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Tropical tuber crops like cassava, sweet potato, yams and aroids (elephant foot yam, taro and tannia) and minor tuber crops (coleus and arrow root) constitute the subsidiary food for millions of people since time immemorial. These group of ethnic crops owing to its biological efficiency, adaptation to marginal environments both soil and climate, tolerance to pests and diseases, high starch content in tubers, better physico-chemical properties of tuber starch in making value added products gained much significance in the food, nutritional and social security of people in the recent times. Recent research conducted in these crops could reveal many of its nutraceutical and medicinal properties which in turn also helped in promoting its consumption to some extent both as raw and as

value added products.

The industrial utility of tuber crops especially cassava deserves special mention as cassava starch can be used for making many products of commercial importance like biodegradable plastics, ethanol, super absorbent polymers, hard boards, films etc. Similarly, the antioxidants in sweet potato and yams (carotenoids and anthocyanins), phenols in coleus and elephant foot yam and the mucilage in taro and yams and fibres in all tuber crops are medicinally significant from the point of health benefits to the consumers. In addition, though the tubers of these crops are very low in protein, nature gifted their leaves with sufficient protein so that they can be consumed as leafy vegetables too.

The research experience in the plant nutrition of

Table 1: Tuber yield of cassava under different treatments over a period of 12 years of continuous cultivation

Treat	Years												Pooled
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
T1	24.316	18.531	28.048	32.030	29.225	33.110	29.790	25.098	30.844	32.851	25.160	14.238	26.937
T2	23.795	12.624	30.965	31.020	32.571	32.130	24.700	24.901	25.173	27.615	23.060	11.425	24.998
T3	23.546	15.851	31.065	26.159	26.236	27.121	21.320	22.871	22.571	22.272	23.180	11.502	22.808
T4	17.015	6.583	17.999	13.975	15.926	11.027	17.280	12.140	17.933	15.171	14.270	8.002	13.943
CD	3.092	2.001	3.198	7.927	8.092	6.816	6.356	6.395	5.867	7.109	9.624	4.552	5.919

T1: NPK @ 125:50:125, T2: POP (NPK@ 100:50:10), T3: STBF (NPK @ 82:0:74 kg ha⁻¹), T4: AC (Absolute Control)

tropical tuber crops over half a century clearly revealed that, these crops as highly responsive to manures and fertilizers. Moreover, the long term fertilizer experiment in cassava since 1977 at ICAR-CTCRI also indicated cassava responds very strongly and positively to plant nutrition. However, the same experiment also showed cassava as a benign crop for continuous cultivation in the same field even without

application of manures and fertilizers.

The nature of cassava is unique with respect to its sustainability for continuous cultivation without manures and fertilizers, climate resilience of cassava in terms of carbon sequestration, response of cassava to low input management and nutrient use efficiency of some genotypes of cassava and need based nutrient management practices like soil test

Table 2. Potential of cassava for carbon sequestration (Mean over 20 years)

Management practice	Leaf dry matter (t ha ⁻¹)	Leaf Carbon (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)
Recommend-ed fertilizer practice (POP)	3.726	1.677	62.96	297.04	10460	2460	31.02
Absolute Control (AC)	2.643	1.189	44.659	315.341	8360	1660	13.98



The industrial utility of tuber crops especially cassava deserves special mention as cassava starch can be used for making many products of commercial importance like biodegradable plastics, ethanol, super absorbent polymers, hard boards, films etc.

based application of manures and fertilizers in cassava, best management practices in cassava and elephant foot yam, customized fertilizer formulations and use of NUE microbes in elephant foot yam in abating soil pollution. All these features will definitely imply the fact that, cassava, though responds positively to plant nutrients, it can also be suited to situations of no or low input of nutrients without adversely affecting the yield, thus can be a solution to soil pollution to some extent.

a. Sustainability of cassava for long term cultivation without manures and fertilizers

At ICAR-CTCRI, under the long term fertilizer experiment (initiated in 1977) since 2005, the treatment 'absolute control' where there was no nutrient application either through manures and fertilizers revealed for the last 12 years that, it is a sustainable crop for continuous cultivation in the same field with an yield range of 6.583 to 17.999 t ha⁻¹ and a mean tuber yield of 13.943 t ha⁻¹ (Table 1).

