Journal of Root Crops, 2015, Vol. 41 No. 2, pp. 42-48
Indian Society for Root Crops
ISSN 0378-2409, ISSN 2454-9053 (online)

Low Cost Cassava Production Strategy through Nutrient Use Efficient Genotypes Integrated with Low Input Management

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Received: 4 March 2015; Accepted: 3 August 2015

Abstract

Nutrient use efficient (NUE) genotypes and low input nutrient management practices are becoming important at present due to escalating fertilizer prices and its hazardous impact on the environment. Cassava, being a crop managed with low inputs by resource poor farmers, the present study was taken up to test the possibility of integrating NUE genotypes with low cost soil fertility management practices in reducing the quantity of external inputs to generate an economically feasible and environmentally sustainable management practice for the crop. Having been understood the superiority of NUE genotypes under low input management under controlled conditions for cassava, field experiments were conducted for two years (2012-2014) in split plot design with four genotypes (3 NUE plus one check) as main plot treatments and four nutrient management practices as subplot treatments. NPK efficient genotypes (Acc. No. 905 and 906) under low input management practice comprising green manuring *in situ* with cowpea as organic manure source, soil test based fertilizer (STBF) application for major, secondary and micronutrients and nutrient efficient bio fertilizers were found promising in terms of tuber yield and B: C ratio, saving P, K, Mg and Zn to the tune of 100, 11.5, 62.5 and 80 % respectively over POP. The percentage increase in input cost under the other practices over the low input practice varied significantly up to 55%.

Key words: Nutrient uptake, tuber yield, root architecture, C sequestration, B:C ratio

Introduction

According to Fageria et al. (2008), during this millennium, the essential plant nutrients would be the single most important factor limiting crop yield especially in developing countries. Though fertilizer use is attributed to higher yield percentage, its efficiency is around 40-60% only. In this regard, the potential of NUE genotypes need to be explored to exploit their unique attribute in scavenging the slowly available and unavailable soil nutrient reserves to reduce/substitute for chemical fertilizers. Rengel and Paul (2008) had already reported genotypic differences in K efficiency, uptake and utilization for all major economically important plants. According to Graham (1984), the genotypic variation in nutrient uptake and utilization is associated with better root geometry, ability of plants to take up sufficient nutrients from lower or sub soil concentrations, plants' ability to solubilize nutrients in the rhizosphere, better transport, distribution and utilization within plants and balanced source sink relationships.

Among the tropical tuber crops, cassava (*Manihot esculenta* Crantz) is the most important one as it provides food, nutrition, income and employment security to more than 500 million people globally. Cassava is having high N and K requirement and K is considered as the key nutrient with respect to both productivity and tuber quality. Since cassava being primarily cultivated for edible and industrial uses, preliminary efforts were streamlined for identifying K efficient genotypes suited for the above purposes. Later, realizing the worth of K efficient genotypes in reducing the K fertilizer dosage, attempts were made to identify NPK efficient genotypes as well as their potential under different nutrient management regimes for the possibility to substitute/ reduce chemical fertilizers. NUE potential of the crop is associated with other unique characters viz., C sequestration, tuber yield, root architecture, enzyme activity etc. The high leaf dry matter production coupled with the leaf shedding nature of cassava contributes to the innate C sequestering potential of the crop (Susan John et al., 2014). Dry matter production and partitioning are important determinants of storage root yield in cassava (Augustin et al., 1977) and is governed by plant nutrient availability either through nutrient management or NUE genotypes to extract soil nutrients (Kamara et al., 2003). Hence, these factors need to be explored elaborately to understand and modify the existing nutrient management practices in evolving an economically feasible and environmentally sustainable integrated approach for crop management. The present integrated nutrient management (INM) strategy for the crop involving chemical fertilizers are costlier and environmentally non sustainable from the point of view of escalating fertilizer prices, its hazardous effect on environment as well as the non renewable nature of the raw materials for fertilizer manufacture. Taking into account the above constraints, an attempt was initiated at ICAR-CTCRI from 2008 onwards to identify some nutrient use efficient (NUE) genotypes with a view to reduce the fertilizer inputs.

