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Effects of Iodine Agronomic Bio- fortification on selected Physiological Characteristics of Cassava in Calabar, Southeastern Nigeria

Ansa, J. E. O

Department of Agriculture, Ignatius Ajuru University of Education, Ndele Campus, Rivers State, Nigeria.

Tel: +2348035467241 Email: joseph.ansa@iaue.edu.ng

Binang, W. B.

Department of Crop Science, University of Calabar, Cross River State, Nigeria.

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Abstract

Field experiments were conducted between November 2011 and May 2014 at the Crop Science Teaching and Research Farm of the University of Calabar, (Southeastern rainforest agro-ecological zone of Nigeria) to determine the effectiveness of Iodine agronomic fortification of cassava. The field experiment was a 2x3x4 factorial experiment arranged in randomized complete block design replicated three times, conducted using two cassava varieties,(TME 419 and TMS 30555); four iodine rates(0, 2.5, 5.0 and 10.0) kg/ha KI; applied at 8, 10 and 12 WAP. Physiological data were obtained by determination of Iodine content [in cassava tuber]; tuber cyanide content (HCN); Carbohydrate content of tuber; starch content of tuber and tuber protein contents. Iodine absorption and retention in cassava tuber flesh was significantly positively correlated with Iodine doses at the times of application (p0.05 and 0.01). TME 419 retained more Iodine in tissues than TMS 30555 and recorded highest correlation co-efficient at 10WAP. Iodine doses and time of application did not significantly control ($P \geq 0.05$) contents of cyanide, carbohydrate and starch in cassava tubers. Protein content was significantly varied in cassava varieties and rate and time of Iodine application influenced tuber protein content. TME 419 produced more tuber protein, Iodine doses of 2.5kg/ha KI and 0kg/ha KI had higher protein content than 5kg and 10kg/ha KI. Application at 8WAP and 10WAP were not significantly different. For favourable

physiological cassava characteristics, 2.5kg/ha KI is recommended applied 10 weeks after planting (WAP).

Keywords: Agronomic biofortification, Iodine, Cassava, Cyanide content, Protein, carbohydrate, starch

1. Introduction

Bio fortification can be defined as raising the amounts of minerals and vitamins in crop plants that greatly enhance consumer health either by genetic or agronomic means of fertilization (White and Broadley 2009, Yang et al. 2007, Zhao and McGrath 2009). It is different from food fortification because it centers on making plants or crops more nutritious, rather than incorporating nutrients into the foods when they are being processed. Biofortification is an approach that targets increasing nutrients in staple food crops for the enhancement of diets composed mainly of carbohydrate staples (Johns and Eyzaguirre 2007). It takes the advantage of the usual daily intake of the normal staple food, thus trying to meet the nutritional needs of low-income households who cannot afford a diet that includes fruits and vegetables.

Cassava is a major staple that feeds over 800 million of the world population, mainly situated in sub-Saharan Africa (Knirsch 1996). It is an important source of dietary energy food for most people living in the low-land tropics and the sub-humid tropics of West and Central Africa (Tsegia and Kornawa 2002). Cassava products are utilized in different forms as human food, livestock feed and in the making of industrial products (Ene 1992). In Nigeria, IITA (2002) has recognized the common forms in which cassava is utilized as garri, fufu, cassava chips, cassava flour, starch, farina, tapioca, macaroni, pudding and cassava bread. Kormawa and Akoroda (2003) also pointed out that cassava is consumed in different forms of garri, akpu/fufu, lafun, starch and abacha as traditional meal in five of the six geopolitical zones of Nigeria. It is therefore a good candidate for Bio fortification.

Micronutrients including iodine make up the main human nutrient needs and 43 percent of the African populace takes in less than recommended amount of iodine (McWilliams 2011). Iodine is an essential micro nutrient in man, required to produce thyroid hormone. It is found in food and human body in the ionized form called Iodide. The thyroid gland unites iodine with amino acid tyrosine to make thyroxin and triiodothyronine hormones that control the body relaxing speed (basal metabolic rate) and support normal growth and development. Symptoms of lack of Iodine include sluggishness (hypothyroidism), addition of weight and in most cases an enlarged thyroid gland (goiter) (Abraham et al. 2002).

