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Management of Waste Lands by Exploiting the Carbon Sequestration Potential and Climate Resilience of Cassava

K. Susan John, S.U. Shanida Beegum and V. Ravi

Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, 695017, Kerala, India
Corresponding Author: Susan John K, email: susanctcri@gmail.com
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Abstract

Among the tropical tuber crops, cassava is regarded as the most sustainable as evident from the results of a long term fertilizer experiment (LTFE) at CTCRI since 1977 as the crop could maintain an yield of 10-15 t ha^{-1} without any manures and fertilizers from the same field. The inherent physiological mechanism of the plant to shed its leaves at times of drought coupled with high leaf dry matter production and high leaf nutrient content is directly related to the C sequestration potential and the physio-chemical and biological nutrition of the soil for better tuberization and tuber bulking. The experience over 20 years under LTFE indicated that, through the acquisition of 60.38 ppm of atmospheric CO_2, the leaf dry matter production was 3.573 t ha^{-1}, reducing the atmospheric CO_2 to 317 ppm, increasing the SOC by 2780 ppm resulting a tuber yield to 26 t ha^{-1} under the recommended practice. The above potentialities of the cassava crop designate it as a sustainable climate resilient food security crop. These crop specificities need to be exploited to utilize the neglected waste lands to partially meet the rising food demand in addition to combating the current issues of rising atmospheric temperature under global warming.

Key words: Leaf carbon, soil organic carbon, tuber yield, global warming, food security

Introduction

Tropical root and tuber crops form an important staple serving as secondary or subsidiary food for about one fifth of the world population in tropics and sub tropics and are the third most important food crop after cereals and pulses (Edison, 2006). These crops possess higher biological efficiency (cassava- 121 megajoules/ha/day) as food producers and can serve as substitute for cereals (rice-121 megajoules/ha/day, wheat- 132 megajoules/ha/day) due to higher carbohydrate and calorie contents. Besides, they have potential as sources of alcohol, starch, sago flour, liquid glucose, vitamin C, raw materials for many other industrial products and animal feed. Hence, tropical tuber crops share a place with cereals as dietary staples both in raw and processed forms. They can be grown on a wide range of soil, climate and environment and have the capacity to withstand adverse biotic and abiotic stresses producing profitable yields. With surveys predicting acute food shortage (Prasad, 2013) with burgeoning population in India, in order to meet the food requirements by 2030, tuber crops assume importance with the due support of improved tuber crops technologies.

Among the tropical tuber crops, cassava is the most important which was introduced to India during 1880-1885 from Malaya by Sri Visakham Thirunal Maharaja of Travancore. It rescued the people to sustain their livelihoods during the days of famine by supplying same quantum of energy as that of rice. The main attributes of the crop can be listed as high biological efficiency comparable to rice and wheat, high yield potential to the tune of 20-50 t ha^{-1}, ability to sustain under marginal environments (especially drought)/ management conditions, less susceptibility to pests and diseases etc. The tolerance/resistance of the crop to drought can be attributed to its innate physiological mechanism by partial closure of stomata, shedding older leaves and forming smaller new leaves to reduce light interception, extracting water slowly from deep soils and ability to recover fast from stressed conditions (El-Sharkawy, 2007). Long-term experiments provide opportunities for assessing long term changes in SOC and crop yields and estimating C sequestration potential (CSP) of agricultural lands (Ladha et al., 2003). A LTFE experiment conducted at CTCRI, Thiruvananthapuram, India over three decades (1977-2014) on nutrient management of cassava demonstrated that, cassava was highly responsive to manures and fertilizers i.e. tuber yield was nearly doubled (26 t ha^{-1}) with recommended package of practices (POP) than absolute control (14 t ha^{-1}). At the same time, an yield range of 10-15 t ha^{-1} reported during these 20 years under LTFE through continuous cultivation of cassava without any manures and fertilizers in the same field could be due to its climate resilient attributes and C sequestration potential like the high leaf dry matter production, leaf shedding during water stress and high leaf nutrient content which in turn are directly related to its productivity. This paper discusses climate resilience and C sequestration potential of cassava to justify its sustainability under continuous cultivation as well as cassava's strong positive response to INM based on the results of LTFE conducted over a period of 20 years.

