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Nutrient Efficient Genotypes and Nutrient Management Practices in the Carbon Sequestration Potential of Cassava: a Theoretical Approach

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Abstract

Cassava is an important food security crop of the present millennium, which is tolerant to vagaries of weather, especially drought. An attempt has been made to assess the impact of nutrient efficient genotypes and nutrient management practices on the C sequestration ability of the crop so as to delineate it as a benign crop to combat climate change. For this, an experiment was conducted in factorial CRD during 2011 under controlled condition with combinations of four genotypes (Acc. No. 766, Acc. No. 788, Acc. No. 130 and H-1687) and four nutrient management practices. The nutrient management practices were Package of Practices recommendation (POP) (organic + major nutrients), soil test based fertilizer (STBF) recommendation (organic + major + secondary + micronutrients), POP + biofertilizers and low input management practice (green manuring *in situ* with cowpea as organic manure source + STBF (major + secondary + micronutrients) + nutrient efficient biofertilizers). The parameters calculated theoretically were leaf dry matter production, C content in leaf dry matter, atmospheric CO_2 absorbed for leaf dry matter production, total biomass production and soil organic C. The genotype Acc. No.130 was significantly different with the highest leaf dry matter production, leaf C and CO_2 absorption potential. However, H-1687 sequestered the maximum C, which was on par with Acc. No. 130 and Acc. No. 788. Though the nutrient management practices had significant effect on all parameters, there was no significant effect on C sequestered, as the final soil organic C was not significantly different. The Acc.No.130 under STBF recommendation resulted in significantly highest leaf dry matter production (0.84 t ha^{-1}), leaf C content (0.38 t ha^{-1}) and CO_2 absorption (13.86 ppm).

Key words: Cassava, nutrient efficiency, low input, STBF, biofertilizers, C sequestration

Introduction

Carbon sequestration, global warming and food security are the three major interrelated hot topics associated with global environmental change. Increase in CO_2 concentration of the atmosphere has prompted renewed interest in increasing the carbon (C) stocks in the world's crop lands to mitigate climate change and also to improve soil quality (IPCC, 2000; Lal, 2004a; 2004b).

Carbon sequestration is an important strategy for enhancing soil quality and increasing agronomic productivity through removal of atmospheric CO_2 by plants and storage of fixed C as soil organic matter (Lal, 2004c). Soil organic carbon (SOC) constitutes a significant proportion of the terrestrial C store and has important roles in several physical, chemical and biological soil processes that contribute to soil productivity and sustainability (Ghosh et al., 2010). Soils are the largest carbon reservoirs of the terrestrial C cycle and contain about three times more C than vegetation and twice as much as that present in the atmosphere (Batjes, 1996).

The amount and length of storage of C stock of soil and vegetation is mainly dependent upon factors viz., climate, natural vegetation, soil type, drainage, plant species and crop and soil management practices (CBO, 2007). Among the different options to mitigate global warming, sustainable soil management of agro-ecosystems deserves special mention. Optimum levels of SOC can be managed through selection of appropriate crop species and proper soil fertility management. Better soil fertility management through soil testing, precision farming and proper nutrient application can also lead to lowering of green house gas emissions (Kumar et al., 2006).

Among the tropical tuber crops, cassava (*Manihot esculenta* Crantz) is considered most important due to its high biological efficiency (250 kcal $ha^{-1}day^{-1}$), yield potential (80-100 t ha^{-1}), ability to sustain marginal management conditions, less incidence of pests and diseases, high starch extraction rate and excellent physico-chemical properties. Because of its high leaf dry matter production, cassava absorbs more atmospheric CO_2 with high C output/input ratio.

Crops like cassava, which has the inherent property of leaf shedding to withstand rising atmospheric temperature increase the SOC through leaf shedding and its high leaf dry matter production absorbs more atmospheric CO_2. Since the average leaf dry matter production in cassava is to the tune of 3 - 4 t ha^{-1}, as per the theoretical approach we are trying to project the quantum of CO_2 absorbed for producing the above quantity of leaf dry matter. It absorbs CO_2 and assimilates that into biomass and hence utilizes CO_2 with very high conversion efficiency with a tuber output of 25-50 t ha^{-1}. Moreover, sufficient foliage canopy gives a cool soil climate, slowing down the organic matter mineralization minimizing the effects of resource quality and quantity on C input and output through temperature and moisture mediated effects on SOC mineralization and carbon leaching.

Based on a preliminary study conducted to understand the C sequestration potential of cassava (Susan John et al., 2011), the present study aimed at assessing the C sequestration capacity of different nutrient efficient cassava genotypes, different nutrient management practices and their interaction in laterite soils under controlled condition.

