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**Research Paper**

# Response of cassava (*Manihot esculenta*) minisetts to varying levels of drip fertigation

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## ABSTRACT

A field experiment was conducted during 2014–15, 2015–16 and 2016–17 at Sreekariyam, Thiruvananthapuram, Kerala, to investigate the response of cassava (*Manihot esculenta* Crantz) minisetts to different levels of drip fertigation. Short-duration variety of cassava 'Sree Vijaya' was used for the study. The experiment was laid out in $3^2$ factorial design with 9 treatments (3 levels each of nitrogen and potassium 75, 100 and 125 kg/ha applied through drip fertigation) in 3 replications. Full phosphorus was applied as basal soil application. A control with soil application of standard recommended dose of fertilizers (100, 50 and 100 kg N, P and K per ha) was also kept for comparison. Minisetts of cassava raised in nursery were transplanted during December every year and harvested during May. Drip irrigation was given uniformly @ 100% cumulative pan evaporation. Pooled data analysis of the 3 years indicated that a combination of N @ 75 kg/ha and K @ 125 kg/ha through drip fertigation was the best in terms of tuber yield (48.68 t/ha), net income (₹331,900/ha), benefit: cost ratio (3.14) and energy-use efficiency (19.06) for cultivation of cassava minisett under drip fertigation.

***Key words :*** Cassava, Drip fertigation, Economics, Energy-efficiency indices, Growth attributes, Minisetts, Tuber yield

Tropical root and tuber crops are the third most important food crops after cereals and pulses. These crops have gained an inevitable niche in the socio economic improvement of marginal and small farmers of India. Tropical tuber crops have greater adoption in the marginal land and environments and rank foremost among the cultivated plants in terms of energy produced/unit area/unit time. Cassava is an important tropical tuber crop that plays a significant role in the food and nutritional security in rural livelihoods. It is one of the most important food crops in the world, after rice, wheat and maize, but ahead of potato in terms of total area planted (Howeler, 2017). Cassava is ranked as the fourth most important source of calories in human diet worldwide having higher carbohydrate content than either maize or rice. Having high biological efficiency, the crop provides about 110–149 kcal of food energy/100 g of tubers (Bradbury and Holloway, 1988). The edible energy production comes to 152 MJ/ha/day for sweet potato, 121 for cassava and 182 for yams and they are quite comparable with that of rice (121), wheat (135) or maize (159) (Horton and Fano, 1985). More than a food crop, the industrial potential of cassava is well recognized nowadays as for the production of native and modified starch and bioethanol apart from its use as cattle feed. Of late, there has been a tremendous increase in research efforts to improve the productivity of cassava.

In India, cassava is cultivated in approximately 0.23 million ha mainly, covering Tamil Nadu, Kerala, Andhra Pradesh, Maharashtra and North-eastern states with a total production of 8.14 million tonnes. India ranks first in terms of cassava productivity (35.65 t/ha) compared to the world average of 11.2 t/ha (FAOSTAT, 2014); the main reasons attributed to the improved varieties and agro-technologies. Though the crop can tolerate water stress to some extent by way of shedding their leaves and retaining only few leaves at the top to preserve plant water status, yield loss of 32–60% has been reported (Commor *et al*., 1981; Oliveira *et al*., 1982). Moreover, studies have shown positive response of cassava to supplemental irrigation in terms of productivity (Nayar *et al*., 1993; Odubanjo *et al.*, 2011, Sunitha *et al*., 2013). Water productivity of cassava was worked out to be 2.6 kg/m$^3$ under surface irrigation, whereas it was 8.2 kg/m$^3$ under drip irrigation at the rate of 100% cumulative pan evaporation (Sunitha *et al*., 2016).

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Precise application of water as well as nutrients is the need of the hour to improve the productivity of crops. So, wherever cassava is raised under irrigated conditions, fertigation also may be linked in order to realise the full tuber yield potential of cassava, especially in the industrial belts. Along with the use of adequate fertilizers and irrigation water, with limited land availability, the increase in crop productivity also requires additional mechanical and electrical power. Hence crop productivity has to be linked with profitability as well as energy balance. So far, no such studies have been undertaken in cassava. Hence an attempt was made to study the response of cassava to different levels of drip fertigation, to assess the tuber productivity, and to work out the economics and energy-efficiency indices of minisett cassava cultivation under drip fertigation.