Materials and Methods

Field experiments to study the integrated approach involving NUE genotypes along with low cost nutrient management practices were conducted during 2012-2013 and 2013-2014 at Block IV of ICAR- CTCRI farm. The soil of the experimental site was acidic (pH 4.98) with an overall low soil fertility as available N, P, K, Mg, Zn and organic carbon content to the tune of 84.97, 54.08, 157.46 kg ha^{-1}, 0.989 meq 100 g^{-1}, 2.20 μg^{-1} and 0.48 % respectively (these soil test values were used to arrive at the soil test based FYM, N, P, K, Mg and Zn recommendation under STBF). The experiment was laid out in split plot design having three replications with four selected cassava genotypes including three NUE lines as the main plot treatments and four nutrient management practices as sub plot treatments. The selected genotypes were: G1: Acc. No. 766, G2: Acc. No. 905, G3: Acc. No. 906 and G4: H-1687 (Check). The four nutrient management practices were: N1: Package of Practices (POP) recommendation for cassava (FYM @12.5 t ha^{-1}+NPK @ 100:50:100 kg ha^{-1}), N2: STBF recommendation for FYM, N,P, K, Mg, Zn (FYM @ 12.5 t ha^{-1}+NPK @ 106:0:88.5 kg ha^{-1} + $MgSO_4$@ 7.5 kg ha^{-1} + $ZnSO_4$@ 2.5 kg ha^{-1}) (Aiyer and Nair, 1985; Susan John et al., 2010), N3: POP + bio fertilizers (mixture of N fixer, P and K solubilizers @ 10 g each $plant^{-1}$), N4: 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 N2 + bio fertilizers as in N3). Compared to POP (N1), the low input management (N4) comprised the low cost organic manuring practice of green manuring *in situ* with cowpea in place of FYM @ 12.5 t ha^{-1}, low external fertilizer input of P, K, $MgSO_4$, $ZnSO_4$ @ 0: 88.5:7.5:2.5 kg ha^{-1} in place of the POP recommendation of P, K, $MgSO_4$, $ZnSO_4$ @ 50:100: 20:12.5 kg ha^{-1}.

Biometric observations were recorded along with destructive sampling of representative plants at 3 months interval up to 9 months after planting (MAP). The leaf samples were processed and from the dry weight of the samples at 3 intervals, the total leaf dry matter production per plant was calculated. Tuber yield from net plot at harvest was recorded and was converted to per hectare. The C sequestration potential was assessed based on a theoretical approach taking into account the leaf dry matter production, atmospheric CO_2 absorbed for leaf dry matter production, hence its reduction in atmosphere and consequent increase in soil organic carbon status through cassava leaf shedding. CO_2 absorbed from the atmosphere to produce the leaf dry matter was arrived following Singh et al. (2007) that is, to produce 1g dry matter, 1.69g CO_2 is absorbed from the atmosphere. Initial soil samples as well as at 3 months interval samples up to 9MAP were processed and analysed for all chemical parameters (Jackson,1973). Soil enzymes viz., dehydrogenase, urease, nitrate reductase and acid phosphatase (Chhonkar et al., 2005) activity also was determined.

Since root architecture is considered as one of the important factors contributing to better nutrient uptake and utilization, rooting pattern also was studied by growing the plants in pots and taking the observations of different root characters viz., root length, mean root diameter, mean root weight and number of white roots at monthly intervals till 5MAP. Economic parameters viz., cost of cultivation, gross income, net income and B:C ratio were also computed. The data obtained were statistically analysed using SAS for the independent as well as interaction effect of genotypes, management practices and plant growth stages and were compared using Duncan's multiple range test (DMRT).

Results and Discussion

The major parameters computed to confirm the efficacy of NUE plants coupled with nutrient management practices in reducing the nutrient dosage, and hence the inputs and its ultimate impact on tuber yield and economics is as follows:

Tuber yield

During both the years, the independent effect of genotypes and interaction effect of genotypes and nutrient

Table 1. Effect of genotypes and nutrient management practices on tuber yield (t ha^{-1})