The reason can be attributed to the innate physiological mechanism of the crop to shed its leaves during the crop growth period as well the high leaf dry matter production to the tune of 1.515-5.426 t ha⁻¹ with an average value of 2.693 t ha⁻¹ under absolute control during this period. Moreover, cassava leaves are rich in all nutrients especially N. The content of nutrients viz., N, P, K, Ca, Mg, Fe, Cu, Mn and Zn in cassava leaves accounts to the tune of 4.41, 0.28, 1.25, 0.21, 0.321, 0.016, 0.0008, 0.0154 and 0.0064 % 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 even without plant nutrition.

The sustainable yield index worked during these years for package of practices (POP) and absolute control (AC) indicates that without any plant nutrient application, cassava can sustain its yield and nature.

b. Climate resilience of cassava in terms of

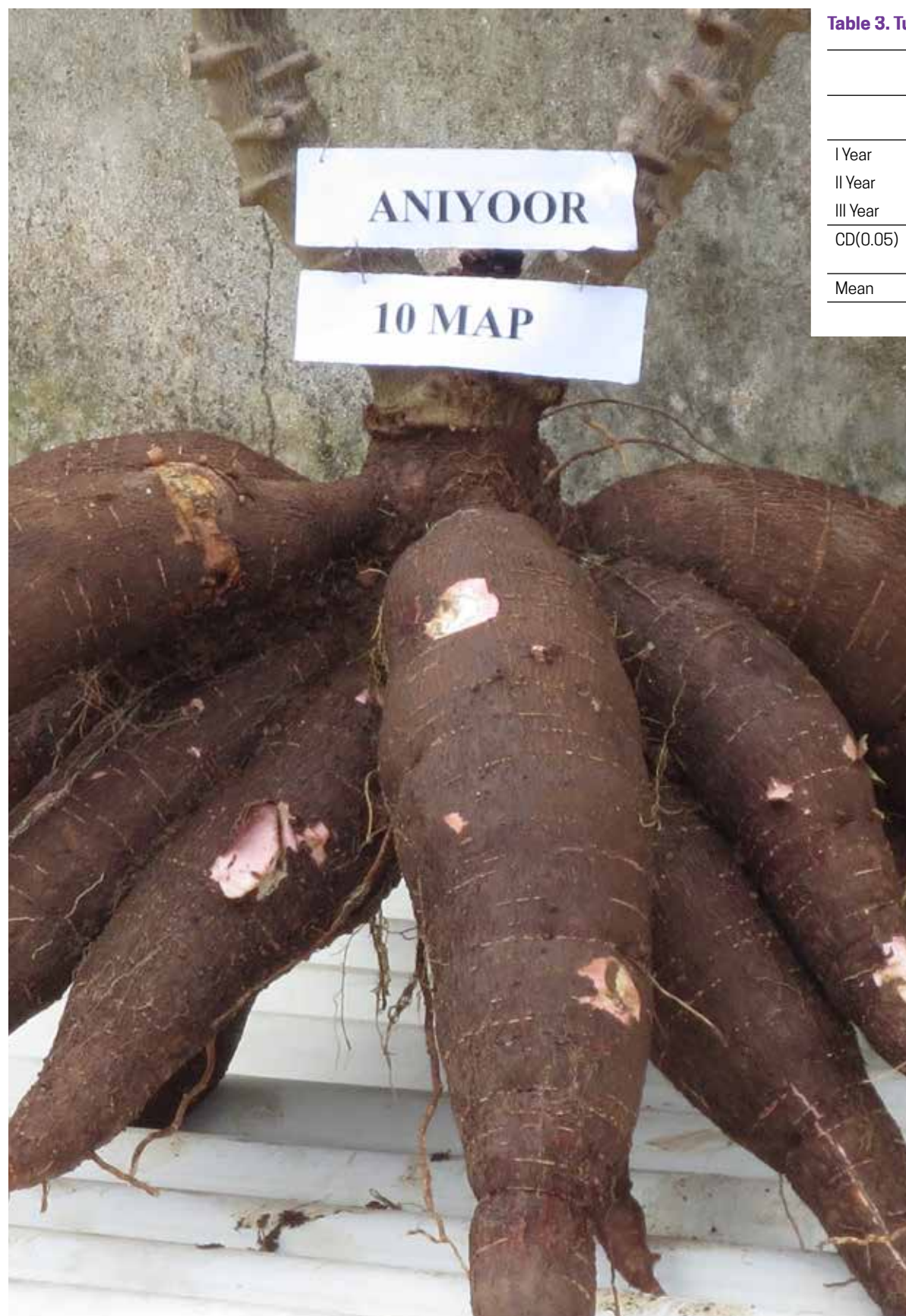


Table 3. Tuber yield at Levels of NPK (I,II &III seasons)

	Tuber yield (t/ha)			
	25%	50%	75%	100%
I Year	39.767	41.575	44.342	46.199
II Year	19.850	21.150	17.837	21.290
III Year	36.479	36.347	40.698	41.032
CD(0.05)	NS			
Mean	32.032	33.024	34.292	36.174

carbon sequestration

Climate resilience of a crop denotes the ability of the crop to adapt and adjust to the adversities of climate change. Increasing CO₂ concentration of the atmosphere is considered as the predominant cause of global warming and this indirectly indicates that, by decreasing the CO₂ concentration of the air, global warming can be reduced. Carbon sequestration is the removal of atmospheric CO₂ by plants and storage of fixed carbon as soil organic matter. If the crop can absorb more CO₂ from the atmosphere and if the absorbed CO₂ can be converted to soil organic carbon, it can be designated as a high C sequestering crop and thereby reduce the atmospheric CO₂ and hence global warming.

