# Nutrient efficient genotypes in cassava: Scope to substitute for chemical fertilizers and in C sequestration

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# Nutrient efficient genotypes in cassava: scope to substitute for chemical fertilizers and in C sequestration

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***Abstract***

**Though cassava is a climate resilient crop having innate physiologic ability to sustain under rising atmospheric temperature, escalating fertilizer prices and its marginal availability has resulted in imbalanced plant nutrition affecting tuber yield, soil health as well as farmers' income. Hence, an attempt was made to see the response of some selected nutrient efficient cultivars under different nutrient management practices in substituting for chemical fertilizers as well as on growth and yield attributes. The study over 5 years revealed a better scope for these genotypes in sustaining the productivity in low innate fertile soils like Ultisols. Screening 100 elite genotypes for their agronomic and physiological efficiency resulted in the selection of six K efficient lines, 3 each for edible and industrial uses. Evaluation of these genotypes at 4 levels (0, 50, 100, and 150 kg ha$^{-1}$) of K for 3 consecutive years and computation of NUE parameters and physiologic parameters other than tuber yield, tuber quality, drought and mosaic tolerance and plant architecture resulted in identifying Aniyoor (edible) and 7 III E3-5 (industrial) as K efficient. These genotypes could perform better at K50 and K0 at which the root biomass and LAI supported their efficacy to scavenge the fixed native soil K and its better utilization. Screening 300 land races resulted in the identification of fifteen NUE lines. Experiments with three NPK efficient lines viz., Acc. No. 906, Acc. No. 766 and Acc. No. 905 indicated higher potential of Ac. No. 906 in low input management (soil test based) and in higher C sequestration.**

**Keywords:** climate resilient, K efficient, NUE parameters, tuber yield, fine roots, low input management

## INTRODUCTION

Tropical tuber crops in general and cassava (*Manihot esculenta* Crantz) in particular is perceived as a climate resilient, food security crop which can sustain soil productivity owing to its innate physiological ability to shed its leaves at times of drought. The facts and figures from the long term fertilizer experiment (LTFE) at CTCRI since 1977 thoroughly established the above fact and the reason was attributed to the high leaf dry matter production (2.5-4.0 t ha$^{-1}$) annually. This leaf dry matter being formed through the atmospheric $CO_2$ acquisition, reduces the atmospheric $CO_2$ concentration and later the leaf dry matter forming a part of the soil organic carbon (SOC). The leaf dry matter other than contributing to SOC nourishes the soil through all essential elements viz., N, P, K, Ca, Mg, Fe, Cu, Mn and Zn contained in it to the tune of 4.41, 0.28, 1.25, 0.21, 0.321, 0.016, 0.0008, 0.0154 and 0.0064% respectively and hence assuring soil productivity also. The unique attribute of the sustenance of the crop through a yield realization of about 13 t ha$^{-1}$ from the same field even after continuous cultivation for 10 years without any manures and fertilizers as proved from the LTFE further establishes the above facts (Susan John et al., 2014; Shanida Beegum et al., 2013).

Though the crop is having specific capabilities as above including strong positive response to manures and fertilizers, the crop is managed by resource poor farmers through indiscriminate use of inputs especially fertilizers resulting in adverse environmental impacts. According to Fageria et al. (2008), during this millennium, the essential plant



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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 nutrient use efficient (NUE) genotypes need to be explored to exploit their unique attribute in scavenging the slowly available and unavailable soil nutrient reserves as a possibility to substitute for chemical fertilizers.

Cassava being a crop having high N and K requirement with K being the key nutrient (Susan John et al., 2010) and is primarily cultivated for edible and industrial purposes, efforts were streamlined for identifying K efficient genotypes suited for the above purposes. Rengel and Damon (2008) had already reported genotypic differences in K efficiency uptake and utilization for all major economically important plants. Later realizing the worth of the K efficient genotypes in reducing the K fertilizer dosage, further, attempts were made to identify NPK efficient genotypes and their potential under different nutrient management regimes were explored for the possibility to substitute for chemical fertilizers and in C sequestration.

## MATERIALS AND METHODS

This paper encompasses three different sections viz., identification of K efficient genotypes and NUE genotypes and NUE genotypes in combination with nutrient management practices as a low input management strategy to substitute for chemical fertilizers.