Materials and Methods

The C sequestering potential of cassava was estimated by determining (i) leaf dry matter production as an index of atmospheric CO_2 absorption by cassava for leaf dry matter production thereby reducing the CO_2 levels in the environment and (ii) soil organic carbon formed as a result of leaf shedding (during water stress condition) over a period of 20 years since 1991. From the LTFE, during each crop season, the number of fallen and retained leaves including the fresh weight of 10 leaves was taken at tri-monthly intervals since 3MAP till harvest. The leaf samples taken were dried in an oven at 65±5^{0}C to estimate dry weight. The total leaf dry matter produced per plant was calculated by combining data from fallen and retained leaves. According to Singh et al. (2007), plants absorb 1.69g atmospheric CO_2 to produce one gram of leaf dry matter which was used to estimate the atmospheric CO_2 utilized to produce the total leaf dry matter in cassava. The reduction in CO_2 content of the atmosphere through leaf production was calculated using the base CO_2 concentration of 360 ppm in 1990 along with an estimated annual increase of 1.5 ppm (Ramakrishna et al. 2006). All the observations were recorded on per plant basis and converted to per hectare by multiplying with the number of plants per hectare (12345). The initial soil organic carbon content at the base year of the experiment (1991) and the status after harvest of the crop during every year was calculated by collecting soil samples from individual plots to a depth of 0-20 cm and determining the soil organic carbon status through Walkley and Black (1934) wet digestion followed by titration method. Since the nutrient management practices involving the application of manures and fertilizers as per the recommended POP had significant effect on tuber yield over absolute control, the tuber yield during these years under both practices viz., absolute control and POP was recorded. After harvest, the leaf samples were collected, processed and analysed for nutrients viz., N, P, K, Ca, Mg, Fe, Cu, Mn and Zn using standard analytical procedures (Piper, 1970).

Results and Discussion

The main attributes viz., total leaf dry matter production, C sequestration, tuber yield and soil productivity in relation to cassava productivity under continuous cultivation under two management practices viz., absolute control and recommended POP are discussed in detail to substantiate the potential of cassava to sustain under continuous cultivation without plant nutrition as well as the strong positive response of the crop to plant nutrition with respect to the above parameters over a period of 20 years .

Reduction in atmospheric CO_2

In the field experiment, the total leaf dry matter produced under the two practices viz., absolute control and recommended POP ranged from 1.515 to 5.426 t ha^{-1} with an average value of 2.693 t ha^{-1} and 2.415 to 7.69 t ha^{-1} with an average value of 3.573 t ha^{-1} respectively (Fig.1).

The reduction in the atmospheric CO_2 was estimated from the base level of 360 ppm in 1990 as estimated by Ramakrishna et al., (2006). Using this value, the mean CO_2 concentration of the atmosphere during these 20 years

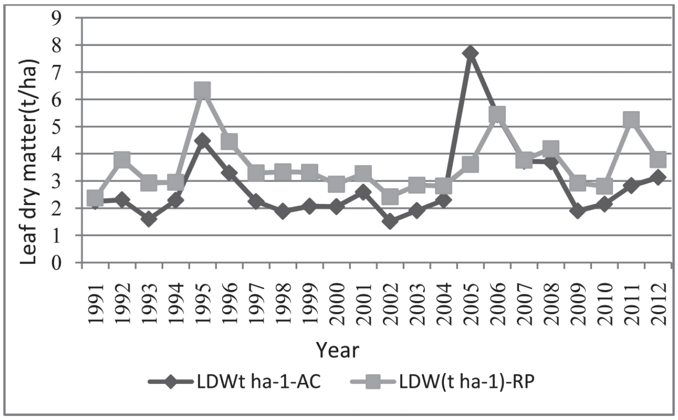

Fig.1. Leaf dry matter production (t ha^{-1}) under absolute control (AC) and recommended POP (RP) over a period of 20 years (1991-2012)

from 1991 to 2012 was calculated as 377.25 ppm. To produce the leaf dry matter as above to the tune of (average) 2.693 and 3.573 t ha^{-1}, the CO_2 absorbed from the atmosphere as per Singh et al. (2007) is arrived as 45.51 and 60.38 ppm respectively. Hence, the reduction in atmospheric CO_2 is calculated as 331.74 and 316.87 ppm respectively under absolute control and recommended POP respectively (Fig.2).