Cassava because of its high leaf dry matter production (average 2.5-3 t ha⁻¹) absorbs more CO₂ from the atmosphere to produce more leaf dry matter and due to the innate physiological mechanism of leaf shedding especially during drought will result in incorporating the leaf dry matter into the soil and get converted into soil organic matter. The comparison made between recommended fertilizer practice (POP) and an absolute control (AC) with respect to change in soil organic carbon (SOC) through leaf dry matter addition over a period of 20 years (1990-2009) to highlight the C sequestering efficiency of cassava and thereby global warming is presented. Jian Ni (2004) accomplished the relation that, 1 g dry matter contains 0.45g carbon and hence estimated the carbon content in the leaf dry matter. According to Singh et al., (2007), to produce 1g dry matter, 1.69g CO₂ is absorbed from the atmosphere, thus the atmospheric CO₂ utilized to produce the leaf dry matter was arrived. The atmospheric CO₂ concentration during 1990 is taken as 360 ppm (Ramakrishna et al., 2006) and from this, the reduction in CO₂ content of the air through leaf production was calculated.

In the absolute control, the CO₂ acquisition

and concomitant increase in SOC ranged from 25-50% of POP only. The ultimate effect of sequestering the atmospheric CO₂ through reduction in atmospheric CO₂ and increase in SOC was manifested as increase in tuber yield. Hence, it can be inferred that cassava can sequester atmospheric CO₂ into SOC and mitigate global warming to a great extent.

c. Response of cassava to low input management in cassava

Field experiments conducted for two years resulted in evolving a low input management strategy for cassava involving NUE genotypes viz., CI-905, CI-906, soil test based application of N, P, K, Mg and Zn, green manuring in situ with cowpea as low cost organic manure source and NUE microbial isolates viz., N fixers, P solubilizers and K solubilizers with tuber yield of 33.68 and 34.72 t ha⁻¹ and B:C ratio of 4.43 and 4.57 respectively under the above genotypes including a saving of P, K, Mg and Zn to the tune of 100, 11.5, 62.5 and 80% respectively and the percentage increase in cost of inputs under the other high input practices over the low input practice varied significantly up to 55%. The saving of fertilizer inputs and even organic manure in the form of farm yard manure (FYM) can definitely abate soil pollution.