### Identification of K efficient cassava genotypes

A total of 100 elite cassava genotypes belonging to land races, top cross hybrids, hybrids and selections were planted in a replicated row trial with 20 plants in each row adopting the normal spacing (90×90 cm) without applying any K fertilizers. But FYM, N and P were applied as per soil test data. Observations on sett sprouting, incidence of cassava mosaic disease, biometric characters, quality parameters viz., cyanogenic glucosides and starch, plant (leaf, stem and tuber) dry matter and its K content were recorded at 6, 8 and 10 months after planting (MAP). At 10 MAP, the crop was harvested and yield and yield attributes were recorded. The physiological efficiency computed along with the above observations was used to select three K efficient genotypes each for edible and industrial uses.

Further, the selected genotypes were evaluated for their NUE parameters viz., agronomic efficiency (AE, kg tuber $kg^{-1}$ K applied), physiological efficiency (PE, kg plant biomass $kg^{-1}$ K uptake), agro physiological efficiency (APE, kg tuber $kg^{-1}$ K uptake), apparent recovery efficiency (ARE, total plant K uptake $kg^{-1}$ K applied), utilization efficiency (UE, kg plant biomass $kg^{-1}$ K applied) (Fageria et al., 2008), harvest index (HI), K harvest index (KHI) (Desai and Bhatia, 1978), K uptake ratio (K Up R, g K plant $g^{-1}$ K soil), K utilization for biomass (K Ut B, g plant biomass $mg^{-1}$ plant K) as well as for tuber (K Ut T, g tuber $mg^{-1}$ plant K) (Fernández et al., 2009) along with tuber yield (t $ha^{-1}$) and quality traits. For this, field experiments were conducted for 3 consecutive years since 2009 with two replications in a split plot design with genotypes as the main plot and levels of K (0, 50, 100 and 150 kg $ha^{-1}$) as the sub plot treatments. Observations as in the screening trial were undertaken.

### Identification of NUE genotypes

NUE genotypes were identified through screening of 300 elite land races which were separately grown for the purpose in replicated rows and all observations as mentioned under identification of K efficient genotypes were followed and agro physiological efficiency was taken as the criteria to delineate the lines as NUE.

### NUE genotypes in association with nutrient management practices in substituting chemical fertilizers

This field experiment was conducted for two consecutive years for 2011-12 and 2012-13 in a split plot design using one NPK efficient line viz., Acc. No. 766 and two PK efficient lines viz., Acc. No.905 and 906 as the main plot treatment and four nutrient management practices as sub plot treatments. The nutrient management practices included

1. Package of practices recommendation for cassava (NPK at 100:50:100 kg $ha^{-1}$+ FYM at 12.5 t $ha^{-1}$) (POP)
2. Soil test based fertilizer recommendation for FYM, major, secondary and micronutrients (NPK at 106:0:83 kg $ha^{-1}$ + FYM at 12.5 t $ha^{-1}$ + $MgSO_4$ at 2.5 kg $ha^{-1}$ + $ZnSO_4$ at 12.5 kg $ha^{-1}$) (STBF)
3. POP recommendation for NPK, FYM along with nutrient efficient biofertilizers viz., N fixers, P and K solubilizers at 10 g $plant^{-1}$ (POP+ BF)
4. Low input management strategy for cassava including green manuring in situ with cowpea as source of organic manure, soil test based application of NPK, secondary (Mg) and micronutrient (Zn) and nutrient efficient bio fertilizers (N fixers, P solubilizers and K solubilizers) (Low input).

The observations mainly recorded were tuber yield, tuber quality, soil nutrient status, carbon sequestration ($CO_2$ absorbed for leaf dry matter production, reduction in atmospheric $CO_2$ and build up in SOC). In the case of selected K efficient and NPK and PK efficient genotypes, used for field experimentation, both LAI and root characters especially fresh weight of white roots/thin roots involved in water/nutrient absorption were also recorded.

**RESULTS AND DISCUSSION**

The results emanated from the three sub projects which in turn comprised of different sets of field experiments for five years are summarised below.

