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Potassium Fertilization Effects on the Field Performances and Post-Harvest Characteristics of Imported Indian Ginger Cultivars in Abia State, Nigeria

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Abstract: Varying levels of potassium (K) fertilizer (0, 25, 50, 75 and 100 kg K ha^{-1}), with basal application of Nitrogen (N) and Phosphorus (P) were used to determine the effect of adequate K nutrition on the field performance and post harvest characteristics of three elite Indian ginger cultivars (Maran, Wynad local and Himachel Pradesh) in Abia State, Nigeria. The results showed that in terms of ginger plant height, fresh rhizome yield and rhizome storability, the non-split application of 50 kg ha^{-1} (with 60 kg ha^{-1} N, 15 kg ha^{-1} P) during planting gave the optimum positive effect in the 2 years trial (2006-2007). However, the application of K at $\geq$50 kg ha^{-1} is required for a significant suppression ($p\geq0.05$) of the ginger yellow leaf spot disease amongst the experimental cultivars. Field application of the 50 kg K ha^{-1} also gave $\geq$80% wholesome (unrotten) rhizomes at 6 months of storage.

Key words: Ginger, cultivars, potassium fertilization, yield parameters, rhizomes, post-harvest storability

INTRODUCTION

Ginger (*Zingiber officinale* Roscoe), is an important economic spice crop (Ravindran and Nirmal, 2005). The part of the crop which has food, medicinal and industrial uses is the underground tuberous rhizome (Borget, 1993; Kumar *et al*., 2004; Ravindran and Nirmal, 2005). Nigeria largely exports ginger at the international market in the form of split dried ginger rhizome (Ravindran and Nirmal, 2005; Asumugha *et al*., 2006). Though the country is the largest producer and exporter of the crop in Africa (FAO, 2008), it has only two identifiable cultivars or landraces known as UG1 (Tafin Giwa or Yellow Ginger) and UG2 (Yatsum Biri or Black Ginger). This paucity of the crop genetic base (for conventional breeding work) in Nigeria led National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria (which has the national mandate on the crop development in the country) to import some elite ginger cultivars from India some two decades ago (Okwuowulu, 1992). Recently, these imported cultivars were deliberately allowed to diffuse out to neighbouring local ginger farmers in Abia State, Nigeria.

Feedback reports from these local farmers whose soil is characteristically ultisol (Enwezor *et al*., 1988) indicated that the exotic cultivars from India (Maran, Wynad local and Himachel Pradesh) largely out-yielded the indigenous cultivars (in terms of fresh rhizome) but were unfortunately more susceptible to the crop's yellow leaf spot disease and additionally had relatively poor fresh rhizome shelf life (as a source of planting material).

Adequate potassium (K) nutrition has been shown to enhance yield and disease resistance in roots and tubers (Jansson, 1978) and some other crops (Smethurst, 2001; Guo *et al*., 2007). Unfortunately, earlier work on K requirement for ginger in Nigeria (Abia State inclusive) by NRCRI was limited to those of the two indigenous ginger cultivars (Njoku *et al*., 1995). This necessitated a well coordinated investigation that will provide the information on the optimum potassium requirement for the imported Indian ginger cultivars in Abia State, Nigeria with basal Nitrogen (N) and Phosphorus (P) fertilizer application. This investigation was therefore planned to show the effect of varying levels of K nutrition on the field yield parameters, amelioration to ginger yellow leaf spot disease, selected food nutrient content of harvested fresh rhizomes and the post-harvest storability of the fresh rhizomes in the humid tropical rain forest agro-ecology of Abia State, Nigeria.

MATERIALS AND METHODS

Source of materials: Rhizomes of the three experimental Indian ginger cultivars (Maran (MN), Wynad local (WYL) and Himachel Pradesh (HPL)) were randomly collected from Ginger Programme, NRCRI, Umudike, Abia State, Nigeria. These cultivars were originally collected from

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India through the International Exchange of Cultivars Programme of NRCRI. Muriate of potash (Boliv Fertilizer and Chemicals, Nigeria), Urea (Fertilizer and Chemicals, Nigeria) and Single Super Phosphate (Fertilizer and Chemicals, Nigeria) fertilizers used in the fertilizer trials were collected from Central Store of NRCRI.