Under the LTFE, soil test based fertilizer cum manurial recommendation with NPK @ 82:0:74 kg ha⁻¹ along with FYM @ 5 t ha⁻¹ for the last 12 years could realize yield on par with POP linking cassava and its nutrient management through soil test based low input as best solutions to manage soil pollution. This type of need based application of chemical fertilizers and organic manures can avoid non judicious blanket fertilizer application and can definitely be a solution to abate soil pollution.

d. Nutrient use efficient (NUE) cassava genotypes

Research work conducted in fostering the significance of NUE genotypes since 2006 at ICAR-CTCRI resulted in releasing the first K efficient cassava variety 'Sree Pavithra' in 2005 which can yield at low levels of K due to the root architecture with more number of root hairs/ white roots in this variety which can mobilize the fixed K from lower layers to the surface resulting a saving of up to 50% K. Similarly, two N use efficient genotypes viz., W-19 and CR 43-8 were identified which can save N up to 50%. Moreover, three NPK use efficient genotypes viz., CI-905, CI-906 and 7 III E3-5 were screened after conducting field experiments continuously for three seasons for their efficacy to yield even up to 25% NPK for yield on par with 100% NPK, with yield as 32.032, 33.024, 34.292, 36.174 t ha⁻¹ respectively at the above NPK levels indicating that, by using these NPK efficient genotypes, NPK fertilizers can be saved up to 75% (Table 3).



Hence, it can be well stated that, by using the NUE genotypes, the use of chemical fertilizers can be reduced and thereby soil pollution to a great extent.

e. Best management practices for cassava and elephant foot yam under intercropping in coconut

The BMP evolved and validated for cassava and EFY after conducting 14 field trials for three years in AEU 3 and AEU 9 under intercropping in coconut comprised of organic manures viz., FYM as per POP for EFY @ 25 t ha⁻¹ and soil test based application of FYM @ 7.5 t ha⁻¹ for cassava, NPK fertilizers based on soil test @ 71:12.5:106.5 and 78:12.5:60 kg ha⁻¹ for AEU 3 and AEU 9 respectively, lime as per surface soil pH @ 1t ha⁻¹, gypsum as per subsurface soil pH (below 5) @ 2 t ha⁻¹, Dolomite @ 1.5 t ha⁻¹, MgSO₄ @ 80 kg ha⁻¹, ZnSO₄ @ 25 kg ha⁻¹ and borax @ 12.5 kg ha⁻¹. This type of need based application of nutrients based on soil test data can be the better means to abate soil pollution.

f. Customized fertilizer (CF) formulations for elephant foot yam under intercropping in coconut

Customized fertilizer formulations developed based on soil nutrient status and plant nutrient requirement as the three CF's developed for EFY under intercropping in coconut for AEU 3 and AEU 9 with grades as N: P₂O₅: K₂O: Mg: Zn: B @ 8:11:21:3.5:1:0.3 (CF1), 7:12:24:2.5:1.25:0.4 (CF2), 7:3:25:3:1.25:0.4 % (CF3) is the best option to reduce soil pollution as it implies to need based nutrient management.

g. NUE microbes in reducing the chemical fertilizer use in elephant foot yam

NUE microbes viz., N fixers, P and K solubilizers viz., *Bacillus cereus*, *Bacillus megaterium* and *Bacillus subtilis* respectively as a component of the INM practice in EFY and sweet potato resulted in saving of 25% each of N and K and P up to 50-75%, thereby reducing the use of chemical fertilizers to manage soil pollution to a great extent.

The significance of tuber crops and its need based integrated nutrient management strategy in managing the soil pollution can be regarded as the need of the present time where people are very much health conscious. In this respect, the value of soil is immense as it is the foremost substrata for food production and incidentally it put forth the need to take care of the soil health by avoiding all sorts of pollution due to human interventions.