**Identification of K efficient cassava genotypes**

During the first year, the elite genotypes were grown under a soil test based fertilizer cum manurial dose of NPK at 78:0:0 kg $ha^{-1}$ along with FYM at 7.50 t $ha^{-1}$ without applying K fertilizer to exploit the K efficiency potential of the genotypes. P was not applied as the soil was inherently high in P. From the observations, 3 genotypes each viz., Aniyoor, W-19 and 7 Sahya (2) for edible and 6-6, 7 III E3-5 and CR43-8 for industrial uses were selected. The characteristics of these genotypes are presented in Table 1. The variation in the physiological efficiency noticed among genotypes can be attributed to the significant difference exists among crop species and genotypes of the same species in nutrient uptake and utilization (Fageria and Baligar, 2005).

Table 1. Characteristics of the genotypes selected.

| Genotypes | Plant height (m) | Stem girth (cm) | Tuber dry matter (%) | Tuber K (%) | Tuber yield (kg $plant^{-1}$) | Starch (%) | HCN (ppm) | Physiological efficiency of K (kg plant biomass $kg^{-1}$ K uptake) |
|---|---|---|---|---|---|---|---|---|
| 1. Aniyoor | 3.00 | 10.00 | 31.52 | 1.218 | 7.78 | 20.12 | 34.5 | 138.82 |
| 2. W-19 | 2.95 | 11.50 | 24.44 | 1.62 | 3.29 | 13.75 | 35.1 | 111.76 |
| 3. 7 Sahya (2) | 2.71 | 10.00 | 24.36 | 0.656 | 5.50 | 14.62 | 119.6 | 243.65 |
| 4. Triploid 6-6 | 2.30 | 11.50 | 30.18 | 0.648 | 3.71 | 18.35 | 137.8 | 97.78 |
| 5. 7III E3-5 | 3.15 | 10.00 | 27.72 | 1.068 | 7.00 | 16.41 | 173.6 | 120.96 |
| 6. CR 43-8 | 2.60 | 9.00 | 26.56 | 0.988 | 7.50 | 15.03 | 47.5 | 96.36 |
| Check H-1687 | 2.65 | 12.00 | 12.14 | 0.954 | 3.00 | 16.07 | 92.3 | 144.39 |

The results of the three years' field experiment with respect to tuber yield, tuber quality, NUE and physiologic parameters are described below.

**1. Tuber yield.**

During the first year, the tuber yield was significantly influenced by genotypes and among the 6 genotypes, 7III E3-5 recorded the highest tuber yield of 49.9 t $ha^{-1}$ and was on par with CR 43-8 (47.9 t $ha^{-1}$). However, Aniyoor (edible) as well as 7III E3-5 (industrial) respectively was selected as the K efficient lines as they produced a tuber yield of 43.8 and 45.4 t $ha^{-1}$ respectively without any K fertilizers (Table 2). During the second year, levels of K significantly influenced the tuber yield, with all the cultivars performing on par at K at 50, 100 and 150 kg $ha^{-1}$ indicating the possibility of reducing K dose to half of the present recommendation for the K efficient genotypes. The third year data showed significant effect of genotypes and genotypes and K level interaction in tuber yield. As the tuber yield was not affected by levels of K with all the four levels performing equally well, it was presumed as a genotypic character. The interaction effect of genotypes and K levels during this year indicated that, Aniyoor at 100 kg $ha^{-1}$ (32.08 t $ha^{-1}$) and 7III E3-5 without K (27.29 t $ha^{-1}$) and at 50 kg $ha^{-1}$ (23.92 t $ha^{-1}$) performing better. Similar results indicating variation due to genotype, levels of K or their interaction in cotton lint yield was reported by Gwathmey et al. (2009) and the reason being the difference in root systems influencing the K uptake and hence the rate of biomass accumulation.