To combat lack of Iodine, addition of iodine in edible salt (iodized salt) has been adopted and it is now the most common, easy and less expensive way of iodine supplementation in human diet. However, salt which is the major source of sodium in human diet has long been shown to raise blood pressure (Jacobson 2009) and its continuous and excess intake has been linked to increased incidence of cardiovascular disease (Smolen and Sady 2011a). This has led World Health Organization to recommend drastic reduction in human sodium intake (WHO 2007). Reduction in the use of iodized salt may reduce the occurrence of cardiovascular diseases, but it may likely reduce quantity of iodine intake with consequent increase in its deficiency disease. Therefore fortifying a widely consumed staple like cassava may likely serve as a healthy alternative to iodized salt and indeed reduce incidence of Iodine deficiency disease (IDD).

Cassava varietal trials on iodine agronomic fortification by Ansa et al (2016), Binang et al (2016) and Ansa et al (2017) have shown that fertilizing the soil with iodine as potassium iodide (KI), resulted in the retention of iodine in cassava tuber and in processed cassava. They also reported that iodine fertilization was not detrimental to the growth and yield of cassava. To be a complete technology package which can be adoptable by farmers, it is important to access the effect of iodine inclusion on some important cassava physiological characteristics.

The objectives of this study therefore were to evaluate the:

(i) Effect of rate and time of iodine application on carbohydrate content in cassava.

(ii) Influence of iodine fertilization on starch content in cassava.

(iii) Effect of iodine inclusion on cyanide content in cassava, and

(iv)Influence of rate and time of iodine fertilization on protein content in cassava

2. Materials and methods

2.1 Study Area

The experiment was conducted at the teaching and research farm of the Department of Crop Science, Faculty of Agriculture, University of Calabar , Cross River State, Nigeria. Calabar falls within the tropical rainforest climatic zone (Effiong 2011), exhibiting characteristic humid tropical climate with distinct dry and wet season. Annual rainfall ranges from 1900 mm to 3000 mm with a relative humidity between 80 and 90 percent (Afangide et al 2010). The period of sunshine ranges between 4.1 and 4.9 hours with an average of 4.6 hours (Nwajiuba and Onyeneke 2010).

2.2 Experimental Design

The experiment involved three factors: cassava varieties, rate of Iodine applied and time of Iodine application. The field experiment was conducted on flat tilled plots measuring 4.0 m x 4.0 m, with I.0 m space between plots and 2.0 m between blocks. Cassava plants were spaced at 1m by 1m in all plots. Two varieties (TME 419 and TMS 30555) were selected and used for the field experiments in 2012 and 2013. Iodine was applied as Potassium Iodide (KI) at rates of 0, 2.5, 5.0 and 10kg/ha respectively at 8, 10 and 12 weeks after planting. The experimental design was a 2 x 3 x 4 factorial arranged in a randomized complete block design replicated three times to give 72 experimental units.

2.3 Planting and post planting operations

2.3.1 Planting of cassava

Field planting was done in the first week of August 2012 and 2013. Mature and healthy cassava stems were cut to 20 cm long cuttings and planted 1.0 m apart in 4 m by 4 m plots.

2.3.2 Application of Iodine and fertilizer

The required quantity of Iodine applied as potassium iodide (KI) was weighed using a sensitive balance (Model; ScoutPro). The rates applied were 0, 0.25, 0.50 and 1.0 g KI per plant (equivalent to 0, 2.5, 5.0 and10 Kg/ha KI). Iodine was applied to individual plants by band placement at 8, 10, and 12 WAP. Two hundred (200) kg /ha NPK 15-15-15 fertilizer was applied in 2012 and 2013 at three months after planting to enhance cassava growth.

2.3.3 Weed management

Experimental plots/units were kept weed-free by hand-pulling and weeding as at when due. Weeds were completely removed to avoid competition for water and the applied nutrients to ensure maximum uptake of Iodine.

