7	T_1	T_4
T_{10}	T_6	T_3
T_5	T_2	T_8
T_6	T_{10}	T_7
T_1	T_3	T_9
T_8	T_7	T_5
T_4	T_5	T_1
T_3	T_9	T_2
T_9	T_4	T_6

5m

5m

Fig. 2 Layout of the field experiment

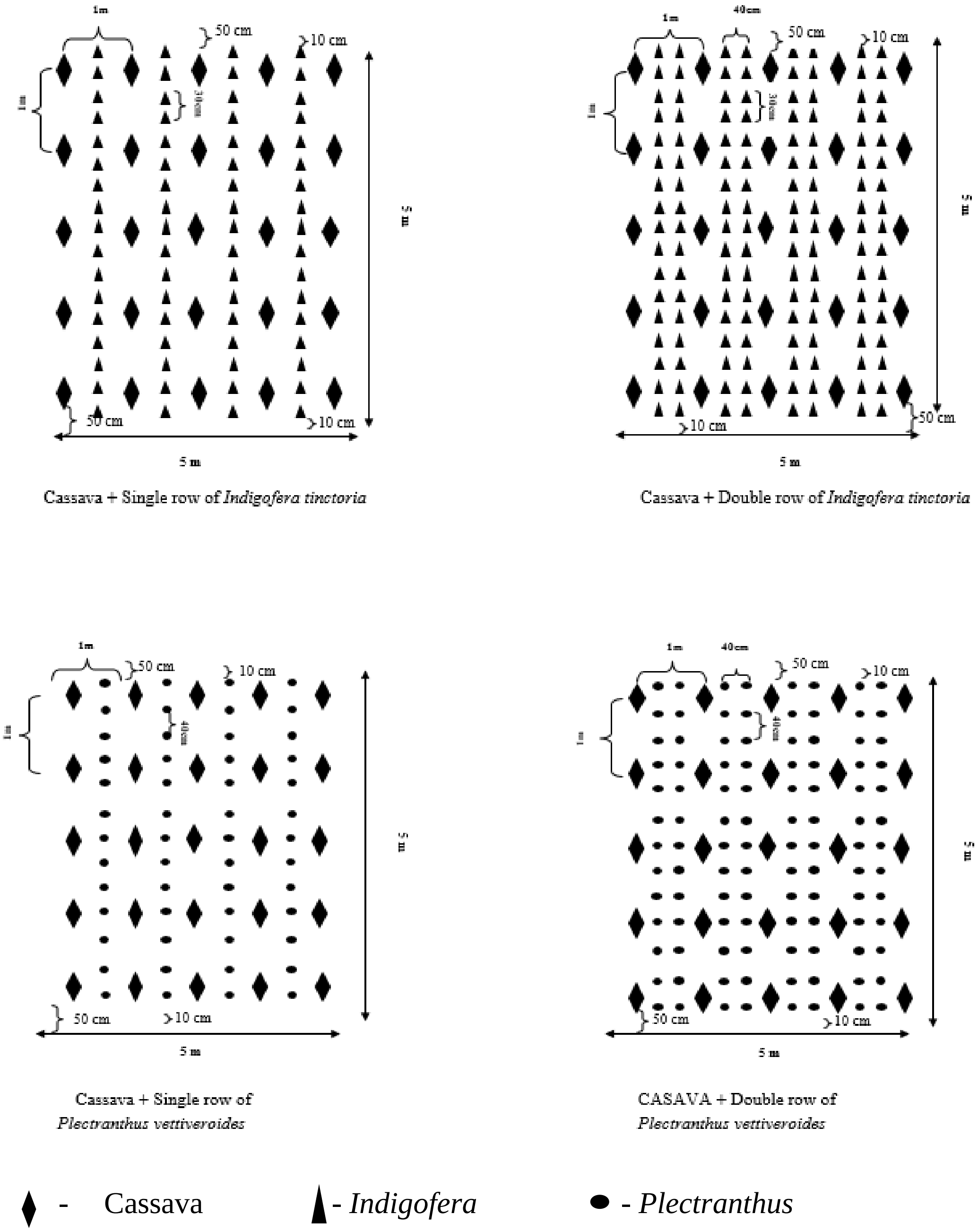


Fig. 3. Schematic representation of the intercropping system

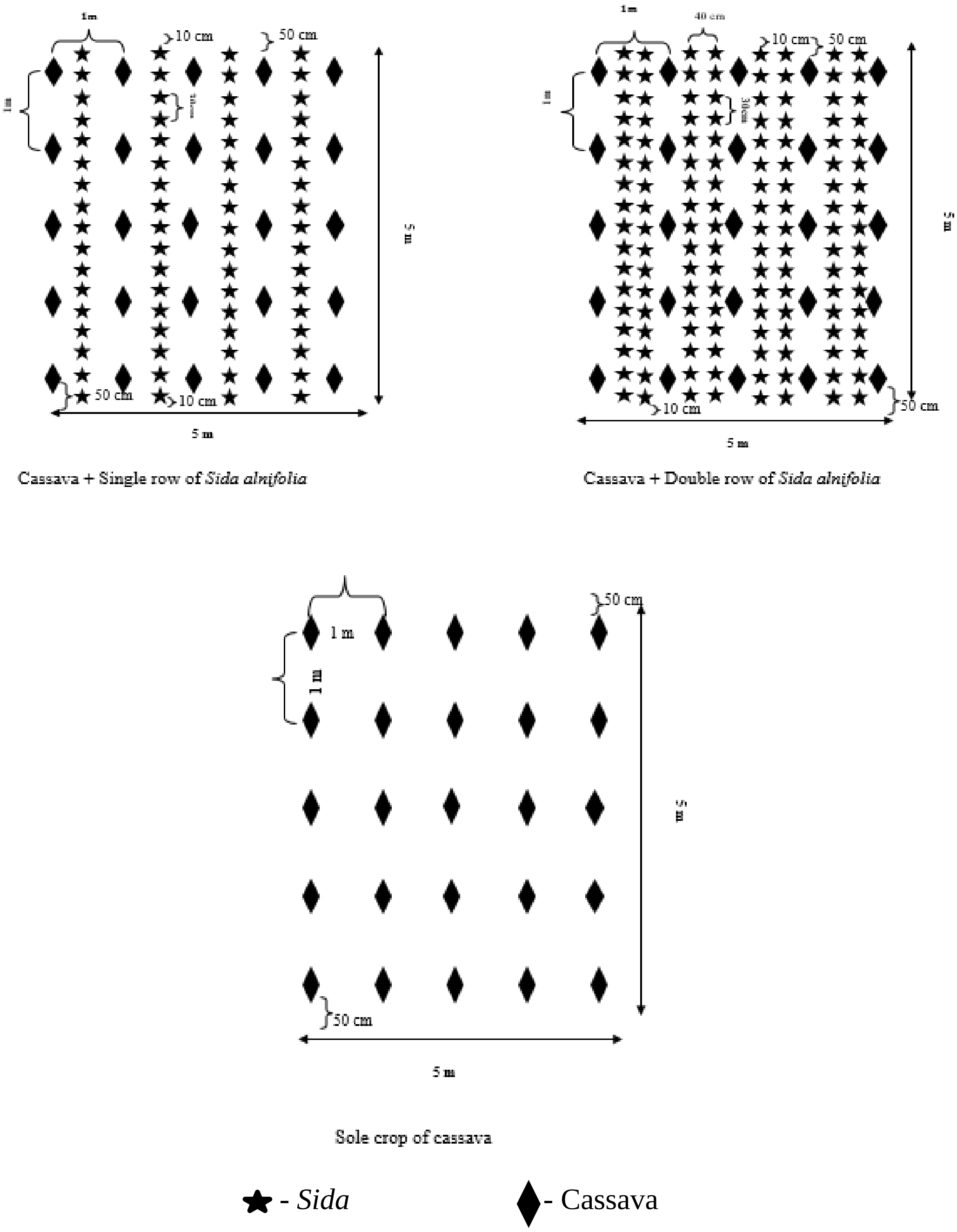


Fig. 4. Schematic representation of the intercropping system

Land preparation

The plot was initially ploughed thoroughly with disc plough and then worked with a cultivator to a fine tilth. After removing the weeds and stubbles of the preceding crop, ridges and furrows of 50 cm width were laid out as per the layout plan.

Planting of main crop and intercrops

Cassava setts of 15 cm length (three nodes) from high yielding local cultivar were planted on ridges at a spacing of 1m x1m. Plot size was 5 m x 5 m. As intercrops, medicinal plants were planted in single row and double row in between cassava. Table 2. gives details of crops included in the study. For single row, plants were planted in middle of furrows whereas for double rows, plants were planted on either side of furrow at recommended spacing (Fig. 3 and 4).

Nursery for the medicinal plants was prepared one month before planting and thirty days old seedlings were planted in main field. Planting was done manually by digging small holes. The plots were irrigated immediately after planting.

Irrigation

Irrigation was not necessary and crops were raised under rainfed system.

Manures and Fertilizers

As per the package of practices recommendations, manures and fertilizers were given to cassava and intercrops (KAU, 2016).

Intercultural operation

Hand weeding followed by earthing-up was done at 30, 60 and 90 days after planting for all treatments which included cassava. However, in double row planting of medicinal plants, intercultural practices were not done at 90 DAP. For the sole culture of medicinal plants, hand weeding alone was done at 30 DAT, 60 DAT and 90 DAT.

Plant protection

Initially, leaf eating caterpillar *Spilisoma* sp. attack was observed in *Sida*.

Ekalux ® @ 2ml/L was sprayed on 12/10/2020 to bring the pest population under control.

Plectranthus was affected by wilt disease caused by *Fusarium chlamydosporum.* At initial stage of infection Pseudomonas @ 20g/L was drenched in soil. Later since there was no reduction in the disease severity, fungicide Kocide® @ 2g/L was drenched in soil on 22/12/2020.

Harvesting of main crop and intercrops

Cassava tubers were harvested seven months after planting (MAP) when the bottom leaves started to turn yellow. Harvesting of tubers was done by uprooting the cassava plants. *Plectranthus vettiveroides* and *Sida alnifolia* were harvested three and five months after planting respectively by uprooting the plants. To pull out the plants easily, crops were irrigated on previous day. Roots were then separated and shade dried. A total five harvests were done for *Indigofera*. Details of harvest of main and inter crops are given in Table 2.

3.3 Observations recorded

3.3.1. Soil analysis

The pH, organic carbon and major nutrients were estimated before the conduct of study. The soil samples were collected, dried, powdered and passed through a 0.5 mm sieve for analyzing the organic carbon content. Major nutrients viz., available N, available P and available K were estimated using standard procedures as detailed in Table 1.

3.3.2 Observations on main crop and intercrops

For recording the following observations five plants per replication were randomly selected and tagged.

Observations on cassava

Plant height

Plant height was measured from the ground level to the growing tip of plants at 30 DAP, 60 DAP, 90 DAP and at harvest and average was expressed in cm.

Number of branches per plant

Branches arising from main stem of the tagged plants were counted at 30 DAP, 60 DAP, 90 DAP and at harvest and the average number of branches per plant was worked out.

Number of leaves per plant

Total numbers of fully opened leaves were counted at 30 DAP, 60 DAP, 90 DAP and at harvest and the average number of leaves per plant was worked out.

Tuber yield (kg/plant)

Fresh tuber weights from the plants were recorded after the tubers were detached and washed to eliminate any adhered soil.

Top yield at harvest (kg/plant)

Top yield was noted for cassava by weighing all above ground parts from the base.

Dry matter production at harvest

At the time of harvest plants were uprooted and dried under shade and then oven dried at $60 \pm 5^{\circ}C$ till constant weight was achieved. The total dry matter production was expressed as kg/ha

Observations on *Indigofera tinctoria*

Plant height

Plant height was measured from the ground level to the growing tip of plants at 30 DAT, 60 DAT and 90 DAT and average expressed in cm.

Number of branches per plant

Branches arising from main stem of the tagged plants were counted at 30 DAT, 60 DAT and 90 DAT and the average number of branches per plant was worked out.

Number of leaves per plant

Count total number of fully opened leaves per plant at 30 DAT, 60 DAT and

90 DAT and the average number of leaves per plant was worked out.

Herbage yield

Leaves along with tender branches were harvested 20 cm above the ground and total yield expressed as kg/ha.

Number of harvests

Number of cuts that could be made during the crop period was noted.

Observations on *Plectranthus vettiveroides*

Plant height

Plant height was measured from the ground level to the growing tip of plants at 30 DAT, 60 DAT and 90 DAT and average was expressed in cm.

Number of branches per plant

Branches arising from main stem of the tagged plants were counted at 30 DAT, 60 DAT and 90 DAT and the average number of branches per plant was worked out.

Number of leaves per plant

Total number of fully opened leaves per plant was counted at 30 DAT, 60 DAT and 90 DAT.

Total root yield at 3 MAP

At three months after planting, plants were uprooted, roots separated, washed and weighed.

Observations on *Sida alnifolia*

Plant height

Plant height was measured from the ground level to the growing tip of plants at 30 DAT, 60 DAT and 90 DAT and average was expressed in cm.

Number of branches per plant

Branches arising from main stem of the tagged plants were counted at 30 DAT, 60 DAT and 90 DAT and the average number of branches per plant was worked out.

Number of leaves per plant

Total numbers of fully opened leaves were counted at 30 DAT, 60 DAT and 90 DAT.

Total root yield at 5 MAP

At five months after planting, roots were harvested by uprooting whole plants and yields were recorded.

3.3.3 Biochemical observations in medicinal plants

a) Indican content in *Indigofera tinctoria*

Total indican content in *Indigofera tinctoria* was determined using the methanol extract. Leaf sample of 50 mg was ground thoroughly using a pestle and motor in 15 ml of 80 per cent methanol. The suspension was transferred into a beaker. It was kept at 70^0C in an oven for 10 minutes and then in shaker for 20 minutes. Contents were filtered and at O.D. at 280 nm in UV spectrophotometer. (Wu *et al.,* 1999). Indican standard was treated in the same way and a graph was plotted with concentration *vs*. O.D. From the graph indican content of the sample was calculated.

b) Essential oil content in rots of *Plectranthus* at harvest

As per AOAC (1975), essential oil content of *Plectranthus* was estimated by hydro distillation method, using Clevenger apparatus and expressed in per cent. Powdered root sample of 25g was distilled for 4 hours and the oil yield obtained was expressed in per cent. Essential oil yield was computed by multiplying oil content with yield.

c) Total alkaloid content in roots of *Sida* at harvest

Total alkaloid content in *Sida* roots was estimated by the procedure given by Harborne (1973). Five gram of powdered root sample was taken in a 250 ml beaker, 200 ml of 10 per cent acetic acid in ethanol added, and covered. It was then allowed to stand for four hours. Contents were filtered and the aliquot was concentrated to one quarter of the original volume on a water bath. After decreasing its volume, concentrated ammonium hydroxide was added drop wise to the content until the precipitation was complete. The solution was allowed to settle down, and filtered.

Beaker was washed with dilute ammonium hydroxide and the precipitate was collected in the filter paper. The residue obtained was dried and weighed.

3.3.4 Observation on weeds

a) Observations on weed count

Weed count was recorded by placing a 1m x1m quadrat randomly in each plot. Weeds were uprooted and classified into grasses, sedges and broad leaf weeds and observations were taken. The observations were recorded at 30 DAP, 60 DAP and 90 DAP. Weed count was denoted as number per square meter.

b) Observation on weed dry weight

Weeds collected from the quadrat were washed, cleaned, air dried and then oven dried at 80 ± 5ºC and dry weight of grasses, sedges and broad leaf weeds were recorded separately in g/m^2.

3.3.5 Evaluation of intercropping system

a) Land equivalent ratio (LER)

The land equivalent ratio (LER) is a parameter used as a yard stick to measure the efficacy and land productivity of intercropping system (Brintha and Seran, 2009). It denotes the relative land area under pure crop required to give the same yield as obtained under a mixed or an intercropping system at the same management practice. The LER was calculated using the formula given by Willey (1979b).

$$LER = LER_c + LER_m$$

$$LER = \frac{Y_{cm}}{Y_{cc}} + \frac{Y_{mc}}{Y_{mm}}$$

Y_{cm} = Yield of cassava in intercropping system

Y_{mc} = Yield of medicinal plants in intercropping

Y_{cc} = Yield of cassava in sole cropping

Y_{mm} = Yield of medicinal plants in sole cropping

3.3.5.2 Relative Crowding Coefficient (RCC)

De wit (1960) put forth the concept of relative crowding coefficient (RCC or K) in an intercropping system. This enables to evaluate and compare the competitive ability of one crop species to the one another in a mixture (Zhang *et al*., 2011). The K was calculated as follows:

$$\mathbf{K \text{ or } RCC = K_c \times K_m}$$

$$K_c = \frac{Y_{cm} \times Z_{mc}}{(Y_{cc} - Y_{cm}) \times Z_{cm}}$$

$$K_m = \frac{Y_{mc} \times Z_{cm}}{(Y_{mm} - Y_{mc}) \times Z_{mc}}$$

K_c = RCC of cassava

K_m = RCC of medicinal plants

Z_{mc} = Proportion of land occupied by medicinal plants

Z_{cm} = Proportion of land occupied by cassava

c) Competitive Ratio (CR)

Competitive ratio gives the measure of competitive ability of the crops (Willey and Rao, 1980).

$$CR_c = \frac{LER_c \times Z_{mc}}{LER_m \times Z_{cm}}$$

$$CR_m = \frac{LER_m \times Z_{cm}}{LER_c \times Z_{mc}}$$

Where,

CR_c and CR_m are competition ratios of cassava and medicinal plants respectively

d) Cassava Equivalent Yield (CEY)

The yields of intercrops of medicinal plants were converted into equivalent yield of cassava based on the price of the produce, and the cassava equivalent yield of the intercropping system was calculated by the following formula:

$$CEY = \text{Cassava yield} + \frac{(\text{Intercrop yield x price})}{\text{Price of cassava}}$$

(Reddy and Reddy, 2016)

e) Aggressivity

Aggressivity (A) is an estimate of competitive ability of component crops which indicates how much the relative yield increase in component 'a' is greater than that of component 'b'. Mc Gilchrist (1965) suggested the following formula to calculate aggressivity of intercropping systems.

$$A_{cm} = \frac{Y_{cm}}{Y_{cc} \times Z_{cm}} - \frac{Y_{mc}}{Y_{mm} \times Z_{mc}}$$

$$A_{mc} = \frac{Y_{mc}}{Y_{mm} \times Z_{mc}} - \frac{Y_{cm}}{Y_{cc} \times Z_{cm}}$$

Where,

A_{cm} and A_{mc} are the aggressivity of cassava with respect to medicinal plants and aggressivity of medicinal plants with respect to cassava respectively

Y_{cm} and Y_{mc} are the yields of cassava and medicinal plants respectively under intercropping.

Y_{cc} and Y_{mm} are the yields of cassava and medicinal plants respectively as sole crops.

Z_{cm} and Z_{mc} are the proportions of cassava and medicinal plants respectively in the mixture.

3.3.6 Economic analysis

For main and intercrop the cost of inputs along with prevailing labour expenses were considered to find out gross expenditure, and market price of these crops were used to calculate the total returns, both expressed in rupees per hectare. The Benefit: Cost ratio (BCR) was worked out using the formula given below:

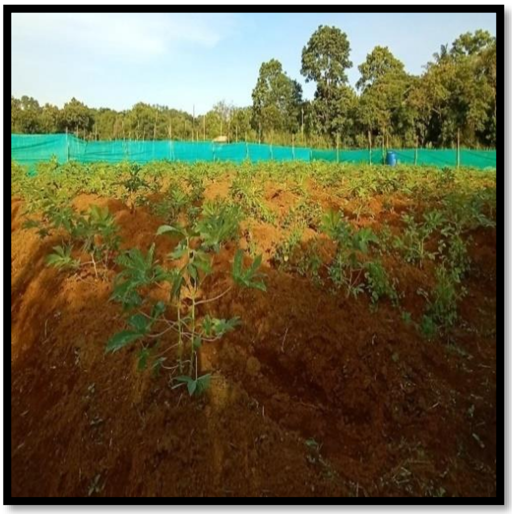
$$\text{BCR} = \frac{\text{Net returns}}{\text{Total cost of cultivation}}$$

3.3.7 Statistical analysis

The data collected on main crop were subjected to analysis of variance (ANOVA) using the statistical package 'WASP' (Web based Agricultural Statistics Software Package). For the statistical analysis of intercrops, two-way Anova with multiple observations per cell (without interaction) was used for satisfying the degrees of freedom. The statistical package used was version 1.0.0 of GRAPES (General Rshiny Based Analysis Platform Empowered by Statistics) (Gopinath *et al.,* 2020).

In order to make analysis of variance valid, the data on weed count and weed dry weight which showed wide variation were subjected to square root transformation (Gomez and Gomez, 1984).

Plate 1. General field view



Crop stand at 30 DAP

Crop stand at 60 DAP

Crop stand after 90 DAP

Crop stand at harvest

Plate 2. Field view at different crop growth stages

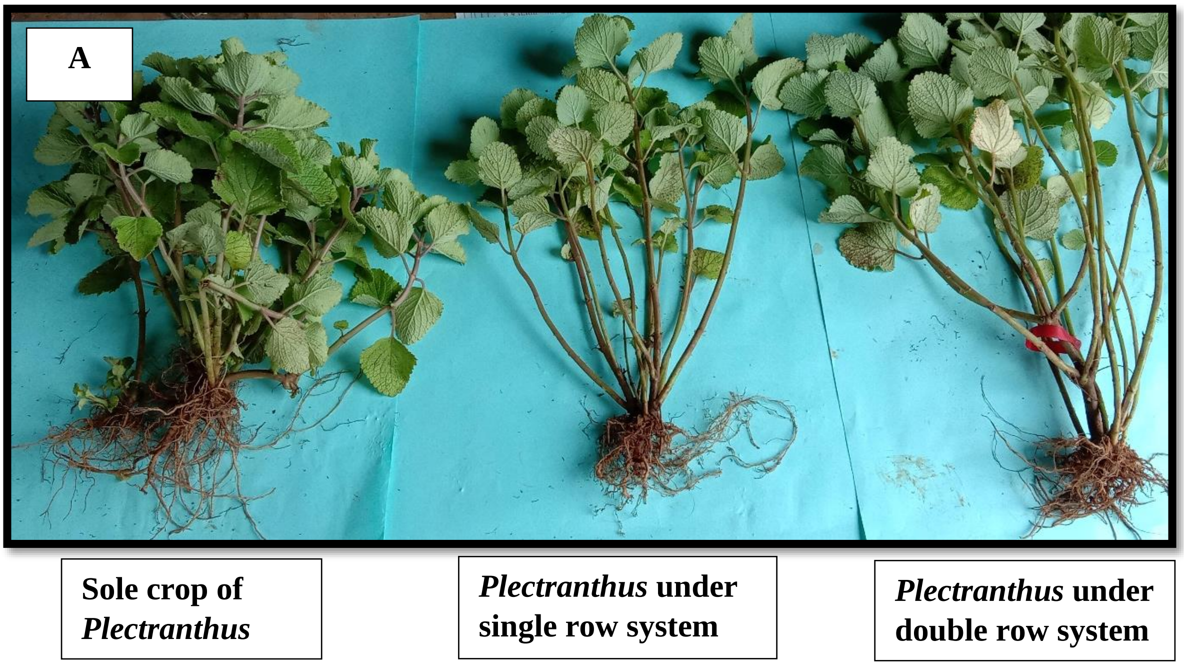


Plate 3. Effect of intercropping with cassava at harvest on (A) *Plectranthus* (B) *Sida*

4. RESULTS

4. RESULTS

The results of the M.Sc. thesis research work on ‘‘Medicinal plants as intercrops in cassava (*Manihot esculenta* Crantz)’’ carried out at Agronomy Farm, attached to the Department of Agronomy, College of Agriculture, Vellanikara from September 2020 to April 2021 are given below.