Table 2. Effect of genotypes, levels of fertilizers and their interaction on tuber yield of selected cassava genotypes.

| Treatments genotypes (G)/ K levels (K) | K0 | K50 | K100 | K150 | Mean (G) |
|---|---|---|---|---|---|
| **2009** | | | | | |
| Aniyoor | 43.8 | 25.0 | 36.7 | 33.5 | 34.8$^{bc}$ |
| W-19 | 35.2 | 25.6 | 41.8 | 31.5 | 33.5$^{c}$ |
| 7Sahya(2) | 33.9 | 29.4 | 34.2 | 29.1 | 31.7$^{c}$ |
| 6-6 | 43.8 | 32.4 | 43.5 | 41.7 | 40.4$^{ab}$ |
| 7III E3-5 | 45.4 | 44.4 | 44.6 | 45.2 | 44.9$^{a}$ |
| CR 43-8 | 33.0 | 35.9 | 44.8 | 47.9 | 40.4$^{ab}$ |
| Mean (K) | 39.2 | 32.2 | 40.9 | 38.2 | |
| **2010** | | | | | |
| Aniyoor | 38.79 | 45.81 | 45.87 | 50.83 | 45.33 |
| W-19 | 28.25 | 37.51 | 40.50 | 38.55 | 36.20 |
| 7 Sahya-2 | 35.03 | 47.51 | 43.13 | 36.36 | 40.51 |
| 6-6 | 23.10 | 38.98 | 33.02 | 33.67 | 32.19 |
| CR 43-8 | 36.73 | 38.33 | 50.29 | 46.73 | 43.02 |
| 7 III E 3-5 | 32.69 | 43.33 | 44.44 | 44.44 | 43.10 |
| Mean (K) | 32.43$^{B}$ | 41.91$^{AB}$ | 42.88$^{A}$ | 41.76$^{AB}$ | |
| **2011** | | | | | |
| Aniyoor | 23.35$^{defgh}$ | 25.28$^{bcdef}$ | 32.08$^{abc}$ | 28.92$^{abcde}$ | 27.41$^{a}$ |
| W-19 | 25.19$^{bcdef}$ | 29.81$^{abcd}$ | 25.32$^{bcdef}$ | 32.55$^{ab}$ | 28.22$^{a}$ |
| 7 Sahya 2 | 13.27$^{j}$ | 15.89$^{hij}$ | 25.15$^{bcdef}$ | 13.39$^{ij}$ | 14.42$^{c}$ |
| 6-6 | 21.13$^{efghi}$ | 24.89$^{bcdef}$ | 24.17$^{cdef}$ | 16.31$^{ghij}$ | 21.62$^{b}$ |
| CR 43-8 | 27.09$^{abcdef}$ | 29.56$^{abcd}$ | 24.56$^{bcdef}$ | 33.97$^{a}$ | 28.79$^{a}$ |
| 7 III E3-5 | 27.29$^{abcdef}$ | 23.92$^{defg}$ | 25.90$^{bcdef}$ | 19.54$^{fghij}$ | 24.16$^{b}$ |
| Mean(K) | 22.89 | 23.23 | 26.20 | 24.11 | |
| **Pooled Mean** | | | | | |
| Aniyoor | 35.31$^{abcde}$ | 32.03$^{bcdefg}$ | 38.22$^{abc}$ | 37.75$^{abc}$ | 35.83$^{ab}$ |
| W-19 | 29.55$^{defg}$ | 30.97$^{cdefg}$ | 35.87$^{abcde}$ | 34.20$^{abcdefg}$ | 32.65$^{bc}$ |
| 7 Sahya 2 | 27.40$^{fg}$ | 30.93$^{cdefg}$ | 34.16$^{abcdefg}$ | 26.28$^{g}$ | 29.69$^{c}$ |
| 6-6 | 29.34$^{efg}$ | 32.09$^{bcdefg}$ | 33.56$^{bcdefg}$ | 30.56$^{cdefg}$ | 31.39$^{bc}$ |
| CR 43-8 | 36.41$^{abcde}$ | 37.43$^{abcd}$ | 39.82$^{ab}$ | 41.97$^{a}$ | 38.91$^{a}$ |
| 7 III E3-5 | 30.99$^{cdefg}$ | 34.38$^{abcdef}$ | 38.38$^{abc}$ | 37.29abcd | 35.26$^{ab}$ |
| Mean(K) | 31.50$^{b}$ | 32.97$^{ab}$ | 36.67$^{a}$ | 34.68$^{ab}$ | |