Field trials: The field trials were conducted at the Research Farm of the NRCRI, Umudike, Abia State, Nigeria (Latitude 05°29'N, Longitude 07°33'E; Altitude 122 m) in 2006 and 2007 cropping seasons. Ginger rhizome setts (seed materials) weighing about 20 g were cut from large, healthy mother rhizomes of the three experimental ginger cultivars or genotypes. Planting depth of 5 cm was used to plant the ginger rhizome setts on seed beds (made on a tractor-slashed, ploughed and harrowed land) measuring 3×2 m. The rhizome seeds were sown at an intra-row spacing of 0.20 m and inter row spacing of 0.20 m. The inter-plot distance was maintained at 0.5 m. The treatments were laid out in a randomized complete block design with three replications. Planting was done on 10th May and 16th May for 2006 and 2007, respectively.

Five levels of K (0, 25, 50, 75 and 100 kg K ha^{-1}) equivalent to 0, 50, 100, 150 and 200 kg of muriate of potash were applied in factorial combinations with the experimental ginger cultivars. At each of the incremental levels of K tested, a basal dressing of N and P as recommended for low fertility soils (Njoku *et al*., 1995) was added as follows: N,60 kg ha^{-1}, equivalent to130 kg ha^{-1} of urea; P, 15 kg ha^{-1}, equivalent to 219 kg ha^{-1} of single super phosphate. Application of zero level of K was used as the control. Fertilizer application was done by broadcasting during planting.

The plots were mulched 2 days After Planting (DAP) using 20 t ha^{-1} of mature wilted *Panicum maximum* grass. The plots were kept weed-free through out the duration of the field trials by rogueing (hand weeding). Data on percentage establishment at 6 Wweeks After Planting (WAP), plant height (at 20 WAP) and yellow leaf disease score (at 16, 20 and 24 WAP), number of leaves per plant (at 20 WAP) and fresh rhizome yield (at 32 WAP) were collected in the field. The data on plant height and number of leaves per plant were collected on five plants from the inner-most row of each plot. Disease score was made using visual observation and ranking according to the following format described by Nwaogu *et al*. (2009):

Severity estimation (%)	Scale	Interpretation
0	0	No infection
1-20	1	Slight infection
21-40	2	Moderate infection
41-60	3	Extensive infection
61-80	4	Very extensive infection
81-100	5	Leaves completely infected

The 2 years data for yellow leaf spot disease incidence and fresh rhizome yields were pooled after a non-significant test for heterogeneity of variances was established (Gomez and Gomez, 1984). The harvesting of the fresh rhizomes at 8 months after Planting (MAP) was done with digging fork.

Laboratory analyses: Pre-trial determinations of the relevant physico-chemical properties of the soil of the experimental fields were undertaken using standard methods as reported by SSSA (1996). The determined soil characteristics included total Nitrogen (N); available Phosphorus (P); exchangeable potassium (K), Calcium (Ca) and Magnessium (Mg); pH; soil Organic Matter (OM) and texture.

Standard methods (Bainbridge *et al*, 1996) were also used to analyse selected food nutrient contents (crude protein, crude fibre, ash) of the freshly harvested experimental ginger samples in triplicates (on dry matter basis).

Storage trial: Randomly selected samples (in triplicates) of the harvested experimental rhizomes were covered with dry *Panicum maximum* grass and stored in small heaps (of about 3.0 kg) under shade provided by surrounding orange (*Citrus sinenis*) trees. The rhizomes were kept in storage for a period of 12 months after Harvest (MAH) with sprouts removed by hand nipping. While in storage, rhizomes damaged by rot were periodically recorded, sorted out and removed. At the end of the storage, the final weights of rhizomes were also recorded.

Data analysis: The obtained data from all the experimentations were analyzed statistically using Analysis of Variance (ANOVA) and treatment means with significant effects were detected using $LSD_{(0.05)}$ (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The physico-chemical properties of the soils of the study area (Table 1) show that the soil was sandy loam in texture and of low fertility (0.10-0.14% N, 6.1-9.30 mg kg^{-1} P, 0.10-0.11 cmol kg^{-1} exchangeable K and 1.20-1.50% organic matter) according to the soil fertility classification for ginger production in Nigeria (Njoku, *et al*., 1995). Though ginger may grow well in clay loam, sandy loam, red loam and sandy soils, it requires high K and basal N for optimum yield (Ravindran and Nirmal, 2005). Therefore, the low levels obtained for N and K in the experimental plots really called for additional N and K used in the trial. The institute (NRCRI) had recommended 90 kg N, 20 kg P and 40 kg K per hectare as optimum NPK fertilizer rates for the local ginger landraces or cultivars in Umudike, Abia State, Nigeria (to be applied split at planting and 12-14 weeks after planting).