4.1 Plant characters of cassava

The growth and growth attributes of cassava are given below

4.1.1 Plant height

The data on the height of cassava at 30, 60, 90 days after planting (DAP) and at harvest are illustrated in Table 4. In the initial stages (30 and 60 DAP), intercropping had no significant influence on plant height of cassava. However, significant variation in height of cassava due to intercropping was observed at the later stages. At 90 DAP, taller cassava plants were observed when cassava was intercropped with single row of *Plectranthus vettiveroides* (128.25cm). It was on par with sole crop of cassava (123.33 cm), cassava intercropped with single row of *Indigofera tinctoria* (119.75 cm), cassava intercropped with single row of *Sida alnifolia* (119.08 cm), cassava intercropped with double row of *Plectranthus vettiveroides* (119.58 cm). The shorter cassava plants were recorded from plots which were intercropped with double row of *Sida alnifolia* (T_5, 103.33 cm).

At the time of harvest, all the treatments except intercropping with double row of *Sida alnifolia* (T_7) were on par. Shorter cassava plants were observed when cassava was intercropped with *Sida alnifolia* (162.84 cm). Plant height of cassava at the time of harvest ranged between 162.84 cm to 217.79 cm.

4.1.2 Number of leaves

The data on the number of leaves of cassava at 30, 60, 90 DAP and at harvest are depicted in Table 5. At 30 DAP there was no statistical difference in number of leaves among the treatments. The number of leaves at this stage ranged from 20.33 to 23.60.

At 60 DAP there was a considerable difference among various treatments. Higher number of leaves was observed when cassava was intercropped with *Indigofera* either as double row of (73.16) or as single row (73.00). These treatments were on par with intercropping cassava with single or double rows of *Plectranthus* (70.08 and 69.08 respectively). Pure crop of cassava produced 61.16 numbers of leaves and lowest number was noted for cassava intercropped with double row of *Sida* (55.25).

At 90 DAP also, cassava intercropped with single row of *Indigofera* produced more number of leaves (141.75), and was on par with sole crop of cassava (141.18) and cassava with single row of *Plectranthus* (135.63). This was followed by intercrops of cassava with single row of *Sida* (T_4), double row of *Plectranthus* (T_6) and double row of *Indigofera* (T_5). Intercropping cassava with double row of *Sida* (T_7) resulted in lowest number of leaves (104.08).

At the time of harvest, all the treatments except intercropping cassava with double row of *Sida* were on par with each other. Double row intercropping of *Sida* with cassava resulted in lowering of number of leaves of cassava. The number of leaves per plant at the stage of harvest varied from 99.60 to 65.57.

4.1.3 Number of branches

The data on the number of branches per cassava plant at 30, 60, 90 DAP and at harvest are given in the Table 6. At different growth stages intercropping cassava with medicinal plants either as single or as double row had no significant effect on number of branches in cassava. The number of branches ranged between 2.07 to 2.86, 2.34 to 3.45 and 5.48 to 6.07 at 60, 90 DAP and at harvest respectively.

Table 4. Effect of treatments on plant height of cassava

Treatments		Plant height (cm)			
		30 DAP	60 DAP	90 DAP	Harvest
T_1	Sole crop of cassava	24.53	77.75	123.33	206.62
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	23.80	77.75	119.75	210.55
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	24.13	84.58	128.25	217.79
T_4	Intercropping cassava with *Sida alnifolia* (single row)	24.66	76.55	119.08	189.29
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	21.53	73.83	114.00	203.96
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	22.86	76.50	119.58	209.33
T_7	Intercropping cassava with *Sida alnifolia* (double row)	23.53	68.37	103.33	162.84
CD(0.05)		NS	NS	11.81	28.81
SE(m)		0.41	1.83	2.97	7.02

Table 5. Effect of treatments on number of leaves per plant of cassava

Treatments		Number of leaves (nos./plant)			
		30 DAP	60 DAP	90 DAP	Harvest
T_1	Sole crop of cassava	20.60	61.16	140.18	99.59
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	21.73	73.00	141.75	96.75
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	22.00	70.08	135.63	92.38
T_4	Intercropping cassava with *Sida alnifolia* (single row)	22.60	65.41	126.50	86.81
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	20.33	73.16	114.09	99.60
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	20.66	69.08	126.50	88.90
T_7	Intercropping cassava with *Sida alnifolia* (double row)	23.60	55.25	104.08	65.57
CD (0.05)		NS	10.80	18.24	18.54
SE(m)		0.45	2.42	5.25	4.48

Table 6. Effect of treatments on number of branches per plant of cassava

Treatments		Number of branches per plant (nos./plant)			
		30 DAP	60 DAP	90 DAP	Harvest
T_1	Sole crop of cassava	2.00	2.66	3.13	6.00
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	1.98	2.86	3.37	5.98
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	1.98	2.85	3.45	6.07
T_4	Intercropping cassava with *Sida alnifolia* (single row)	1.98	2.46	2.85[a]	5.77
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	1.95	2.62	3.04	5.90
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	1.95	2.50	2.81	5.90
T_7	Intercropping cassava with *Sida alnifolia* (double row)	1.90	2.07	2.34	5.48
CD (0.05)		NS	NS	NS	NS
SE(m)		0.01	0.10	0.14	0.07

4.1.4 Number of tubers

The data on the number of tubers per cassava plant at harvest due to the effect of intercropping with medicinal plant are given in the Table 7. The number of tubers ranged from 6.62 to 7.48. However, there was no significant difference among the treatments regarding the number of tubers.

4.1.5 Top yield at harvest

The data showing the effect of intercropping cassava with medicinal plants on top yield of cassava at harvest are given in the Table 8. Top yield of cassava showed significant difference among treatments. The higher top yield was observed in sole crop of cassava (2.31 kg) this was on par with cassava with single row of *Plectranthus* (2.29 kg), cassava with single row of *Indigofera* (2.25 kg) and cassava with double row of *Plectranthus* (2.13 kg). The lowest top yield was observed when cassava was intercropped with double row of *Sida* (1.39 kg).

4.1.6 Tuber yield of cassava

The data pertaining to tuber yield per plant and tuber yield per hectare at harvest are depicted in the Table 9. Generally, single row of medicinal plants with cassava had more tuber yield than double row intercropping. The sole crop of cassava (T_1) produced higher per plant tuber yield of 3.24 kg (32417 kg/ha) and was on par with cassava with single row of *Plectranthus* (T_3, 3.12 kg/plant or 31250 kg/ha) and cassava with single row of *Indigofera* (T_2, 2.83 kg/plant or 28333 kg/ha). Intercropping cassava with double row of *Plectranthus* (T_6, 2.56 kg) was on par with double row of *Indigofera* (T_6, 2.45 kg) and single row of *Sida* (T_4, 2.40 kg). The lowest tuber yield was recorded when cassava was intercropped with double row of *Sida* (T_7, 1.77 kg/plant or 17733 kg/ha).

4.1.7 Dry matter production at harvest

The results of effect of intercropping cassava with medicinal plants on dry matter production at harvest (in kilogram per plant of cassava) are given in the Table 10. There was significant effect of treatments on total dry matter production.

Table 7. Effect of treatments on number of tubers per plant of cassava

Treatments		Number of tubers (nos./ plant)
T_1	Sole crop of cassava	7.48
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	7.02
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	7.13
T_4	Intercropping cassava with *Sida alnifolia* (single row)	6.96
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	6.68
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	6.77
T_7	Intercropping cassava with *Sida alnifolia* (double row)	6.62
CD (0.05)		NS
SE(m)		0.11

Table 8. Effect of treatments on top yield at harvest of cassava

Treatments		Top yield at harvest (kg/plant)
T_1	Sole crop of cassava	2.31
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	2.25
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	2.29
T_4	Intercropping cassava with *Sida alnifolia* (single row)	1.82
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	2.03
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	2.13
T_7	Intercropping cassava with *Sida alnifolia* (double row)	1.39
CD(0.05)		0.32
SE(m)		0.12

Table 9. Effect of treatments on tuber yield of cassava

Treatments		Tuber yield per plant (kg/plant)	Tuber yield per hectare (kg/ha)
T_1	Sole crop of cassava	3.24	32417
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	2.83	28333
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	3.12	31250
T_4	Intercropping cassava with *Sida alnifolia* (single row)	2.40	24070
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	2.45	24500
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	2.56	25600
T_7	Intercropping cassava with *Sida alnifolia* (double row)	1.77	17733
CD(0.05)		0.54	5490
SE(m)		0.18	1878

Table 10. Effect of treatments on dry matter production at harvest of cassava

Treatments		Dry matter production at harvest (kg/plant)
T_1	Sole crop of cassava	1.98
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	1.81
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	1.95
T_4	Intercropping cassava with *Sida alnifolia* (single row)	1.51
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	1.60
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	1.67
T_7	Intercropping cassava with *Sida alnifolia* (double row)	1.13
	CD(0.05)	0.26
	SE(m)	0.11

The highest dry matter was observed in sole crop of cassava (T_1, 1.98 kg) followed by cassava with single row of *Plectranthus* (T_3, 1.95 kg) and was on par with single row intercropping of *Indigofera* (T_2, 1.81 kg). Intercropping of cassava with *Sida* either as single row or as double row significantly reduced dry matter production of cassava. The lowest dry matter production was noticed when cassava intercropped with two rows of *Sida* (T_7, 1.13 kg).

4.2 Plant Characters of *Indigofera tinctoria*

4.2.1 Plant height

The data pertaining to plant height of *Indigofera tinctoria* at 30, 60 and 90 DAT are given in the Table 11. Since *Indigofera* was harvested for the herbage at different intervals, significant variation in plant height was observed at different stages. At 30 DAT *Indigofera* planted as single row between cassava plants exhibited taller plants than other two treatments. However, at 60 DAT (76.99 cm) and 90 DAT (106.67 cm), sole crop of *Indigofera* had tallest plants. This was followed by single row intercropping of *Indigofera* (69.70 cm) and then double row cropping of the plant T_5 (63.26 cm) at 60 DAT. A reverse trend could be found at 90 DAT with paired row greater than single row (97.13 cm and 95.17cm respectively).

4.2.2 Number of leaves

The data on number of leaves of *Indigofera tinctoria* are given in the Table 12. Mono crop of *Indigofera* (T_8) was superior in terms of production of number of leaves than intercropping at all stages of observation. The number of leaves in sole cropped *Indigofera* was 602.80, 1272.60 and 2049.40 respectively at 30, 60 and 90 DAT. Significant difference with respect to number of leaves was observed between single row and double row of *Indigofera* at 30 and 60 DAT. However, at 90 DAT these two treatments were at par.

4.2.3 Number of branches

The data on number of branches of in *Indigofera tinctoria* are given in the Table 13. At 30 DAT there was no significant difference in number of branches of

Indigofera between the treatments. The highest number of branches was recorded in sole crop of *Indigofera* (10.66) followed by single row (9.73) and double row of *Indigofera* (9.06).

At two months after planting the same trend was observed with remarkable variation among the treatments. The highest number of branches was observed in sole crop of *Indigofera* (33.73) followed by single row *Indigofera* (29.93) and then double row of *Indigofera* (27.06). At 90 DAT also, sole crop of *Indigofera* recorded the highest number of branches per plant (42.53). At this stage of observation double row planting recorded 38.66 number branches and single row planting recorded 31.13 numbers of branches.

4.2.4 Total number of harvests and herbage yield

The data on herbage yield of *Indigofera* for five harvests are illustrated in the Table 14. Perusal of the data on herbage yield of *Indigofera* at different cuts showed that the sole crop of *Indigofera* had the highest herbage yield at all the harvests and recorded a total herbage yield of 185.82 g. Single row planting and double row planting were statistically at par with total herbages yields of 122.73 g and 118.84 g respectively. Meanwhile, the highest herbage yield was noted in sole crop of *Indigofera* (12300.50 kg/ha) followed by cassava with double row of *Indigofera* (6464.90 kg/ha) and lowest was in cassava with single row of *Indigofera* (3338.26 kg/ha).

4.2.5 Indican content

The data on indican content of *Indigofera* at first harvest are depicted in Table 15. Sole crop and single row inter crop of *Indigofera* were on par with respect to indican content with 1.40 per cent and 1.39 per cent respectively. The lowest indican content of 1.34 per cent was observed in double row inter cropping of *Indigofera* with cassava

Table 11. Effect of treatments on plant height of *Indigofera tinctoria*

Treatments		Plant height (cm)		
		30 DAT	60 DAT	90 DAT
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	48.80	69.70	95.17
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	43.00	63.26	97.13
T_8	Sole crop of *Indigofera tinctoria*	35.13	76.99	106.67
CD (0.05)		4.23	2.96	4.27
SE(m)		1.48	1.03	1.49

Table 12.Effect of treatments on number of leaves per plant of *Indigofera tinctoria*

Treatments		Number of leaves (nos./plant)		
		30 DAT	60 DAT	90 DAT
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	464.60	917.53	1490.20
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	407.53	835.00	1507.60
T_8	Sole crop of *Indigofera tinctoria*	602.80	1272.60	2049.40
CD (0.05)		22.36	67.39	115.66
SE(m)		7.82	23.57	40.46

Table13. Effect of treatments on number of branches per plant of *Indigofera tinctoria*

Treatments		Number of branches (nos./plant)		
		30 DAT	60 DAT	90 DAT
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	9.73	29.93	31.13
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	9.06	27.06	38.66
T_8	Sole crop of *Indigofera tinctoria*	10.66	33.73	42.53
CD (0.05)		NS	2.97	3.24
SE(m)		0.52	1.04	1.13

Table 14. Effect of treatments on herbage yield of *Indigofera tinctoria* at different harvest

Treatments	Harvest details (g/plant)						Herbage yield per hectare (kg/ha)
	1st cut	2nd cut	3rd cut	4th cut	5th cut	Total	
Intercropping cassava with *Indigofera tinctoria* (single row)	29.31	26.05	26.04	22.79	18.50	122.73	3338.26
Intercropping cassava with *Indigofera tinctoria* (double row)	30.16	24.94	23.95	20.99	18.80	118.84	6464.90
Sole crop of *Indigofera* tinctoria	44.86	43.34	37.61	32.7	27.21	185.82	12300.50
CD(0.05)	3.74	4.72	4.28	4.215	3.92	11.96	857.26
SE(m)	1.31	1.65	1.49	1.47	1.37	4.18	299.92

Table 15. Effect of treatments on indican content of *Indigofera tinctoria*

Treatments		Indican content (per cent) at first cut
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	1.39
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	1.34
T_8	Sole crop of *Indigofera tinctoria*	1.40
CD(0.05)		0.016
SE(m)		0.006

4.3 Plant characters of *Plectranthus vettiveroides*

4.3.1 Plant height

The data regarding the plant height of *Plectranthus vettiveroides* at 30, 60 and 90 DAT are shown in Table 16. AT 30 DAT, there was no significant difference in plant height between the three treatments.

At 60 DAT, intercropped *Plectranthus* recorded taller plants than sole crop. *Plectranthus* grown as double row in cassava has a height of 44.99 cm and plant height in single row of *Plectranthus* was 36.92 cm. The shorter plants were observed in sole crop of *Plectranthus* (30.34 cm).

Similar trend was observed at 90 DAT. Taller plants were observed in double row intercropping of *Plectranthus* with cassava (69.42cm), followed by single row of *Plectranthus* (58.44 cm). The lowest plant height was observed in sole crop of *Plectranthus* (45.48 cm).

4.3.2 Number of leaves

The data pertaining to the number of leaves per plant in *Plectranthus* are given in the Table 17. At 30 DAT there was significant difference among treatments. The highest number of leaves was observed in double row intercropped *Plectranthus* (48.73). Single row (36.00) and sole crop (36.26) plants were on par.

The data recorded at 60 DAT and 90 DAT had more or less similar trends. The highest number of leaves was observed in sole crop of *Plectranthus* (135.20 and 197.60 at 60 and 90 DAT respectively). At 60 DAT, number of leaves in double row of *Plectranthus* was 123.60 whereas in single row it was 90.93. At 90 DAT the intercropping treatments were on par with 139.46 leaves in double row and 134.26 in single row.

4.3.3 Number of branches

Table 18 gives the data regarding the number of branches of *Plectranthus* at 30, 60 and 90 DAT. Initially, at 30 DAT highest branches was recorded

Plectranthus grown as double row with cassava (5.66), which was on par with single row *Plectranthus* (4.60). Sole crop of *Plectranthus* produced the lowest number of branches (3.93).

At 60 DAT, the highest number of branches were observed in sole crop of *Plectranthus* (15.60) followed by double row intercrop of *Plectranthus* (12.33) and single row intercrop of *Plectranthus* (9.33).

Similar trend was observed at 90 DAT also with highest number of branches in sole crop of *Plectranthus* (21.60), followed by double row of *Plectranthus* (18.80) and lowest number in single row of *Plectranthus* (17.60).

4.3.4 Total root yield

Data on total root yield of *Plectranthus* at harvest are given in the Table 19. The treatments vary significantly with respect to total root yield. Sole crop of *Plectranthus* recorded the highest root yield 42.29 g/plant, followed by single row intercropped *Plectranthus* (40.12 g/plant), which was at par with double row *Plectranthus* (39.23 g/plant). The highest root yield per hectare was observed in sole crop of *Plectranthus* (2643.13 kg/ha) followed by cassava with double row of *Plectranthus* (1631.97 kg/ha) and the lowest was in cassava with single row of *Plectranthus* (834.50 kg/ha).

4.3.5 Essential oil content

The data on essential oil content of *Plectranthus* at harvest are given in the Table 20. There was a significant difference in oil content among treatments. The highest content was found in sole crop of *Plectranthus* (0.60 per cent), followed by single row of *Plectranthus* (0.40 per cent). The lowest oil content was obtained from double row intercrop of *Plectranthus* (0.26 per cent).

Table 16. Effect of treatments on plant height of *Plectranthus vettiveroides*

Treatments		Plant height (cm)		
		30 DAT	60 DAT	90 DAT
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	20.80	36.92	58.44
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	21.86	44.99	69.42
T_9	Sole crop of *Plectranthus vettiveroides*	20.10	30.34	45.48
C.D.(0.05)		NS	3.38	4.50
SE(m)		0.83	1.18	1.57

Table 17. Effect of treatments on number of leaves per plant of *Plectranthus vettiveroides*

Treatments		Number of leaves (nos./plant)		
		30 DAT	60 DAT	90 DAT
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	36.00	90.93	134.26
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	48.73	123.60	139.46
T_9	Sole crop of *Plectranthus vettiveroides*	36.26	135.20	197.60
C.D.(0.05)		5.745	14.755	16.22
SE(m)		2.01	5.162	5.67

Table 18. Effect of treatments on number of branches per plant of *Plectranthus vettiveroides*

Treatments		Number of branches (nos./plant)		
		30 DAT	60 DAT	90 DAT
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	4.60	9.33	17.60
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	5.66	12.33	18.80
T_9	Sole crop of *Plectranthus vettiveroides*	3.93	15.60	21.60
C.D.(0.05)		0.88	1.78	2.48
SE(m)		0.30	0.62	0.87

Table 19. Effect of treatments on root yield per plant of *Plectranthus vettiveroides*

Treatments		Root yield per plant (g)	Root yield per hectare (kg/ha)
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	40.12	834.50
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	39.23	1631.97
T_9	Sole crop of *Plectranthus vettiveroides*	42.29	2643.13
C.D.(0.05)		1.81	84.59
SE(m)		0.63	29.59

Table 20. Effect of treatments on essential oil content of *Plectranthus vettiveroides*

Treatments		Essential oil (%)
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	0.40
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	0.26
T_9	Sole crop of *Plectranthus vettiveroides*	0.60
C.D.(0.05)		0.017
SE(m)		0.006

4.4 Plant characters of *Sida alnifolia*

4.4.1 Plant height

The data with reference to the plant height of *Sida alnifolia* at 30, 60 and 90 DAT are presented in Table 21. At one month after transplanting there was appreciable difference between the treatments with respect to plant height of *Sida*. Taller plants were noticed in sole crop, with average plant height of 39.89 cm.

Eventually at 60 DAT, the tallest plants were observed in double row planted *Sida* (72.69 cm) followed by single row (66.74 cm) and then sole crop of *Sida* (58.82 cm).

At 90 DAT same trend was noticed among the treatments. Intercropped *Sida* plants were taller than sole cropped *Sida*. Tallest plants (127.78 cm) were recorded in double row planting followed by single row planting (106.14 cm) and sole crop (89.93 cm).

4.4.2 Number of leaves

The data on number of leaves per plant at 30, 60 and 90DAT in *Sida alnifolia* are depicted in Table 22. At 30 DAT there was significant difference between treatments with higher number of leaves in sole crop of *Sida* (283.06) followed by single row (248.53) and double row (226.33).

During subsequent observations at 60 and 90 DAT, there was significant difference in number of leaves in sole and intercrop. Sole crop of *Sida* resulted in the highest number of leaves with 837.46 and 1835.06 at 60 and 90 DAT respectively. The numbers of leaves in single and double crop of *Sida* at 60 DAT were on par (730.40 and 723.53 respectively). At 90 DAT the number of leaves in single row intercropped *Sida* was 1242.80 and in double row it was 1155.20.

4.4.3 Number of branches

Table 23 shows details on number of branches in *Sida alnifolia* at 30, 60 and 90 DAT. The observations recorded revealed that number of branches was not significantly affected by treatments at 30 DAT. It was noted that at one month after transplanting the mean values were 17.13, 15.06 and 14.66 for sole crop, double row and single row respectively.

AT 60 DAT considerably higher numbers of branches were produced in sole crop (99.86), followed by intercrops. Mean number of branches in double row and single row were 89.20 and 83.13.

At 90 DAT sole cropping resulted in the higher number branches (276.80). The branches in intercrops were on par with each other and the mean values were 196.26 and 187.26 for double row and single row intercropping.

4.4.4 Total root yield

The total root yield of *Sida* at harvest is represented in Table 24. A notable difference in root yield was observed among treatments. Root yield per plant was highest in sole crop of *Sida* (9.00 g) followed by cassava with single row of *Sid*a (7.50 g), and the lowest per plant yield was in cassava with double row of *Sida* (7.00 g). However, while the highest root yield per hectare was noted in sole crop of *Sida* 750.00 kg/ha, it was followed by cassava with double row of *Sida* (380.80 kg/ha) and the lowest yield was found in cassava with single row of *Sida* 204.00 kg/ha.

4.4.5 Alkaloid content

Table 25 reveals the effect of planting on alkaloid content of *Sida* roots at harvest. The highest alkaloid content was observed in sole crop of *Sida* (3.07 per cent) followed by single row intercrop (2.94 per cent). The lowest alkaloid content was noticed in double row planting of *Sida* (2.67 per cent).