## MATERIALS AND METHODS

A field experiment was conducted with cassava raised through minisetts during 2014–15, 2015–16 and 2016–17 at the ICAR-Central Tuber Crops Research Institute, Sreekariyam (8.54° N and 76.91° E, 50 m above mean sea-level), Thiruvananthapuram, Kerala, India. It comes under the humid tropical climatic zones of India. The region receives an average annual rainfall of 2,100 mm, mainly confined to SW and NE monsoons and the temperature ranges between 24 and 32°C. Soil of the experimental site was Typic kandiustult (Order Ultisols), having *p*H towards acidic range (5.1), low in available N (79.3 kg/ha) and medium in available P (25.6 kg/ha) and K (147.8 kg/ha) (Table 1).

The study was conducted during the summer season from December to May. The location receives an average of less than 300 mm rainfall during summer season. Short-duration variety (6 months) of cassava developed at the ICAR-CTCRI, 'Sree Vijaya' was used for the study. The experiment was laid out in $3^2$ factorial design with 9 treatments (3 levels each of N and K) in 3 replications. The three levels of nutrients tried in the study were 75, 100 and 125 kg/ha each of N and K applied through drip fertigation. A control of standard recommended dose of fertilizers (100, 50 and 100 kg N, P and K/ha) applied as soil application was kept for comparison.

Minisetts of cassava (2-node cuttings) were initially raised in a nursery during November (George *et al.,* 2004). Seedlings with 2 to 3 fully-opened leaves were uprooted and transplanted after 4 weeks in the main field. Transplanting was done on ridges made at a distance of 60 cm and planting was done at a spacing of 45 cm. After ridge formation, drip system was laid out and drips were placed, so as to coincide with the spacing of the minisetts. Each plot had 36 plants with a net plot size of 16 plants. At the time of land preparation, farmyard manure @ 12.5 t/ha and full dose of P fertilizer (50 kg/ha) were applied basal. For initial 2 weeks, irrigation was given daily for establishment of minisetts and thereafter on alternate days up to 5 months. Crop factor was taken into account at different stages of growth as suggested by Allen and Pruitt (1991) and quantity of irrigation water was calculated based on daily pan evaporation rate and pan factor. Irrigation was given at the rate of 100% cumulative pan evaporation from December to April, which ranged from 350 ml to 900 ml/plant/day depending on the growth stage (Sunitha *et al*., 2016). Fertigation was given at weekly intervals, starting from the second week of transplanting up to a period of 120 days after planting. Fertigation schedule was fixed based on earlier findings in cassava using urea and muriate of potash as N and K sources. Dose of 50% N and K was applied during the initial 6 weeks (6 splits), 30% dose during 6–12 weeks (6 splits) and remaining 20% was given during 12–18 weeks period (5 splits) ( Sunitha *et al.,* 2013).

Biometric observations, viz. height of plants, stem girth, number of green and fallen leaves, and leaf area were recorded from 3 tagged plants from each plot at 2-month interval from transplanting. Leaf-area index at 2 months interval and leaf-area duration at different growth stages were calculated (Power *et al*., 1967). Destructive sampling of 1 plant from each plot was also done at 2 months interval to assess the biomass production and partitioning. The crop was harvested after 6 months, yield attributes and tuber yield were recorded from different treatments from the net plot and estimated on per hectare basis. The data were pooled at the end of 3 years. Economic indices, viz. cost of cultivation, gross income, net income, benefit: cost ratio, profitability/ha/day and relative

**Table 1.** Physical and chemical properties of the soil in experimental plot

| Physical | | | | | | Chemical | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sand (%) | Silt (%) | Clay (%) | FC (%) | WP (%) | BD (g/cc) | pH | EC (ds/m) | OC (%) | Available nutrients (kg/ha) | | |
| | | | | | | | | | N | P | K |
| 69 | 7 | 24 | 24.5 | 7.8 | 1.10 | 5.1 | 0.08 | 0.96 | 79.3 | 25.6 | 147.8 |

FC, Field capacity; WP, wilting point; BD, bulk density; EC, electrical conductivity; OC, organic carbon; N, nitrogen; P, phosphorus; K, potassium.

economic efficiency were worked out based on various inputs, including the cost of installation of fertigation unit and labour costs as per prevailing rates. Energy flux was computed taking into account the equivalents of all crop inputs ( planting materials, fertilizers, fuel, human labour and mechanical power) and outputs of main and by-products (Singh and Mittal, 1992; Devasenapathy *et al.*, 2006). Energy-efficiency indices, viz. energy-use efficiency, energy productivity, energy intensity and energy-output efficiency, were worked out as per Dazhong and Pimental (1984). The data over the 3 years were analysed statistically using analysis of variance technique (SAS, 2010) and the treatment pooled means were compared with critical differences at 5% level of significance.

