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Effect of Soil Moisture Status on Seed Quality of Bambara Groundnut (*Vigna subterranea* L. Verdc.) Cultivars in Ghana

[1]J.K. Laary, [2]K. Ofori and [2]F.K. Kumaga

[1]Department of Ecological Agriculture, Bolgatanga Polytechnic, P.O. Box 767, Bolgatanga, Ghana, West Africa

[2]Department of Crop Science, P.O. Box 44, University of Ghana, Legon, Accra, Ghana, West Africa

Corresponding Author: J.K. Laary, Department of Ecological Agriculture, School of Applied Sciences and Arts, Bolgatanga Polytechnic, P.O. Box 767, Bolgatanga, Ghana, West Africa

ABSTRACT

Studies were carried out in Ghana, to determine seed quality of Bambara groundnut, using two cultivars; Jabajaba (cream-seeded) and Chichele Balgu (red-seeded), under three soil moisture regimes of 30-40, 50-60 and ≥70%. Soil moisture significantly (LSD 5%) affected seed size, protein and tannin contents of Bambara groundnut. Tannin content was lower at ≥70% soil moisture than at 50-60% soil moisture but highest at 30-40% soil moisture. The 50-60% soil moisture favored good seed size and protein content than at 30-40 and ≥70% soil moisture regimes. The 30-40% soil moisture did not favor good quality seed development of Bambara groundnut cultivars. At each moisture regime, cream-seeded cultivar (Jabajaba) recorded lower seed sizes, higher protein and lower tannin contents than red-seeded cultivar (Chichele Balgu). Selecting cultivars with high protein and low tannin contents and growing them under optimum conditions that favor 50-60% soil moisture regime will improve seed quality of Bambara groundnut.

Key words: Bambara groundnut, protein, seed size, selection, soil moisture, tannins

INTRODUCTION

Moisture is an important determinant of crop growth and yield and plays significant role in food sufficiency and food quality. Soil moisture deficit therefore has detrimental effects on yield and nutritional attributes of food crops. Bambara groundnut, as an indigenous African leguminous crop grown primarily for its nutritious seeds, has a potential of contributing to increased food production but the major problem associated with its production is the very low yields often obtained by farmers (Sesay *et al*., 1999; Hampson *et al*., 2000) largely due to variable and inadequate rainfall in Sub-Saharan Africa (Doku, 1996).

Available literature however indicate that, mature seeds of various Bambara groundnut landraces have varying but rich source of protein, ranging from 16-25% (Linnemann and Azam-Ali, 1993), 17.5-21.1% (Ominawo *et al*., 1999) and 14-23% (Ofori *et al*., 2001), as well as carbohydrate (53-60.8%) and crude fat (7.3-8.5%) (Ominawo *et al*., 1999). Bambara groundnut seed protein content is therefore comparable or superior to other legumes (Doku *et al*., 1978; Linnemann and Azam-Ali, 1993), making it a good complement for cereal-based diets. For instance, its protein has high lysine content (Adu-Dapaah and Sangwan, 2004) and therefore has beneficial complementary effect when consumed together with cereals which have low lysine content (Massawe *et al*., 2005).

The crop dietary pattern could therefore provide all essential nutrient elements (Brough and Azam-Ali, 1992; Juliano, 1999) and make a greater contribution to relieving protein malnutrition, especially if the most appropriate cultivars are identified (Ofori *et al*., 2001). The crop can therefore be used in various food formulations and can play important role in protein supply to rural population and hence help alleviate protein mal-nutrition in Africa (Nti and Plahar, 1995; Massawe *et al*., 2002).

The protein availability in human nutrition however depends on the levels of anti-nutritional factors such as tannins (Papadopoulos *et al*., 1985) which are present in Bambara groundnut seeds (Poulter, 1981). There are reports on varying levels of tannins as, 3.6-9.4 mg CE g^{-1} (Poulter, 1981), 0.34-6.88 mg CE g^{-1} (Papadopoulos *et al*., 1985) and 0.25-2.27% (Ofori *et al*., 2001), ranging from cream-seed coated to red-seed coated Bambara groundnut landraces.

Depending on the levels of soil moisture on which a plant is grown, its protein and tannin levels may vary (Vadivel and Janardhanan, 2000a, b). Bambara groundnut though drought tolerant, with ability to produce variable and low but significant yields in soils where moisture is a major constraint, than similar legumes (Linnemann and Azam-Ali, 1993; Collinson *et al*., 1996; Doku, 1996) and regarded as an ideal food crop in Sub-Saharan Africa, its seed and nutritional quality could be greatly affected under moisture constraint conditions. Therefore, selecting genotypes that can efficiently utilize soil moisture and maintain good seed yield and nutritional quality will be of great value.

There is therefore the need to access salient seed yield and quality features of the crop using principal factors like soil moisture which can be adjusted across a pre-determined range. This calls for the evaluation of seed yield and nutritional quality of the crop under different moisture regimes.

MATERIALS AND METHODS

Two contrasting Bambara groundnut cultivars, Jabajaba (cream-seeded, early and bunch) and Chichele Balgu (red-seeded, late and spreading) were obtained as planting materials from Crop Science Department of University of Ghana in 2010. Soil samples were taken in June, 2010, from an area within University of Ghana Experimental Farm, in a day between morning hours of 7-11 a.m. The samples were then analyzed in triplicates using standard procedures and methods (Chapman and Pratt, 1982; AOAC, 1990), for their physical and chemical properties as shown in Table 1.