C Sequestration

As indicated earlier, C sequestration potential of cassava can be assessed through its ability to bring down atmospheric CO_2 through increased dry matter production and transferring them into soil organic carbon (SOC) through leaf shedding. In this case, the initial SOC under AC (0.67%) and POP (0.80%) were increased to 0.82 and 1.08% respectively in these treatments over a period of 20 years. The C sequestered during this period was calculated as 0.147 (1470 ppm) and 0.278% (2780 ppm) for AC and POP respectively. Though the C sequestration values varied across years, attributing these process being mediated to a great extent by soil physico-chemical and biological processes influenced by environmental factors, the enhancement appears to be high in POP than AC (Fig.3). This could be due to cassava's potential to respond positively to manures and fertilizers.

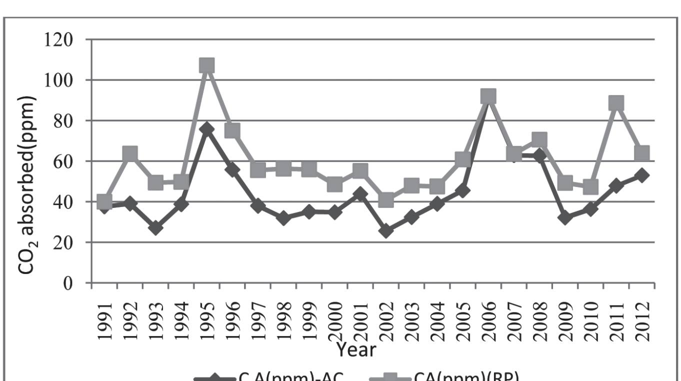

Fig.2. CO_2 absorbed (ppm) from the atmosphere for leaf dry matter production under absolute control (AC) and recommended practice (POP) over a period of 20 years (1991-2012)

Tuber yield

In this experiment, the mean tuber yield obtained in AC and POP over these years was 14.274 and 25.692 t ha^{-1} respectively.. The data clearly depicts the strong positive response of the crop to manures and fertilizers over absolute control during this period (Fig.4). The data on tuber yield under AC also establishes the sustainability of the crop by maintaining an yield of 7-25 t ha^{-1} over these years without any manures and fertilizers cultivated in the same field. Though the climatic and soil conditions differed during this period, the crop produced substantially good amount of leaf dry matter which might have increased the SOC and consequently improved the soil physico-chemical and biological properties for better tuberization and bulking. At the same time, the data demonstrated the positive effect of manures and fertilizers applied (as per recommended levels) in enhancing the leaf dry matter productivity than absolute control.

A comparative analysis of the effect of POP on C sequestration in comparison with AC is presented in Table 1. The quantum of C sequestration by cassava are consistent with the findings of Swarup (1998)

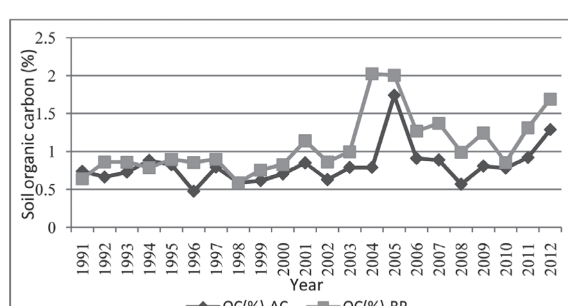

Fig.3. SOC (%) under absolute control (AC) and recommended practice (POP) over a period of 20 years

Table 1. A comparison of the parameters under absolute control and recommended practice (Mean over 20 years)

Management practices	Leaf dry matter (t ha^{-1})	Atmospheric CO_2 absorbed (ppm)	Reduction in atmospheric CO_2 (ppm)	Soil organic carbon content (ppm)	Carbon sequestered (ppm)	Tuber yield (t ha^{-1})
Recommended Practice (POP)	3.759	60.38	316.87	1.078	2780	25.692
Absolute Control (AC)	2.693	45.51	331.74	0.817	1470	14.274