(2012-13) Genotypes (G)	Management practices POP (N1)	STBF (N2)	POP+BF (N3)	Low input (N4)	Mean (Genotypes)
Acc. No. 766 (G1)	29.72	20.69	24.39	18.16	23.24
Acc. No. 905 (G2)	29.44	24.07	25.80	32.19	27.87
Acc. No. 906 (G3)	26.94	30.34	30.04	36.45	30.94
H-1687 (G4)	27.33	23.28	24.50	22.05	24.29
Mean (Management practices) (M)	28.50	27.87	30.94	29.44	
CD(G)	3.265				
CD(GXM)	3.362				
CD(M)	NS				
2013-14					
Acc. No. 766	30.22	23.54	28.58	20.17	25.63
Acc. No. 905	33.68	31.95	29.96	35.17	32.69
Acc. No. 906	26.70	30.19	28.74	32.99	29.66
H-1687	22.16	23.10	25.85	23.73	23.71
Mean (Management practices)	28.19	27.20	28.28	28.02	
CD(G)	2.98				
CD(GXM)	2.06				
CD(M)	NS				
Pooled Mean					
Acc.No.766	29.97	22.11	26.48	19.16	24.43
Acc. No. 905	31.56	28.01	27.88	33.68	30.28
Acc. No. 906	26.82	30.26	29.39	34.72	30.30
H-1687	24.74	23.19	27.61	23.26	24.00
Mean (Management practices)	28.34	27.53	29.61	28.73	
CD(G)	3.12				
CD(GXM)	2.71				
CD(M)	NS				

management practices showed significant effect on tuber yield (Table1). During the first year, among the genotypes, Acc. No. 906 recorded the highest tuber yield (30.94 t ha^{-1}) which was on par with Acc. No. 905 (27.87 t ha^{-1}) and in the second year, Acc. No. 905 recorded significantly the highest tuber yield (32.69 t ha^{-1}) followed by Acc. No. 906 (29.66 t ha^{-1}). However, during both the years, management practices did not show any significant difference indicating that, low input management strategy involving low cost nutrient management practices like green manuring *insitu* with cowpea and STBF recommendation of major, secondary and micronutrients and NUE bio fertilizers is on par with other high input practices. As regards to the interaction effect, Acc. No. 906 under low input management recorded the highest tuber yield (36.45 t ha^{-1}) which was significantly superior to all other combinations during the first year. During the second year, Acc. No.905 under low input management registered significantly higher tuber yield (35.17 t ha^{-1}) followed by Acc. No. 906 (32.99 t ha^{-1}). The pooled mean over these two years indicated, the genotypes viz., Acc. No. 905 and Acc. No. 906 as superior, as these genotypes under low input nutrient management performed outstandingly well with on par yields to the tune of 34.72 and 33.68 t ha^{-1} respectively (Table 1) suggesting that, NUE genotypes under low input INM strategy is a better practice for reducing the chemical fertilizers as well as traditional organic manure (FYM) for cassava. These findings corroborate to the reports of Smith et al. (1994) regarding the need to breed crop plants for better nutrient use efficiency so that the dependence on chemical fertilizer can be reduced.

The reasons attributed for the low input requirement of these NUE genotypes can be partially attributed to the potential of these genotypes in leaf dry matter production and hence high C sequestration, better root biomass and sufficient soil enzyme activities.

Leaf dry matter production

Though there was no significant effect of genotypes, management practices and their interaction on total leaf dry matter production during the second year, genotypes indicated significant effect on leaf dry matter during the first year with Acc. No.905 having the maximum (1.14 t ha^{-1}) which was on par with Acc. No. 906. The effect of management practices were significant during 9MAP with N3 recording the highest (0.836 t ha^{-1}) which was on par with low input practice (0.701 t ha^{-1}) (Fig.1a and 1b). The findings were in conformity with the reports of Akparobi et al. (1999) that, cassava genotypes that produce high leaf dry matter also produce high root yield.