Table 21. Effect of treatments on plant height of *Sida alnifolia*

Treatments		Plant height (cm)		
		30 DAT	60 DAT	90 DAT
T_4	Intercropping cassava with *Sida alnifolia* (single row)	39.50	66.74	106.14
T_7	Intercropping cassava with *Sida alnifolia* (double row)	33.75	72.69	127.78
T_{10}	Sole crop of *Sida alnifolia*	39.89	58.82	89.93
CD(0.05)		2.91	2.83	4.20
SE(m)		1.02	0.99	1.47

Table 22. Effect of treatments on number of leaves per plant of *Sida alnifolia*

Treatments		Number of leaves (nos./plant)		
		30 DAT	60 DAT	90 DAT
T_4	Intercropping cassava with *Sida alnifolia* (single row)	248.53	730.40	1242.80
T_7	Intercropping cassava with *Sida alnifolia* (double row)	226.33	723.53	1155.20
T_{10}	Sole crop of *Sida alnifolia*	283.06	837.46	1835.06
CD(0.05)		13.19	26.31	44.01
SE(m)		4.616	9.20	15.39

Table 23. Effect of treatments on number of branches per plant of *Sida alnifolia*

Treatments		Number of branches (nos./plant)		
		30 DAT	60 DAT	90 DAT
T_4	Intercropping cassava with *Sida alnifolia* (single row)	14.66	83.13	187.26
T_7	Intercropping cassava with *Sida alnifolia* (double row)	15.06	89.20	196.26
T_{10}	Sole crop of *Sida alnifolia*	17.13	99.86	276.80
CD(0.05)		NS	11.10	12.34
SE(m)		0.87	3.88	4.31

Table 24. Effect of treatments on root yield at harvest of *Sida alnifolia*

Treatments		Root yield (g)	Root yield (kg/ha)
T_4	Intercropping cassava with *Sida alnifolia* (single row)	7.50	204.00
T_7	Intercropping cassava with *Sida alnifolia* (double row)	7.00	380.80
T_{10}	Sole crop of *Sida alnifolia*	9.00	750.00
CD(0.05)		0.24	12.58
SE(m)		0.08	4.403

Table 25. Effect of treatments on alkaloid content of *Sida alnifolia*

Treatments		Alkaloid (per cent)
T_4	Intercropping cassava with *Sida alnifolia* (single row)	2.94
T_7	Intercropping cassava with *Sida alnifolia* (double row)	2.67
T_{10}	Sole crop of *Sida alnifolia*	3.07
CD(0.05)		0.05
SE(m)		0.019

4.5 Observation on weeds

4.5.1 Weed count

4.5.1.1 Weed count at 30 DAP

Data on the effect of various treatments on total number of weeds including grasses, sedges and broad leaf weeds at 30 DAP are depicted in the Table 26. Higher number of grasses were recorded in sole cassava (36.33 no./m^2) followed by single row of *Indigofera* (T_2, 32.00 no./m^2), cassava +single row *Plectranthus* (T_3, 28.33 no/m^2), cassava + double row of *Plectranthus* ($T_{6,}$ 22.00 no./m^2) and cassava + double row of *Indigofera* ($T_{5,}$ 15.66 no./m^2), cassava + single row of *Sida* (T_4, 19.33 no./m^2) and cassava + double row of *Sida* (18.00 no./m^2). The lower number of grasses were observed in *Sida* and *Indigofera* sole crops with 8.33 no./m^2 respectively, followed by sole crop of *Plectranthus* (11.00 no./m^2).

Sedges were recorded maximum in sole crop of cassava with 11.00no./m^2, followed by T_3 (cassava +single row *Plectranthus*, 10.33 no./m^2). Among intercropping treatments T_4 and T_7 (6.66 no./m^2 and 6.33no./m^2) recorded the minimum number of sedges. The lowest number of sedges were observed in sole crop of *Indigofera* (4.33 no./m^2) followed by sole crop of *Plectranthus* (5.33 no./m^2). The sole crop of cassava recorded the highest broad leaf weed count of 250.33 no./m^2 followed by cassava with single row of *Plectranthus* (173.33 no./m^2), cassava with *Indigofera* in single row (169.66 no./m^2). Broad leaf weeds were less when cassava was intercropped with double row of medicinal plants than in single row. The number of weeds in cassava with single row of *Sida alnifolia* was on par with double row of *Plectranthus* in cassava (162.66 no./m^2 and 142.66 no./m^2). The lowest broad leaf weeds was found in sole crop of *Sida* (50.00 no./m^2).

Total weed count was highest in sole crop of cassava (297.66 no./m^2) followed by single row of *Plectranthus* (212 no./m^2) and *Indigofera tinctoria* (211.00 no./m^2). Double row of planting medicinal plants gave appreciable reduction in weed count than the single row. In double row intercropping, the lowest count was observed in cassava + double row *Sida* (157.00 no./m^2) followed by cassava + double row *Indigofera* (158.66 no./m^2). The lowest weed count was observed in sole crop of *Sida* (64.00 no./m^2).

4.5.1.2 Weed count at 60 DAP

Table 27 gives the weed count for different treatments at 60 DAP. In general, double row of intercropping medicinal plants resulted in lower weed count compared to single row. Sole crop of cassava recorded higher number of weeds viz. grasses, sedges and broad leaf weeds. The highest grass count of 24.33 no./m^2 was found in T_1 followed by single row of *Plectranthus* in cassava (18.00 no./m^2), T_2 (cassava + single row *Indigofera*, 16.66 no./m^2), T_6 (cassava + double row *Plectranthus* 14.66 no./m^2). The least monocot weeds were recorded in sole crop of *Sida alnifolia* (5.00 no./m^2) followed by sole crop of *Plectranthus* (6.00 no./m^2).

Higher number of sedges was observed in sole crop of cassava (9.66 no./m^2) followed by T_3 (cassava + single row of *Plectranthus*, 7.00 no./m^2) followed by T_2 (cassava + single row of *Indigofera*), T_5 (cassava + double row of *Indigofera*) and T_6 (cassava + double row of *Plectranthus*). The least count of sedges was recorded in sole crop of *Sida* (3.00 no./m^2).

Dicot weeds were prominently higher in sole crop of cassava (176.00 no./m^2) followed by T_3 (cassava + single row of *Plectranthus*, 146.00 no./m^2 and T_2(cassava + single row of *Indigofera*, 138.00 no/m^2) which were on par with T_4 (cassava + single row of *Sida*, 125.00 no./m^2). Minimum number of broad leaf weeds was in sole crop of *Sida* (24.00 no./m^2).

Total weed population was maximum in sole crop of cassava (210.00 no./m^2) followed by T_3 (cassava + single row of *Plectranthus*, 171.00 no./m^2), and T_2(cassava + single row of *Indigofera*, 160.66 no./m^2) which were on par, followed by T_4 (cassava + single row of *Sida*, 141.00 no./m^2). Among the double row intercropping higher number of weeds was recorded in T_6 (cassava + double row of *Plectranthus*, 121.00 no./m^2) followed by T_5 (cassava + double row of *Indigofera*, 103.33 no./m^2) and T_7 (cassava + double row of *Sida*, 78.00 no./m^2). Least total weed count was in sole crop of *Sida alnifolia* (32.00 no./m^2).

4.5.1.3 Weed count at 90 DAP

The data regarding weed count at 90 DAP are illustrated in the Table 28. More or less similar trend was observed in broad leaf weed density with the lowest was noted in sole crop of *Sida* (20.67 no./m^2) followed by sole crop of *Indigofera* (34.30 no/m^2). The highest dicot weed density was in sole crop of cassava (133.33 no./m^2), followed by cassava with single row of *Plectranthus* (113.33 no./m^2) which was on par with cassava + single row of *Indigofera*. Among medicinal plants in double row with cassava, the minimum density was found in cassava with double row of *Sida* (88.33no/m^2). The sedges density was insignificant at 90 DAP, however the value ranged from 3.33no./m^{2}to 1.33 no./m^2.

The population of grasses were highest in sole crop of cassava (12.66no./m^2) followed by cassava with single row of *Plectranthus* (10.66 no./m^2) and cassava with single row of *Sida*. The least grass population was in sole crop of *Sida* (4.33 no./m^2) followed by sole crop of *Plectranthus* (5.00 no./m^2).

The widely spaced cassava sole crop recorded highest total weed count (158.32 no./m^2) followed by cassava with single row *Plectranthus* (T_3, 125.99 no./m^2), cassava with single row of *Indigofera* (T_2, 123.33 no./m^2), single row of *Sida* (119.66 no./m^2), cassava with double row of *Plectranthus* (114.00 no./m^2) and cassava with double row of *Indigofera*. The lowest weed population was in *Sida* grown as sole crop (25.67 no./m^2) followed by sole crop of *Indigofera* (45.66 no./m^2).

Table 26. Effect of intercropping cassava with medicinal plants on weed count at 30 DAP (no./m^2)

Treatments		Weed count at 30 DAP (no./m^2)			
		Grasses	Sedges	Broad leaf weeds	Total weed count
T_1	Sole crop of cassava	36.33** (6.02)	11.00** (3.30)	250.33[a]** (15.80)	297.66** (17.24)
T_2	Inter cropping cassava with *Indigofera tinctoria* (single row)	32.00 (5.65)	9.33 (3.03)	169.66 (13.01)	211.00 (14.51)
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	28.33 (5.31)	10.33 (3.18)	173.33 (13.14)	212.00 (14.54)
T_4	Intercropping cassava with *Sida alnifolia* (single row)	19.33 (4.39)	6.66 (2.57)	162.66 (12.70)	188.66 (13.68)
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	15.66 (3.94)	9.33 (3.02)	133.66 (11.54)	158.66 (12.57)
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	22.00 (4.68)	8.67 (2.93)	142.66 (11.92)	173.33 (13.15)
T_7	Intercropping cassava with *Sida alnifolia* (double row)	18.00 (4.22)	6.33 (2.50)	132.66 (11.49)	157.00 (12.52)
T_8	Sole crop of *Indigofera tinctoria*	8.33 (2.86)	4.33 (2.06)	60.66 (7.69)	73.33 (8.51)
T_9	Sole crop of *Plectranthus vettiveroides*	11.00 (3.30)	5.33 (2.29)	62.67 (7.82)	79.00 (8.81)
T_{10}	Sole crop of *Sida alnifolia*	8.33 (2.87)	5.66 (2.36)	50.00 (7.00)	64.00 (7.95)
	CD(0.05)	(0.56) 4.83	3.67 (0.641)	36.26 (1.703)	38.44 (1.598)
	SE(m)	3.09 (0.35)	0.73 (0.13)	19.65 (0.89)	23.22 (0.95)

**original values, √x transformed values are in parentheses.

Table 27. Effect of intercropping cassava with medicinal plants on weed count at 60 DAP(no./m^2)

Treatments		weed count at 60 DAP (no./m^2)			
		Grasses	Sedges	Broad leaf weeds	Total
T_1	Sole crop of cassava	24.33** (4.92)	9.66** (3.09)	176.00** (13.25)	210.00** (14.48)
T_2	Inter cropping cassava with *Indigofera tinctoria* (single row)	16.66 (4.08)	6.00 (2.44)	138.00 (11.74)	160.66 (12.67)
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	18.00 (4.23)	7.00 (2.64)	146.00 (12.07)	171.00 (13.07)
T_4	Intercropping cassava with *Sida alnifolia* (single row)	11.00 (3.30)	5.00 (2.22)	125.00 (11.16	141.00 (11.86)
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	11.33 (3.36)	4.00 (1.98)	88.00 (9.30)	103.33 (10.11)
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	14.66 (3.82)	4.66 (2.13)	101.66 (10.06)	121.00 (10.99)
T_7	Intercropping cassava with *Sida alnifolia* (double row)	10.00 (3.16)	3.00 (1.71)	65.00 (8.00)	78.00 (8.79)
T_8	Sole crop of *Indigofera tinctoria*	8.00 (2.81)	4.33 (2.07)	38.33 (6.15)	50.66 (7.10)
T_9	Sole crop of *Plectranthus vettiveroides*	6.00 (2.42)	4.33 (2.06)	54.66 (7.35)	65.00 (8.04)
T_{10}	Sole crop of *Sida alnifolia*	5.00 (2.20)	3.00 (1.71)	24.00 (4.87)	32.00 (5.63)
	CD (0.05)	3.24 (0.48)	2.32 (0.49)	22.63 (1.19)	21.22 (1.41)
	SE(m)	1.88 (0.26)	0.63 (0.13)	15.90 (0.87)	18.24 (0.90)

**original values, √x transformed values are in parentheses

Table 28. Effect of intercropping cassava with medicinal plants on weed count at 90 DAP (no./m^2)

Treatments		Weed count at 90 DAP (no./m^2)			
		Grasses	Sedges	Broad leaf weeds	Total
T_1	Sole crop of cassava	12.66** (3.54)	3.33** (1.93)	133.33** (11.53)	158.32** (12.21)
T_2	Inter cropping cassava with *Indigofera tinctoria* (single row)	8.66 (2.92)	2.33 (1.65)	112.33 10.59	123.33 (11.10)
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	10.66 (3.26)	2.66 (1.73)	113.33 10.63	125.99 (11.33)
T_4	Intercropping cassava with *Sida alnifolia* (single row)	10.33 (3.20)	2.00 (1.55)	107.33 10.31	119.66 (10.91)
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	8.00 (2.81)	1.66 (1.42)	100.33 10.00	110.00 (10.47)
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	7.00 (2.64)	2.00 (1.55)	105.00 10.24	114.00 (10.67)
T_7	Intercropping cassava with *Sida alnifolia* (double row)	6.33 (2.50)	1.00 (1.17)	88.33 9.39	95.66 (9.77)
T_8	Sole crop of *Indigofera tinctoria*	7.66 (2.73)	1.33 (1.34)	34.30 5.77	45.66 (6. 73)
T_9	Sole crop of *Plectranthus vettiveroides*	5.00 (2.22)	1.33 (1.26)	43.00 6.52	49.33 (6.99)
T_{10}	Sole crop of *Sida alnifolia*	4.33 (2.06)	1.33 (1.05)	20.67 4.53	25.67 (5.06)
	C.D.(0.05)	3.393 (0.60)	NS	27.144 (1.13)	20.13 (1.01)
	SE(m)	0.82 (0.14)	0.30 (0.09)	12.24 (0.76)	13.03 (0.75)

**original values, √x transformed values are in parentheses.

4.5.2. Weed dry weight

4.5.2.1 Weed dry weight at 30 DAP

The data pertaining to weed dry weight at one month after planting are illustrated in Table 29. The highest number of monocot weeds was observed in sole crop of cassava (37.50 g/m^2) followed by cassava with single row of *Plectranthus* (26.02 g/m^2), cassava with single row of *Indigofera* (25.13 g/m^2), cassava with double row of *Plectranthus* (20.79 g/m^2), cassava with single row of *Sida* (18.02 g/m^2), cassava with double row of *Sida* (15.75 g/m^2). The least monocot weed dry weight was observed in sole crop of *Sida* (7.59 g/m^2).

The dry weight of sedges was highest in sole crop of cassava (2.80 g/m^2) followed by cassava with single row of *Indigofera* (1.56 g/m^2), cassava with single row of *Plectranthus* (1.30 g/m^2), cassava with double row of *Indigofera* (1.26 g/m^2), cassava with double row of *Plectranthus* (1.18 g/m^2), cassava with single row of *Sida* (1.08 g/m^2). The least was in sole crop of *Sida* (0.85 g/m^2).

The highest broad leaf weeds were present in sole crop of cassava (228.43 g/m^2), followed by cassava with single row of *Plectranthus* (157.31 g/m^2), cassava with single row of *Sida* (156.89 g/m^2), cassava with single row of *Indigofera* (154.56 g/m^2). The least dicot weeds were in sole crop of *Sida* (37.21 g/m^2) followed by sole crop of *Indigofera* (52.46 g/m^2).

Total weed dry weight was highest in sole crop of cassava (268.74 g/m^2) followed by cassava with single row of *Plectranthus* (184.64 g/m^2), cassava with single row of *Indigofera* (181.26 g/m^2), cassava with single row of *Sida* (176.00 g/m^2), cassava with double row of *Plectranthus* (158.80 g/m^2), cassava with double row of *Indigofera* (138.26 g/m^2). The least weed dry weight was observed in sole crop of *Sida* (45.65 g/m^2).

4.5.2.2 Weed dry weight at 60 DAP

The data pertaining to weed dry weight at two months after planting are illustrated in Table 30. The highest weed dry weight was observed in sole crop of cassava (22.42 g/m^2) followed by cassava with single row of *Plectranthus* (17.32 g/m^2) on par with cassava with single row of *Indigofera* (15.50 g/m^2), cassava with single row of *Sida* (10.64 g/m^2), and cassava with double row of *Plectranthus* (5.85 g/m^2). The least monocot weed dry weight was observed in sole crop of *Sida* (2.26 g/m^2).

The dry weight of sedges was highest in sole crop of cassava (1.22 g/m^2) followed by cassava with single row of *Indigofera* (1.04 g/m^2), cassava with single row of *Plectranthus* (0.95 g/m^2), cassava with single row of *Sida* (0.88 g/m^2) cassava with double row of *Plectranthus* (0.83 g/m^2), and cassava with double row of *Indigofera* (0.80 g/m^2). The least was in sole crop of *Sida* (0.18g/m^2).

The highest dry weight for broad leaf weeds were present in sole crop of cassava (137.67 g/m^2), followed by cassava with single row of *Plectranthus* (99.16 g/m^2) and cassava with single row of *Indigofera* (93.93 g/m^2), and cassava with single row of *Sida* (78.33 g/m^2). The least dicot weeds were in sole crop of *Sida* (18.51 g/m^2) followed by sole crop of *Indigofera* (22.80 g/m^2).

Total weed dry weight was least in sole crop of cassava (161.31 g/m^2) followed by cassava with single row of *Plectranthus* (117.44 g/m^2), cassava with single row of *Indigofera* (110.48 g/m^2), cassava with single row of *Sida* (89.86 g/m^2), cassava with double row of *Plectranthus* (71.75 g/m^2), and cassava with double row of *Indigofera* (61.10 g/m^2). The least weed dry weight was observed in sole crop of *Sida* (21.27 g/m^2).

4.5.2.3 Weed dry weight at 90 DAP

The data pertaining to weed dry weight at three months after planting are illustrated in Table 31. Dry weight of grass weeds was higher in sole crop of cassava (10.82 g/m^2) followed by cassava with single row of *Plectranthus* (7.47 g/m^2), cassava with single row of *Indigofera* (6.11 g/m^2), cassava with single row of *Sida* (4.82 g/m^2), sole crop of *Indigofera* (3.45 g/m^2), cassava with double row of *Indigofera* (3.39 g/m^2), cassava with double row of *Plectranthus* (3.21 g/m^2), and cassava with double row of *Sida* (2.73 g/m^2). The lowest dry weight of grass weeds was observed in sole crop of *Sida* (1.68 g/m^2).

The dry weight of sedges was the highest in sole crop of cassava (1.02g/m^2) and the lowest in sole crop of *Sida* (0.31 g/m^2). The dry weight of sedges was on par in all treatments.

The highest dry weight of broad leaf weeds was present in sole crop of cassava (106.95 g/m^2), followed by cassava with single row of *Indigofera* (85.17 g/m^2). Cassava with single row of *Plectranthus* (78.28 g/m^2), and cassava with single row of *Sida* (64.66 g/m^2) were on par. The lowest dry weight of broad leaf weeds was in sole crop of *Sida* (15.00 g/m^2) followed by sole crop of *Indigofera* (18.63 g/m^2).

Total weed dry weight was lowest in sole crop of cassava (118.79 g/m^2) followed by cassava with single row of *Indigofera* (92.02 g/m^2), single row of *Plectranthus* (86.45g/m^2), cassava with single row of *Sida* (70.13 g/m^2), cassava with double row of *Plectranthus* (52.12 g/m^2), and cassava with double row of *Indigofera* (44.77 g/m^2). The least total weed dry weight was observed in sole crop of *Sida* (16.99 g/m^2).

Table 29. Effect of intercropping cassava with medicinal plants on weed dry weight at 30 DAP

Treatments		Weed dry weight at 30 DAP(g/m^2)			
		Grasses	Sedges	Broad leaf weeds	Total
T_1	Sole crop of cassava	37.50** (6.11)	2.80** (1.67)	228.43** (15.10)	268.74** (16.38)
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	25.13 (5.00)	1.56 (1.24)	154.56 (12.42)	181.26 (13.46)
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	26.02 (5.09)	1.30 (1.13)	157.31 (12.50)	184.64 (13.54)
T_4	Intercropping cassava with *Sida alnifolia* (single row)	18.02 (4.24)	1.08 (1.03)	156.89 (12.47)	176.00 (13.22)
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	13.82 (3.71)	1.26 (1.12)	123.17 (11.08)	138.26 (11.74)
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	20.79 (4.55)	1.18 (1.07)	136.29 (11.65)	158.80 (12.56)
T_7	Intercropping cassava with *Sida alnifolia* (double row)	15.75 (3.96)	1.01 (1.00)	114.78 (10.68)	131.55 (11.45)
T_8	Sole crop of *Indigofera tinctoria*	8.83 (2.96)	0.95 (0.97)	52.46 (7.19)	62.28 (7.84)
T_9	Sole crop of *Plectranthus vettiveroides*	10.57 (3.24)	0.92 (0.95)	51.13 (7.04)	62.63 (7.84)
T_{10}	Sole crop of *Sida alnifolia*	7.59 (2.74)	0.85 (0.92)	37.21 (6.02)	45.65 (6.70)
CD(0.05)		4.99 (0.53)	0.533 (0.22)	32.79 (1.58)	33.43 (1.45)
SE(m)		2.92 (0.33)	0.18 (0.06)	18.89 (0.92)	21.83 (0.97)

**original values, √x transformed values are in parentheses.

Table 30. Effect of intercropping cassava with medicinal plants on weed dry weight at 60 DAP

Treatments		Weed dry weight at 60 DAP(g/m^2)			
		Grasses	Sedges	Broad leaf weeds	Total
T_1	Sole crop of cassava	22.42** (3.29)	1.22** (1.10)	137.67** (11.71)	161.31** (12.68)
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	15.50 (4.78)	1.04 (1.02)	93.93 (9.68)	110.48 (10.50)
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	17.32 (3.93)	0.95 (0.97)	99.16 (9.94)	117.44 (10.82)
T_4	Intercropping cassava with *Sida alnifolia* (single row)	10.64 (4.15)	0.88 (0.93)	78.33 (8.83)	89.86 (9.47)
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	4.83 (2.80)	0.80 (0.88)	52.42 (7.17)	61.10 (7.77)
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	5.85 (3.12)	0.83 (0.91)	60.76 (7.77)	71.75 (8.46)
T_7	Intercropping cassava with *Sida alnifolia* (double row)	4.69 (2.73)	0.20 (0.42)	36.55 (5.95)	44.34 (6.59)
T_8	Sole crop of *Indigofera tinctoria*	3.43 (2.55)	0.18 (0.43)	22.80 (4.72)	29.57 (5.40)
T_9	Sole crop of *Plectranthus vettiveroides*	2.70 (2.22)	0.23 (0.37)	33.36 (5.71)	38.78 (6.19)
T_{10}	Sole crop of *Sida alnifolia*	2.26 (1.55)	0.18 (0.89)	18.51 (4.26)	21.27 (4.59)
	CD(0.05)	4.15 (0.511)	0.257 (0.19)	21.16 (1.39)	20.99 (1.21)
	SE(m)	1.93 (0.30)	0.12 (0.09)	12.18 (0.77)	14.19 (0.82)

**original values, $\sqrt{x}$ transformed values are in parentheses.

Table 31. Effect of intercropping cassava with medicinal plants on weed dry weight at 90 DAP

Treatments		Weed dry weight at 90 DAP (g/m^2)			
		Grasses	Sedges	Broad leaf weeds	Total
T_1	Sole crop of cassava	10.82** (3.28)	1.02** (1.23)	106.95** (10.31)	118.79** (10.87)
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	6.11 (2.45)	0.73 (1.10)	85.17 (9.20)	92.02 (9.56)
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	7.47 (2.72)	0.69 (1.08)	78.28 (8.81)	86.45 (9.26)
T_4	Intercropping cassava with *Sida alnifolia* (single row)	4.82 (2.18)	0.64 (1.06)	64.66 (7.97)	70.13 (8.31)
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	3.39 (1.83)	0.67 (1.07)	40.71 (6.94)	44.77 (6.68)
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	3.21 (1.79)	0.62 (1.05)	48.29 (6.94)	52.12 (7.21)
T_7	Intercropping cassava with *Sida alnifolia* (double row)	2.73 (1.64)	0.36 (0.91)	29.81 (5.41)	32.90 (5.69)
T_8	Sole crop of *Indigofera tinctoria*	3.45 (1.82)	0.81 (1.14)	18.63 (4.25)	22.90 (4.75)
T_9	Sole crop of *Plectranthus vettiveroides*	2.50 (1.56)	0.513 (0.98)	25.67 (5.04)	28.68 (5.34)
T_{10}	Sole crop of *Sida alnifolia*	1.68 (1.27)	0.31 (0.88)	15.00 (3.83)	16.99 (4.10)
	CD(0.05)	1.32 (0.46)	NS	21.10 (1.37)	21.89 (1.29)
	SE(m)	0.88 (0.19)	0.06 (0.03)	9.87 (0.69)	10.75 (0.71)

**original values, $\sqrt{x}$ transformed values are in parentheses

4.6 Competition indices

Different competition indices analysed in the study were land equivalent ratio (LER), relative crowding coefficient (RCC), competitive ratio (CR), cassava equivalent yield (CEY) and aggressivity.