2.4 Data Collection

Iodine content of the cassava samples were determined using X-ray fluorescence spectrometer in accordance to Allen (1989). The cyanide content in the cassava root was determined by the Alkaline Titration Method (AOAC, 1984). The starch yield analysis was carried out using the formula:

$$Starch\,yield\,(\%) = \frac{Weight\ of\ starch}{Weight\ of\ sample} \times 100$$

The proximate analysis was conducted to determine Protein and Carbohydrate content by AOAC (2000), [carbohydrate content was determined by difference: 100- (% Moisture + % Ash + % Protein + % Fat + Crude Fiber)].

2.5 Data Analysis

Data analysis was done by the analysis of variance (ANOVA) and factorial experiment for the field experiment. The means were separated using the Duncan's Multiple Range Tests (DMRT) at 5 % level of probability, using the PASW statistical analysis method 18th edition.

3. Results

3.1 Effect of iodine on tuber content

The effect of rates and time of iodine application on the tuber iodine contents of the two varieties of cassava is shown in Table 1. In both varieties iodine absorption in the tubers increased with each incremental rate of KI applied. Plants without KI recorded the least iodine content in all treatment combinations. Increasing the levels of KI produced corresponding increase in fresh tuber iodine content.

3.2 Physiological parameters

Tables 2 and 3 highlights the influence of iodine rates and time of application on cassava tuber cyanide, carbohydrate, starch and protein contents in the two seasons. In both seasons, cyanide content (HCN), carbohydrate and starch content were not significantly influenced by rate and time of iodine fertilization. However, protein content was markedly affected by rates and time of iodine application as shown in Table 4. Interaction effects were also significant.

When we compare the varieties, TME 419 produced more protein in its tuber than TMS 30555. The table also showed that increasing iodine supply reduced protein content in the tubers. Control plants and plants that received least iodine (0g and 0.25g ie 0kg/ha and 2.5kg/ha) had the highest protein contents that were not significantly different. Applying iodine 10 WAP resulted in more protein in cassava tuber. Applying iodine 8 WAP and 12 WAP were not significantly different.

4. Discussion

4.1 Iodine absorption

Iodine retention in cassava tuber was significantly positively correlated with iodine supply. In addition plants that received iodine significantly had higher content than the control plants, in most cases recording value that were twice as much as the control plants. This finding is in accordance with the observation of several authors. For instance, Smolen and Sady (2011a), obtained significant increase in iodine content with iodine application in fresh vegetable leaves of spinach. Smolen et al (2011) reported that in carrot storage root all treatment combination of iodine had significantly higher amounts of iodine than control plants. Zhu et al (2003) and Strzetelski et al (2009) also reported increasing absorption of iodine in tissue content of spinach and radish.

4.2 Starch and Cyanide content

Starch and cyanide content were not negatively affected by iodine doses and time of application. This is an important factor, especially of starch, for the adoption of the inclusion of iodine fertilizer program in cassava production. Several new improved crops varieties and new production technology have not been easily accepted. Gilbert (1984) reported the unwillingness of villages to accept the use of iodized salt, thereby reducing the success in the program for reducing iodine deficiency in third world countries.

From the cassava variety handbook of Dixon et al (2010), the starch content of cassava tuber in this study were either higher or about the same value with those reported for the improved varieties. TME 419 in this study recorded higher starch content than the corresponding reported value for TME 419.

Cyanide contents of this study were also less than those reported in the (Dixon et al (2010) IITA proved variety handbook. These two favorable findings of cyanide and starch contents in this study are important experimental factors to explore in cassava production.

4.3 Protein content

Plants that received least iodine supply (2.5 kg/ha KI) had statistically higher levels of tuber protein content. This lower iodine dose might reflect the optimum needed to improve protein levels in cassava. It has been reported that iodine increases total N in crops (Smolen and Sady 2011 a & b, Smolen et al 2011). These researchers reported a positive influence of iodine fertilization on total nitrogen content in spinach and carrot. The values for protein in this study were higher than those reported for various improved IITA cassava varieties (Dixon et al 2010). The tuber protein and carbohydrate contents of the two test varieties (TME 419 and TMS 30555) are compared with values obtained for the various improved IITA cassava varieties as reported by Dixon et al (2010) in Table 5.