**2. NUE parameters.**

During the first year, K levels significantly influenced the K uptake ratio which takes into account the soil as well as applied K. As different levels of K did not affect the other NUE parameters, it can be inferred that, these cultivars can perform well under low levels of K or even without K. However, these values were higher at K at100 kg ha$^{-1}$. During the second year, harvest index (HI), plant dry matter production and K utilization ratio of the genotypes varied significantly. Among the six genotypes, Aniyoor (0.60) and 7 III E3-5 (0.54) had the maximum HI values. Among the industrial genotypes, 7 III E3-5 had significantly the highest total plant dry matter production (29.93 t ha$^{-1}$) and K utilization ratio (1.09). However, the edible genotypes were on par with respect to these parameters. Agronomic efficiency, K efficiency ratio, K utilization for biomass and K uptake ratio were influenced by K levels, however these were on par at 50, 100 and 150 kg ha$^{-1}$. The third year data indicated significant interaction effect of genotypes and K levels for HI, KHI, stem K%, tuber K uptake and % K utilization for tuber. NUE parameters viz., K efficiency ratio, K utilization for tuber, K utilization for biomass, K uptake ratio, K HI also justified the K utilization efficacy of the selected genotypes. The variation in NUE parameters of the selected genotypes can be attributed to the difference in the efficiency of acquisition, transport and utilization of nutrients among crop species, genotypes, and cultivars (Baligar et al., 2001). Isfan (1993) reported that, among the different NUE parameters, the N, P K harvest indices is the most important as this will determine the capability of the genotype to use the nutrient input more efficiently.

**3. Quality attributes.**

During all these years, genotypes significantly influenced the cyanogenic glucoside content of cassava tubers with Aniyoor having the lowest (25.8 ppm) and 6-6 the highest (201.8 ppm). K at 150 kg ha$^{-1}$ had the minimum HCN (114.3 ppm) which was on par with K at 100 kg ha$^{-1}$ (125.9 ppm). The interaction effect of genotypes and K levels was significant in the case of starch where in Aniyoor at 100 kg ha$^{-1}$ recorded the highest starch content which in turn was on par with the starch content recorded in W-19, 6-6 and 7III E3-5 without K, 7III E3-5 at 50 kg ha$^{-1}$, 6-6, CR43-8 and 7III E3-5 at 100 kg ha$^{-1}$ and Aniyoor, 6-6 and CR 43-8 at 150 kg ha$^{-1}$ . In the following year, there was significant interaction between genotypes and K levels on tuber starch content, the maximum being 33.84% in 7 III E3-5 at 100 kg ha$^{-1}$ $K_2O$. Starch was significantly influenced by genotypes with W-19 having the maximum (33.27%) on par with Aniyoor (32.49%) and the industrial genotypes were on par, varied from 27.7-29.1%. There are several reports establishing the effect of genotypes in quality traits such as starch and cyanogenic glucosides (Sánchez et al., 2009; Maziya-Dixon et al., 2007). Similarly, level of K also exhibits significant influence on the above quality traits (Susan John et al., 2005).

**4. Physiologic parameters.**

During the second year, among the edible and industrial genotypes, Aniyoor at 50 kg ha$^{-1}$ (9.50 g day$^{-1}$) and 7 III E3-5 at 100 kg ha$^{-1}$ (10.12 g day$^{-1}$) recorded the highest tuber bulking rate (TBR). The Physiologic parameters viz., RGR, CGR, TBR, LAI and HI supported the potential of the selected genotypes. The present result of genotypic as well as nutrient level influence on physiologic parameters conform to the findings of Pettigrew and Meredith (1997) that, cultivars and K levels can affect the dry matter distribution and plant K content which in turn indirectly affect the physiologic attributes as evidenced in cotton (Gwathmey et al., 2009).

However, taking into account all the observed and measured parameters, it was inferred that, 2 cultivars viz., Aniyoor (edible) and 7 III E3-5 (industrial) as K efficient which can be grown without K and K at 100 kg ha$^{-1}$ to get normal and maximum yield respectively.