Materials and Methods

The experiment was conducted in a glass house during 2011 to monitor the changes in C sequestration potential of four selected cassava genotypes including three nutrient efficient lines under four nutrient management practices. The selected genotypes were:

G_1: Acc. No. 766

G_2: Acc. No. 788

$G_{3:}$ Acc. No. 130

$G_{4:}$ Sree Visakham (H-1687)

The four nutrient management practices were:

N_1: package of practices (POP) recommendation of cassava (FYM @12.5 t ha^{-1}+NPK @ 100:50:100 kg ha^{-1})

N_2: soil test based fertilizer (STBF) recommendation (FYM @ 10 t ha^{-1}+NPK @ 78:0:83 kg ha^{-1} + $MgSO_4$ @ 20 kg ha^{-1} + $ZnSO_4$ @ 12.5 kg ha^{-1} (Aiyer and Nair, 1985; Susan John et al., 2010)

N_3: POP +biofertilizers (N fixer + P solubilizer + K solubilizer @ 10 g $plant^{-1}$) and

N_4: low input management practice (green manuring *in situ* with cowpea as the source of organic manure + STBF recommendation (N, P, K, Mg and Zn) as in N_2+ biofertilizers as in N_3).

The experiment was conducted in fibre glass pots of 0.6 m^3 volume filled with 12 kg soil and the treatments were imposed at specific intervals as basal and top dressing.The number of fallen and retained leaves and leaf fresh weight were recorded at three months interval till 9 months after planting (MAP). The leaf samples were dried in an oven at 65 ± 5^0C and from the dry weight of the leaves at three intervals and from the number of retained and fallen leaves, the total leaf dry matter production per plant was calculated.

The leaf C content in the leaf dry matter was estimated based on the relation that 1 g dry matter contains 0.45 g carbon (Jian Ni, 2004). The CO_2 absorbed from the atmosphere to produce the leaf dry matter was estimated based on the fact that 1.69 g atmospheric CO_2 is absorbed to produce 1g dry matter (Singh et al., 2007). As per IPCC (2001), the atmospheric CO_2concentration during 1999 was 367 ppm and the CO_2 concentration of the atmosphere was increasing @ 1.5 ppm per year (Ramakrishna et al., 2006). From these information, the CO_2 concentration during 2011 was estimated as 385 ppm. Hence, the conversion efficiency of the crop towards total biomass production was calculated. All the above parameters were correlated with the initial and final soil organic C content, which was determined by Walkley and Black (1934) titration method. Analysis of variance was performed on different parameters studied to determine the effects of different treatments. Critical difference (CD) test was used at 0.05 level of probability to test differences between treatment means. The mean values were compared using Duncan's Multiple Range Test (DMRT).

Results and Discussion

The effect of different genotypes, nutrient management practices and their interaction showed significant effect on almost all parameters. In the case of cassava genotypes, Acc. No.130 (G_3) resulted in the maximum leaf dry matter production, leaf C and CO_2 absorption from the atmosphere (Table 1). Crop species play an important role in maintaining quantity and quality of SOC stock despite diverse nature of crop residues with highly variable turnover or residence time in the soil (Mandal et al., 2007).

The final soil organic C content was significantly higher for all the genotypes, compared to the initial status as all the leaves produced by the plant were shed in the same pot itself and contributed to the organic C content of the soil after decomposition. However, the check variety, H-1687 (G_4) showed the maximum C sequestration (1.13 %), which in turn was on par with G_2 (Acc. No. 788) and G_3 (Acc. No. 130).

In the case of nutrient management practices, significant effects were noticed for leaf dry matter production, leaf C and CO_2 absorption from the atmosphere (Table 2). Significantly highest values of the above parameters were observed for the treatment N_1. As no significant effect of management practices was noticed in the case of final soil organic C content, the C sequestered also did not show any significant effect. It can hence be presumed that the low input nutrient management strategy (N_4) can be considered as a better option for the conversion of atmospheric CO_2 to SOC. As this is an integrated nutrient management (INM) practice that involves the use of organic manures, chemical fertilizers and biofertilizers, it can lead to the sustenance of soil quality and soil health to a great extent (Lal, 2011).

According to Li and Feng (2002), by following proper management practices in agricultural soils, C emissions from agricultural activities can be reduced by the conversion of atmospheric CO_2 to SOC. This increased SOC in agricultural soils through the application of inorganic and organic materials can enhance the soil quality, reduce soil erosion and degradation, nutrient use efficiency of the crop and thereby soil productivity.