4.6.1 Land Equivalent Ratio

The data pertaining to land equivalent ratio (LER) are given in Table 32. The LER of all intercropping systems recorded values higher than one, indicating the yield advantage over sole cropping of cassava and medicinal plants. The highest LER (1.41) was recorded in intercropping cassava with *Plectranthus vettiveroides* as double row (T_6), followed by T_3 (cassava with *Plectranthus* as single row (1.28) and T_5 (cassava with *Indigofera tinctoria* as double row (1.28). The lowest LER was noticed in treatments with *Sida* as intercrop either as single row or as double rows (T_4 and T_7) (1.01 and 1.05 respectively).

4.6.2 Relative Crowding Coefficient

Table 33 gives the details of relative crowding coefficient (RCC) between treatments. The RCC value of cassava was found to be higher than that of medicinal plants which indicated that the cassava was a dominant crop over medicinal plants in all intercropping treatments. K (RCC) of all treatments was greater than one, indicating yield advantage. The highest RCC was recorded for T_3 (cassava+ single row of *Plectranthus*) with a RCC value of 12.36 followed by T_6 (cassava + double row of *Plectranthus*, 6.29), T_5 (cassava + double row of *Indigofera*, 3.43) and T_2 (cassava + single row of *Indigofera*, 2.58). The least values were observed when cassava was intercropped with *Sida alnifolia* where the RCC values were 1.25 and 1.08 respectively in double and single row.

4.6.3 Competitive ratio (CR)

Competitive ratios (CR) for different treatment combinations with cassava and medicinal plants are depicted in Table 34. The higher CR values for cassava indicated its better competitive ability than medicinal plants in the present intercropping system. Cassava intercropped with *Indigofera tinctoria* as single row had the highest competitive ratio of 8.76 followed by cassava with double row of *Indigofera* (T_5, 7.82), T_4 (cassava + *Sida alnifolia* as single row, 7.48), cassava with *Plectranthus vettiveroides* as double row (6.35). The lowest CR value (5.36) was observed when cassava intercropped with *Plectranthus* (single row). The competition ratios for intercropped medicinal plants were less than one indicating that they were less competitive. Among the medicinal plants, the higher CR value of 0.19 was observed when *Plectranthus vettiveroides* was intercropped as double row in cassava. The least CR value of 0.11 was for *Indigofera tinctoria* as single row with cassava (T_2).

4.6.4 Cassava Equivalent Yield

The details pertaining to effect of cassava and medicinal plants intercropping systems on cassava equivalent yield (CEY) is presented in Table 35. While comparing the number of rows, double row planted *Indigofera tinctoria* had higher cassava equivalent yield than single row. The highest CEY was recorded for T_5 (cassava + *Indigofera* double row) with cassava equivalent yield of 43895 kg/ha followed by T_2 (cassava + *Indigofera* single row, 38348 kg/ha), T_8 (sole crop of *Indigofera*, 36900 kg/ha), T_3 (cassava+ *Plectranthus* single row, 33754 kg/ha), T_1 (sole crop of cassava, 32416 kg/ha) and T_6 (cassava + *Plectranthus* double row 30696 kg/ha). Among intercropping systems cassava with *Sida alnifolia* as double row recorded lower cassava equivalent yield of 19257 kg/ha. The sole cropping of medicinal plants other than *Indigofera tinctoria* recorded lower CEY and the lowest CEY was for *Sida alnifolia* (3000 kg/ha) followed by *Plectranthus vettiveroides* (7929 kg/ha).

4.6.5 Aggressivity

The data on the effect of intercropping medicinal plants in cassava on aggressivity of component crops are given in Table 36. The aggressivity indicated the competitive ability of component crops. Aggressivity of cassava in all intercropping systems was positive which reflects the dominant nature of cassava over the component crop.

Table 32. Effect of intercropping systems with cassava and medicinal plants on Land Equivalent Ratio (LER)

Treatments		LER c	LER m	LER
T_1	Sole crop of cassava	1.00	-	1.00
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	0.87	0.27	1.15
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	0.96	0.32	1.28
T_4	Intercropping cassava with *Sida alnifolia* (single row)	0.74	0.27	1.01
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	0.76	0.53	1.28
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	0.80	0.62	1.41
T_7	Intercropping cassava with *Sida alnifolia* (double row)	0.55	0.51	1.05
T_8	Sole crop of *Indigofera tinctoria*	-	1.00	1.00
T_9	Sole crop of *Plectranthus vettiveroides*	-	1.00	1.00
T_{10}	Sole crop of *Sida alnifolia*	-	1.00	1.00

Table 33. Effect of intercropping systems with cassava and medicinal plants on Relative Crowding Coefficient (RCC)

Treatments		K_c	K_m	K (RCC)
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	18.87	0.14	2.58
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	55.71	0.22	12.36
T_4	Intercropping cassava with *Sida alnifolia* (single row)	7.84	0.14	1.08
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	16.84	0.20	3.43
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	16.22	0.39	6.29
T_7	Intercropping cassava with *Sida alnifolia* (double row)	6.57	0.19	1.25

K_c - RCC of cassava

K_m - RCC of medicinal plants

K- K_c x K_m

Table 34. Effect of intercropping systems with cassava and medicinal plants on competitive ratio (CR)

Treatments		CRc	CRm
T_2	Inter cropping cassava with *Indigofera tinctoria* (single row)	8.76	0.11
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	6.35	0.16
T_4	Intercropping cassava with *Sida alnifolia* (single row)	7.48	0.13
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	7.82	0.13
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	5.36	0.19
T_7	Intercropping cassava with *Sida alnifolia* (double row)	5.86	0.17

Table 35. Effect of cassava and medicinal plants intercropping systems on Cassava Equivalent Yield (CEY)

Treatments		CEY (kg/ha)
T_1	Sole crop of cassava	32416
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	38348
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	33754
T_4	Intercropping cassava with *Sida alnifolia* (single row)	24886
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	43895
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	30696
T_7	Intercropping cassava with *Sida alnifolia* (double row)	19257
T8	Sole crop of *Indigofera tinctoria*	36900
T9	Sole crop of *Plectranthus vettiveroides*	7929
T10	Sole crop of *Sida alnifolia*	3000

Table 36. Effect of intercropping medicinal plants in cassava on aggressivity of component crops

Treatments		A_{cm}	A_{mc}
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	0.77	-0.77
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	0.81	-0.81
T_4	Intercropping cassava with *Sida alnifolia* (single row)	0.68	-0.68
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	0.66	-0.66
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	0.65	-0.65
T_7	Intercropping cassava with *Sida alnifolia* (double row)	0.49	-0.49

A_{cm}– Aggresivity of cassava with respect to medicinal plants

A_{mc} - Aggresivity of medicinal plants with respect to cassava

The aggressivity of cassava over medicinal plants was more pronounced in single row of *Plectranthus* (T_3) with an aggressivity value of 0.81 followed by T_2 (cassava + single row of *Indigofera*, 0.77) and T_4 (cassava + single row of *Sida*, 0.68). The lowest aggressivity was recorded in cassava with double row of *Sida* (0.49).

4.7 Economics of cultivation

The effect of cassava based intercropping system with medicinal plants on economics of cultivation is depicted in the Table 37. The cost of cultivation was higher in double row intercropping followed by single row intercropping and then the sole crop. The total cost of cultivation was the lowest for sole crop of *Sida* (Rs. 120000/ha) followed by sole crop of *Plectranthus* (Rs. 175000/ha) and sole crop of *Indigofera* (Rs. 308020/ha). Among the single row intercropping treatments, the lowest cost of production was in T_4 (cassava + single row of *Sida*- Rs. 355000/ha) followed by T_3 (cassava + single row of *Plectranthus* - Rs. 356320/ha), T_2 (cassava + single row of *Indigofera* - Rs. 368000/ha). Among the double row of intercropping highest cost of cultivation was in T_5 (cassava + double row of *Indigofera* - Rs. 383000/ha) and least in T_7 (cassava + double row of *Sida*- Rs. 370000/ha).

Analysis of economics indicated that planting of cassava with double row of *Indigofera* (T_5) gave the highest net returns of Rs. 494894/ha, followed by sole crop of *Indigofera* (Rs. 429980/ha), T_2 (cassava + single row of *Indigofera* - Rs. 398962/ha), T_3 (cassava + single row of *Plectranthus* - Rs. 324150/ha) and T_1 (sole crop of cassava Rs. 305403/ha). All the sole crops of medicinal plants except *Indigofera* recorded lower net income compared to their corresponding intercropping treatments.

Intercropping medicinal plants in cassava expressed Benefit: Cost ratio (BCR) higher than one. The sole crop of *Indigofera* resulted in highest BCR of 2.40 which was followed by planting of cassava with double row of *Indigofera*- (T_5, 2.29), T_2 (cassava + single row of *Indigofera*, 2.08), T_3 (cassava + single row of *Plectranthus,* 1.91), T_1 (sole crop of cassava 1.89) and T_6 (cassava + double row of *Plectranthus*). A lower BCR value of 1.04 in intercropping was observed for T_7 (cassava + double row of *Sida*) followed by T_4 (cassava + single row of *Sida*). The lowest BCR values were recorded from sole cropping of medicinal plants (other than *Indigofera* especially in T_{10} (sole crop of *Sida*, 0.50).

Table 37. Economics of cultivation

Treatments		Cost of cultivation (Rs.)	Gross returns (Rs.)	Net Returns (Rs.)	B:C ratio
T_1	Sole crop of cassava	342930	648333	305403	1.89
T_2	Intercropping cassava with *Indigofera tinctoria* (single row)	368000	766962	398962	2.08
T_3	Intercropping cassava with *Plectranthus vettiveroides* (single row)	356320	680470	324150	1.91
T_4	Intercropping cassava with *Sida alnifolia* (single row)	355000	497720	142720	1.40
T_5	Intercropping cassava with *Indigofera tinctoria* (double row)	383000	877894	494894	2.29
T_6	Intercropping cassava with *Plectranthus vettiveroides* (double row)	380000	609918	229918	1.61
T_7	Intercropping cassava with *Sida alnifolia* (double row)	370000	385067	15067	1.04
T_8	Sole crop of *Indigofera tinctoria*	308020	738000	429980	2.40
T_9	Sole crop of *Plectranthus vettiveroides*	175000	158588	-16413	0.91
T_{10}	Sole crop of *Sida alnifolia*	120000	60000	-60000	0.50

Labour charge Rs. 628/-

Sale price (a) Cassava - Rs. 20/-, (b) *Indigofera* and *Plectranthus*- Rs. 60/-,
(c) *Sida* -Rs. 80/-

5. <u>DISCUSSION</u>

5. DISCUSSION

The study entitled “Medicinal plants as intercrops in cassava (*Manihot esculenta* Crantz)” was conducted at Agronomy farm in College of Agriculture Vellanikara during 2020-2021. The objective of study was to assess the feasibility of intercropping the medicinal plants *Indigofera tinctoria*, *Plectranthus vettiveroides* and *Sida alnifolia* in cassava and, to find the effect of intercropping on growth attributes, yield and yield parameters, biochemical quality, competitive indices and economics of intercropping system. In this chapter the results of the investigation are briefly discussed based on available literature.

5.1. Effect of intercropping cassava with medicinal plants on plant height of cassava and component crops

Cassava has a wide range of growth habits which may influence the amount of solar radiation intercepted during growth period (Shivananda, 2005). In general, there was an increase in plant height of cassava from planting to the harvest (Fig. 5 and Table 4). At 30 and 60 DAP, among the treatments, there was no significant difference in plant height and the plant height ranged from 21.53 cm to 24.66 cm and 68.37cm to 84.58 cm respectively at 30 and 60 DAP. However, at 90 DAP, cassava with single row of *Plectranthus vettiveroides* was 4.92 cm taller than the sole crop of cassava. Shorter cassava plants were observed when intercropped with double row of *Sida* a*lnifolia*, which was 16.21 per cent less than sole crop of cassava. At harvest, taller plants were observed when cassava intercropped with single row of *Plectranthus vettiveroides* and *Indigofera tinctoria*. Ekwaro *et al.* (2019) also reported shorter cassava plants under monoculture. According to them, intercropped cassava plants were taller than mono crop cassava because of higher plant population and higher competition for growth resources.

Even though enhanced plant height of cassava was observed in treatments with *Plectranthus* and *Indigofera*, reduction in height of cassava was observed when intercropped with *Sida alnifolia*. At harvest height reduction was 21.18 per cent in cassava with double row of *Sida* than sole crop of cassava. This might be due to vigorous growth of *Sida* which hindered the growth and development of cassava. Amanullah *et al*. (2007) reported the reduction in plant height of cassava in cassava-cowpea intercropping system due to the smothering effect of cowpea during initial growth period.

Since *Indigofera tinctoria* was harvested for the herbage at different intervals, significant variation in plant height was observed (Fig. 7 and Table 11). At 30 DAT *Indigofera* planted as single row between cassava was 28.01 per cent and cassava with double row of *Indigofera* was 18.30 per cent taller than sole crop. However, at 60 DAT sole crop was 7.29 cm and 13.73 cm taller than single and double row of *Indigofera* with cassava. At 90 DAT plant height of intercropped *Indigofera* was 8.94 per cent (double row) and 10.78 per cent (single row) lesser than sole crop of *Indigofera*. Increased plant height in sole crop of *Indigofera* might be due to abundant resources with no interspecific competition, whereas under intercropping, plants might suffer from competition leading to reduction in plant height. Sarada (2004) reported higher plant height of *Indigofera* under open condition than intercropping in coconut garden.

Competition for resource occurs between plants in crop mixtures than when they are grown as pure stand. *Plectranthus* at 30 DAT did not show significant variation in plant height since there was less competition from the main crop and the mean value of plant height ranged from 21.86 cm to 20.10 cm (Fig. 8 and Table 16). However, during the later stages long and lanky *Plectranthus* plants were observed when intercropped with cassava. *Plectranthus* double row intercropping with cassava recorded tallest plants which were 14.65 cm and 23.94 cm more than sole crop at second and third months after planting. As compared to sole crop at 60 and 90 DAT there was an increase of 17.82 per cent and 22.17 per cent in height for *Plectranthus* intercropped with cassava as single row. This result is in agreement with Roopa (2017), who observed maximum height for *Plectranthus forskohlii* in *Plectranthus forskohlii* - fenugreek intercropping system and minimum height in sole crop of *Plectranthus*. Sabika (2019) also reported increased plant height of *Plectranthus vettiveroides* in shade than in open condition.

At 30 DAT taller *Sida alnifolia* plants were observed when grown as sole crop (39.89 cm) and were on par with single row intercrop (39.50 cm). Double row intercrop of *Sida* was 6.14 cm less than sole crop (Fig. 9 and Table 21). At 60 DAT double row intercropped *Sida* was 13.87 cm and single row intercropped *Sida* was 7.92 cm taller than sole crop. Similar trend was followed at 90 DAT also. Single row intercropped *Sida* plants were 16.21 cm taller and double row intercrop of *Sida* was 37.85 cm taller than sole crop. Priyadarsini *et al.* (2020) observed taller plants of *Sida* under shade than in open condition in Kerala.

In general, plants grown under intercropping system showed higher plant height, except for *Indigofera*. As per Abdel-Mawgoud *et al.* (1995), plants growing under shade attempts to improve capturing of intercepted light by promoting interception area which eventually lead to escalated plant height. A change in environmental conditions has the ability to manipulate the morphology and adaptation mechanisms among plants (Gong *et al*., 2015). There are morphological, physiological and anatomical adaptations of plants when they grow in low light intensity which includes increase in plant height as a mechanism to minimise the use of metabolites which further reduce the transmitted and reflected light (Hale and Orcutt, 1987).

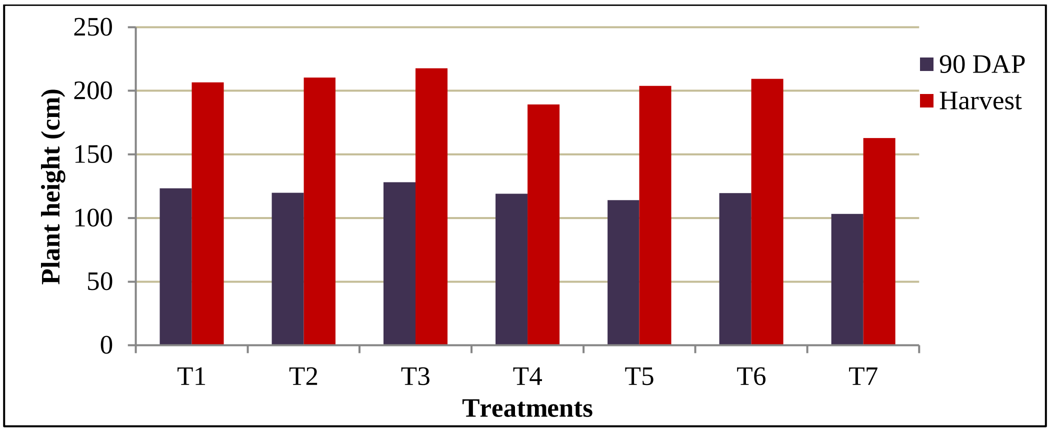


Fig. 5 Effect of intercropping cassava with medicinal plants on plant height of cassava

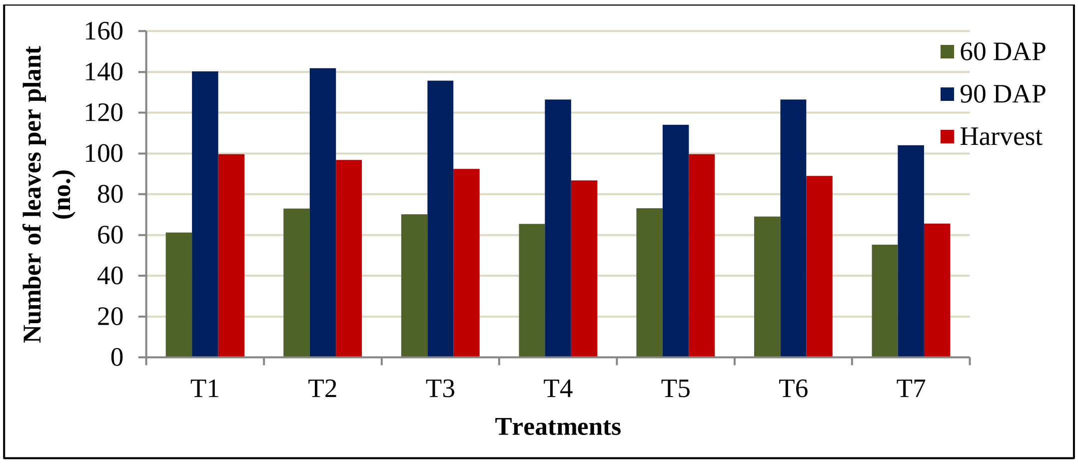


Fig. 6. Effect of intercropping cassava with medicinal plants on number of leaves of cassava

T_1- Sole crop of cassava T_2- Intercropping cassava with *Indigofera tinctoria* (single row) T_3- Intercropping cassava with *Plectranthus vettiveroides* (single row) T_4- Intercropping cassava with *Sida alnifolia* (single row) T_5- Inter cropping cassava with *Indigofera tinctoria* (double row)	T_6- Intercropping cassava with *Plectranthus vettiveroides* (double row) T_7 - Intercropping cassava with *Sida alnifolia* (double row) T_8 - Sole crop of *Indigofera tinctoria* T_9 - Sole crop of *Plectranthus vettiveroides* T_{10} - Sole crop of *Sida alnifolia*

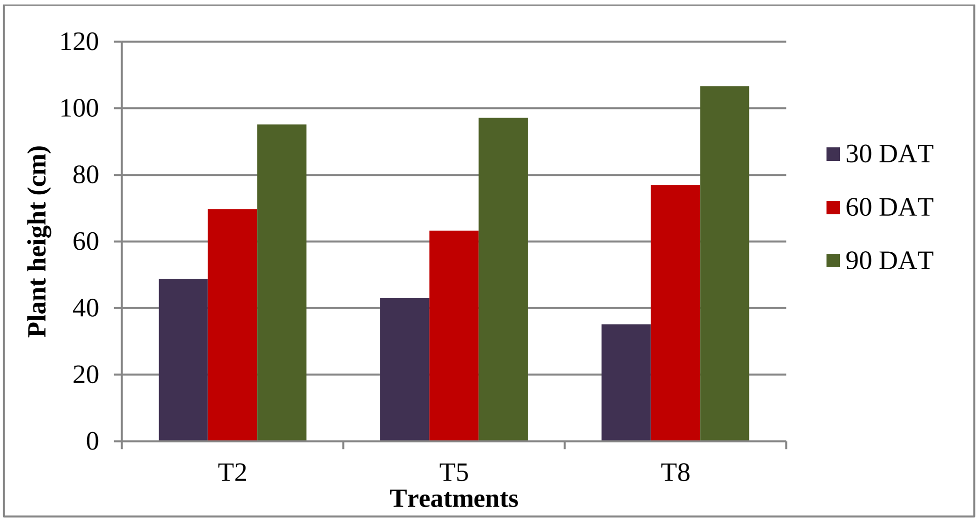


Fig. 7. Effect of intercropping on plant height (cm) of *Indigofera tinctoria*

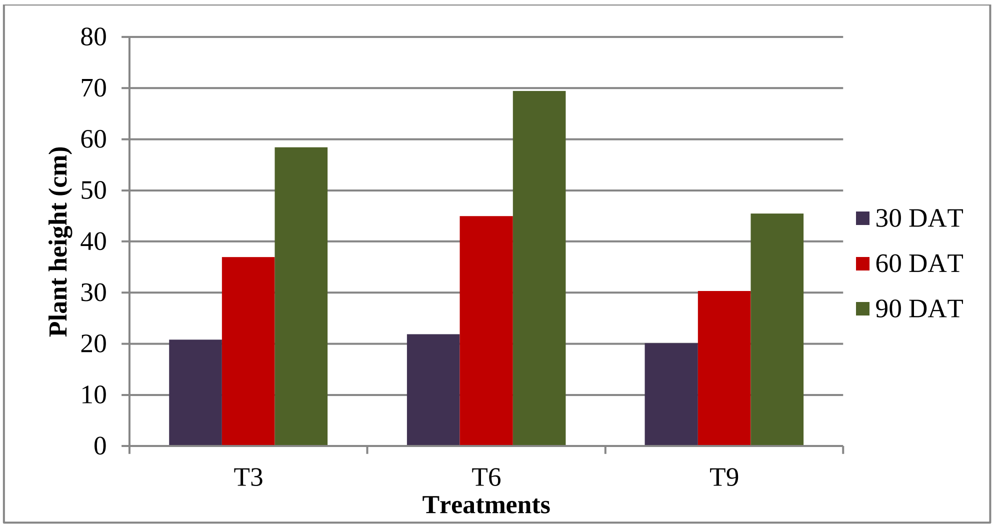


Fig. 8. Effect of intercropping on plant height (cm) of *Plectranthus vettiveroides*

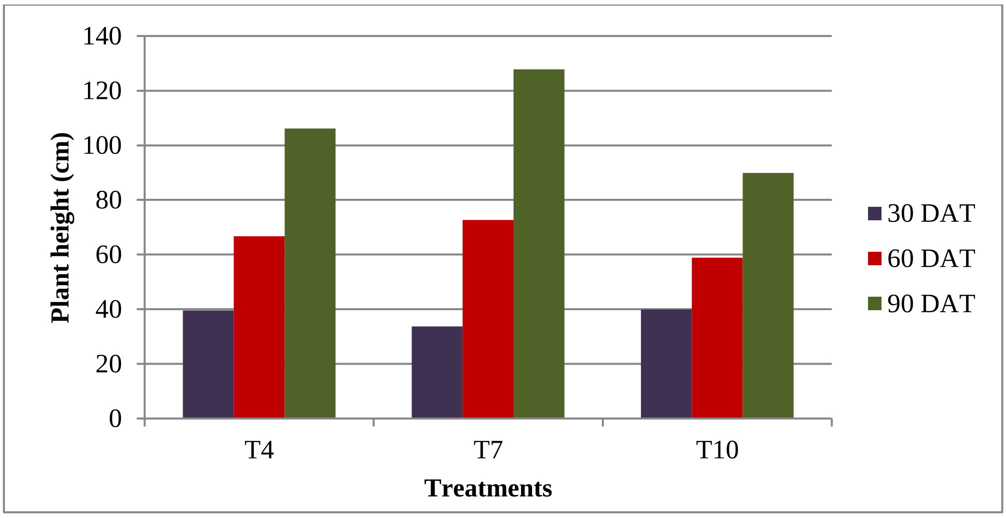


Fig. 9. Effect of intercropping on plant height (cm) of *Sida alnifolia*

5.2 Effect of intercropping cassava with medicinal plants on number of leaves

Effect of intercropping medicinal plants with cassava on number of leaves of cassava is depicted in (Fig. 6 and Table 5). During initial growth period there was no significant difference in number of leaves of cassava and the values ranged from 23.60 to 20.33 nos./plant. At 60 DAP cassava with double row of *Indigofera* recorded 16.40 per cent higher number of leaves than sole crop, whereas cassava with *Sida* in double row recorded 5.91 less number of leaves than sole cassava. Compared to 60 DAP, at 90 DAP a pronounced increase of 56.37 per cent in number of leaves was observed in sole crop whereas 36.10 less number of leaves was recorded in cassava with double rowed *Sida*. At harvest the pure stands of cassava and those planted as intercrops experienced a decline in number of leaves, might be due to shedding of older leaves in order to decrease the rate of transpiration during the dry spell (Reddy and Wiley, 1981; Lavigne, 1987,). Similar to height, the numbers of leaves were also lowest in cassava intercropped with *Sida*. The reduction in growth parameters such as height and number of leaves can be corroborated with the findings of Arubalueze *et al* (2017). According to them when cassava was intercropped with maize severe interspecific competition masked cassava plants and retarded the vegetative growth and resulted in decreased supply of photosynthates to the sink. Likewise, compared to other medicinal plants *Sida* might have exhibited high interspecific competition to cassava which led to poor growth parameters.