## RESULTS AND DISCUSSION

### *Growth attributes*

There was no significant difference in height and girth of plants at different intervals between the treatments. Pooled data analysis indicated no statistical difference in total leaf production or number of fallen leaves at different intervals. However, the leaf-area index (LAI) varied among the fertigation treatments. The LAI was maximum for $N_3K_3$ (125 kg each of N and K) at 2 months after planting (MAP: 3.07), 4 MAP (3.69) and 6 MAP (4.16). The minimum value was recorded by $N_1K_2$ ( 75: 100) at 2 MAP (2.08) and 6 MAP (2.61) and $N_1K_1$ (75:75) at 4 MAP (2.54). Though no difference was noted for leaf number in any of the growth stages; variation in LAI showed the difference in plant vigour due to nutrients by way of canopy spread.

Leaf-area duration followed a similar trend and was the maximum for $N_3K_3$ (125 : 125) at all the growth stages. The values ranged from 62.4 (75 N : 100 K) and 92.1 (125 N : 125 K) during the initial stages of active vegetative growth and tuber initiation (up to 2 MAP); 141.9 (75 N : 75 K) and 202.8 (125 N : 125 K) during vegetative growth and active tuber bulking stage (2–4 MAP); 164.4 (75 N : 75 K) and 235.5 (125 N : 125 K) during tuber bulking and maturity stage (4–6 MAP). Crop-growth rate was the maximum for $N_3K_1$ (10.53 g/plant/day) during initial stage (up to 2 MAP), $N_3K_3$ from 2 to 4 MAP (28.21 g/plant/day) and $N_2K_3$ (24.38 g/plant/day) towards the later stages of 4 to 6 MAP (Fig.1).

### *Tuber yield and yield attributes*

Tuber bulking rate varied from 0.56 to 1.51 g/day up to 2 MAP. During 2 to 4 MAP, bulking rate showed an increase with the increase in K levels and the values ranged from 2.75 g/day (75 N : 75 K) to 4.93 g/day (125 N : 125 K). During 4 to 6 MAP, tuber bulking rate almost remained same or increased with low nitrogen levels (75 kg and 100 kg N) compared to 125 kg of N. Tuber bulking rate and crop-growth rate almost followed a similar trend (Fig. 1).

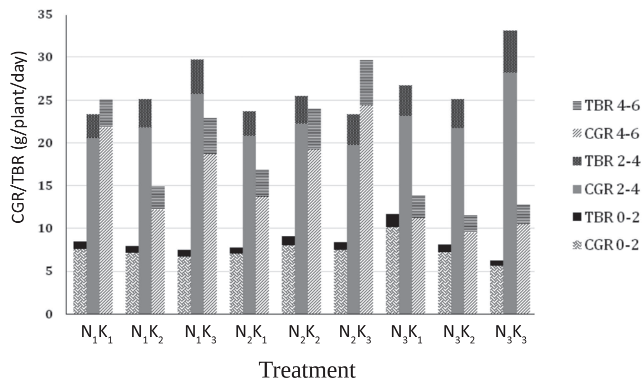


**Fig. 1.** Crop-growth rate (CGR) and tuber bulking rate (TBR) of cassava minisetts at different intervals under fertigation treatments

Pooled data analysis of 3 years indicated that the number of tubers under different levels of nitrogen or potassium were at par. Among the interactions, N and K @ 100 and 125 kg/ha respectively recorded maximum number of tubers (7.77 /plant) and was on a par with N and K @ 75: 125, 125 : 75, 125 : 100 and 125 : 125 kg. Tuber yield of cassava/ha was at par under different levels of N. However, increasing levels of K from 75 to 125 kg resulted in increase in the tuber yield (Table 2). Higher 2 levels, i.e. 100 and 125 kg/ha of K were at par with respect to tuber yield. Different combinations of N and K resulted in more or less same tuber yield, except N and K @ 75 : 75, and 100 : 75 kg/ha. The combination effect of N @ 75 and K @ 125 kg/ha recorded the maximum tuber yield (48.68 t/ha). Application of 25 kg more of K alone resulted in 37% increase in tuber yield and 50 kg more of K resulted in 44% increase compared to 75 kg/ha of K. Pooled data analysis also showed that interaction effects over the years were not significant (P=0.088).

