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Effects iodine doses on bio fortification of cassava (*Manihotesculenta*) in Calabar, Southeastern Nigeria

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Abstract

A 2 by 4 factorial experiment replicated 3 times, arranged in a randomized complete block design was conducted to determine the effectiveness of agronomic iodine biofortification of two varieties of cassava (TME 419 and TMS 30555) using different rates of potassium iodate (0, 2.5, 5.0 and 10kg/ha) in Calabar, southeastern Nigeria. Parameters measured were growth rate (plant height), tuber number, tuber weight and tuber weight per plot. Iodine content in harvested tuberswere also determined. Results indicated that plant height, number of stem, number of leaves, LA and LA1 were not markedly affected by applied iodine (P> 0.05); tuber number, weight and plot yields did not vary significantly with iodine rates. Iodine absorption and retention in tuber flesh and processed product were significant positively correlated with iodine doses (P<0.05 and 0.01). TMS 419 retained iodine better than TMS 30555. Effective dose for agronomic bio-fortification of TME 419 is 2.5 kg/ha KI and10kg/ha KI for TMS 30555.

Keywords: Bio-fortification, Iodine application, Cassava, Human nutrition, Nigeria.

Introduction

A major concern of stakeholders of the human health nutrition sector is that a large population of people in the underdeveloped and developing world lack quality food and suffer from different food and mineral deficiencies or "hidden hunger"[1]. This lack of nutritious food is further compounded by the fact that the populace in these areas rely mainly on a single or few staple crops for their nutrition[2]. Deficiencies in protein, vitamins and such micronutrients as iron, zinc, selenium and iodine constitute nutrient deficiency or hidden hunger. Forty three percent of African and about 54 percent Eastern Mediterranean people are iodine deficient[2].

This reliance on few staples can be exploited to becoming an avenue to combat nutrient deficiency. Since the conventional approaches of giving dietary supplement, consumption of food with varieties of fruits, vegetable, animal product and processed fortified food is beyond reach of the target population, biofortification of popular staples like cassava with higher nutritional content will have better impact[3].

Iodine is an important micronutrient required in human health and is been consumed below recommended levels by a good number of Africans[2,4]. It is required in the thyroid gland to produce thyroxin a hormone that controls the body relaxing speed (basal metabolic rate) and support normal growth and development. Symptoms of iodine deprivation include sluggishness (hypothyroidism), addition of weight and in most cases an enlarged thyroid gland i.e. goiter[5]. Iodine deficiency disorders (IDD) is a preventable and treatable human health problem and addition of iodine in edible salt iodized salt has been adopted as the most common inexpensive iodine supplementation in human diet[6]. Although use of iodized salt is common, iodine deficiency is still a major health problem in most parts of the world[4]. The high temperature of cooking could be responsible for this[7]. They further explained that high temperatures of oil used in frying and baking (usually above 360 °C), typical of cooking ethnic Chinese food leads to volatilization of iodine. High temperature cooking, frying and roasting is a common practice in Africa. These therefore suggest that other avenues for supplementation in human diet can be exploited.

Biofortification is a strategy employed to increase nutrient concentration in staple food crops to enhance diets composed mainly of carbohydrate staples[8]. The process involves raising the levels of minerals and vitamins in edible portions of plants that efficiently improves consumer health either by genetic or agronomic means of fertilization[9-11]. The beauty of the strategy is that it aims to improve the staple diet of the low-income household who cannot afford a more diverse diet thereby supplementing iodine intake the diet that may have been reduced by volatilization during cooking[3].

The cereals (rice wheat and maize) are the most popular staple for over 4 billion people across the world[12]. These crops would have been ideal choice for agronomic fortification with Iodine. In iodine fertilized rice, large accumulation of Iodine was found in the roots, stem and leaves against extremely small amounts in the grain[13,14]. Since Iodine translocation requires active phloem transport, it means that phloem transport of iodine to rice grains is low[14]. Iodine concentration in rice grain was far below required levels even with high doses of iodine application[13].

Therefore adopting cassava, a widely consumed staple in Nigeria after maize, which physiologically accumulates organic substances via the phloem transport, may be a suitable choice for agronomic Iodine biofortification.

The objectives of the research were therefore to: i. Evaluate the effect of iodine fertilization on growth and yield in two cassava varieties. ii. Determine the dosage of iodine application for effective agronomic fortification.