Mono crop of *Indigofera* was superior in producing higher number of leaves than intercropping at all stages of growth (Fig. 10 and Table 12). At 30 DAT *Indigofera* grown as single and double row with cassava had 22.93 per cent and 32.40 per cent less number of leaves than the sole crop. While at 60 and 90 DAT only a marginal difference in number of leaves could be observed among treatments. At 60 DAT sole crop had 27.90 per cent and 34.38 per cent increase in number of leaves over single row and double row of *Indigofera*. At 90 DAT compared to sole crop, single and double row *Indigofera* recorded 27.29 per cent and 26.44 per cent reduction in number of leaves. Budiastuti *et al*. (2021) also reported decrease in number of leaves for *Indigofera tinctoria* due to reduction in light intensity.

The highest number of leaves was observed in sole crop of *Plectranthus* (135.20 and 197.60 at 60 and 90 DAT respectively) (Fig. 11 and Table 17) than intercropped *Plectranthus*. At 60 DAT, number of leaves in double row *Plectranthus* was on par with sole crop whereas at 90 DAT number of leaves in single and double row *Plectranthus* was on par. Similar result of reduced number of leaves in *Plectranthus forskohlii* intercropped with palak was observed by Roopa (2017). Reduction in number of leaves can be correlated with better competitive ability of cassava which utilised available resources more effectively and deterred the growth of intercropped *Plectranthus.*

Sole cropping of *Sida* exhibited superiority in number of leaves than intercropping (Fig. 12 and Table 22). Compared to sole crop at 30 DAT 12.19 per cent and 20.04 per cent less number of leaves was observed in *Sida* intercropped as single and double row. During 60 DAT also there was higher number of leaves in sole crop than intercropped *Sida*. During third month after transplanting sole crop possessed 32.27 per cent and 37.04 per cent more number of leaves than *Sida* intercropped in single and double rows. This result can be corroborated with the study by Pushpa *et al*. (2017), who reported higher number of branches and leaves in sole crop of basil compared to intercropping with castor and pigeon pea. Basavaraju (2010) also reported lower number of branches, number of leaves per plant and dry matter per plant in basil under intercropping in coconut garden.

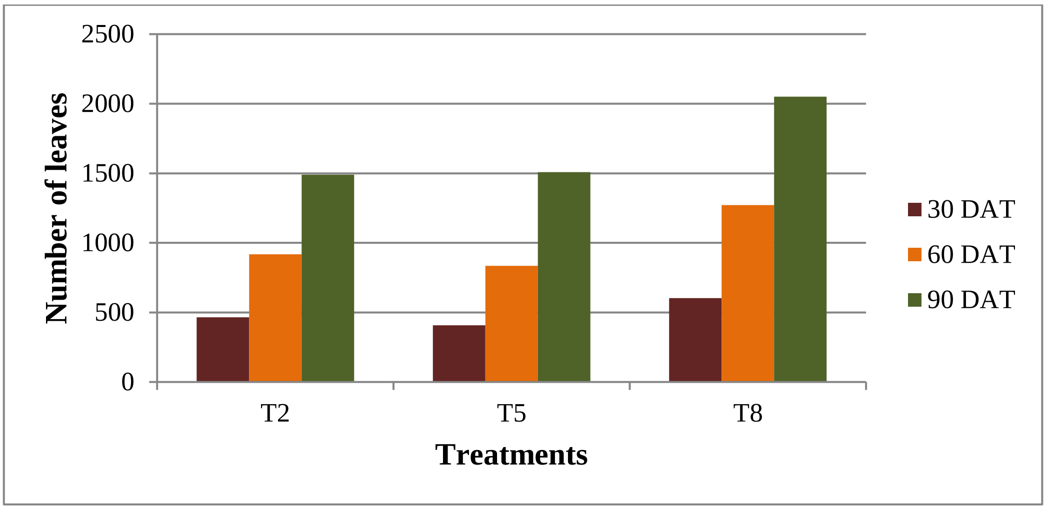


Fig. 10. Effect of intercropping on number of leaves of *Indigofera tinctoria*

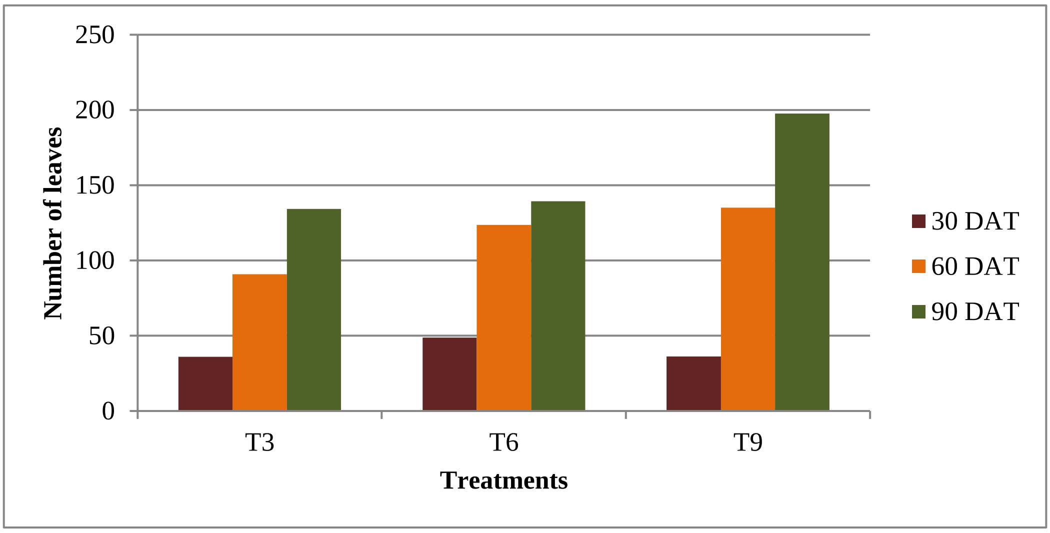


Fig. 11. Effect of intercropping on number of leaves of *Plectranthus vettiveroides*

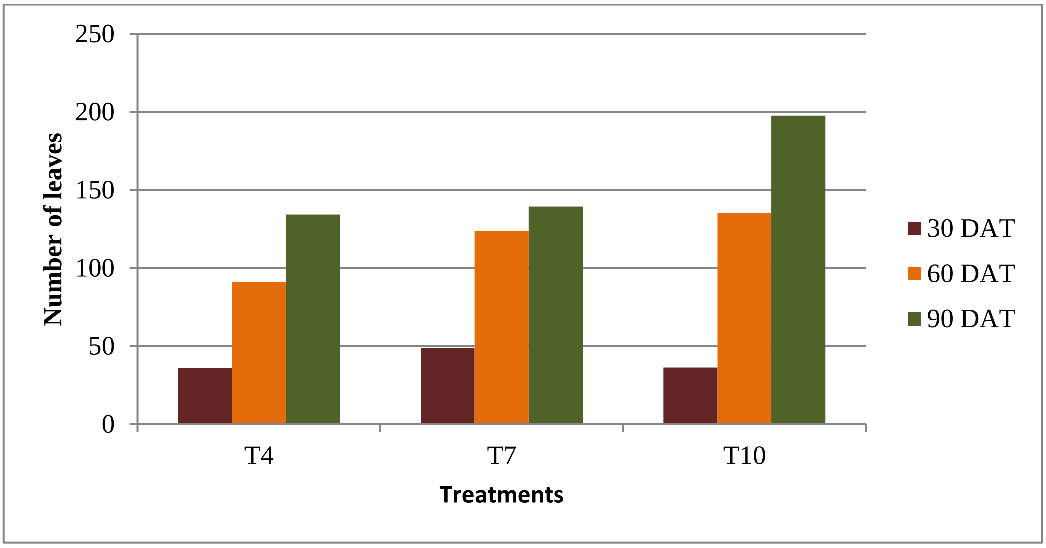


Fig. 12. Effect of intercropping on number of leaves of *Sida alnifolia*

5.3 Effect of intercropping cassava with medicinal plants on number of branches

Cassava when intercropped with medicinal plants, there was no significant difference in number of branches at different stages of observation (Table 6) and number of branches ranged from 6.07 to 5.48 nos./plant at harvest. As per Njoku *et al.* (2010) different cowpea planting densities had no effect on number of branches of cassava in cassava cowpea intercropping system.

Indigofera tinctoria exhibited difference in number of branches when planted as sole, single row and double rows. In general, compared to sole crop a reduction in number of branches was observed under intercropping (Fig. 13 and Table 13). In sole crop of *Indigofera,* number of branches observed at 90 DAT was 20.69 per cent more than that at 60 DAT. At 90 DAT, in single row and double row number of branches was 11.40 and 3.87 less than sole crop. According to Sarada (2004) in *Indigofera* open condition facilitated production of more number of branches than shaded condition.

As in the case of *Indigofera*, *Plectranthus* also recorded a greater number of branches in sole crop than intercropping at 60 and 90 DAT (Fig. 14 and Table 18). During the initial stages of observation double row intercropped *Plectranthus* had the highest number of branches but a reverse trend could be observed during subsequent observations. At 60 DAT single row intercropped *Plectranthus* had 6.27 and double row of intercropped *Plectranthus* had 3.27 less number of branches than sole crop of *Plectranthus*. While at 90 DAT number of branches in single row and double row intercropped *Plectranthus* were on par but less than sole crop of *Plectranthus*. Kumar (2013) observed higher number of branches for *Plectranthus* in open condition rather than shaded condition.

Intercropped *Sida* had less number of branches than sole crop of *Sida.* At 30 DAT there was no significant difference in number of branches. However, at 60 DAT 10.66 and 16.73 less number of branches were observed in double and single row intercropped *Sida* than the sole crop (Fig. 15 and Table 23). An increment of 63.92 per cent in number of branches was noted at 90 DAT than 60 DAT in sole crop of *Sida* indicating its profuse branching nature.

In general intercropping with cassava resulted in reduction in number of branches for all the three medicinal plants studied. Solanki *et al.* (2014) reported similar findings in medicinal plants like *Ocimum sanctum, Andrographis paniculata* and *Mentha arvensis*. They observed remarkably a greater number of branches under sole crop compared to intercropping with Sapota and Jatropha. According to them as light passes upper canopy with less penetration to lower stand crops in a cropping system, it will induce marked morphogenetic changes in plants and inhibit branching.

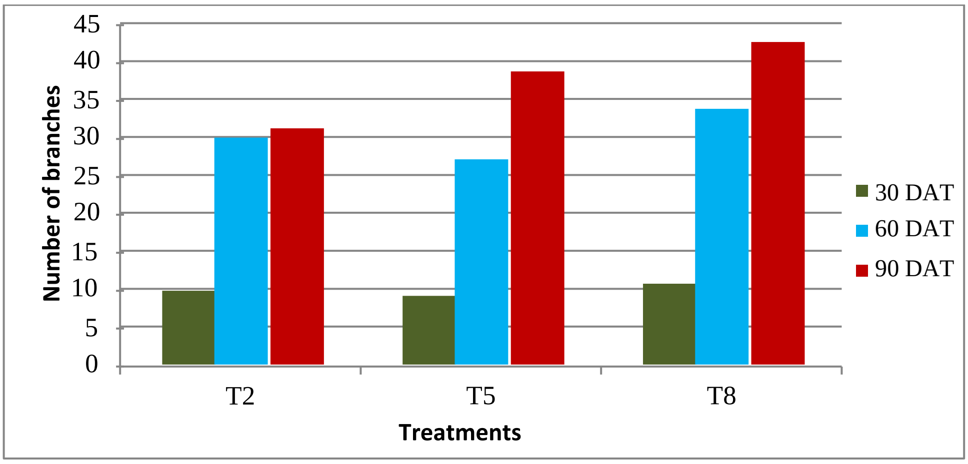


Fig. 13. Effect of intercropping on number of branches of *Indigofera tinctoria*

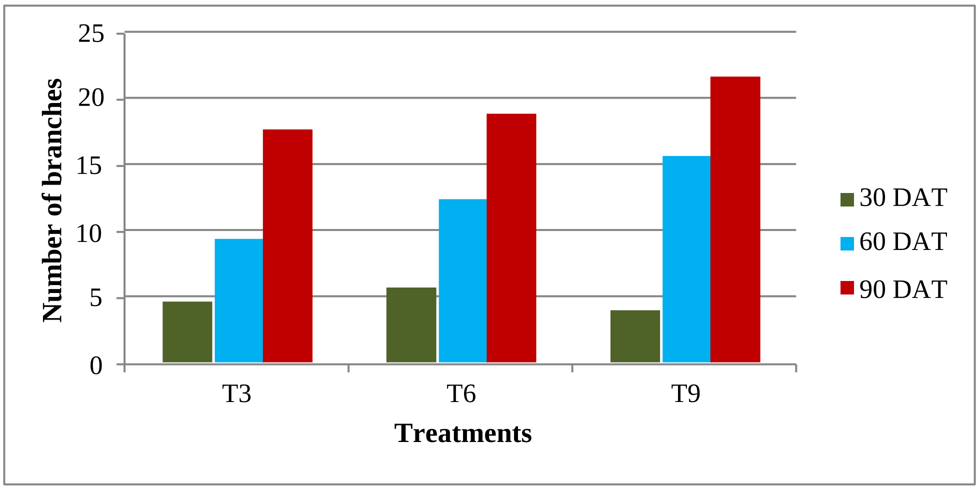


Fig. 14. Effect of intercropping on number of branches of *Plectranthus vettiveroides*

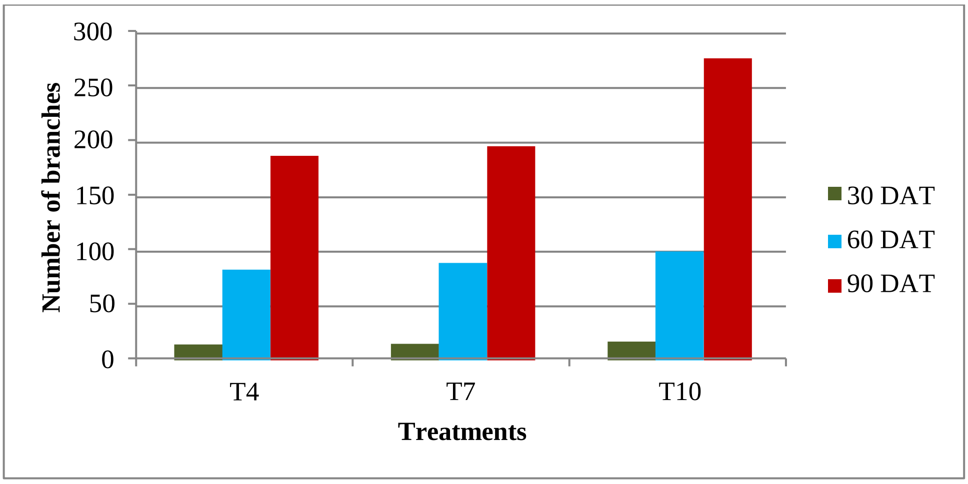


Fig. 15. Effect of intercropping on number of branches of *Sida alnifolia*

5.4 Effect of intercropping of cassava with medicinal plants on yield and yield attributes

Higher tuber yields of 3.24 kg/plant (32417 kg/ha) and 3.12 kg/plant (31250 kg/ha) was obtained from sole cropping of cassava and cassava intercropped with *Plectranthus vettiveroides* as single row (Fig. 16 and Table 9). The per cent reduction in per plant cassava yield between sole crop and single row *Plectranthus* was only 3.59. As an intercrop *Plectranthus* was there in the field only for three months. Harvesting was done at three months after transplanting. After harvesting of the intercrop, field was as equivalent to sole crop of casssava. There was no interspecific competition for cassava after three months of crop growth. Lack of competition during critical growth stages of cassava might have contributed to better tuber yield in single row intercropping with *Plectranthus*. According to Savithri and Alexander (1995) there was no remarkable difference in yield parameters of cassava when intercropped with suitable short duration crops like cowpea.

In general cassava yield reduction was less conspicuous in single row intercropping. However, significant yield reduction was noticed by double row intercropping of medicinal plants. According to Ekwaro *et al*. (2019) root yield of cassava under low intercrop density was higher than that of higher intercrop density in cassava - maize intercropping. The lowest cassava yield was obtained in cassava intercropping with double row of *Sida alnifolia*. A yield reduction of 45.37 per cent was noticed in this treatment. The reduction in tuber yield of cassava intercropped with *Sida alnifolia* might be attributed to the higher competition by *Sida* in the early stages and the resultant effect on the growth and yield parameters. As an intercrop *Sida* was there in the field till five months after transplanting. Growth recommencement of cassava after removal of *Sida* may not been sufficient to compensate for the earlier growth suppression.

From the yield data of cassava single row planting of *Plectranthus* can be recommended as the most ideal intercrop for cassava. Single row planting of *Indigofera* was the next best alternative.

Higher dry matter production at harvest was observed in sole crop of cassava (1.98 kg) which was on par with cassava with single row crop of *Plectranthus* (1.95

kg) followed by cassava with single row of *Indigofera* (1.81 kg) (Fig. 17 and Table 10). This might be probably due to wide maturity gap between *Plectranthus* (three months) and cassava and frequent cutting of *Indigofera* for its herbage yield which paved the way for better dry matter production in intercropping system. As in the case of tuber yield, the least dry matter production (42.92 per cent less than sole crop of cassava) was in cassava with double row of *Sida*.

In general, economic yield of all the three medicinal plants studied viz. *Indigofera, Plectranthus* and *Sida* were higher under sole cropping. Padma *et al.* (2018) reported yield reduction of medicinal and aromatic plants when grown as intercrop in coconut garden compared to their mono crop yields.

Following the trend of growth parameters there was remarkable decrease in yield of *Indigofera* under intercropping situation (Fig. 18, 19 and Table 14). Herbage yield was significantly higher in sole crop of *Indigofera*. The per plant yield reduction was to the tune of 33.95per cent and 36.04 per cent respectively when *Indigofera* was intercropped as single or double row with cassava than sole crop. The poor performance of *Indigofera tinctoria* might be due to shading effect of tall growing cassava plant. Moreover, in *Indigofera* reduction in growth and growth parameters would be directly linked to the yield as biomass yield was economic yield in this crop. However, double row intercropping had 48.36 per cent more herbage yield per hectare than single row intercropping, mainly due to increase in plant population.

Sole crop of *Plectranthus* recorded highest per plant root yield and root yield per hectare (Fig. 20, 21 and Table 19). Single row and double row intercropping resulted in 2.17 g and 3.06 g less root yield per plant than sole crop. Due to less plant population per hectare yield of single row intercropped *Plectranthus* was 68.42 per cent and 48.86 per cent lower than sole crop and double row intercropped *Plectranthus*.

Root yield per plant and root yield per hectare of *Sida* was found to be the highest in sole crop of *Sida* (Fig. 22, 23 and Table 24). Among intercropping situations higher per plant root yield of *Sida* was noticed in single row intercropping. Root yield was less under double row intercropping. Mutual shading due to increased population might have reduced root yield of *Sida* under double row intercropping.

Yield reduction of *Sida* under shaded condition was reported by Priyadarsini *et al*. (2020). Latha and Radhakrishnan (2015) also reported reduction in yield and yield parameters such as number of roots, root yield per plant and root length under shaded condition in *Sida*.

