Cyanogenic Potential of Cassava Cultivars Grown Under Varying Levels of Potassium Nutrition In Southwestern Ethiopia

by

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Abstract

Three cassava cultivars (NR-44/72, NW-45/72 and OY-44/72) were grown at 0, 50, 100, 150, 200 and 250 kg K2O ha-1 in a field experiment at Jimma Agricultural Research Center. The experiment was carried out to determine the effect of potassium nutrition on root cyanide (HCN) content of cassava cultivars. The three cultivars investigated in this experiment were found to have inherently high HCN content; however, there was a significant variety by potassium interaction in which the lowest root HCN content (50.65 ppm) was recorded for cultivar NR-44/72 at a potassium rate of 250 kg K2O ha-1, while the highest root HCN (108.37 ppm) was found in cultivar OY-44/72 at the control (no potassium). A significant cultivar difference for HCN content was also observed. Cultivar OY-44/72 had the highest level of HCN (80.59 ppm), while cultivar NR-44/72 contained the lowest level of HCN (71.76 ppm) in its root.

Introduction

Cassava is widely cultivated in many parts of the world. The carbohydrate rich but low in protein storage roots represent an important energy source and are a staple foodstuff for more than 500 million people throughout tropical Africa, Latin America and parts of Asia (Yeoh et al. 1998). Cassava can grow under poor soil conditions and can withstand drought. It is therefore usually considered as an important famine reserve crop in countries with unreliable rainfall. Although cassava can grow on poor soils, adequate levels of nitrogen (N) and potassium (K) are required for optimum top growth and tuber yields (Obigbesan and Fayemi 1976, Howeler 1991). Hence, soils that have low N (< 0.10 % total N) and K (< 0.15 meq per 100g) will require fertilization for optimum tuberous root yield (Kang and Okeke 1991).

Cassava contains the potentially toxic compounds cyanogenic glucosides. If present in sufficient quantities, these compounds can cause acute cyanide poisoning and death in humans and animals when consumed. At concentrations less than 50 ppm, cassava products are considered harmless. Consumption of such non-toxic cassava over long periods of time results however in chronic toxicity (Food Safety Network 2005). There are over 5000 known phenotypically distinctive cassava cultivars (Best and Hargrove 1993). All contain varying concentrations of the cyanogenic glucosides linamarin and lotaustralin, which are hydrolyzed to hydrogen cyanide (HCN) by endogenous linamarase when the tissue is damaged (Haque and Bradbury 2003, Wilson, 2003). The cyanogenic potential of known cassava cultivars ranges from less than 10 mg kg-1 as HCN fresh weight basis to more than 500 mg kg-1 as HCN fresh weight basis (O'Brien et al. 1994).

Consumption of cassava and its products is thought to cause cyanide poisoning with symptoms of vomiting, nausea, dizziness, stomach pains, weakness, headache and diarrhea and occasionally death (Mling et al. 1992, Akintonwa et al. 1994). Moreover, high dietary cyanogen exposure from poorly processed cassava roots may be associated with the occurrence of the neurological disorder konzo –an irreversible paralysis of the legs (Ernesto et al. 2002). It is therefore crucial to characterize cassava cultivars based on their cyanogenic potential and assess factors affecting level of HCN in cassava roots such as growing conditions and plant nutrients so that cultivars for household consumption and industrial use can easily be identified and better strategies to reduce HCN content in cassava can be devised.

One strategy to reduce the cyanide content of processed cassava is to improve processing methods used for conversion of roots to storable cassava products such as flour. The major methods of flour making in Africa involve sun drying of peeled roots followed by crushing in a pestle and mortar and sieving. This method retains 25 to 33% of the original linamarin present (Cardoso et al. 2005). Bradbury (2004) also indicated other methods (such as heap fermentation), which are known to remove twice as much linamarin as does sun drying, but still 12.5 to 16.5 % of linamarin is retained because of the lack of intimate contact between the linamarin that is located inside each tiny cell and the hydrolyzing enzyme linamarase that is located in each cell wall. He further described that in order to produce cassava flour with 10 mg HCN equivalents per kg of flour (ppm) –i.e., the WHO safe level, one would need to use sweet cassava roots containing not greater than 32 ppm linamarin. It is therefore clear that attempts made to reduce the HCN content of cassava roots and products to safe levels by using processing techniques alone are not successful. Hence, manipulation of the growing conditions such as moisture and mineral nutrients is also very crucial.