Table 1. Carbon sequestration potential of cassava genotypes

Genotypes	Leaf dry matter (t ha^{-1})	Leaf C (t ha^{-1})	Atmospheric CO_2 absorbed (ppm)	Initial soil organic C (%)	Final soil organic C (%)	C sequestered (%)
G_1	0.404^{d}	0.181^{d}	6.67^{d}	0.83^{a}	1.58^{b}	0.76^{b}
G_2	0.460^{c}	0.207^{c}	7.60^{c}	0.77^{c}	1.69^{b}	0.92^{a}
G_3	0.601^{a}	0.270^{a}	9.91^{a}	0.75^{d}	1.78^{a}	1.04^{a}
G_4	0.541^{b}	0.243^{b}	8.93^{b}	0.81^{b}	1.94^{a}	1.13^{a}

Values with the same superscript in a coloumn are not significantly different

Table 2. Effect of management practices on C sequestration

Management practice	Leaf dry matter (t ha^{-1})	Leaf C (t ha^{-1})	Atmospheric CO_2 absorbed (ppm)	Initial soil organic C (%)	Final soil organic C (%)	C sequestered (%)
N_1	0.605^{a}	0.272^{a}	9.99^{a}	0.81^{b}	1.85^{a}	1.04^{a}
N_2	0.603^{b}	0.271^{b}	9.95^{b}	0.74^{c}	1.67^{a}	0.93^{a}
N_3	0.437^{c}	0.197^{c}	7.21^{c}	0.85^{a}	1.83^{a}	0.98^{a}
N_4	0.361^{d}	0.162^{d}	5.96^{d}	0.75^{c}	1.65^{a}	0.90^{a}

Values with the same superscript in a coloumn are not significantly different

The interaction effect of genotypes and management practices was significant. Highest leaf dry matter production (0.84 t ha^{-1}), leaf C content (0.37 t ha^{-1}) and CO_2 absorbed (13.86 ppm) were observed in the case of Acc. No.130 under N_2 (STBF recommendation for FYM, N, P, K, Mg and Zn) (Tables 3, 4 and 5). The findings are in conformity with the reports of Lal (2007) that soil, crop type and management practices can affect the C sequestering ability of a soil. Long-term field experiments have contributed significantly to the current knowledge of soil condition and have been used to study the influence of crop management, fertilizer application and tillage practices on SOM content (Hernanz et al., 2002). Such long-term experiments have also added much to the understanding of the complex issue of C sequestration in soil and particularly the quantification and prediction of the C sink potential of arable soils (Rogasik et al., 2004).

Table 3. Interaction effect of cassava genotypes and nutrient management practices on leaf dry matter production (t ha^{-1})

Genotypes	N_1	N_2	N_3	N_4	Mean
G_1	0.411	0.298	0.587	0.320	0.404^d
G_2	0.702	0.585	0.305	0.250	0.460^c
G_3	0.535	0.840	0.368	0.663	0.601^a
G_4	0.774	0.689	0.490	0.214	0.541^b
Mean	0.605^a	0.603^b	0.437^c	0.361^d	

CD (0.05) (G) : 0.056; CD (0.05) (N) : 0.056; CD (0.05) (G × N) : 0.112

Mean values with the same superscript within a row or coloumn are not significantly different

Table 4. Interaction effect of cassava genotypes and nutrient management practices on total biomass production (t ha^{-1})

Genotypes	N_1	N_2	N_3	N_4	Mean
G_1	1.36	1.00	1.17	1.24	1.18^d
G_2	1.43	1.64	1.24	1.17	1.37^c
G_3	1.26	2.19	1.51	1.71	1.67^a
G_4	1.71	1.54	1.76	1.12	1.53^b
Mean	1.44^b	1.59^a	1.42^c	1.30^d	

CD (0.05) (G) : 0.01; CD (0.05) (N) : 0.01; CD (0.05) (G × N): 0.09

Mean values with the same superscript within a row or coloumn are not significantly different

Table 5. Interaction effect of cassava genotypes and nutrient management practices on atmospheric CO_2 absorbption (ppm)

Genotypes	N_1	N_2	N_3	N_4	Mean
G_1	6.788	4.924	9.693	5.278	6.670^d
G_2	11.587	9.659	5.032	4.123	7.600^c
G_3	8.822	13.867	6.055	10.933	9.919^a
G_4	12.764	11.372	8.082	3.532	8.937^b
Mean	9.990^a	9.955^b	7.215^c	5.965^d	

CD (0.05) (G) : 0.011; CD (0.05) (N) : 0.011; CD (0.05) (G × N) : 0.022

Mean values with the same superscript within a row or coloumn are not significantly different

The inherent leaf shedding property coupled with high leaf dry matter production (3-4 t ha^{-1}) of cassava is directly related to the C sequestration potential of the crop through the conversion of atmospheric CO_2 as leaf C, which forms a part of SOC through leaf residue and reduces the air CO_2.

According to Hooper et al (2005), promotion of soil C input relative to soil C loss can be achieved through complementarity or through the facilitation of plant traits that enhance C sequestration at community level.

Conclusion

This preliminary study based on a theoretical approach with nutrient efficient genotypes and nutrient management practices on the C sequestration potential of cassava indicated a wide variation in cassava genotypes with respect to CO_2 acquisition and its conversion towards biomass production and hence the C sequestered as SOC. Hence, this information can be very well utilized in selecting crop species from the point of view of mitigating climate change along with attaining food security.

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