Ravindran and Nirmal (2005), specifically observered that adequate K nutrition is required for good establishment of ginger setts planted in the field. Results in Table 2 support this assertion while the results in Tables 3 and 4 show that the optimum K level for ginger plant height (mean of 99.6 cm) and fresh rhizome yield (of 9.56 t ha^{-1} for Maran) is 50 kg K ha^{-1} (with 60 kg ha^{-1} N and 15 kg ha^{-1} P) for the experimental agro-ecology of Abia State, Nigeria, which is largely of rain forest vegetation with a soil type that is dominated by ultisol (Enwezor *et al*., 1988).

Ravindran and Nirmal (2005) recorded that Kerala Agricultural University, India gave the optimum K requirment for ginger as 40 kg ha^{-1} (with basal application of N and P), under the cumbersome (with attendant extra labour cost) split applications at 60 days and 120 days after planting, for ginger farmers in Kerala State, India. Eventhough we used the more convenient (with less labour cost) non-split fertilizer application during planting, the obtained yield values in our field experiment (Table 4) show that fresh rhizome yield was increased by 92% for Maran, 42% for Wynad local and 121% for Himachel Pradesh cultivars at 50 kg ha^{-1} K when compared with the experimental control (0 kg ha^{-1} K application). On the other hand, Attoe and Osodeke (2009) in their research in Akamkpa and Obubra areas of Cross River State, Nigeria that adjoin Abia State of Nigeria got maximum Nigerian ginger rhizome yield (8.07 t ha^{-1} at Obubra) with an optimum NPK treatment combination of 200:80:100 kg ha^{-1} (with a split application of 30 and 90 days after planting). The advantages (economic and agronomic) or otherwise of non-split (over split) application of the K fertilizer in mulched ginger farms in various agro-ecologies need to be further investigated by other inter-disciplinary research teams.

The increasing number of leaves formed per plant at optimum K nutrition (Table 5) might explain an earlier observed increase in rhizome starch content with appropriate K fertilization (Ravindran and Nirmal, 2005). Plant leaves are known to photosynthesize glucose monosaccharide molecules (Heldt, 2004) that may be transformed and translocated to the underground tuberous rhizome for storage as starch molecules, which are polysaccharrides (Heldt, 2004; Ravindran and Nirmal, 2005).

Table 1: Selected physico-chemical properties of soils of the study area before commencement of trials

Years	N (%)	P (mg k^{-1})	K	Ca	Mg	pH	OM (%)	Texture
			--------(cmol kg^{-1})----					
2006	0.14	9.30	0.11	0.80	0.40	5.8	1.50	Sandy loam
2007	0.10	6.10	0.10	0.60	0.20	5.3	1.20	Sandy loam

Table 2: Effect of K nutrition on the percentage establishment of the experimental ginger cultivars after planting

	2006 ginger establishment (%)				2007 ginger establishment (%)			
	Cultivar				Cultivar			
K-level (kg K ha^{-1})	MN	WYL	HPL	Mean	MN	WYL	HPL	Mean
0	76.8	83.1	72.1	77.3	79.8	80.1	77.3	79.1
25	83.4	89.5	80.4	84.4	80.6	87.3	84.3	84.1
50	90.3	95.6	88.7	91.5	88.4	89.7	86.1	88.1
75	91.4	97.3	88.9	92.5	94.4	98.0	86.9	93.1
100	94.2	98.9	91.4	94.8	95.1	98.3	88.7	94.0
Mean	87.2	92.9	84.3	-	87.7	90.7	84.7	-
LSD (0.05)								
K-Level	2.64	-	-	-	2.25	-	-	-
Genotype	0.12	-	-	-	NS	-	-	-
K-level x Genotype	NS	-	-	-	NS	-	-	-

Table 3: Effect of K fertilization on the plant height response of the three experimental ginger cultivars

	2006 plant height (cm)				2007 plant height (cm)			
	Ginger cultivar				Ginger cultivar			
K-level (kg K ha^{-1})	MN	WYL	HPL	Mean	MN	WYL	HPL	Mean
0	62.30	88.1	71.0	73.8	70.20	92.1	76.3	79.5
25	77.40	96.2	81.4	85.0	80.60	95.4	84.0	86.7
50	88.90	116.7	93.2	99.6	86.70	109.7	90.6	95.7
75	86.40	103.4	88.7	92.8	83.40	98.1	90.2	90.6
100	77.50	91.6	74.3	81.1	80.20	94.3	87.4	87.3
Mean	78.50	99.2	81.7	-	80.20	97.9	85.7	-
LSD (0.05)								
K-level	3.89	-	-	-	2.44	-	-	-
Genotype	0.29	-	-	-	0.25	-	-	-
K-level x Genotype	2.81	-	-	-	2.36	-	-	-

There was also an observed remarkable delay in the occurance of yellow leaf spot disease incidence in the experimental ginger cultivars at K fertilizer rates $\geq$50 kg K ha^{-1} (Table 6). The three experimental cultivars or genotypes responded differently to yellow leaf spot disease even with respect to K application.While Wynad local recorded the least number of diseased leaves/plant across the three measurement periods (4, 5, 6 MAP). Maran gave the highest infestation records. Nwaogu *et al.* (2009) had also oberved the relatively high susceptability of Maran to the yellow leaf spot disease in Abia State, Nigeria.