There seems to be some irregularity in results obtained from experiments involving the relationships between some nutrients especially potassium (K) and the content of cyanogens in cassava roots. Many authors have reported significant reduction in the hydrocyanic acid (HCN) content of cassava tubers in response to potassium fertilization (Susan John et al. 2005, El-Sharkawy and Cadavid 2000, Tandon and Sekhon 1988). Attalla et al. (2001) described however results of a field experiment where high HCN level in tuber tissues of cassava was noticed with increasing rates of potassium fertilizer (K_2SO_4). Hence, the objective of this research was to evaluate the effect of potassium fertilization (as muriate of potash, KCl) on the cyanogenic potential of three cassava cultivars under the prevailing conditions of southwestern Ethiopia.

Materials and Methods

Description of the study area The experiment was carried out at Jimma Agricultural Research Centre located 343 km southwest of Addis Ababa at an altitude of 1753 meters above sea level, 7o46'N and 36oE. The area receives an average annual rainfall of 1595 mm. The mean minimum and maximum temperatures of the area are 11.3 and 25.9 OC respectively. The soil is slightly acidic (Table 1), and it is classified as Nitosol (Paulos and Tesfaye 2000).

Field experiment A factorial combination of three cassava cultivars (NR–44/72, NW–45/72 and OY – 44/72) at six potassium rates (0, 50, 100, 150, 200, and 250 kg K_2O ha-1) were investigated in a randomized complete block design with three replications. A composite soil sample was taken initially (before treatment application) for analysis. Soil and plant tissue samples were also taken at harvesting. The experimental site was uniform and previously under cassava cultivation with out any fertilization.