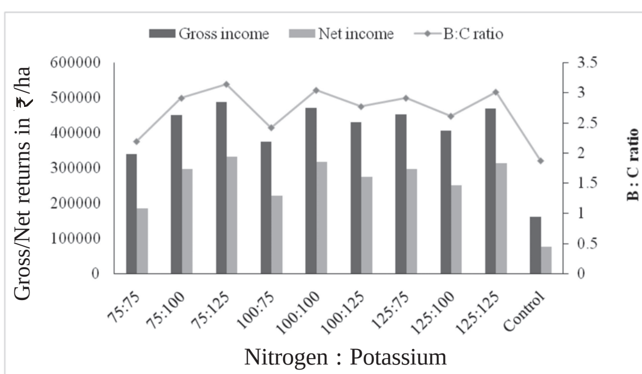


**Fig. 2.** Economics of cassava minisett cultivation under different fertigation levels

**Table 2.** Effect of nitrogen levels, potassium levels and their interaction effects on number of tubers and tuber yield of cassava minisetts (pooled mean of 2014–15, 2015–16 and 2016–17)

| Treatment | Tubers/ plant | Tuber yield (t/ha) |
|---|---|---|
| *N levels (kg/ha)* | | |
| $N_1$, 75 | 6.13 | 42.5 |
| $N_2$, 100 | 6.70 | 42.52 |
| $N_3$, 125 | 6.89 | 44.18 |
| SEm± | 0.27 | 1.71 |
| CD (P=0.05) | NS | NS |
| *K levels (kg/ha)* | | |
| $K_1$, 75 | 6.30 | 38.79 |
| $K_2$, 100 | 6.38 | 44.23 |
| $K_3$, 125 | 7.04 | 46.18 |
| SEm± | 0.27 | 1.71 |
| CD (P=0.05) | 0.76 | 4.86 |
| *Interaction effects (kg/ha)* | | |
| N, K – 75 : 75 | 5.81 | 33.82 |
| N, K – 75 : 100 | 5.88 | 45.01 |
| N, K – 75 : 125 | 6.69 | 48.68 |
| N, K – 100 : 75 | 6.15 | 37.43 |
| N, K – 100 : 100 | 6.19 | 47.09 |
| N, K – 100 : 125 | 7.77 | 43.02 |
| N, K – 125 : 75 | 6.93 | 45.13 |
| N, K – 125 : 100 | 7.08 | 40.57 |
| N, K – 125 : 125 | 6.66 | 46.85 |
| Control | 5.00 | 16.11 |
| SEm± | 0.47 | 2.96 |
| CD(P=0.05) | 1.33 | 8.42 |

There was a positive relation between LAI and tuber yield. Positive contribution of LAI to storage root yield of cassava has been reported (Ekanayake, 1996; Phuntupan and Banterng, 2017). Higher LAI led to high leaf-area duration (LAD) and crop-growth rate (CGR) values. Crop stand with insufficiently developed leaf area releases a lot of solar radiation to ground, thereby CGR decreases. The efficiency of conversion of intercepted solar radiation into dry matter falls with decreasing LAI (Sharifi *et al*., 2009). However, an increase in CGR need not contribute to tuber bulking. In this study, higher CGR towards later stages of 4–6 MAP led to less tuber bulking. The shoot and the root compete for photosynthetic assimilates due to cassava's unique simultaneous development of these 2 sinks (El-Sharkawy and Cock, 1987); however, to achieve high yield, shoot and root growth must be well balanced. More of N without adequate K must have resulted in preferential partitioning of more assimilates to the growing shoots at the active growth stage leading to reduction of assimilates translocated to storage roots. A decrease in CGR mostly contributing to tuber bulking towards later stages leads to high tuber productivity.