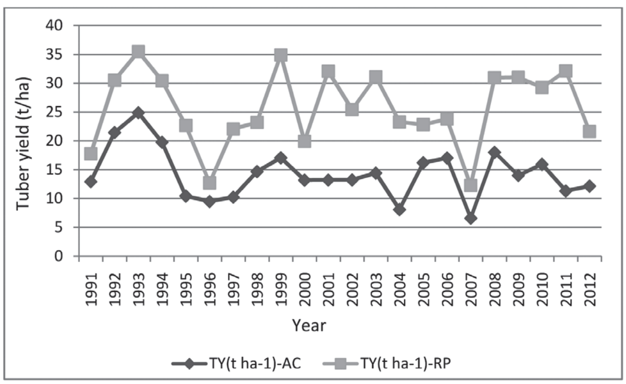

Fig.4. Tuber yield (t ha^{-1}) under absolute control (AC) and recommended practice (RP) over a period of 20 years

in rice and Ryan (1998) from other long term fertilizer experiments where the SOC pool increased with application of manures and fertilizers as per the POP recommendation. According to Lal (2007), the average rate of C sequestration in uplands is 300-500 kg ha^{-1} (0.013-0.0223%) and in wet lands, 800-1000 kg ha^{-1} (0.0357- 0.0446 %). Moreover, the average rate of C sequestration by adopting recommended crop management practices ranged from 50 to 1000 kg ha^{-1}. High rate of C sequestration by cassava can be attributed to its high leaf dry matter production to the tune of 3-6 t ha^{-1}, coupled with leaf residue incorporation in soil due to leaf shedding which in turn resulting an increase in SOC and sufficient foliage canopy giving a shade and thereby a cool soil climate slowing down organic matter mineralization and increases SOC accretion.

Cassava as a crop to mitigate global warming

As indicated earlier, the increase in CO_2 level of the atmosphere is the major cause for increase in atmospheric temperature, which in turn results in warming up of the entire environment including land, water and air. Crops like cassava can be presumed to possess global warming mitigation potential due to its effect in reducing the atmospheric CO_2 and consequently the atmospheric temperature through the production of large quantities of leaf biomass.

Cassava as a food security crop

The high biological efficiency of the crop in terms of conversion of solar energy into chemical energy (carbohydrate or starch) is well known and is comparable to any other starch yielding crops like rice, wheat or potato. Moreover, the high yield potential to the tune of 6-15 t ha^{-1} without plant nutrition and 20-50 t ha^{-1} with adequate manures and fertilizers narrate the significance of the crop as one which can sustain the food requirements of mankind.

It is also important to note that, the low management conditions the crop need after establishment compared to other field crops also encourages the farmers to cultivate this crop. The ability of the crop to thrive in marginal soil and adverse climatic conditions especially drought are factors favouring its cultivation by farmers in small homesteads and on a commercial scale. Further, the good monetary returns guaranteed by the crop even under marginal management conditions, makes it lucrative, insuring the farmer against any kind of adversities that may occur.

C sequestration versus soil productivity

Relation between C sequestration and food security can be interpreted in terms of two aspects viz., enhanced soil acquisition of carbon and humus/ residue accumulated in the soil forming a source of nutrients. Enhancing soil carbon acquisition results in increasing soil organic carbon levels, increase in soil quality, improvement in soil environment and increase in nutrient use efficiency which helped to increase the biomass yield. As regards to the latter, cassava leaf was observed to be rich in all nutrients, especially N. The cassava leaves collected and analysed found containing 4.41, 0.28, 1.25, 0.21, 0.321, 0.016, 0.0008, 0.0154 and 0.0064 % of N, P, K, Ca, Mg, Fe, Cu, Mn and Zn respectively. Hence, the maintenance of soil fertility through improvement in both soil organic matter as well as other plant nutrients also is another factor sustaining soil productivity contributing to high crop productivity and thereby food security through the cultivation of this crop.

Conclusion

Taking into account the above potentialities of cassava under rain fed conditions and the extent of neglected / waste lands on a regional national and global perspective comprising of barren and uncultivable land, cultivable waste, current fallow and fallow other than current fallow, effective utilisation of these lands through cassava cultivation can not only address the food requirement but also improve the soil carbon and nutrient status and mitigate global warming by reducing the atmospheric CO_2 concentration The experience over 20 years in cassava as regards to the potential of the crop to produce substantial quantum of leaf biomass by utilizing the atmospheric CO_2 which in turn forms a part of the SOC through C sequestration vividly points to the need for the exploitation of the above potentials of the crop in managing the neglected waste lands to meet partially the rising food demand in addition to addressing the issues related to global warming.

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