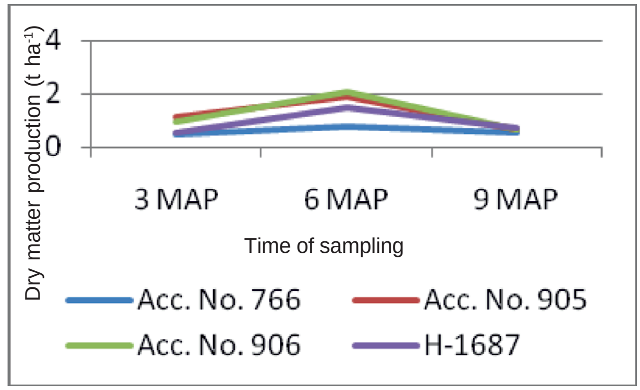

Fig.1a. Effect of genotypes on leaf dry matter (t ha^{-1}) production

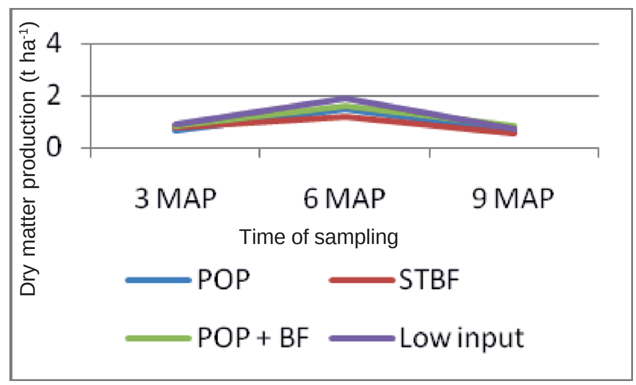

Fig.1b. Effect of management practices on leaf dry matter (t ha^{-1}) production

Root biomass

The pot experiment carried out for 5 months with monthly sampling indicated the presence of maximum number of white roots (responsible for water and nutrient absorption) including highest root biomass for Acc. No. 905 and 906 to the tune of 8-10 g/plant compared to 3-5 g/plant in other two genotypes (Table 2) which in turn affirm the NUE potential of these two genotypes. Rengel and Paul (2008) stated that, the main mechanism underlying K utilization efficiency is the ability of the genotypes in K uptake through larger surface area of contact between roots and soil and increased uptake at the root–soil interface to maintain a larger diffusive gradient towards roots.

Table 2. Root dry matter of different genotypes

	Thin white roots (g/plant)					Thick roots (g/ plant)			
Genotype	1MAP	2MAP	3MAP	4MAP	5MAP	2MAP	3MAP	4MAP	5MAP
Acc. No.766	0.10	0.83	3.17	0.99	0.73	0.003	0.029	0.010	0.011
Acc. No.905	1.11	4.07	7.46	2.30	2.81	0.097	0.037	0.040	0.034
Acc. No.906	0.46	4.89	9.47	2.66	4.85	0.097	0.039	0.037	0.041
H-1687	0.03	2.85	4.84	1.40	1.41	0.087	0.032	0.039	0.041

Carbon sequestration potential

Since leaf dry matter production (LDMP) is taken as an index to compute the atmospheric CO_2 absorbed to produce leaf carbon which in turn through leaf shedding formed a part of soil organic C (SOC) (conversion of atmospheric CO_2 to SOC is C sequestration), the LDMP taken at different growth stages was used to arrive at the C sequestration potential of the crop. Among the different nutrient management practices, the maximum leaf dry matter production, leaf carbon, CO_2 absorption from the atmosphere were observed under low input management strategy, and hence the maximum C sequestration in the form of SOC (0.25%) during both the years. As regards to the interaction effect, Acc. No. 905 under POP recommendation resulted in maximum C sequestration which was on par with the same genotype under low input management. Since soil organic C is the most important indicator for C sequestration, SOC determined during both the years indicated significantly higher status with low input management to the tune of 0.75% (Table 3). Lal (2007) and Li and Feng (2002) reported that, soil, crop type and management practices can affect the C sequestering ability of a soil through reduction in C emissions from agricultural activities through the conversion of atmospheric CO_2 to SOC.

Enzyme activities

Soil enzymatic activity is a critical index of soil fertility because enzymes play an important role in nutrient cycles (Dick et al., 1996). During the first year, variation in enzyme activities was observed among different genotypes at 3MAP (Table 4) and the nitrate reductase activity was significant (0.0833 μg/h/g) under POP at 3MAP which was on par with STBF and low input management. Though, no significant effect of either genotypes, management practices or their interaction was recorded during the second year, highest dehydrogenase, acid phosphatase and nitrate reductase activity was observed under Acc. No. 906 and lowest under Acc. No. 905 among the genotypes. Urease activity was highest under H-1687 and lowest under Acc. No. 766 throughout the growth stages. As soil organic matter is the recalcitrant complex for microbial enzyme activities, the SOC must have a bearing on the C sequestered which in turn affect the soil aggregate structure and stability, plant nutrient availability, water retention and incidentally the tuber yield (Powlson et al., 2011).