5. Conclusion

Both varieties of cassava (TME 419 and TMS 30555) absorbed iodine irrespective of rate and time. Iodine content in the tuber increased with application rate. Iodine content reduced cyanide levels and improved protein content in cassava tubers. Starch content was not affected by rate and time of iodine fertilization. The starch content observed was not lower than those documented for improved cassava varieties.

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TABLE 1. Effect of rates and time of Iodine application on Iodine content in tubers of two cassava varieties (mg/kg)(2012 and 2013 field experiment)

		2012		2013	
Rate kg/haKI	Time WAP	TME 419	TMS 30555	TME 419	TMS 30555
0	8	5.2^{d}	4.8^{d}	9.3^{d}	8.8^{d}
	10	4.5^{d}	3.8^{d}	9.6^{d}	8.5^{d}
	12	4.4^{d}	4.2^{d}	8.1^{d}	6.0^{c}
2.5	8	10.2^{abc}	10.1^{b}	15.8^{bc}	12.7^{b}
	10	8.3^{c}	9.9^{bc}	12.0^{c}	15.1^{a}
	12	10.1^{c}	9.1^{c}	13.6^{c}	12.9^{b}
5.0	8	11.0^{ab}	11.5^{a}	16.8^{b}	13.9^{ab}
	10	7.4^{c}	10.2^{b}	13.8^{d}	12.9^{b}
	12	10.8^{c}	8.45^{c}	14.0^{c}	10.5^{c}
10.0	8	11.1^{ab}	8.0^{cd}	21.3^{a}	15.1^{a}
	10	11.4^{ab}	11.8^{a}	14.3^{c}	13.0^{b}
	12	12.5^{a}	7.1^{cd}	14.10^{c}	10.8^{c}

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

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TABLE 2. Effect of rates and time of iodine fertilization on cyanide, protein and starch content in two cassava varieties (2012)

Variety	Time WAP	Rate Kg/haKI	HCN mg/kg	Carbohydrate %	Starch Content (%)	Protein %
TME 419	8	0	0.07^{a}	92.5^{a}	79.22^{a}	3.55^{b}
		2.5	0.07^{a}	92.18^{a}	79.46^{a}	3.55^{b}
		5.0	0.06^{a}	92.63^{a}	81.26^{a}	4.44^{a}
		10.0	0.05^{a}	91.97^{a}	78.55^{ab}	4.11^{ab}
	10	0	0.03^{a}	94.26^{a}	78.26^{a}	2.4^{c}
		2.5	0.06^{a}	90.341^{a}	67.44^{a}	3.41^{b}
		5.0	0.04^{a}	91.61^{a}	74.69^{a}	3.4^{b}
		10.0	0.03^{a}	91.47^{a}	69.69^{b}	4.13^{a}
	12	0	0.05^{a}	95.15^{a}	77.4^{b}	3.24^{d}
		2.5	0.05^{a}	87.74^{a}	81.77^{a}	5.35^{a}
		5.0	0.09^{a}	90.53^{a}	85.07^{a}	4.52^{b}
		10.0	0.02^{a}	92^{a}	71.34^{b}	3.82^{c}
TMS 30555	8	0	0.07^{a}	92.69^{a}	74.74^{b}	3.48^{b}
		2.5	0.06^{a}	88.62^{a}	75.82^{b}	5.12^{a}
		5.0	0.07^{a}	92.64^{a}	81.15^{a}	1.52^{c}
		10.0	0.09^{a}	93.24^{a}	77.48^{ab}	3.41^{b}
	10	0	0.09^{a}	90.183^{a}	64.13^{b}	4.71^{a}
		2.5	0.08^{a}	92.173^{a}	69.15^{b}	2.96^{b}
		5.0	0.08^{a}	93.87^{a}	80.18^{a}	2.89^{b}
		10.0	0.07^{a}	93.3^{a}	81.70^{a}	1.77^{c}
	12	0	0.09^{a}	91.2^{a}	79.63^{ab}	4.93^{a}
		2.5	0.07^{a}	91.96^{a}	85.13^{a}	1.78^{c}
		5.0	0.05^{a}	93.94^{a}	86.73^{a}	1.98^{c}
		10.0	0.06^{a}	93.41^{a}	76.13^{b}	2.5_{b}