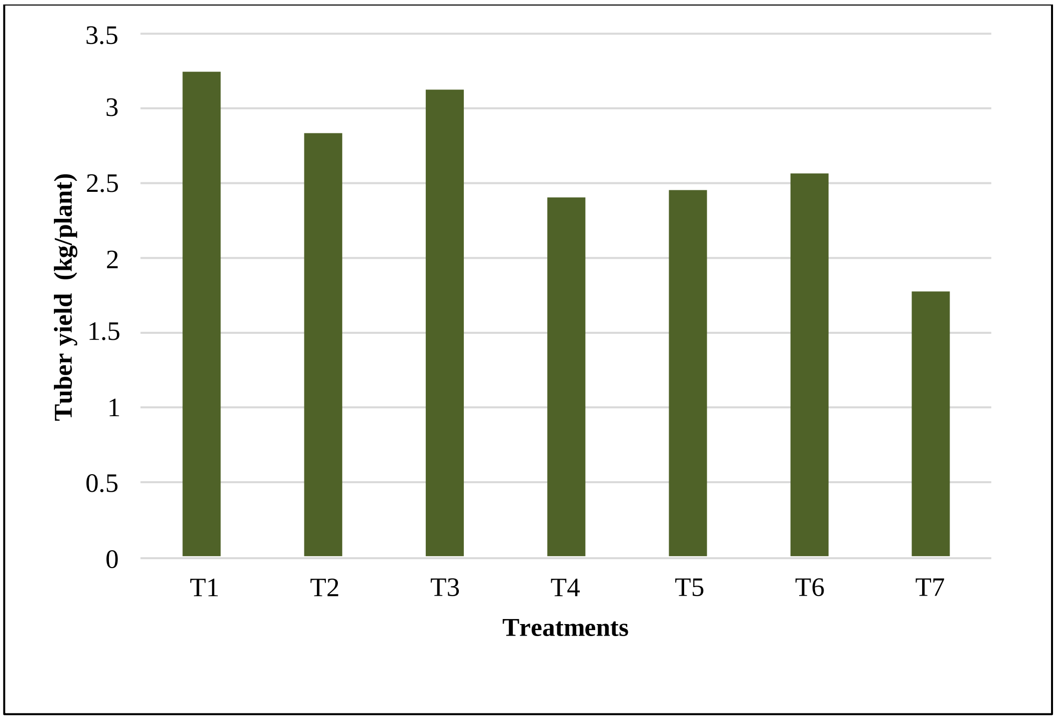


Fig. 16. Effect of intercropping on tuber yield (kg/plant) of cassava

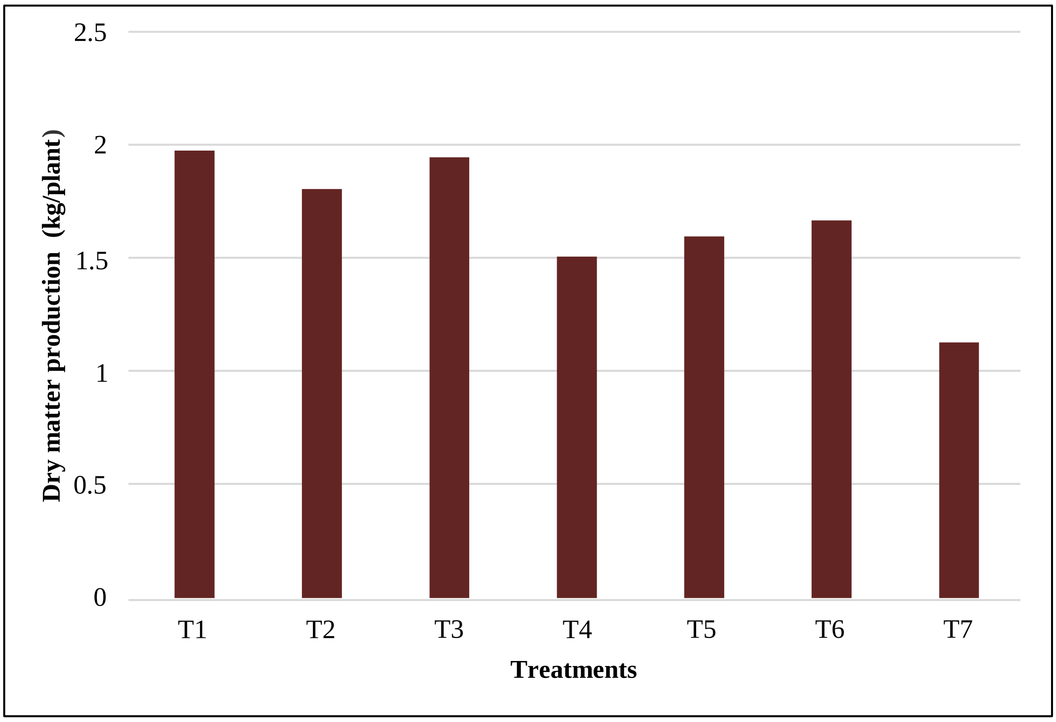


Fig. 17. Effect of intercropping on dry matter production (kg/plant) of cassava

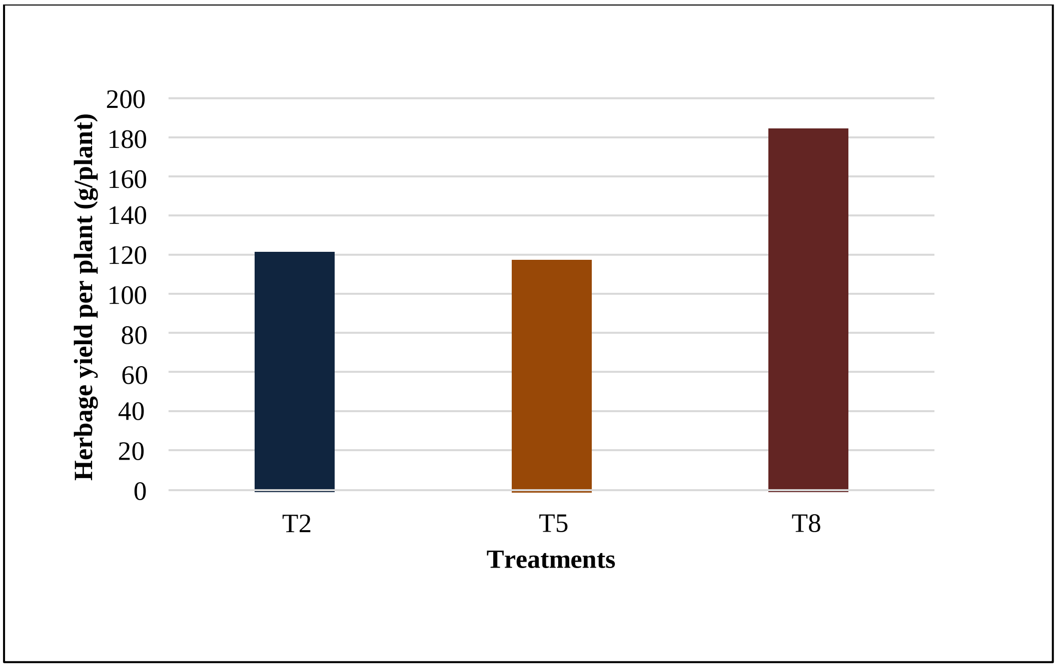


Fig. 18. Effect of intercropping on herbage yield per plant (g/plant) of *Indigofera tinctoria*

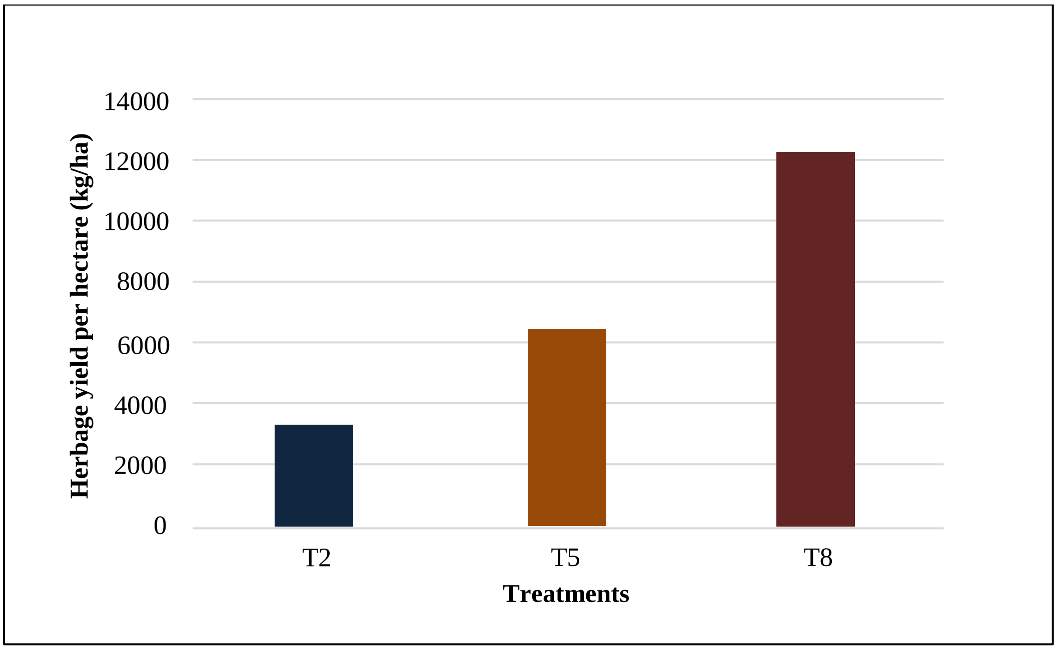


Fig. 19. Effect of intercropping on herbage yield per hectare (kg/ha) of *Indigofera tinctoria*

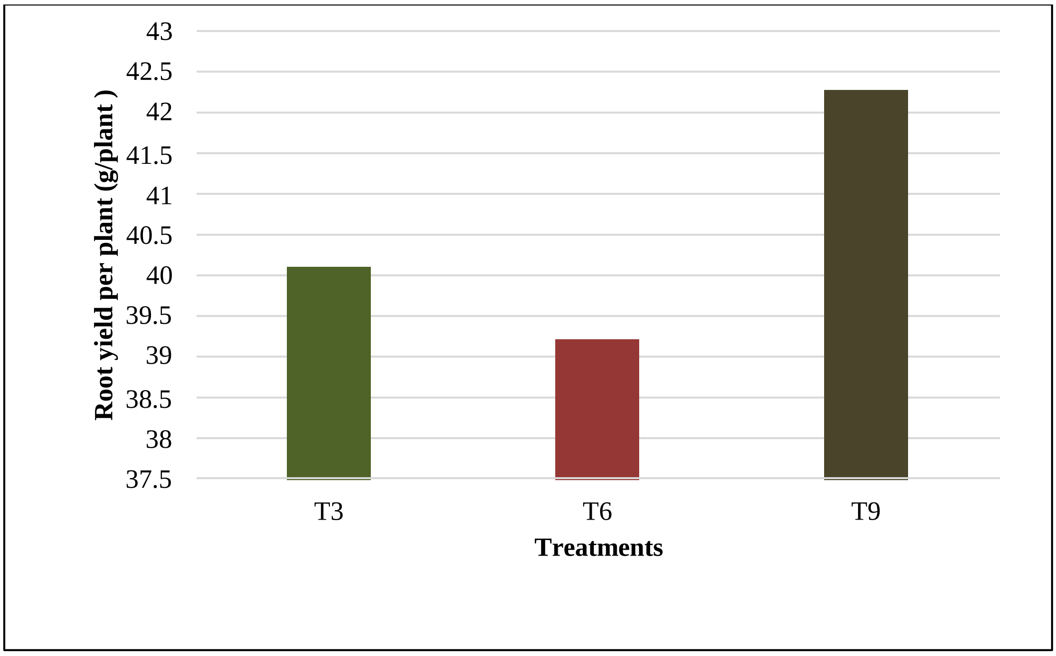


Fig. 20. Effect of intercropping on root yield per plant (g/plant) of *Plectranthus vettiveroides*

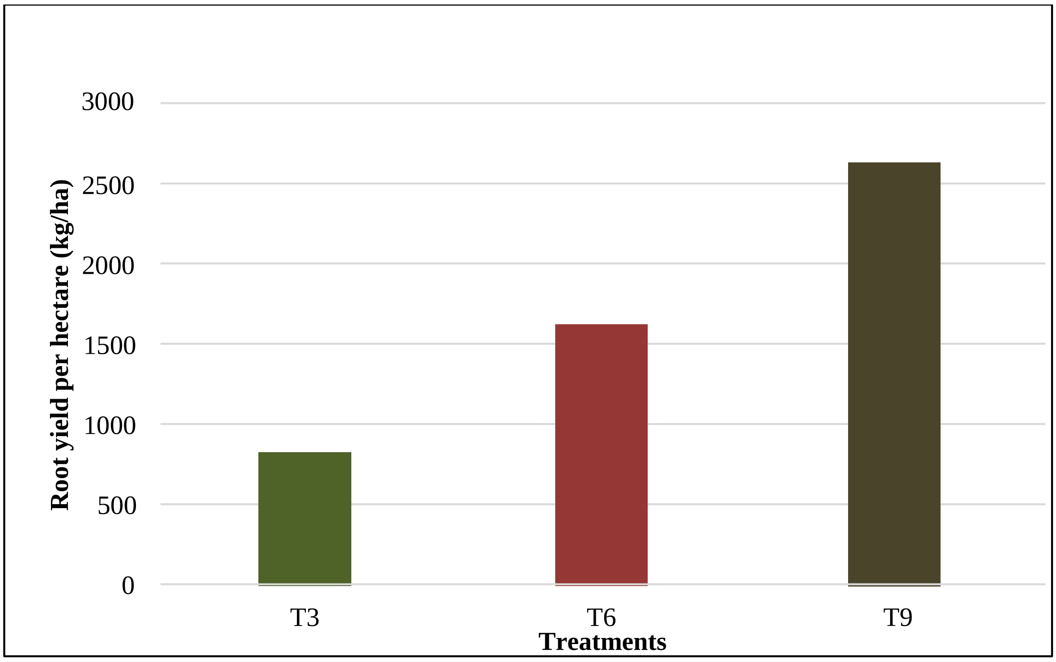


Fig. 21. Effect of intercropping on root yield per hectare (kg/ha) of *Plectranthus vettiveroides*

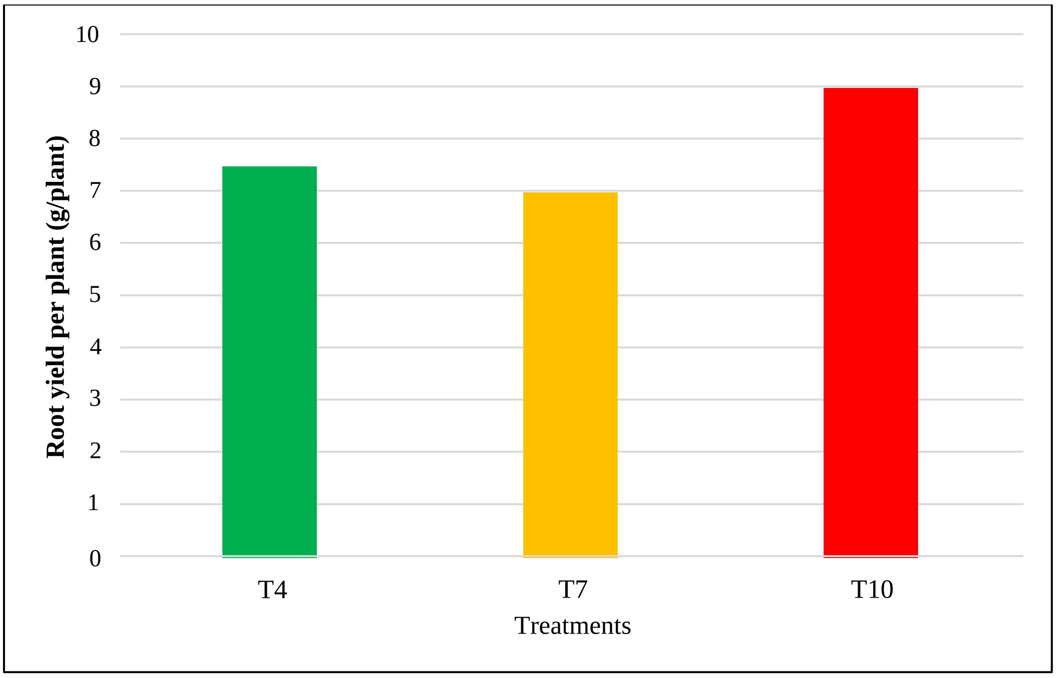


Fig. 22. Effect of intercropping on root yield per plant (g/plant) of *Sida alnifolia*

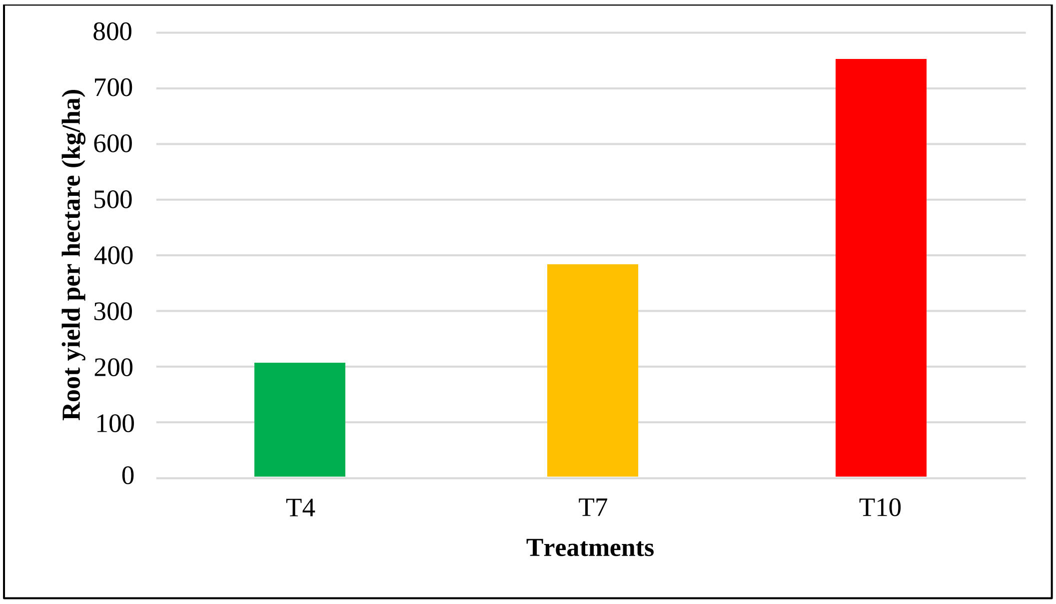


Fig. 23. Effect of intercropping on root yield per hectare (kg/ha) of *Sida alnifolia*

5.5 Effect of intercropping cassava with medicinal plants on principal constituents in medicinal plants

In the present study of intercropping medicinal plants with cassava, the principal biochemical content in medicinal plants varied significantly in sole and intercrop.

Sole crop of *Indigofera* recorded the highest indican content and was on par with single row inter crop. Double row intercropped cassava recorded 4.28 per cent less indican content than sole crop. (Fig. 24 and Table 15). As per Sindhu *et al*. (2018) indican content in *Indigofera tinctoria* was statistically on par at fully open and 25 per cent shaded condition but as the shade intensity increases the indican content decreased significantly. Sarada (2004) also reported higher indican content for *Indigofera* in open condition than when intercropped in coconut garden.

Growing of *Plectranthus* as sole crop resulted in the highest essential oil content than intercropped *Plectranthus*. Single row of intercropped *Plectranthus* yielded 33.33 per cent and double row of intercropped *Plectranthus* yielded 56.66 per cent less essential oil than sole crop of *Plectranthus* (Fig. 25 and Table 20). Kumar (2013) observed higher essential oil in open condition than in shaded condition for *Plectranthus vettiveroides.*

The analysis of data on total alkaloid content of *Sida alnifolia* also showed the significance of sunlight for enhancing quality parameters. The highest alkaloid content was obtained from sole cropping. This was followed by single row intercrop with about 4.23 per cent lower content than sole crop. The least alkaloid content was in double row intercropped *Sida,* which was 13.02 per cent less than sole crop (Fig. 26 and Table 25).

From the findings of present study low content of principal components in medicinal plants could be attributed to increased shade level due to higher plant population as in the case of double row planting. Biscoe and Gallagher (1977) suggested that the variation in the principal medicinal constituents in medicinal and aromatic plants between pure stand and intercrop could be attributed to the role of light on fluctuating photosynthesis and respiration. To explain furthermore, altering the flux of metabolites and lowering power generation through the light reaction might in turn adjust the synthesis and accumulation of chief constituents in medicinal and aromatic plants (Saravanan *et al.*, 2008).

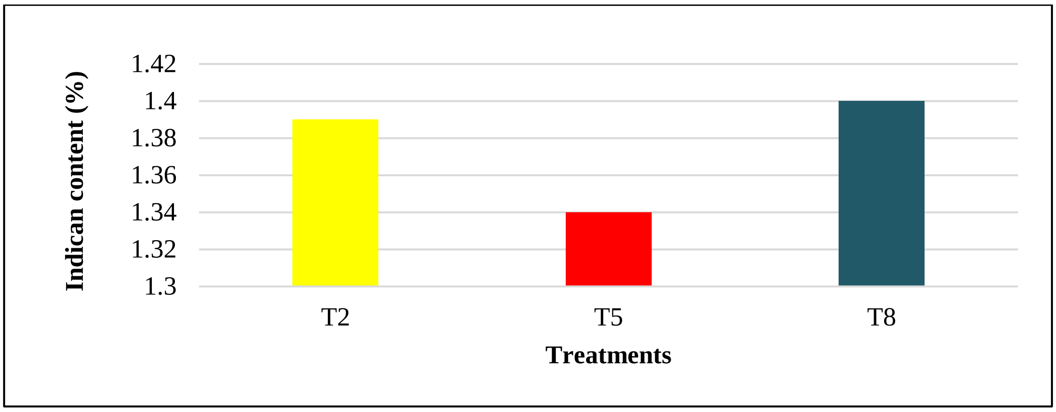


Fig. 24. Effect of intercropping on Indican content (per cent) of *Indigofera tinctoria*

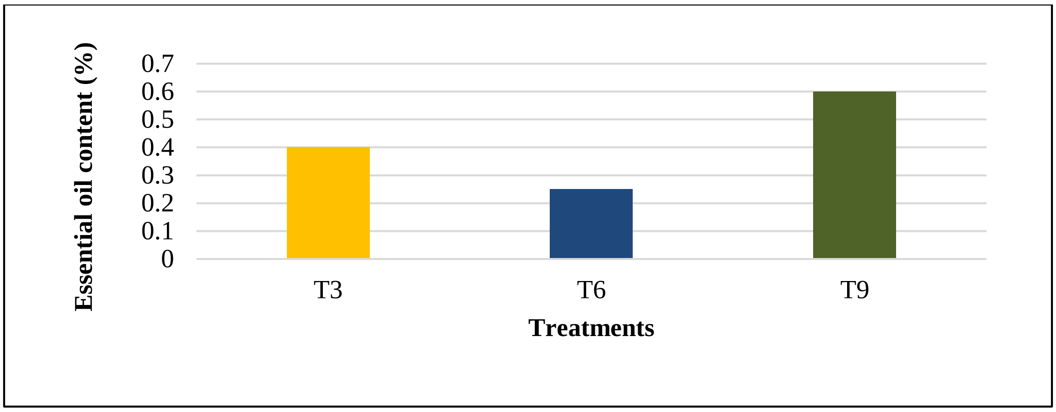


Fig. 25. Effect of intercropping on essential oil content (per cent) of *Plectranthus vettiveroides*

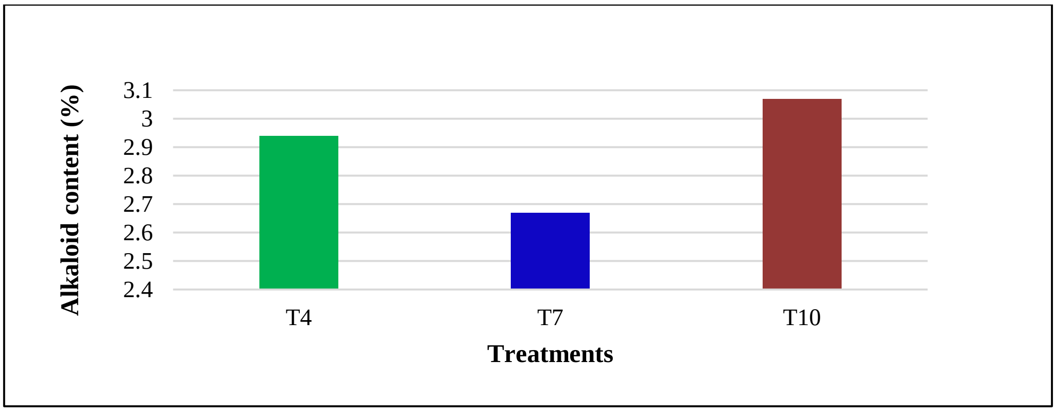
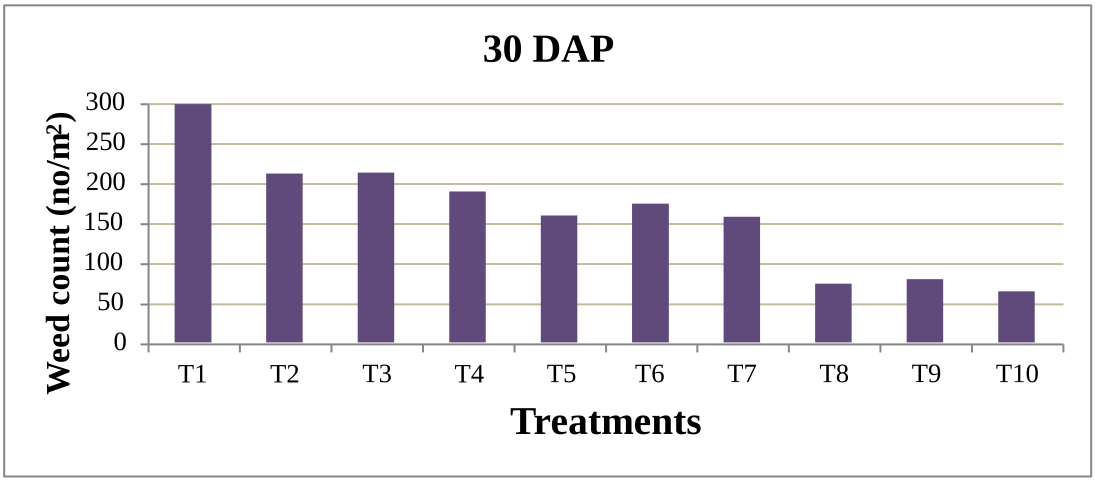


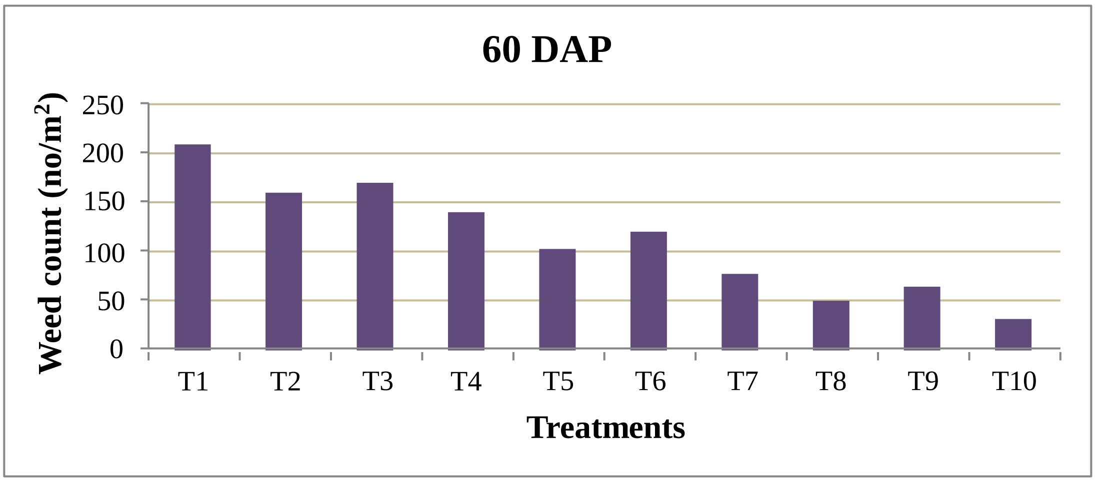
Fig. 26. Effect of intercropping on alkaloid content (per cent) of *Sida alnifolia*

5.6 Effect of intercropping medicinal plants with cassava on weed growth

Fadayomi (1979) reported that weed invasion is one of the serious problems limiting crop production. This field trial was predominantly infested with dicots, monocots and sedges. The major broad leaf weeds found in the experiment were *Synedrella nodiflora, Cleome burmanii, Mollugo pentaphylla, Phyllanthus amara, Ageratum conyzoides, Borreria hispida, Alternanthera bettzickiana, Euphorbia hirta, Euphorbia geniculata, Tridax procumbens, Ludwigia perennis, Mimosa pudica, Portulaca sp., Boerhavia diffusa, Sida acuta, Alycicarpus vaginalis* and *Scoparia dulcis.* The monocot weeds included *Panicum maximum, Digitaria ciliaris, Commelina diffusa, Axonopus compressus, Eleusine indica, Pennisetum polystachion,* and *Cynodon dactylon.* The main sedges were *Cyperus rotundus, Cyperus haspan, Cyperus iria* and *Kyllinga monocephala.*

Intercropping medicinal plants with cassava had significant effect on weed growth and weed dry matter production at all the stages of crop growth. At all the stages of observation broad leaf weeds outnumbered the monocots. Sole crop of cassava recorded the highest weed population followed by single row intercropping and then the double row intercropping with medicinal plants (Fig. 27, 28 and Table 26 to 31). As per Evans (1960) and Ibeawuchi and Ofoh (2003) most crop mixtures suppress weed population by smothering the groundcover due to very high plant density or by vigorous component crop. Taah and Adu (2021) also reported less weed count and weed dry matter production in cassava intercropped with cowpea and groundnut than sole crop of cassava.