In this trial, irrigation was given uniformly to all the treatments, depending on the growth stages up to a period of 150 days ( 350 to 900 ml/plant/day). Hence the significant variation in tuber yield was only due to the nutrient levels, especially K under irrigated conditions. Though cassava thrives in poor and marginal soils, it responds well to added fertilizers, especially potash. Like all rapidly growing plants yielding carbohydrates, cassava has high nutrient requirements and soil depletion of nutrients quickly occurs after the crop cycle (Mohankumar, 2000). Potassium is reported to be a critical element in tuber crops for starch translocation during the active tuber bulking phase, but is an element subjected to maximum loss by way of leaching. The importance of K in translocation of carbohydrates in cassava has been reported by earlier workers (Mohankumar, 2000). Higher rates of K application increases the total dry matter going to the roots and thereby increases cassava storage root yield (Maduakor , 1997). Based on the earlier findings in cassava (George *et al.*, 2016), 50% dose of N and K was applied during first 40 days, 30% during 40–80 days and the remaining 20% during 80–120 days after transplanting minisetts. The crop needs a continuous supply of nutrients especially during the active vegetative and tuber bulking stage, which falls between 45 DAP up to almost 150 DAP in short-duration varieties (Sunitha *et al*., 2016). Cassava plant development at the early stages of growth (1–3 MAP) makes heavy demand on assimilates to the detriment of root bulking. However, growth parameters begin to make significant positive contribution to root yield, once tuber initiation occurs. This period of active growth also coincides with the peak period of leaf-area development which is crucial in assimilate manufacture (Michael *et al*., 2015).

### *Economic indices*

A nursery area of 125 $m^2$ is required for raising minisetts for transplanting in 1 ha of main field, and the nursery incurred an amount of ₹13,600 during every year. The cost of installation of fertigation unit after considering the installation of fertigation unit, depreciation, maintenance cost etc. during subsequent years, was worked out to be ₹58,520/year. The cost of cultivation was same in all the treatments except for the cost of fertilizers applied through fertigation, which was only a minor fraction of the total cost. The cost of cultivation of mini setts of cassava under different levels of drip fertigation ranged from ₹153,900 to ₹155,500/-. Economic indices were compared with the control, the conventional practice of soil application of fertilizers @ 100 kg each of N and K raised simultaneously under similar conditions which resulted in a tuber yield of 16.11 t/ha. Economic analysis revealed that the treatment, $N_1K_3$ involving the combination of 75 kg N and 125 kg K recorded the highest net return of ₹331,900, followed by $N_2K_2$ (100 kg each of N and K) which recorded a net income of ₹316,200. Benefit: cost (B:C) ratio was also maximum for 75 kg N and 125 kg K (3.14) compared to 1.87 with soil application of fertilizers. The tuber yields under 75 : 100 and 75 : 125 kg N and K were at par; however, there was only minor increase in the cost of cultivation due to the extra cost of 25 kg K fertilizer. So the combination N and K @ 75 : 125 resulted in more net income and B:C ratio. Similar trend was observed for profitability/ha/day as well as relative economic efficiency owing to lesser cost of cultivation and high returns in $N_1K_3$. The profitability ranged from 1,023 to 1,843 and economic efficiency 144% to 340%, respectively, under N 75 : K 75 and N 75 : K 125. Considering all the economic parameters, N and K @ 75 and 125 kg, respectively, through drip fertigation was found superior to the rest of the nutrient combinations.

The drip irrigation along with fertigation increases crop, water and nutrient-use efficiencies and thereby crop yield was increased by about 20–30% over the solid fertilizer application directly in soil. In this experiment, cassava yielded 2–3 times more tuber yield under fertigation compared to soil application, which resulted in more gross and net income and benefit : cost ratio (Fig. 2).

### *Energetics*

Energy value of various inputs including human labour (men and women) for raising minisett nursery, mechanical power for main field preparation, transplanting minisetts, intercultural operations, drip irrigation and fertigation, FYM and P fertilizer and harvesting was uniform for all the treatments and computed as 12,671.42 MJ/ha. Energy value of fertilizers differed among the treatments and hence the total input energy was calculated separately. Total input energy ranged from 18,273 to 21,638 MJ/ha and was compared with the conventional practice of soil application of fertilizers which was 16,081 MJ. The total output energy computed from tuber yield and the by-product, (stem and leaves) ranged from 272,917 to 354,600 MJ and the output energy was 113,812 MJ under soil application. Net energy was the maximum under $N_1K_3$ (75 : 125) and was significantly superior to all other treatments except $N_3K_3$ (125 : 125) (Table 3).