Inconclusive investigation at NRCRI has shown that both the local yellow leaf spot disease and post harvest ginger rhizome rot are linked to fungal pathogens. Much earlier research work had shown that adequate K nutrition assist in hardening the epidermal tissues of roots and tubers cells against the microbial pathogens (Jansson, 1978). Increasing level of K fertilization was also observed to reduce post harvest rotting of the stored ginger rhizomes (Table 7). Interestingly, ginger rhizomes produced with the 50 kg ha^{-1} K fertilization maintained up to 80% wholesomeness at 6 months of storage. This is good news for ginger farmers who need the rhizomes for future croppings. Though Maran was also more susceptable to post harvest rotting at zero kg K ha^{-1} application, the use of 50 kg K ha^{-1} could still leave it with up to 66.6% unrotten rhizomes at 12 months of storage (Table 7).

Cropping of the imported ginger cultivars at the observed optimum 50 kg K/ha fertilization (with the basal application of N and P) also produced rhizomes that have nhanced protein content and the desirable decreased crude fibre content, that is, when compared with the control (Table 8). Borget (1993) had earlier given 9% water, 4.7% ash, 8% protein, 3% lipids, 1.8% essential oil, 49% digestable carbohydrates (starch/sugar), 4% fibre as

Table 4: Effect of different levels of K fertilization on the rhizome yield of the experimental ginger cultivars (Average of 2006 and 2007 cropping)

	Fresh rhizome yield (t ha^{-1})			
	Ginger cultivar			
K-level (kg ha^{-1})	MN	WYL	HPL	Mean
0	4.92	5.72	3.94	4.86
25	5.84	5.08	6.20	5.71
50	9.56	8.24	8.16	8.65
75	8.20	6.36	7.12	7.23
100	7.84	6.04	6.76	6.88
Mean	7.27	6.29	6.44	-
LSD (0.05)				
K-level	2.02	-	-	-
Genotype	NS	-	-	-
K-level x Genotype	NS	-	-	-

Table 5: Effect of K fertilization on the number of leaves formed per plant of the experimental ginger cultivars

	2006 No. of leaves/plant				2007 No. of leaves/plant			
	Ginger cultivar				Ginger cultivar			
K-level (kg K ha^{-1})	MN	WYL	HPL	Mean	MN	YL	HPL	Mean
0	10.20	24.4	12.7	15.8	14.80	19.7	15.6	16.7
25	16.30	30.3	20.2	22.3	20.20	36.1	24.3	26.9
50	20.10	32.7	20.3	24.4	23.40	38.8	24.7	29.0
75	18.10	28.1	18.8	21.6	20.10	30.7	18.9	23.2
100	12.60	26.3	18.3	19.1	16.40	20.1	18.2	18.2
Mean	15.40	28.4	18.1	-	19.00	29.1	20.3	-
LSD (0.05)								
K-level	3.89	-	-	-	2.44	-	-	-
Genotype	0.29	-	-	-	0.25	-	-	-
K-level x Genotype	2.81	-	-	-	2.36	-	-	-

Table 6: Effect of K fertilization on the yellow leaf spot disease occurrence amongst the experimental ginger cultivars (average of 2006 and 2007 results)

	4 Map no. of diseased plants/plot				5 Map no. of diseased plants/plot				6 Map no. of diseased plants/plot			
K-level	Ginger cultivar				Ginger cultivar				Ginger cultivar			
(Kg K ha^{-1})	MN	WYL	HPL	Mean	MN	WYL	HPL	Mean	MN	WYL	HPL	Mean
0	12.6	5.2	9.0	8.9	28.3	14.4	18.1	20.3	38.4	22.3	28.2	29.6
25	7.3	3.4	5.0	5.2	18.2	10.5	11.7	13.5	29.7	20.6	17.4	22.6
50	2.6	1.4	3.8	2.6	11.4	7.7	8.6	9.2	17.3	14.7	14.1	15.4
75	1.2	0.0	0.0	0.4	9.3	7.2	5.9	8.4	15.7	9.8	12.4	12.6
100	0.0	0.0	0.0	0.0	7.2	3.5	5.8	5.5	13.8	7.5	10.8	10.7
Mean	4.7	2.0	3.6	-	14.9	8.7	10.0	-	23.0	15.0	16.6	-
LSD (0.05)												
K-level	2.3	-	-	-	3.9	-	-	-	4.5	-	-	-
Genotype	4.5	-	-	-	6.4	-	-	-	2.8	-	-	-
K-level x Genotype	0.3	-	-	-	0.5	-	-	-	0.61	-	-	-