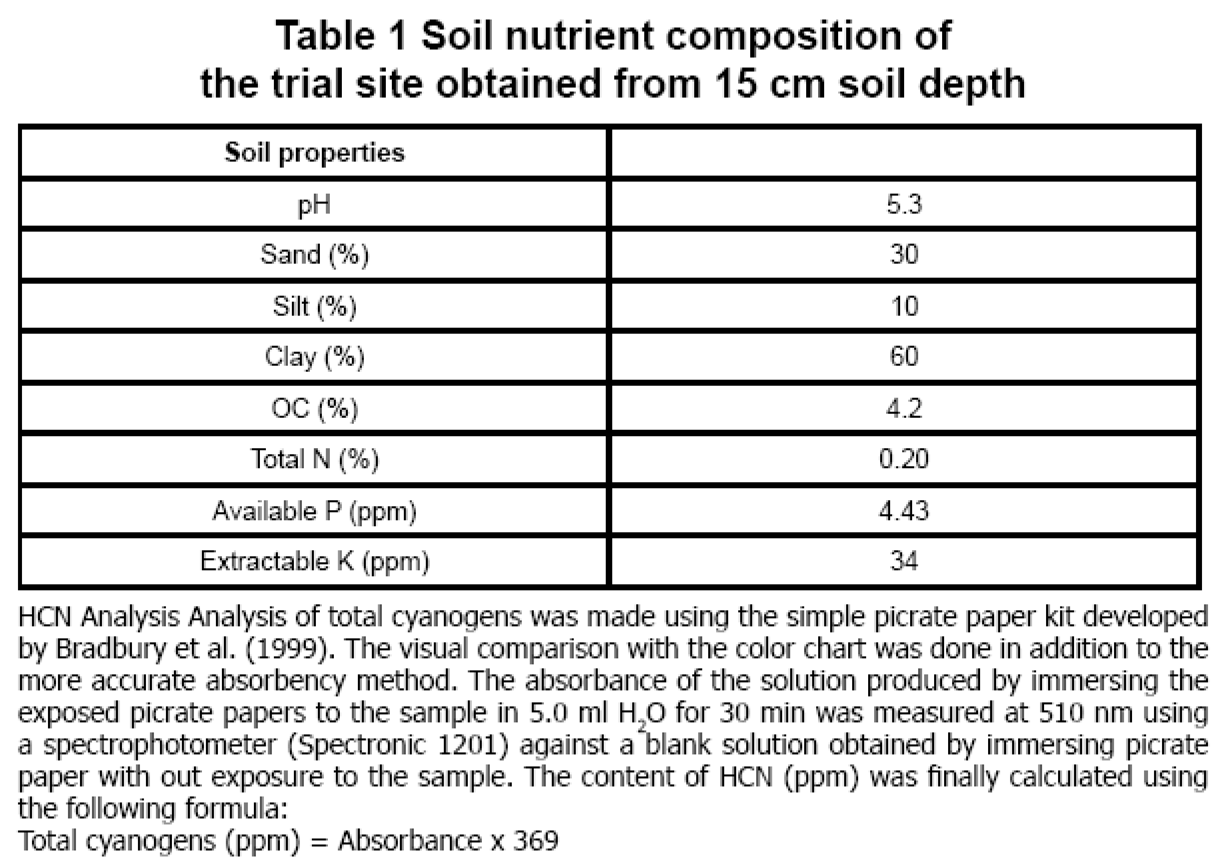

Table 1 Soil nutrient composition of the trial site obtained from 15 cm soil depth

Soil properties	
pH	5.3
Sand (%)	30
Silt (%)	10
Clay (%)	60
OC (%)	4.2
Total N (%)	0.20
Available P (ppm)	4.43
Extractable K (ppm)	34

HCN Analysis Analysis of total cyanogens was made using the simple picrate paper kit developed by Bradbury et al. (1999). The visual comparison with the color chart was done in addition to the more accurate absorbency method. The absorbance of the solution produced by immersing the exposed picrate papers to the sample in 5.0 ml H_2O for 30 min was measured at 510 nm using a spectrophotometer (Spectronic 1201) against a blank solution obtained by immersing picrate paper with out exposure to the sample. The content of HCN (ppm) was finally calculated using the following formula:
Total cyanogens (ppm) = Absorbance x 369

Data analysis was done using MSTATC statistical software.

Results and Discussion

Analysis of tissue samples for HCN indicated that the three cultivars exhibited inherently high and significant root HCN content ($P < 0.05$) (Table 1). The cultivar OY – 44/72 had the highest HCN (80.59 ppm) while NR – 44/72 had the lowest HCN content (71.3 ppm).

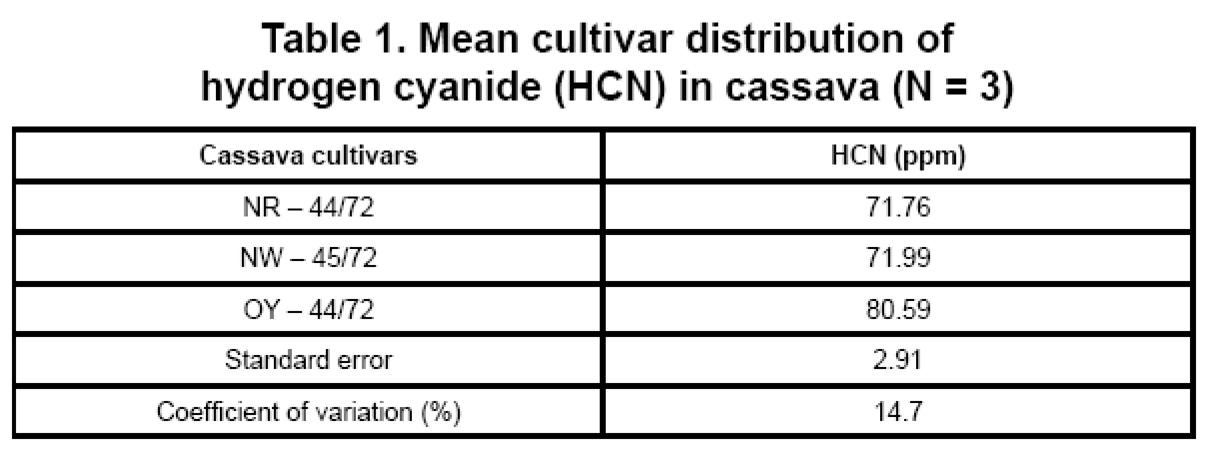

Table 1. Mean cultivar distribution of hydrogen cyanide (HCN) in cassava (N = 3)