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

TABLE 3. Effect of rates and time of iodine fertilization on cyanide, protein and starch content in two cassava varieties (2013)

Varieties	Time WAP	Rate Kg/haKI	HCN mg/kg	Carbohydrate (%)	Starch Content (%)	Protein (%)
TME 419	8	0	0.11[a]	92.50[a]	80.21[b]	3.56[b]
		2.5	0.19[a]	92.20[a]	82.28[b]	3.56[b]
		5.0	0.15[a]	92.69[a]	87.08[a]	4.44[a]
		10.0	0.14[a]	92.01[a]	88.68[a]	4.11[a]
	10	0	0.08[a]	94.28[a]	82.53[a]	2.43[c]
		2.5	0.10[a]	90.42[a]	70.05[b]	3.42[b]
		5.0	0.60[a]	91.62[a]	77.82[a]	3.44[b]
		10.0	0.10[a]	91.49[a]	72.61[b]	4.15[a]
	12	0	0.18[a]	93.54[a]	77.82[b]	3.22[d]
		2.5	0.08[a]	87.76[a]	84.42[a]	5.35[a]
		5.0	0.09[a]	92.62[a]	84.61[a]	4.48[b]
		10.0	0.10[a]	92.230[a]	75.36[b]	3.74[c]
TMS 30555	8	0	0.19[a]	92.78[a]	77.08[b]	3.48[b]
		2.5	0.11[a]	88.76[a]	78.15[b]	5.14[a]
		5.0	0.18[a]	92.75[a]	85.27[a]	1.56[c]
		10.0	0.11[a]	93.40[a]	80.51[a]	3.44[b]
	10	0	0.21[a]	90.26[a]	70.62[b]	4.76[a]
		2.5	0.09[a]	92.28[a]	71.51[b]	3.00[b]
		5.0	0.08[a]	93.87[a]	82.46[a]	2.88[b]
		10.0	0.28[a]	93.25[a]	83.70[a]	1.78[c]
	12	0	0.06[a]	91.24[a]	81.19[b]	4.90[a]
		2.5	0.08[a]	92.06[a]	88.92[a]	1.81[c]
		5.0	0.07[a]	93.97[a]	87.27[a]	1.94[c]
		10.0	0.12[a]	93.65[a]	80.91[b]	2.45[b]

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

TABLE 4. Influence of time and rates of iodine application on tuber protein content in two cassava varieties

Variety	Protein contents 2012	Protein contents 2013
TMS 419	3.83[a]	3.83
TMS 30555	3.05[a]	3.10
SE	0.55	0.59
Rate		
0gKI	3.52[a]	3.52[a]
0.25gKI	3.70[a]	3.72[a]
0.50gKI	3.13[b]	3.12[b]
1.05gKI	3.30[b]	3.28[b]
SE	0.78	0.83
Time		
8WAP	3.65[a]	3.66[a]
10WAP	3.21[b]	3.23[b]
12WAP	3.52[a]	3.49[a]
SE	0.68	0.72
Interaction		
VXR	*	*
VXT	*	*
RXT	*	*
VXRXT	*	*

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. Protein, Starch and Cyanide content in selected improved cassava varieties.

Variety	Protein %	Starch	CNP ppm
TMS (2) 1424	2.35 – 2.65	64.48 – 73.97	9.12
TMS 91/02324	2.55 – 3.49	63.81 – 70.23	15.97
TMS 92/0057	1.38 – 2.65	59.61 – 72.09	7.24
TMS 419	0.80 – 1.52	63.08 – 73.93	6.33
TMS 30555	-	20	High

Adapted from Dixon *et al* (2010).