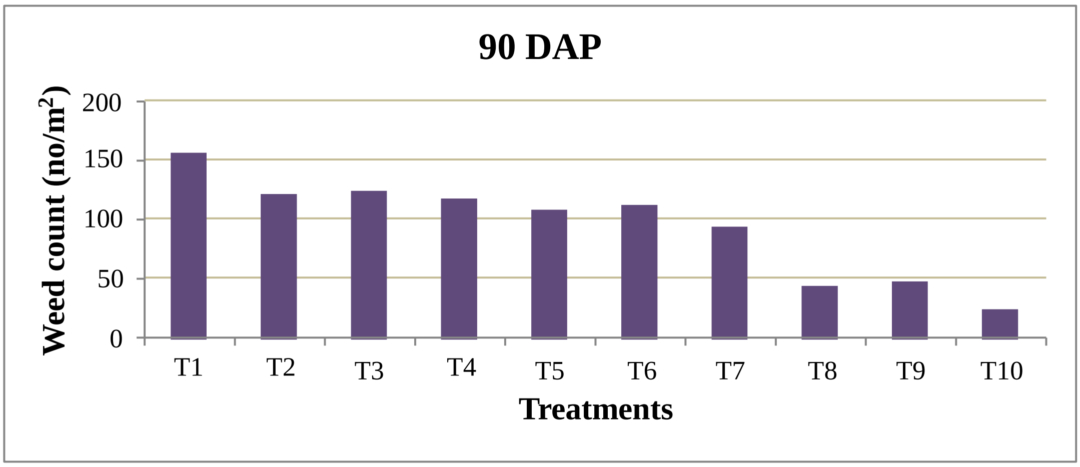


Fig. 27. Effect of treatments on total weed count at different growth stages.

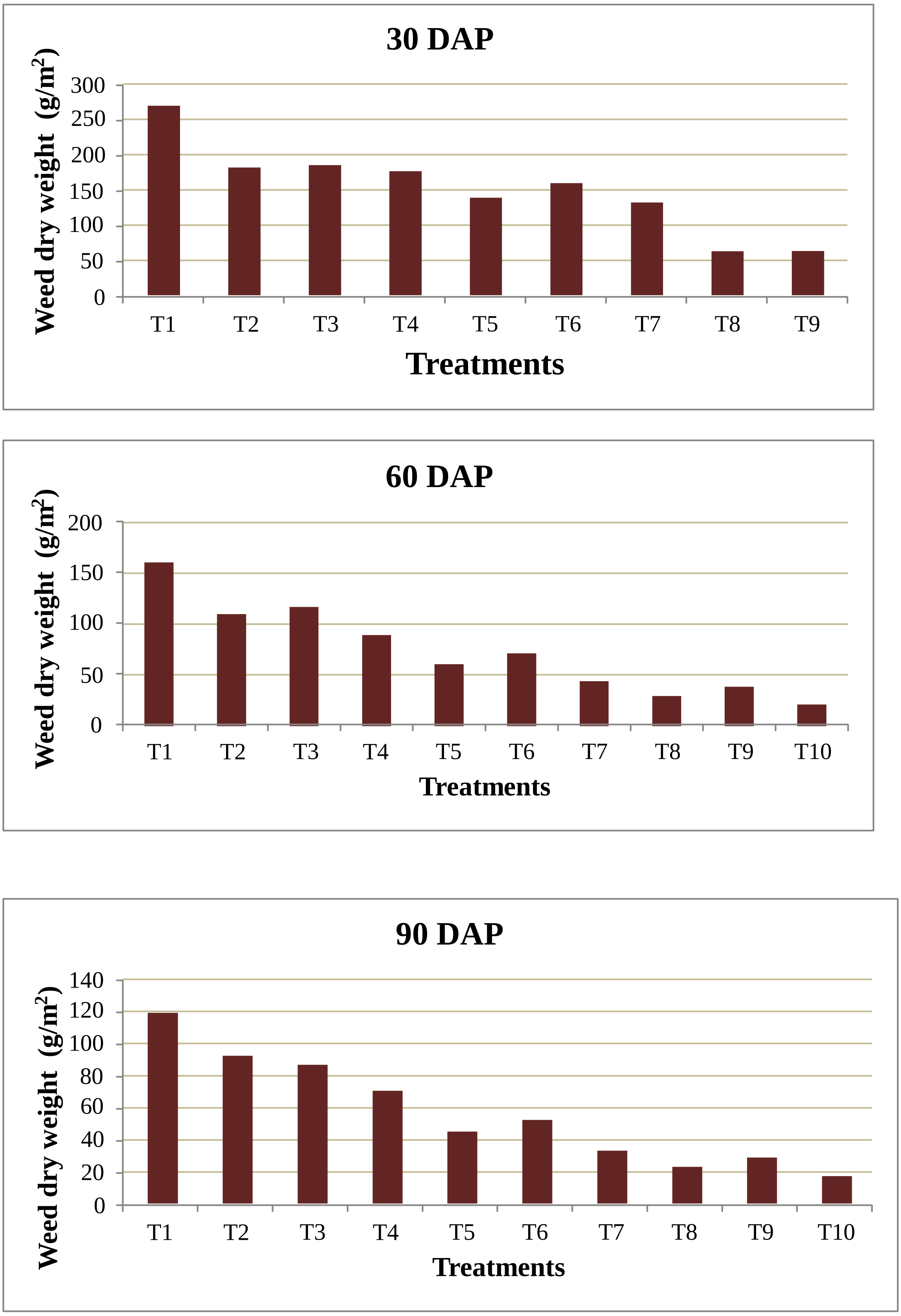


Fig. 28. Effect of treatments on total weed dry weight at different growth stages.

5.7 Competition indices

Intercropping cassava with medicinal plants resulted in LER of more than one with all the medicinal plants tried (Fig. 29 and Table 32). The land equivalent ratio (LER) denotes the land required for pure stands to bring about the yield attained in the intercropping mixture and the LER value greater than unity implies a comprehensive biological advantage of intercropping (Palaniappan and Sivaraman, 1996). The LER of the intercropping system was estimated by summing up the LER values of maincrop with intercrops. High performance in terms of LER was achieved in crop mixtures with low competition or which had greater complementarily which paved the way for higher land use efficiency (Nassab *et al*., 2011; Zhang *et al.,* 2011). The present study revealed the yield advantage of growing medicinal plants as intercrops with cassava over sole cropping of either cassava or medicinal plants. Among the various intercropping systems, cassava with double row of *Plectranthus vettiveroides* recorded the highest LER (1.42). Single row intercropping of *Plectranthus vettiveroides* and double row intercropping of *Indigofera tinctoria* were the next best treatments with higher LER (1.28). Higher LER in intercropping systems compared to their sole cropping was reported earlier by many workers. Doubi *et al.* (2016) reported greater LER values in cassava + bottle gourd system than their sole cropping. Increased LER value for cassava and cowpea intercropping was reported by Legodi and Ogola (2020).

The relative crowding coefficient (RCC or K) is another parameter which allows evaluating and comparing the competitive ability of one species to other in a crop mixture (Zhang *et al*., 2011). As per the interpretation of RCC given by Doubi *et al*. (2016), if Kc is greater than Km, "c" crop species is more competitive than "m" crop and vice versa. RCC of the intercropping system was calculated as the product of the two coefficients of main crop and intercrop. If K value is greater than one, there is a yield advantage, when K is equal to one there is no yield advantage, and when it is less than one there is a disadvantage. In this study, the value of Kc was higher than the Km (Fig. 30 and Table 33) and also more than one, indicating competitive ability of cassava over medicinal plants. Doubi *et al.* (2016) also observed higher RCC for cassava compared to *Lagenaria siceraria*, in cassava + *Lagenaria siceraria* intercropping system. The highest relative crowding coefficient was observed when cassava was intercropped with single row of *Plectranthus* (12.36) followed by cassava with double row of *Plectranthus* (6.29). A higher K value in cassava + single row *Plectranthus* system indicated better utilisation of resources and less competition among the intercrops. Low RCC values were observed when cassava was intercropped with *Sida* either as single row or as double row.

Competitive ratio (CR) is used as a gauge to measure the competitive ability of different species in intercropping (Weigelt and Jolliffe, 2003; Uddin *et al*., 2014). CR value greater than one indicates that the species is more competitive than other in crop mixture. In this study competitive ratio of cassava was greater than one implicating its dominance over component medicinal plants. Intercropped cassava had higher CR values with *Indigofera* either as single or as double rows and the lowest was with *Plectranthus* as double row (Fig. 31 and Table 34).

The yield of medicinal intercrops was converted into equivalent yield (CEY) of cassava based on the price of the produce, so as to evaluate the economic benefit of intercropping system (Reddy and Reddy, 2016). Cassava with double row of *Indigofera* resulted in the highest cassava equivalent yield of 43895 kg/ha, which was 26.15 per cent more than sole crop of cassava (Fig. 32 and Table 35). The obvious reason for this was higher productivity in cassava + *Indigofera* intercropping system. The lowest CEY was observed in sole crop of *Sida alnifolia* which was 90.75 per cent less than sole crop of cassava. This might be due to poor performance of both main and intercrop in terms of yield in intercropping system.

The competitive ability of the component crops in an intercropping system is measured by its aggressivity value (A). The greater the numerical value, the bigger the difference between actual and expected yields. A positive value of aggressivity indicates the dominance and negative value indicates subjugation (Mc Gilchrist, 1965). Aggessivity value of cassava was positive in all intercropping systems (Fig. 33 and Table 36) which proved the dominant nature of cassava over other component medicinal crops. So, it can be inferred that the intercropped cassava utilized the resources more competitively than medicinal plants which appeared to be dominated. The overall competitive ability of cassava on medicinal plants was found to be more pronounced when cassava was intercropped with double row of medicinal plants. This result can be corroborated with the findings of Oroka (2012) who reported positive aggressivity value for cassava over groundnut due to better ability of cassava to capture light and soil resources or a combination of both.

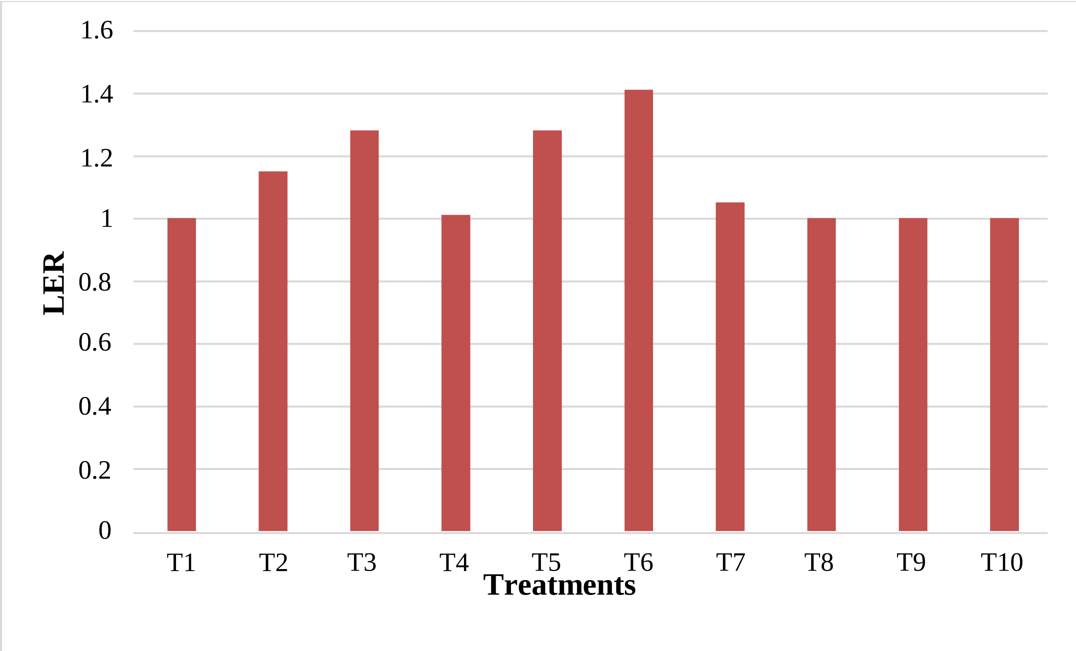


Fig. 29. Effect of intercropping systems of cassava and medicinal plants on Land Equivalent Ratio (LER)

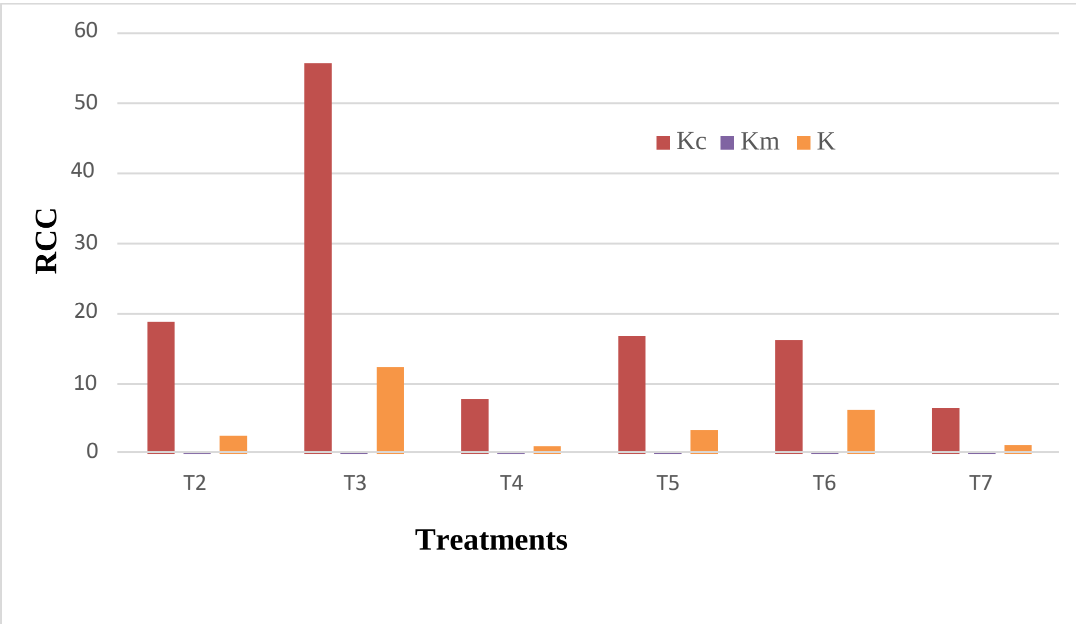


Fig. 30. Effect of intercropping system with cassava and medicinal plants on Relative Crowding Coefficient (RCC/K)

Kc- RCC of cassava

Km- RCC of medicinal plants

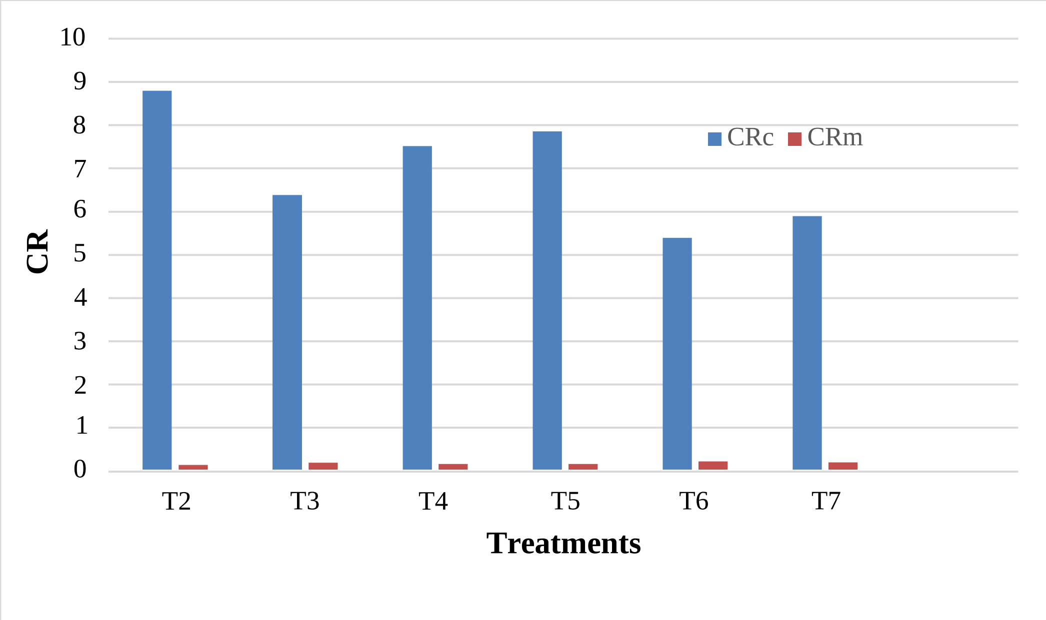


Fig. 31. Effect of intercropping systems with cassava and medicinal plants on Competitive Ratio (CR)

CRc - competitive ratio of cassava

CRm- competitive ratio of medicinal plants

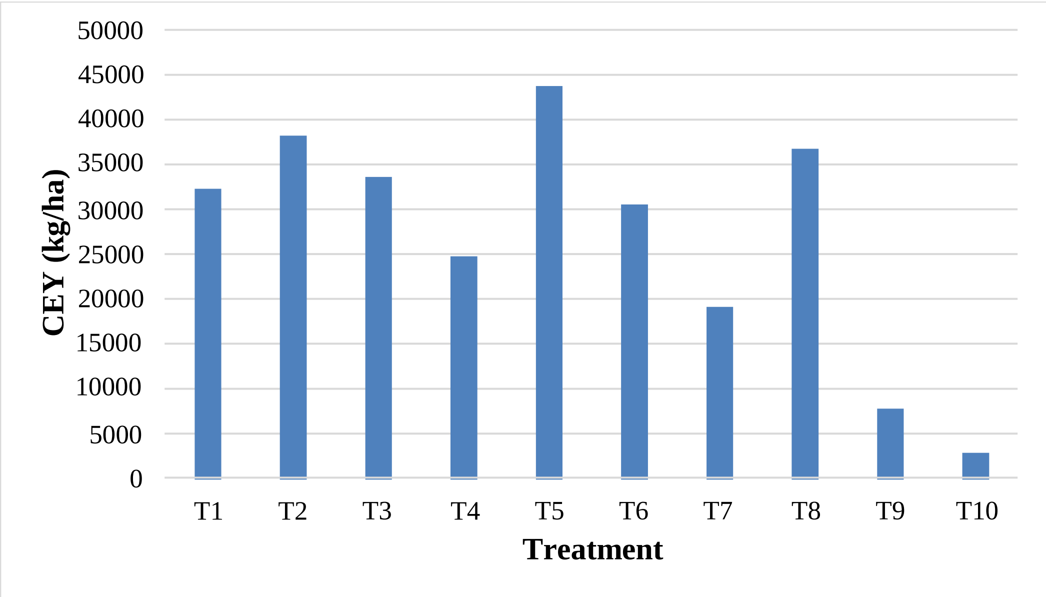


Fig. 32. Effect of intercropping systems with cassava and medicinal plants on Cassava Equivalent Yield (CEY kg/ha)

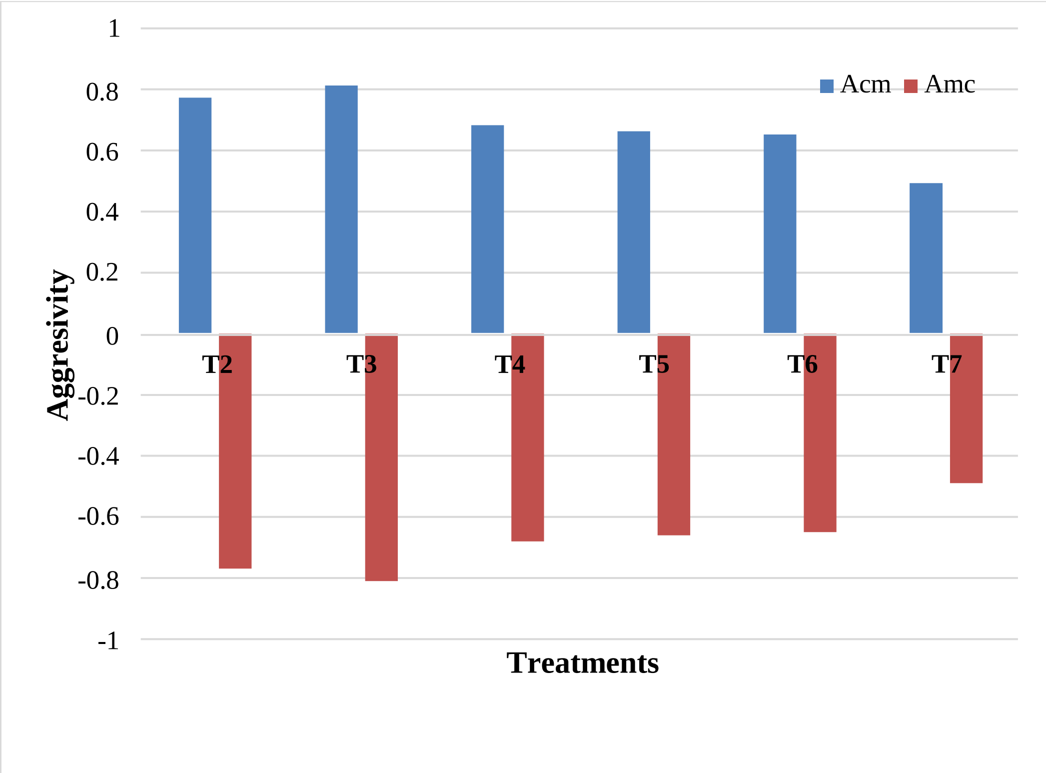


Fig. 33 Effect of intercropping medicinal plants in cassava on aggressivity of component crops

Acm- Aggresivity of cassava with respect to medicinal plants

Amc- Aggresivity of medicinal plants with respect to cassava

5.8 Economics of cultivation

In general, the cost of cultivation was higher in double row intercropping followed by single row intercropping and then sole cropping (Table 37). Intercropping of medicinal plants in cassava consumed more labour and management practices compared to their sole crop which would have consequently elevated the cost of cultivation. However, intercropping systems recorded higher gross returns than sole crops. The yield of component crops would have bridged the disparity of higher cost of cultivation, making the intercropping system a more economically viable and profitable enterprise than their sole cropping. This can be supported with the findings of Polthanee *et al.* (2001) who reported cassava and groundnut intercropping system as more profitable and productive than pure stands of cassava.