The average of 3 years data showed that the treatment combination of N and K @ 75 and 125 kg/ha was superior in terms of all energy-efficiency indices (Table 3). The combination resulted significantly higher tuber yield and biomass yield and hence total output energy was higher. Consequently, high energy-use efficiency and energy productivity were recorded and was followed by N and K @ 75 and 100 kg/ha. It also recorded highest energy intensity of 3.44 MJ/₹ invested followed by N and K @ 100 kg each/ha (3.14). The variety used was of short duration and crop was harvested after 180 days and total energy output efficiency was calculated as 1,970 MJ/ha/day for N : K @ 75 : 125. All the energy-efficiency values were low under soil application of fertilizers and fertigation resulted in 2–3 fold increase in energy efficiency indices compared to soil application, though the energy input was less under soil application. This shows the superiority of fertigation in cassava minisetts, wherein precise application of nutrients along with sufficient soil moisture is ensured in the active root zone of the crop. Abdul Hakkim (2014) reported that, fertigation has been effective in saving labour and energy. Tuber crops have a higher biological efficiency and show the highest rate of dry matter production per day per unit area among all the crops. They are also

**Table 3**. Energy-efficiency indices of cassava minisett cultivation under different fertigation treatments

| Treatment | Energy input (× $10^3$ MJ/ha) | Energy output (× $10^3$ MJ/ha) | Net energy (× $10^3$ MJ/ha) | Energy-use efficiency | Energy productivity (Kg/MJ) | Energy intensity (MJ/₹) | Energy output efficiency (× $10^3$ MJ/ ha/day) |
|---|---|---|---|---|---|---|---|
| N, K – 75 : 75 | 18.27 | 272.92 | 254.65 | 14.93 | 2.31 | 2.67 | 1.52 |
| N, K – 75 : 100 | 18.44 | 318.77 | 300.33 | 17.29 | 2.80 | 3.11 | 1.77 |
| N, K – 75 : 125 | 18.61 | 354.60 | 335.99 | 19.06 | 3.06 | 3.44 | 1.97 |
| N, K – 100 : 75 | 19.79 | 278.67 | 258.88 | 14.08 | 2.24 | 2.72 | 1.55 |
| N, K – 100 : 100 | 19.96 | 323.29 | 303.33 | 16.20 | 2.66 | 3.14 | 1.80 |
| N, K – 100 : 125 | 20.12 | 313.54 | 293.42 | 15.58 | 2.50 | 3.03 | 1.74 |
| N, K – 125 : 75 | 21.30 | 313.03 | 291.73 | 14.69 | 2.40 | 3.04 | 1.74 |
| N, K – 125 : 100 | 21.47 | 276.84 | 255.37 | 12.89 | 2.12 | 2.68 | 1.54 |
| N, K – 125 : 125 | 21.64 | 338.20 | 316.56 | 15.63 | 2.52 | 3.26 | 1.88 |
| Control | 16.08 | 113.81 | 97.73 | 7.08 | 1.15 | 1.29 | 0.63 |
| SEm± | 1.26 | 12.05 | 10.35 | 1.45 | 0.44 | 0.39 | 0.15 |
| CD (P=0.05) | 3.58 | 34.26 | 29.44 | 4.12 | 1.24 | 1.12 | 0.44 |

recognized as the most efficient converters of solar energy (Horton and Fano, 1985). In this study, energy consumption was high under fertigation; however, more tuber yield, short duration and high energy value of cassava tubers resulted in high energy output.

Fertigation is established to be a nutrient-efficient package in most of the crops wherein the nutrients are applied in smaller quantities over a longer spell of crop requirement in the active root zone of the crop. When fertilizer is applied through drip irrigation, the yield could be increased and about 30% of the fertilizer could be saved (Sivanappan and Ranghaswami, 2005). So application of nutrients, especially potassium, in more splits in the active root zone of the crop with adequate amount of moisture helped in better uptake of nutrients and subsequent tuber yield.

The above findings clearly revealed that cassava minisetts when raised under micro irrigation supplemented with fertigation, 25% of N fertilizer could be saved compared to the application of standard recommended dose of fertilizers. There was no saving of K and 100 kg/ha and 125 kg/ha of potassium resulted in optimum tuber yield. Considering the tuber yield, net income, benefit : cost ratio and energy-efficiency indices, a combination of 75 kg N and 125 kg of K/ha was evolved as the best nutrient combination for cassava minisetts under drip fertigation.

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