Materials and methods

Study area: Two field experiments were conducted in Calabar Southeastern Nigeria between August 2012 and May 2014. Calabar lies between latitude 4° 15´and 5° N and longitude 8° 25´ E, it is characterized with distinct dry and wet season of the humid tropical climate, with temperature between 25 °C and 32.8 °C. It also experiences an annual rainfall of 1900 – 3000mmand relative humidity between 80-90 percent[15]. It therefore falls within the tropical rainforest climatic vegetation zone with typical primary and secondary forest re-growth vegetation and able to support crops like maize, cassava, banana, pawpaw, oil palm, rubber and mangoes[16].

Experimental design: The factors of the experiment were cassava variety and rates of Iodine fertilization. Two cassava varieties (TME 419 and TMS 30885) were cultivated and fertilized with four rates of Iodine (0, 0.25, 1.0kg/ha KI); to give a 2 by 4 factorial experiment arranged in randomized complete block design.

Planting of cassava: Mature and healthy cassava stems cut to 20cm by were planted in the field in the first week of August 2012 and 2013, at a planting distance of 1m on a 16m² bed.

Iodine and fertilizer application: Sensitive balance (model: Scout pro) was used to measure out the required iodine rate (0, 0.25, 0.50 and 1.0g KI per plant) equivalent to 0.2.5, 5.0 and 10kg/ha of KI. The KI was applied by banding around individual plants. Iodine was applied at 10WAP, which falls within the recommended time when storage root initiation occurs[17,18].

N:P:K 15:15:15 at the rate of 200kg/ha was applied to the field 3MAP in both 2012 and 2013.

Soil analysis: A representation soil sample of the field was taken to determine soil pH in water, N,P, K, Ca, Mg, ECEC and organic carbon using the methods in[19,20].

Growth and yield data: Vegetative parameters measured were plant height at 8, 12, 16, 20, 24, 28 and 32 WAP; leaf number, leaf area, total leaf area and leaf area index.

The formula for leaf area was determined as follows:
$A = 0.9441 \text{ X } L^{1.8985}$
Where: A = cassava leaf area, L = length of central lobe and 0.9441 = constant[21]. Yield parameters determined were number of tubers (per stand and per plot) and tuber weight (per stand and per plot).

Tissue iodine content: Iodine content in tuber flesh and processed cassava were determined using the x-ray fluorescence method[22].

Results and discussion

Soil analyses results were pH 4.7, total – Nitrogen 0.637%, AvP177.10mg/kg, K, Ca, Mg and ECEC were 0.08, 0.70, 0.40 and 3.19cmol/kg respectively; organic carbon was 4.02% while soil iodine was 0mg/kg.

Tables-1 and 2 show the monthly height increment of the two cassava variation influenced by rate of iodine application in 2012 and 2013. Though the cassava planted in 2012 were taller than those of 2013, within the growing period or year, iodine application was not responsible for the slight variation in height increment or growth rate. However, cassava variety TMS 30555 produced taller plants than TME 419. Interaction between varieties and rate of iodine application was not significant.

Vegetative characteristics: Tables-3 and 4 show the vegetative growth of the two cassava variation influenced by rate of iodine application in 2012 and 2013. Applied doses of Iodine did not ominously affect the number of stems, leaf area (LA) and leaf area index (LAI). More stems and leaves were produce in the 2013. Though the LA of TMS 30555 were less than those of TME 419, the more number of leaves produced by TMS 30555 resulted in higher LAI than TME 419.

Tuber yield: The effects of application of different doses of iodine on yield in the two cassava variation are shown in Tables-5 and 6. No clear trends in relation to yield were expressed by the different iodine doses. While tuber number, tuber weight per stand and tuber yield per plot increased with Iodine doses in 2012, in 2013, cassava plants that did not receive iodine had higher tuber number, average tuber weight and tuber yield per plant than those that received Iodine. However the variation in tuber yield was not significantly different with applied Iodine. Variety and rate interaction was insignificant. Tuber yield for TME 419 where slightly higher in 2012,but in 2013 TME 30555 recorded slightly higher yield than TME 419. In both years, the variance in yield was not pronounced.

Iodine Absorption: The Tables-7 and 8 illustrate that increasing iodine doses increases iodine retention in cassava tuber flesh and processed cassava. In the 2012 planting, Iodine fertilisation was two times more in plants that received the least dose of Iodine compared to those that did not receive iodine, in both cassava varieties. Iodine content in both tubers and processed cassava were higher in 2013 season than the 2012 planting. Considering the cassava varieties, TME 419 shown significantly higher relationship with iodine applied to iodine retained in tissue and processed cassava in both planting seasons. For variety TMS 30555, though there was positive correlation between iodine supply and iodine retain, in 2013 the association between increasing rates of iodine supply and that retain in tuber and processed cassava was not strong.