Among intercropping systems cassava with single or double row of *Indigofera* or single row of *Plectranthus* recorded higher gross returns. Intercropping cassava with double row of *Indigofera* resulted in a net return of Rs. 494894/- which was 21.25 per cent more than sole crop of cassava. All the sole crops of medicinal plants except *Indigofera* recorded lower net income compared to their corresponding intercropping treatments. According to Thakur and Kumar (2006) *Tagetes minuta* and *Ocimum basilicum* under *Leucaena leucocephala* cropping system recorded higher returns than their mono crop.

Perusal of data on BCR clearly revealed the superiority of cassava –*Indigofera* intercropping system either as double row or as single row (2.29 and 2.08 respectively). When cassava was grown as sole crop the BCR was 1.89 which increased to 2.29 by intercropping with double row of *Indigofera* and to 1.91 with single row of *Plectranthus*, indicating economic advantage of intercropping (Table 37 and Fig. 34). Ukaobasi (2018) also reported higher BCR in cassava cowpea intercropping system than sole crop of cassava. The lowest BCR was found in sole crop of *Sida* (0.50). Sole crop of *Indigofera* resulted in a BCR which was more than that of sole crop of cassava. Similar result of very high BCR of 3.51 for *Indigofera* cultivation in Kerala was reported by Sindhu *et al.* (2016).

Results obtained from competition indices clearly demonstrated significant advantage of intercropping cassava with medicinal plants. Better utilisation of resources was observed under cassava- medicinal plant intercropping system. Intercropping cassava with medicinal plants *Indigofera tinctoria* or *Plectranthus vettiveroides* could be identified as the best systems based on economic analysis.

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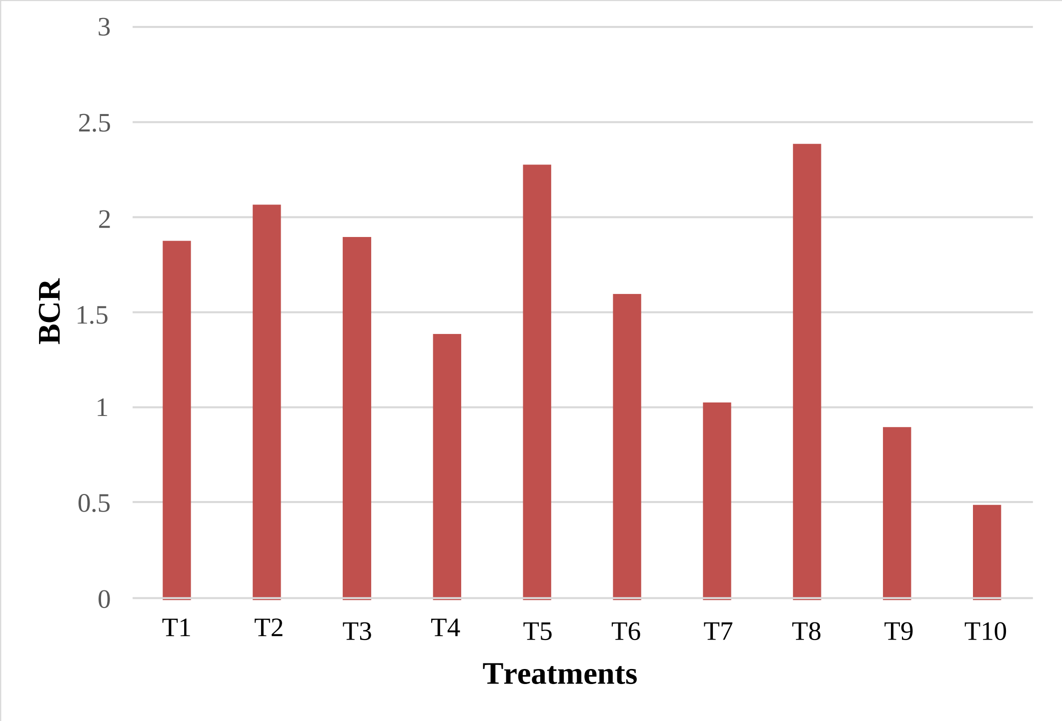

Fig. 34 Effect of intercropping cassava with medicinal plants on benefit cost ratio (BCR)

6. SUMMARY

6. SUMMARY

The study entitled ‘Medicinal plants as intercrops in cassava *(Manihot esculenta* Crantz)’ was designed and conducted at College of Agriculture, Vellanikkara during 2020-2021 to assess the feasibility of intercropping medicinal plants with cassava. The trial was laid out in Randomized Block Design with three replications. Cassava (high yielding local variety) was the main crop and medicinal plants *Indigofera tinctoria*, *Plectranthus vettiveroides* and *Sida alnifolia* were raised as the intercrops in various crop geometries. The treatments consisted of different planting geometries of three medicinal plants with cassava along with their pure stands, Treatments were T_1-Sole crop of cassava,T_2 - cassava + single row of *Indigofera tinctoria*, T_3- cassava + single row of *Plectranthus vettiveroides*, T_4- cassava + single row of *Sida alnifolia*, T_5-cassava + double row of *Indigofera tinctoria*, T_6- cassava + double row of *Plectranthus vettiveroides*, T_7- cassava + double row of *Sida alnifolia*, T_8-Sole crop of *Indigofera tinctoria*, T_9-Sole crop of *Plectranthus vettiveroides*, T_{10}-Sole crop of *Sida alnifolia*. The observations on growth attributes, yield and yield parameters, biochemical quality, competitive indices and economics of cultivation were recorded.

6.1 Effect of intercropping on growth and growth attributes of main crop and intercrops

- At all stages of crop growth, the tallest cassava plants were recorded in cassava + single row of *Plectranthus vettiveroides* which was on par with sole crop of cassava and cassava + single row of *Indigofera tinctoria.*
- Intercropping cassava with *Sida alnifolia* produced shortest cassava plants particularly in cassava + double row of *Sida* (162.84 cm)
- In cassava at harvest the highest number of leaves was observed for sole crop and cassava + single row of medicinal plants and cassava + double row of *Indigofera*
- Intercropping medicinal plants in cassava did not have any influence on number of branches.

- Except for *Indigofera*, taller plants were observed when grown as double row intercrop followed by single row intercrop and lowest was in sole crop.
- Pure stand of medicinal plants produced more number of leaves and branches than their intercrops.

6.2 Effect of intercropping on yield and yield attributes of main crop and intercrops

- Cassava intercropped with single row of medicinal plants performed better than double row intercropping with respect to yield and yield parameters.
- Intercropping with medicinal plants did not have significant effect on number of tubers in cassava.
- Sole crop of cassava registered the highest tuber yield per plant, top yield and dry matter production (3.24 kg/plant, 2.31 kg/plant and 1.98 kg/plant respectively).
- Cassava + single row of *Plectranthus* had better growth attributes, tuber yield, top yield and dry matter production.
- Cassava + double row of *Sida* did not perform well in terms of yield and yield parameters.
- For medicinal plants yield per plant was higher in sole crop, followed by single row intercropping and then double row intercropping.
- Yield per hectare was highest in sole crop followed by double row and then the single row intercropping with cassava.

6.3 Effect of intercropping on quality parameters of medicinal plants

- Biochemical analysis of medicinal plants revealed significant influence of intercropping on quality parameters.
- In *Indigofera*, the indican content was higher in sole crop (1.40 per cent) and was on par with single row inter crop (1.39 per cent).
- The lowest indican content of 1.34 per cent was observed in double row inter cropping of *Indigofera* with cassava.

- Essential oil content was found highest in sole crop of *Plectranthus* (0.60 per cent), followed by cassava + single row of *Plectranthus* (0.40 per cent) and the lowest was in cassava + double row of *Plectranthus* (0.26 per cent).
- Sole crop of *Sida* produced the highest total alkaloid (3.07 per cent) followed by single row intercrop (2.94 per cent) and cassava+ double row planting of *Sida* (2.67 per cent).

6.4 Effect of intercropping on weed control

- Cassava intercropped with double row of medicinal plants was more efficient in controlling weeds than cassava + single row of medicinal plants or sole crop of cassava
- Sole crop of cassava recorded highest total weed count and weed dry matter production at 30 DAP, 60 DAP and 90 DAP.
- *Sida alnifolia* controlled the weeds more effectively than other medicinal plants either as sole crop or as intercrop.

6.5 Effect of intercropping on competition indices

- The LER of all intercropping systems recorded values higher than unity, indicating the yield advantage over sole cropping of cassava and medicinal plants.
- The maximum LER was in intercropping cassava with *Plectranthus vettiveroides* as double row (1.41).
- *Sida* intercrop either as single row or as double rows in cassava (1.01 and 1.05 respectively) had lowest LER.
- The Relative Crowding Coefficient (RCC) value of cassava was found to be higher, indicating that the cassava was a dominant crop over intercropped medicinal plants.
- The highest RCC was found for cassava+ single row of *Plectranthus* with a value of 12.36 and the least RCC was when cassava intercropped with *Sida alnifolia* with values 1.25 and 1.08 respectively in double and single row.

- The higher Competitive ratio (CR) values for cassava indicated its better competitive ability than medicinal plants in the present intercropping system.
- Cassava intercropped with *Indigofera tinctoria* as single row had the highest competitive ratio of 8.76.
- The lowest CR value of 0.11 was for *Indigofera tinctoria* as single row with cassava.
- The double row intercropped medicinal plants had higher cassava equivalent yield than single row, except for *Plectranthus* and sole cropping of medicinal plants recorded lower cassava equivalent yield.
- The highest CEY was recorded for cassava + *Indigofera* double row with cassava equivalent yield of 43895 kg/ha and the lowest CEY was for *Sida alnifolia* (3000 kg/ha).
- Aggressivity of cassava in all intercropping systems was positive reflecting the dominant nature of cassava over the medicinal plants.

6.6 Effect of intercropping on economics of cultivation

- The cost of cultivation was higher in double row intercropping followed by single row intercropping and sole cropping.
- All the sole crops of medicinal plants except *Indigofera* recorded lower net income compared to its corresponding intercropping treatment.
- Intercropping medicinal plants in cassava expressed Benefit: Cost ratio (BCR) greater than unity.
- The sole crop of *Indigofera* resulted in the highest BCR of 2.40.
- Low BCR values were recorded from sole cropping of *Sida* (0.50).

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8. APPENDIX

Appendix 1. Monthly weather data during the experimental period

Months	Max. temp (^{0}C)	Min. temp. (^{0}C)	Mean relative humidity (%)	Total rainfall (mm)	No. of rainy days	Mean evaporation (mm)	Sunshine hours (hrs)
September	30.0	22.4	88.3	19.6	0.7	2.1	2.4
October	31.0	21.5	82.3	10.0	0.4	2.4	5.5
November	33.0	22.0	69.8	1.9	0.1	3.6	6.6
December	32.0	21.9	64.9	0.2	0.0	4.4	6.3
January	32.3	21.3	63.9	1.5	0.0	4.3	6.6
February	34.6	21.6	53.8	0.0	0.0	5.5	9.2
March	36.8	23.0	59.3	1.0	0.0	5.3	8.6
April	34.9	23.6	73.8	2.4	0.1	3.7	6.3
May	32.7	22.9	83.5	17.8	0.5	2.7	4.5

Medicinal plants as intercrops in cassava (*Manihot esculenta* Crantz)

By

Dayana Samson

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ABSTRACT OF THE THESIS

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DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLANIKKARA, THRISSUR – 680656
KERALA, INDIA

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ABSTRACT

Kerala is considered a treasure house of medicinal and aromatic plants, however, due to indiscriminate harvesting; the existence of most of these plants is under threat. Cultivation is the only option to ensure the continual supply of high quality raw materials without diminishing natural resources. Due to small holding size and a greater focus on cash crops, the scope for commercial production of medicinal plants as a pure crop in Kerala is restricted. So, the practical alternative is to bring them under intercropping with priority crops such as food and commercial crops. Cassava (*Manihot esculenta* Crantz) is the most important starchy root crop grown in the tropics. The wide spacing, together with slow initial growth and development, makes cassava compatible to intercropping with short duration annual crops.

The present study entitled "Medicinal plants as intercrops in cassava (*Manihot esculenta* Crantz)" was carried out at the Agronomy farm, Department of Agronomy, College of Agriculture, Vellanikara from September 2020 to April 2021 to assess the feasibility of intercropping cassava with the medicinal plants *Indigofera tinctoria, Plectranthus vettiveroides* and *Sida alnifolia.* The experiment was laid out in Randomized Block Design (RBD) with 10 treatments replicated thrice. The treatments included sole crops of cassava and medicinal plants, cassava + single row of medicinal plants, and cassava + double rows of medicinal plants. The observations on growth, yield and yield attributes of main and intercrops, and quality parameters of medicinal plants were recorded. Competitive indices and economics of cultivation were also computed.

Intercropping significantly influenced the growth and yield attributes of both main and intercrops. With respect to plant height of cassava, significant variation was observed only at later stages of crop growth. Shorter cassava plants were observed when intercropped with *Sida alnifolia* (162.84 cm). In general, medicinal plants grown under intercropping system recorded taller plants, except for *Indigofera,* where sole cropping resulted in taller plants.The sole crop of cassava produced higher per plant tuber yield of 3.24 kg (32417 kg/ha) and was at par with cassava with single row of *Plectranthus* (3.12 kg/plant). The lowest tuber yield was recorded when cassava was intercropped with double row of *Sida* (1.77 kg/plant). Similar trend was observed in

top yield and dry matter production per plant. The yield of medicinal plants was the highest in sole crops, followed by single row intercropping and double row intercropping. Same trend was observed for quality parameters of medicinal plants. The quality of *Indigofera tinctoria*, expressed by indican content, was higher in sole crop (1.40 per cent) and was on par with single row inter crop (1.39 per cent). Sole crop of *Plectranthus vettiveroides* registered the highest essential oil content of 0.60 per cent, followed by cassava + single row of *Plectranthus* (0.40 per cent). Sole crop of *Sida alnifolia* produced highest total alkaloid (3.07 per cent) and was at par with single row intercrop (2.94 per cent).

Cassavas intercropped with double rows of medicinal plants were more efficient in controlling weeds than sole crop of cassava or cassava + single row of medicinal plants. Sole crop of cassava recorded the highest total weed density and dry matter production at 30 DAP, 60 DAP and 90 DAP. *Sida alnifolia* controlled the weeds more effectively than other medicinal plants, both as sole crop or as intercrop with cassava.

Competition indices like land equivalent ratio (LER), relative crowding coefficient (K or RCC), competitive ratio (CR), cassava equivalent yield (CEY) and aggressivity were assessed for evaluating intercropping efficiency. All intercropping systems recorded LER of values greater than one, indicating the yield advantage over sole cropping. The highest LER (1.41) was recorded when cassava was intercropped with double row double row of *Plectranthus vettiveroides* and LER was lower when *Sida alnifolia* was intercropped either as single row or as double rows (1.01 and 1.05 respectively). Higher RCC and CR values and positive aggressivity values for cassava indicated dominance of cassava over medicinal plants. K (RCC) of all treatments was greater than one, indicating yield advantage of the system. The highest CEY was recorded for cassava + *Indigofera* as double row, with cassava equivalent yield of 43895 kg/ha, and the lowest CEY was for sole crop of *Sida alnifolia* (3000 kg/ha). Among the medicinal plants evaluated, *Indigofera tinctoria*, either as double row or as single row, could be recommended as the best medicinal intercrop for cassava. Intercropping cassava with single row *Plectranthus vettiveroides* was the next best alternative.

സംഗ്രഹം

മരച്ചീനിയിൽ ഇടവിളയായി ഔഷധസസ്യങ്ങൾ എന്ന തലകെട്ടോടുകൂടിയ ഗവേഷണ പഠനം സെപ്തംബർ 2020 മുതൽ ഏപ്രിൽ 2021 വരെയുള്ള കാലയളവിൽ കേരള കാർഷിക സർവകലാശാലയിലെ വെള്ളാനിക്കര കാർഷിക കോളേജിലെ അഗ്രോണോമി വിഭാഗത്തിൽ നടത്തുകയുണ്ടായി. നീലയമരി, ഇരുവേലി, കുറുന്തോട്ടി എന്നീ ഔഷധസസ്യങ്ങൾ മരച്ചീനിയിൽ ഇടവിളക്കൃഷി ചെയ്യുന്നതിനുള്ള സാധ്യത വിലയിരുത്തുന്നതിനായി മരച്ചീനിയുടെയും ഔഷധസസ്യങ്ങളുടെയും തനിവിള, രണ്ടു വരി മരച്ചീനികൾക്കിടയിൽ ഒറ്റ വരിയായി ഔഷധ സസ്യങ്ങൾ, രണ്ടു വരി മരച്ചീനികൾക്കിടയിൽ രണ്ട് വരിയായി ഔഷധസസ്യങ്ങൾ എന്നിവയായിരുന്നു പരീക്ഷണത്തിൽ ഉൾപ്പെടുത്തിയിരുന്നത്.

പ്രധാന വിളകളുടെയും ഇടവിളകളുടെയും വളർച്ചയെയും മറ്റ് വിള ഗുണങ്ങളെയും ഇടവിളക്കൃഷി സമ്പ്രദായം വളരെ കാര്യമായ തോതിൽ സ്വാധീനിച്ചു. വളർച്ചയുടെ അവസാന ഘട്ടത്തിൽ മാത്രമാണ് മരച്ചീനിയുടെ ഉയരത്തിൽ കാര്യമായ വ്യത്യാസം കണ്ടത്. കുറുന്തോട്ടി ഇടവിളയായി കൃഷി ചെയ്ത സമ്പ്രദായത്തിൽ നീളം കുറഞ്ഞ മരച്ചീനികൾ കാണുകയുണ്ടായി.

മരച്ചീനി തനി വിളയായി കൃഷി ചെയ്തപ്പോഴാണ് കൂടുതൽ ഉത്പാദനം ലഭിച്ചത് (3.24 കി. ഗ്രാം/ ചെടി), എന്നിരുന്നാലും , ഇരുവേലി ഒറ്റവരിയായി ഇടവിള കൃഷി ചെയ്തപ്പോൾ ലഭിച്ച മരച്ചീനിയുടെ ഉത്പാദനം തനി വിളക്ക് ഏകദേശം തുല്യമായിരുന്നു (3.12 കി. ഗ്രാം/ ചെടി). മരച്ചീനിയുടെ ഇടയിൽ രണ്ടു വരിയായി കുറുന്തോട്ടി നട്ടപ്പോഴാണ് ഏറ്റവും കുറവ് മരച്ചീനിയുടെ ഉത്പാദനം രേഖപ്പെടുത്തിയത് (1.77 കി. ഗ്രാം/ ചെടി).

ഔഷധ സസ്യങ്ങൾ ഏക വിളയായി കൃഷി ചെയ്തപ്പോഴാണ് കൂടുതൽ ഉത്പാദനം ലഭിച്ചത്, തുടർന്ന് യഥാക്രമം ഒറ്റവരി, ഇരട്ടവരി ഇടവിളകൃഷിയിലും.

മരച്ചീനിയിൽ ഇരട്ടവരിയായി ഔഷധസസ്യങ്ങൾ ഇടവിളയായി കൃഷി ചെയ്ത സമ്പ്രദായത്തിൽ മറ്റ് രണ്ട് സമ്പ്രദായത്തെ അപേക്ഷിച്ചു കള നിയന്ത്രണം കൂടുതൽ കാര്യക്ഷമം ആയിരുന്നു.

ഇട വിള സമ്പ്രദായത്തിന്റെ മികവ് രേഖപ്പെടുത്തുന്ന ശാസ്ത്രീയ സൂചകങ്ങളായ ഭൂമി തുല്യ അനുതാപം (എൽ. ഇ. ആർ.), ആപേക്ഷിക സാന്ദ്രതാ ഗുണകം (ആർ. സി. സി.), മത്സരാധിഷ്ഠിത അനുപാതം (സി. ആർ.), മരച്ചീനി തുല്യമായ വിളവ് (സി . ഇ. വൈ.) ആക്രമണക്ഷമത എന്നിവ പഠനത്തിന്റെ ഭാഗമായി രേഖപ്പെടുത്തുകയുണ്ടായി. എല്ലാ ഇടവിള കൃഷി സമ്പ്രദായത്തിലും ലഭിച്ച എൽ. ഇ. ആറിൻറെ മൂല്യം ഒന്നിനേക്കാളും മുകളിലാണ്, ഇത് സൂചിപ്പിക്കുന്നത് ഏകവിളകൃഷിയെ അപേക്ഷിച്ചു ഇടവിള കൃഷിക്കുള്ള ഉത്പാദന മികവിനെയാണ്. ഏറ്റവും ഉയർന്ന എൽ. ഇ. ആർ. ലഭിച്ചത് ഇരുവേലി മരച്ചീനിയിൽ ഇരട്ട വരിയായി ഇടവിള കൃഷി ചെയ്തപ്പോഴാണ് (1.41). അതുപോലെ ഏറ്റവും കുറഞ്ഞ എൽ. ഇ. ആർ. ലഭിച്ചത് കുറുന്തോട്ടി ഇരട്ട, ഒറ്റ വരിയായി കൃഷി ചെയ്തപ്പോഴാണ് (യഥാക്രമം 1.01, 1.05). ഉയർന്ന ആർ. സി. സി., സി. ആർ. മൂല്യങ്ങളും മരച്ചീനിയുടെ പോസിറ്റീവ് ആക്രമണക്ഷമത മൂല്യവും സൂചിപ്പിക്കുന്നത് ഔഷധസസ്യങ്ങളെക്കാൾ മരചീനിക്കുള്ള ആധിപത്യത്തെയാണ്.

മരച്ചീനിയിൽ നീലയമരി ഇരട്ടവരിയായി ഇടവിള കൃഷി ചെയ്ത സംവിധാനത്തിലാണ് ഏറ്റവും ഉയർന്ന സി. ഇ. വൈ. ലഭിച്ചത് (43895 കി. ഗ്രാം/ഹെ.). അതുപോലെ കുറുന്തോട്ടി ഏകവിളയായി കൃഷി ചെയ്തതിലാണ് ഏറ്റവും കുറവ് സി . ഇ. വൈ. ലഭിച്ചത് (3000 കി. ഗ്രാം/ഹെ.).

ഈ പഠനത്തിൽ നിന്നും നീലയമരി ഒറ്റ വരിയായോ ഇരട്ടവരിയായോ മരച്ചീനിക്കിടയിൽ കൃഷിചെയ്യുന്നതിന് ശുപാർശ ചെയ്യാവുന്നതാണ് എന്ന് വ്യക്തമായി. ഒറ്റവരി ഇരുവേലി ആണ് അടുത്ത മികച്ച ഇടവിള.