Table 3. Effect of management practices on carbon sequestration (Mean of 2 years)

Management practice	Leaf dry matter ($t\ ha^{-1}$)	Leaf carbon ($t\ ha^{-1}$)	Atmospheric CO_2 absorbed (ppm)	Initial soil organic carbon (%)	Final soil organic carbon (%)	Carbon sequestered (%)
POP (N1)	0.356	0.160	13.61	0.49	0.63	0.24
STBF (N2)	0.342	0.153	14.92	0.39	0.57	0.18
POP + BF (N3)	0.565	0.254	27.09	0.41	0.58	0.17
Low input (N4)	0.478	0.214	30.65	0.50	0.75	0.25
Mean	0.631	0.284	10.35	0.36	0.55	0.19
p-Value	0.1820	0.1819	0.1884	0.1963	0.0148	0.0269
CV (%)	44.78	44.77	46.50	36.31	25.61	46.91

Table 4. Effect of genotypes on soil enzyme activity

Genotypes	Enzyme activity			
	Dehydrogenase (mg TPF formed g^{-1} h^{-1})	Acid phosphatase (μg PNP released g^{-1} h^{-1})	Urease (mg urea g^{-1} h^{-1})	Nitrate reductase (mg NO_2-N produced g^{-1} h^{-1})
Acc. No. 766	0.0129^{b}	29.14^{ab}	0.221	0.08329^{ab}
Acc. No. 788	0.0094^{b}	23.07^{b}	0.231	0.08330^{a}
Acc. No. 130	0.0178^{a}	32.93^{a}	0.241	0.08328^{b}
H-1687	0.0123^{ab}	28.44^{ab}	0.242	0.08330^{a}
Mean	0.0131	28.39	0.234	0.08329
p-Value	0.0515	0.1719	0.2824	0.0414
CV (%)	44.18	29.29	10.07	0.019

Economics of the nutrient management strategy

Economic analysis of the different nutrient management practices for the different NUE genotypes indicated, the highest B:C ratio of 4.57 for Acc. No. 906 under low input practice closely followed by Acc.No.905 (4.43) under the same practice (Fig.2). Moreover, the percentage increase in cost of inputs was to the tune of 13, 1.5 and 55 % respectively for POP, STBF and POP along with bio fertilizers over the low input practice. The low input management strategy could save P, K, Mg and Zn to the tune of 100, 11.5, 62.5 and 80 per cent.

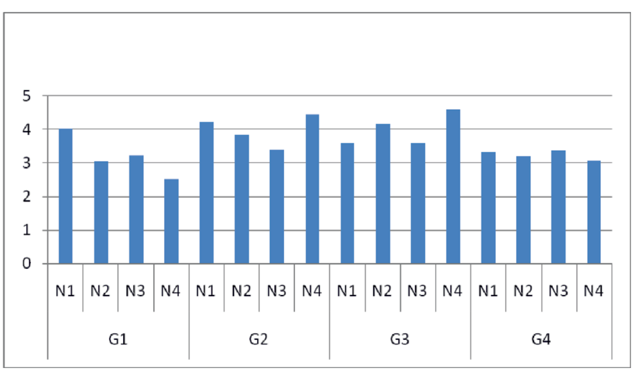

Fig.2. B:C ratio under different nutrient management practices with different NUE genotypes

Conclusion

This maiden attempt could establish the possibility of minimizing the fertilizer cum manurial inputs through NUE genotypes with reduced levels of external nutrient application based on soil test data under the low input INM strategy. This needs to be popularized especially under the present scenario of escalating fertilizer prices, scarce availability of fertilizers at times of need and changing global environment. Studies can be carried out up to molecular level to identify the gene sequence responsible for NUE with respect to nutrient absorption and utilization for each of the identified cultivars of different tuber crops and the extent up to which the dependence on fertilizers can be substituted by these NUE genotypes.

Acknowledgement

The first author is thankful to Kerala State Council for Science, Technology and Environment for the financial support.

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