Cassava cultivars	HCN (ppm)
NR – 44/72	71.76
NW – 45/72	71.99
OY – 44/72	80.59
Standard error	2.91
Coefficient of variation (%)	14.7

The data indicated existence of cultivar difference for HCN content in the three cassava cultivars investigated in this experiment (Table 1). The results are therefore in line with previous reports that the amount of HCN in cassava varies strongly according to cultivars, growing conditions and even different parts of the same plant (Bradbury et al. 1999, Food Safety Network 2005).

Cultivar by potassium interaction was highly significant ($P < 0.01$) (Table 2). Hence, the cyanide level in the roots of variety NR-44/72 supplied with the highest potassium rate (250 kg ha-1 K2O) was 50.65 ppm whereas cultivar OY-44/72 –grown without potassium (control), had a root HCN content of 108.37 ppm. In general, the level of HCN content exhibited a consistent trend of reduction with increasing rates of potassium especially at the higher rates (Fig.1). The results obtained in this experiment are therefore in harmony with results reported by various authors (Howeler 2002, Food Safety Network 2005; Tandon and Sekhon 1988). El-Sharkawy and Cadavid (2000) also found reduced root HCN levels in cassava plants grown with potassium fertilizer. Similarly, from a long term fertilizer experiment with cassava, Susan John et al. (2005) reported low HCN content of roots in cassava plants supplied with ash and crop residues which are known to have high content of K, Ca and Mg.

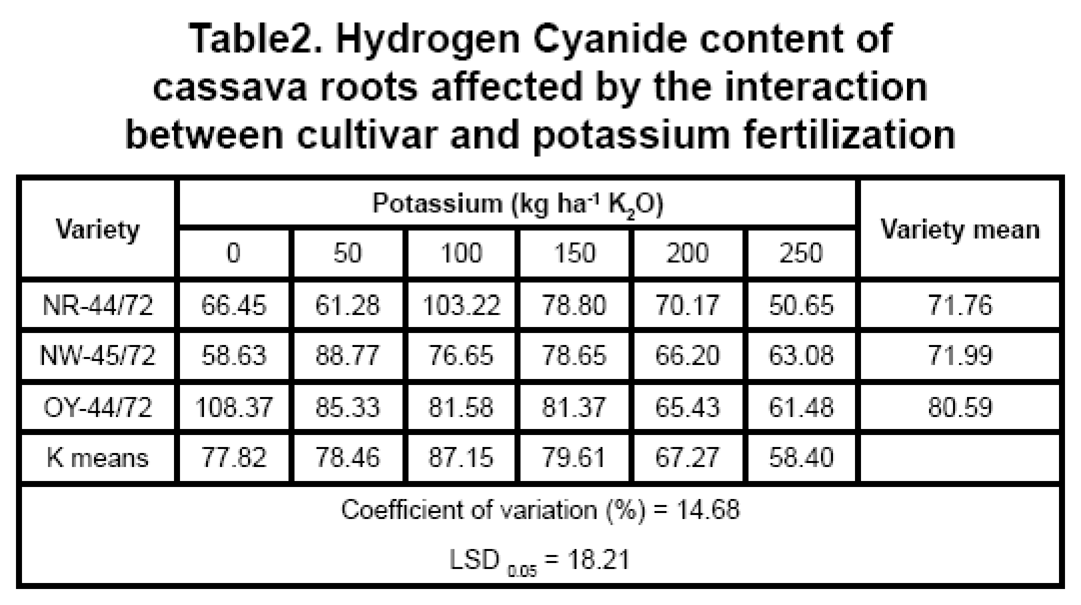

Table2. Hydrogen Cyanide content of cassava roots affected by the interaction between cultivar and potassium fertilization