**IDENTIFICATION OF NUE GENOTYPES**

A total of 300 elite land races evaluated for yield and agro physiological efficiency with respect to N, P and K resulted in the identification of a total of 15 genotypes, of which, 7, 3, 5 were NPK, NP and PK efficient respectively. The selection of these genotypes primarily based on the agro physiological efficiency of the crop adheres to the reports of Wallace et al. (1972) that, physiological components causing varietal difference in relation to nutrient use efficiency needs to be explored rather than accounting quantitative genetical character like yield which in turn is influenced by many genes other than environmental factors.

## NUE GENOTYPES IN ASSOCIATION WITH NUTRIENT MANAGEMENT PRACTICES IN SUBSTITUTING CHEMICAL FERTILIZERS

The field experiment conducted for 2 years revealed significant effect of genotypes and interaction effect of genotypes and nutrient management practices in affecting the tuber yield. Acc. No. 906 registered significantly the highest tuber yield (30.944 t $ha^{-1}$) which was on par with Acc.No. 905 (27.879 t $ha^{-1}$) (Table 3). As all the management practices were on par, it can be inferred that, for cassava, low input management is a better option. Since the NUE genotype, Acc. No. 906 along with the low input management practice was yielding significantly the highest tuber yield (36.457 t $ha^{-1}$), it was established that, by using the NUE genotypes, the fertilizer dose can be reduced with a saving of 100 and 17% P and K respectively thus reducing the cost of cultivation to the tune of 15-20% realizing an yield advantage of 26% over the existing POP. Smith et al. (1994) indicated the need to breed crop plants for better N use efficiency so that the dependence on chemical N fertilizer can be reduced.

Table 3. Tuber yield as affected by genotypes (G) and nutrient management practices (M) (Mean of 2 years).

| Genotypes | POP | STBF | POP+BF | Low input | Mean (G) |
|---|---|---|---|---|---|
| Acc. No. 766 | 29.721$^{bcd}$ | 20.695$^{gh}$ | 24.398$^{efg}$ | 18.165$^{h}$ | 23.245$^{b}$ |
| Acc. No. 905 | 29.442$^{bcd}$ | 24.073$^{efg}$ | 25.807$^{e}$ | 32.195$^{b}$ | 27.879$^{a}$ |
| Acc. No. 906 | 26.943$^{de}$ | 30.343 $^{bc}$ | 30.040$^{bcd}$ | 36.457$^{a}$ | 30.944$^{a}$ |
| H-1687 | 27.331$^{cd}$ | 23.283$^{fg}$ | 24.504$^{ef}$ | 22.056$^{fg}$ | 24.294$^{b}$ |
| Mean (M) | 28.509 | 27.879 | 30.946 | 29.443 | |

## ROOT BIOMASS AND LAI IN NUE GENOTYPES

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 subsoil concentrations, plants ability to solubilise nutrients in the rhizosphere, better transport, distribution and utilization within plants and balanced source sink relationships. Rengel and Damon (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. Since the above mechanism is directly linked to root architecture, an attempt was made to study the root characters which in turn indicated extensive distribution of white roots in the NUE genotypes which are involved in water and nutrient absorption. The genotypes influenced the LAI during both the years with W-19 and CR43-8 recording significantly the highest values.

## NUE GENOTYPES IN CARBON SEQUESTRATION

Management practices significantly influenced the carbon sequestered by the crop through build-up of soil organic carbon. Though POP recorded the highest C sequestration, low input strategy resulted in stable C sequestration during the growth period. Among the different nutrient management practices, highest C sequestration was observed under POP recommendation at 3 MAP and low input management strategy at 9 MAP. Acc. No. 905 under POP recommendation resulted in a significantly higher C sequestration. This finding conforms to the reports of Lal (2007) and Li and Feng (2002) 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.

## CONCLUSIONS

The study threw an insight into the need for exploitation of the nutrient scavenging potential of NUE plants in order to reduce excessive use of fertilizers thereby preventing environmental degradation. In cassava, identification of K efficient genotypes as well as the integration of NUE genotypes with low input nutrient management strategies resulted in reducing the fertilizer dosage and hence the cost of cultivation. Further studies are directed towards identifying the genes contributing to K use efficiency in cassava as well as confirming the N Use efficiency potential of the K efficient genotypes.


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