Table-1: Monthly plant height (cm) of two cassava varieties influenced by rates of Iodine application (2012).

Factors	Weeks after planting					
	8	12	16	20	24	28
Variety						
TME 419	172.0[a]	109.9[a]	147.4[a]	170.4[a]	192.1[a]	266.0[a]
TMS 30555	604 [a]	99.6[a]	141.4[a]	173.4[a]	197.1[a]	320.0 [a]
Rate						
0.gKI	66.2 [a]	98.8 [a]	139.1 [a]	168.9 [a]	188.8 [a]	376.0 [a]
0.25gKI	63.3 [a]	104.9 [a]	147.8 [a]	177.0 [a]	199.9 [a]	261.0 [a]
0.50gKI	67.9 [a]	108.3 [a]	149.2 [a]	171.0 [a]	196.4	272.0 [a]
1.0gKI	67.4 [a]	107.1[a]	143.5[a]	171.1[a]	193.2	262.0 [a]
Interaction						
V x R	NS	NS	NS	NS	NS	NS

Table-2: Monthly plant height (cm) of two cassava varieties influenced by rates of Iodine application (2013).

Factors	Weeks after planting						
	8	12	16	20	24	28	32
Variety							
TME 419	28.814[a]	42.941[a]	93.142[a]	118.741[a]	142.892[a]	153.035[a]	183.358[a]
TMS 30555	29.267[a]	48.984[a]	98.305	113.308	145.788[a]	155.246[a]	183.865
SE	1.601	3.018	2.395	2.935	2.466	1.488	3.473
Rate							
0 kg/ha KI	28.613[a]	45.512[a]	95.129[a]	117.613[a]	145.773[a]	151.5229[a]	192.37[a]
2.5 kg/ha	26.913	49.615[a]	95.586[a]	110.267[a]	148.442[a]	152.257[a]	188.1665
5 kg/ha KI	27.994[a]	45.737[a]	89.660[a]	122.140[a]	637.754[a]	158.540[a]	176.181[a]
10 kg/ha KI	32.651[a]	42.986[a]	86.519[a]	114.078[a]	145.391[a]	154. 141[a]	177.715[a]
SE±	2.331	4.452	3.49	4.306	3.588	2.162	4.99
Interaction							
V x R	NS	NS	NS	NS	NS	NS	NS

Means followed by same letters in each column are not significantly different at p.05 by Duncun multiple range test. * - significant, NS = not significant.

Table-3: Influence of rates of iodine application on vegetative growth in two cassava varieties (2012).

Factors	No of stems	No of leaves	Leaf Area
Variety			
TME 419	1.64	259.47	223.36
TMS 30555	1.83	317.44	206.30
SE	0.081	1.76	4.681
Rate			
0	1.89^{a}	253.56^{a}	206.29
2.5kg/ha	1.56^{a}	299.39^{a}	216.94
3kg/ha	1.67^{a}	298.28^{a}	226.19
10kg/ha	1.83^{a}	302.69^{a}	209.40
SE	0.115	2.49	6.620
Interaction			
V x R	NS	*	NS

Means followed by same letters in each column are not significantly different at p.05 by Duncun multiple range test
* - significant NS = not significant.

Table-4: Influence of rates of iodine application on vegetative growth in two cassava varieties (2013).

Factors	Number of stems	Number of leaves	Leaf Area cm^2	Leaf Area Index
Variety				
TME 419	2.25	268.47	220.25	384.78
TMS 30555	2.58	326.67	187.78	694.31
SE	0.08	1.74	5.38	23.55
Rate				
0	2.17^{b}	263.61^{b}	202.67^{b}	522.50^{b}
2.5kg/ha	2.50^{a}	308.50^{a}	196.61^{b}	354.44^{a}
5 kg/ha	2.56^{a}	306.72^{a}	203.28^{b}	538.33^{a}
10kg/ha	2.4^{a}	311.44^{a}	213.509	542.83^{a}
SE	0.12	2.46	7.6	33.30
Interaction				
V x R	NS	*	NS	NS

Means followed by same letters in each column are not significantly different at p.05 by Duncun multiple range test
* - significant, NS = not significant.

Table-5: Influence of rates of iodine application on yield in two cassava varieties (2012).

Factors	Number of tubers	Average tuber weight per stand (kg)	Tuber yield/plot (kg)
Variety			
TME 419	5.83	6.24	35.1
TMS 30555	5.44	6.03	34.0
SE	0.297	0.34	2.90
Rate			
0	5.17^{a}	5.63^{a}	32.5^{a}
2.5kg/ha	5.61^{a}	6.04^{a}	34.5^{a}
5 kg/ha	5.72^{a}	6.23^{a}	36.6^{a}
10kg/ha	6.06^{a}	5.80^{ab}	34.6^{a}
SE	0.42	0.481	4.10
Interaction			
V x R	NS	NS	NS

Means followed by same letters in each column are not significantly different at p.05 by Duncan multiple range test
* - significant, NS = not significant.