Variety	Potassium (kg ha^{-1} K_2O)						Variety mean
	0	50	100	150	200	250	
NR-44/72	66.45	61.28	103.22	78.80	70.17	50.65	71.76
NW-45/72	58.63	88.77	76.65	78.65	66.20	63.08	71.99
OY-44/72	108.37	85.33	81.58	81.37	65.43	61.48	80.59
K means	77.82	78.46	87.15	79.61	67.27	58.40	

Coefficient of variation (%) = 14.68

$LSD_{0.05}$ = 18.21

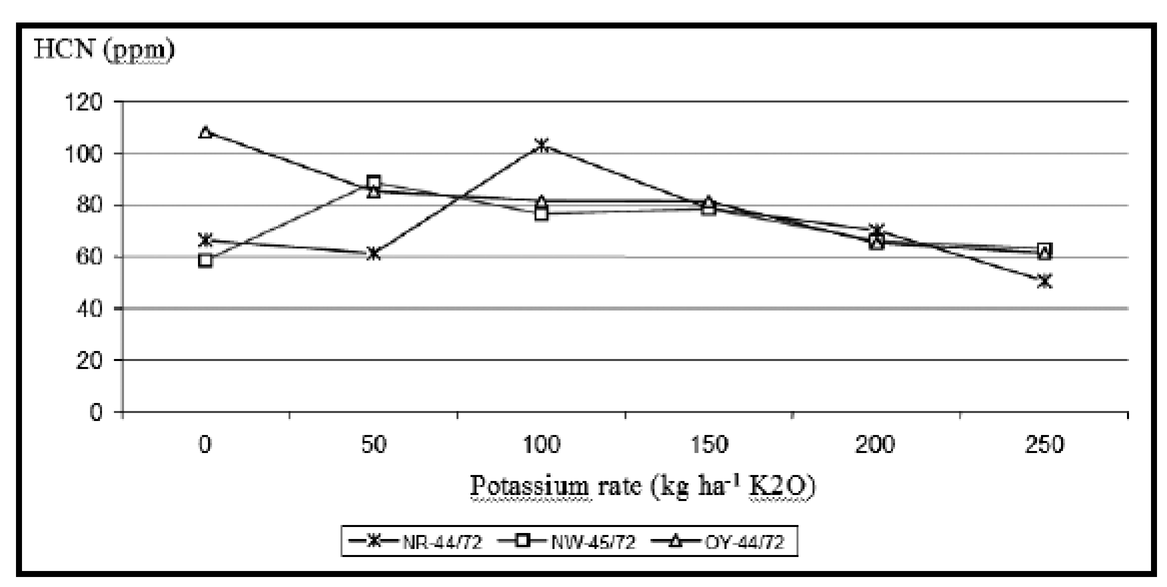

Fig. 1. The effect of potassium application on cyanide (HCN) content of different cassava cultivars

The presence of adequate level of K nutrition promotes CO2 assimilation and the translocation of carbohydrates from the leaves to the tubers of potatoes, which is the reason why the starch content of tubers is high in potatoes when well supplied with potassium (Lachover and Arnon 1966 cited in Mengel and Kirkby 1982, Howeler 2002). Likewise, tubers or tuberous roots of crops where carbohydrates are the main storage material, such as sweet potato, cassava, yam and others respond in a similar way to nutrition (Mengel and

Kirkby 1982). Obigbesan (1973) also indicated that in cassava tuberous roots not only was the starch content enhanced by potassium, but the content of the poisonous cyanide also decreased.

In summary, the potentially toxic HCN content in cassava roots was significantly reduced by potassium application. At lower doses of potassium application root HCN content was relatively high. It substantially decreased at higher rates of potassium, which indicates the need for further experimentation with more cultivars and other sources of potassium. Although potassium is found important in reducing the HCN content of cassava roots, other locally available and cheap sources of potassium such as wood ash can alternatively be used by the mainly subsistent farmers who usually cultivate the crop.

Acknowledgment

The author thanks Prof. Dr. Howard Bradbury (Australian National University, Canberra) for kindly supplying free cassava cyanide kits. He also wishes to thank Mr. Amsalu Nebiyu (Jimma University – College of Agriculture, Jimma) for the technical support through out the course of this work. Finally, the contribution of all staff members of Soil and Water Management Division at Jimma Agricultural Research Centre is highly acknowledged.

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