Table 7: Effect of K fertilization on the percentage non-rottenness (wholesomeness) of the stored fresh ginger rhizomes

K-level (kg K ha^{-1})	Cultivar	Ginder non-rottenness (%) Storage intervals (MAH) 0	3	6	9	12	Mean
0	MN	100	70.0	62.4	46.1	34.3	62.6
25		100	79.3	74.7	63.6	48.1	73.1
50		100	88.7	81.6	75.3	66.6	82.4
75		100	89.1	75.1	70.3	68.3	80.6
100		100	81.4	72.7	67.4	53.7	75.0
Mean		100	81.7	73.3	64.5	54.2	-
0	WYL	100	80.4	76.4	61.2	40.5	71.7
25		100	84.1	80.0	78.6	62.6	79.9
50		100	90.1	84.3	76.7	72.2	84.7
75		100	93.1	88.6	77.3	74.7	86.7
100		100	90.4	86.3	79.4	70.1	85.2
Mean		100	87.6	83.1	74.6	64.0	-
0	HPL	100	71.3	71.3	54.5	43.1	68.0
25		100	77.3	70.6	66.7	56.9	74.3
50		100	86.2	86.0	71.3	66.8	82.1
75		100	82.4	78.7	69.3	57.4	77.6
100		100	80.3	77.1	63.2	61.6	76.4
Mean		100	79.5	76.7	65.0	57.2	-
LSD (0.05)							
K-level		5.11	-	-	-	-	-
Genotype		9.63	-	-	-	-	-
K-level x Genotype		2.76	-	-	-	-	-

Table 8: Effect of K fertilization on selected nutrient content of the freshly harvested experimental ginger rhizomes

Nutrient content (g/100 g dry wt)	Variety	K-level (kg K ha^{-1}) 0	25	50	75	100	Mean	LSD (0.05)
Crude protein	MN	3.3	3.7	5.1	5.1	4.2	4.0	Genotype = 0.90
(N x 6.25)	WYL	1.7	2.3	2.2	2.2	3.0	2.4	K-level = 0.96
	HPL	1.1	2.0	2.8	2.8	3.7	2.4	Genotype x K-level = NS
	Mean	2.0	2.7	3.4	3.4	3.6		
Crude fibre	MN	3.7	2.6	2.4	2.0	1.7	2.5	Genotype = NS
	WYL	4.6	2.4	2.8	1.9	1.9	2.7	K-level = 1.2
	HPL	3.4	3.0	2.4	2.4	1.2	2.5	Genotype x K = NS
	Mean	3.9	2.7	2.5	2.1	1.6		
Total ash	MN	6.4	5.1	4.3	3.7	3.1	4.5	Genotype = NS
	WYL	4.8	3.6	3.6	2.4	1.7	3.2	K-level = 1.7
	HPL	5.3	3.9	3.3	2.7	2.2	3.5	Genotype x K = NS
	Mean	5.5	4.2	3.7	2.9	2.3		

the mean chemical composition of dried fresh ginger. However, the maximum acceptable limits for ash and fibre content of dried ginger in the international markets are respectively 7-8 and 8-9% (Ravindran and Nirmal, 2005).

Further research needs to be done on the effect of prolonged storage on the nutrient composition of these exotic ginger cultivers in Nigeria. It might also be necessary to investigate the cause of the observed decreasing ash content of the rhizomes with increasing level of K fertilization (Table 8).

CONCLUSION

Imported elite Indian ginger cultivars (Maran, Wynad local and Himachel Pradesh) planted in Abia State, Nigeria with varying levels of potassium (K) fertilization (with basal application of N and P during planting) showed that 50 kg ha^{-1} K is not only the optimum level for field yield parameters of these exotic cultivars but also gave desirable decreased rhizome crude fibre content.

The increasing level of K fertilization, especially at $\geq$50 kg ha^{-1}, enhanced induced suppression of the pre-harvest yellow leaf spot disease of ginger and the post harvest rotting of stored fresh ginger rhizomes. The improved storability of the harvested exotic ginger rihzomes at ambiet conditions (in Abia State, Nigeria) favours the local farmers who need the rhizomes for future relayed or extended croppings.

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