Table-6: Effect of rates of iodine fertilization on yield in two cassava varieties (2013).

Factors	Tuber number	Average tuber weight Per stand (kg)	Tuber yield/plot (kg)	Tuber Yield tons/ha
Variety				
TME 419	5.17	15.82	142.40	89.00
TMS 30555	5.20	16.84	151.60	94.00
SE	.30	2.10	18.94	11.84
Rate				
0	5.39^{a}	20.34^{a}	183.10^{a}	114.44^{a}
2.5kg/ha	5.37^{a}	15.52^{b}	139.69^{b}	87.31^{a}
5 kg/ha	5.25^{a}	17.69^{a}	159.17^{a}	99.48^{a}
10kg/ha	4.74^{a}	11.78^{b}	106.03^{b}	66.27^{b}
SE	.43	2.98	26.79	16.74
Interaction				
V x R	Ns	Ns	NS	Ns

Means followed by same letters in each column are not significantly different at p.05 by Duncun multiple range test
* - significant NS = not significant.

Table-7: Tuber and Processed cassava iodine content influenced by rate of iodine fertilization.

Rate (kg/ha)	Tuber content (mg/kg)				Processed Cassava Content (mg/kg)			
	TME 419		TMS 30855		TME 419		TMS 3088	
	2012	2013	2012	2013	2012	2013	2012	2013
0	4.5^{d}	9.6^{d}	3.8^{d}	8.5^{c}	1.8^{d}	3.7^{d}	1.6^{c}	6.1^{b}
2.5	8.3^{bc}	12.0^{c}	9.9b^{c}	15.1^{a}	4.0^{abc}	6.4^{c}	4.8^{b}	7.2^{a}
5.0	7.4^{b}	13.8^{b}	10.2^{b}	12.9^{b}	3.3^{c}	10.8^{b}	5.6^{a}	7.0^{a}
10.0	11.4^{a}	14.3^{a}	11.8^{a}	13.0^{b}	5.8^{a}	14.8^{a}	5.8^{a}	7.6^{a}

Means followed by different letters in each column are significantly different at p.05 by LSD.

Table-8: Correlation Coefficient of rate of iodine application on tuber and processed cassava control in two variations of Cassava.

Variety	Tuber content		Processed cassava content	
	2012		2013	
TME 419	0.92**	0.9**	2012	2013
TMS 30555	0.83**	0.44^{c}	0.91**	0.92

* = significant at 0.05 probability level, ** = significant at 0.05 and 0.01.

Discussion: Vegetative growth and Yield: Vegetative characteristics (plant height, number of stems, number of leaves, leaf area and leaf area index) where not detrimentally affected by iodine fertilization. Plants that did not receive Iodine did not vary significantly from those that received Iodine. Also numbers of tubers, average tuber weight per stand and per plot were not markedly affected by iodine inclusion. The difference in tuber weight was not due to iodine fertilization. These findings indicate that the dose adopted for the research were within the safe doses beyond which iodine may have physiological damaging effects on plant growth. Excess iodine has been reported to produce severe physiological symptoms in plants which may cause death in extreme cases[23,24]. Fluctuation in vegetative growth of spinach occurred at different levels on iodate concentration, though iodine supplied as iodate in nutrient solution did not have significant effect on both shoot and root biomass[4].

Iodine uptake: In both seasons of cultivation and in both cassava varieties (TME 419 and TMS 30555), cassava plants that received iodine, significantly, had higher iodine content than the control plants. The result also showed that iodine retained in the tuber and processed cassava where significantly positively correlated with iodine supply. This finding is in line with the cases of carrot and radish where increasing iodine levels resulted in significantly higher iodine retained in storage roots[25,26].

Conclusion

Iodine fertilization of cassava will not affect the growth and performance of cassava in the rainforest region, especially at the doses adopt in this study. Agronomic Bio fortification of cassava with iodine is possible Cassava variety TME 419 retained iodine better than TMS 30555. Effective rate for agronomic Bio fortification for TME 419 in 2.5kg/ha, while that of TMS 30555 is 10kg/ha. Iodine absorption in tubers may increase because of residual effect of the previous year. Further studies on residual effects of applied soil Iodine on crop growth should be carried out since high doses is detrimental to plants.

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