Bulk soil was then collected at 0-10 cm depth from the same area of previously sampled soil for physical and chemical properties. The soil was dried and homogenized before 72 perforated plastic pots were each filled with 7 kg of the soil and arranged in Randomized Complete Block Design (RCBD) on raised benches in three open plastic houses. There were 24 pots in each plastic house; containing 6 experimental units of 4 pots each.

Calibrated gypsum blocks, were inserted two per pot before they were saturated with water and left till pot capacity. At pot capacity, the pots were weighed and their corresponding moisture content measured with moisture meter through gypsum blocks cables before planting three seeds of each cultivar per pot. The plants, 15 days after sowing, were thinned to two per pot and mulched. Water treatment of 30-40, 50-60 and ≥70% of pot capacities were then imposed at 21 days after sowing and maintained through regular pot weighing, moisture content measurement and watering till final harvest at maturity, 12 weeks for Jabajaba and 14 weeks for Chichele Balgu.

The pods after harvest were sun-dried and shelled to obtain the seeds. The seeds were further sun-dried to 10-11% moisture content. Seed sizes were determined using 100 wholesome dried seeds

Table 1: Physical and chemical characteristics of soil used for the experiment

Properties	Value
Physical	
Sand (%)	76.18
Silt (%)	4.90
Clay (%)	18.82
Water holding capacity (%)	67.65
Bulk density ρ_b (g cm^{-3})	1.64
Chemical	
pH H_2O	5.70
pH $CaCl_2$	4.80
Organic carbon (%)	0.36
Organic matter (%)	0.62
Nitrogen (%)	0.08
Tp (ppm)	86.25
Op (ppm)	36.50
Ap (ppm)	6.85
Exchangeable cations (meq/100 g soil)	
Na^+	0.54
Mg^{2+}	4.20
K^+	0.92
Ca^{2+}	11.30

from each treatment per cultivar. Forty wholesome dried seeds of each treatment combination for each cultivar were ground in an ultra-centrifugal mill and sieved through 0.3 mm mesh. The flour was defatted with 40-60°C petroleum ether and excess solvent was removed in a vacuum evaporator at 50 °C. Flour (0.5 g) of each treatment combination was used in triplicate for protein and tannin determination. The Vanillin-HCl Method (Price *et al*., 1978) was used for tannin estimation with Catechin (+) (Sigma) as standard curve at 0.0-1.0 mg mL^{-1} with extrapolations to higher concentrations. Nitrogen content was determined by the Macro-Kjeldahl procedure (AOAC, 1990) and protein content was taken as % N x Factor of 5.71 (FAO/WHO, 1973).

The data was analyzed using Genstat Statistical Package computer software program (Lawes Agricultural Trust, Rothamsted Experimental Station, UK). Differences between treatment effects reflecting in the soil moisture and cultivar treatment means were separated by Least Significant Difference (LSD) at 5% probability.

RESULTS AND DISCUSSION

Differences in levels of soil moisture have significant (LSD 5%) effect on 100-seed weight, protein and tannin contents of Bambara groundnut cultivars (Table 2); even when cultivars are grown in soils of similar physical and chemical properties (Table 1). Depending on soil moisture level, 100-seed weight varied from 26.5 to 30.7 g in Jabajaba (cream-seeded) and 37.9 to 41.8 g in Chichele Balgu (red-seeded), whilst protein content in Jabajaba varied from 19.3 to 23.1% and in Chichele Balgu from 16.0 to 18.8%. Tannin content also varied from 0.2 to 0.5% in Jabajaba and 1.1-1.6% in Chichele Balgu (Table 2).

In both cultivars, 50-60% soil moisture regime recorded higher seed sizes and protein content, whilst that of tannin was higher at 30-40% soil moisture. Under stress soil moisture of 30-40%, tannin contents in both varieties increased as seed size decreased, whilst moderate moisture of 50-60%, increased seed sizes and decrease tannin content. Under excess soil moisture regime of

Table 2: Soil moisture and seed quality of Bambara groundnut cultivars

Variety	Soil moisture content (%)	100-seed wt. (g)	Protein (%)	Tannin (%)
Jabajaba	≥70	29.0±0.5	19.3±0.3	0.2±0.1
	50-60	30.7±0.9	23.1±0.7	0.3±0.1
	30-40	26.5±0.6	20.1±1.3	0.5±0.1
Within Jabajaba				
Mean		28.7±0.8	20.8±0.8	0.4±0.1
LSD (5%)		2.5	2.4	0.2
Chichele Balgu				
	≥70	39.2±0.3	17.2±1.6	1.1±0.2
	50-60	41.8±1.2	18.8±1.7	1.3±0.1
	30-40	37.0±0.6	16.0±0.4	1.6±0.1
Within Chichele Balgu				
Mean		39.6±0.9	17.3±1.3	1.4±0.1
LSD (5%)		3.2	2.6	0.3
Among varieties				
LSD (5%)		6.9	2.7	0.7

Values are Mean±SD

≥70%, tannin content however decreased regardless of the seed sizes. The above association of seed size and tannin content under each moisture regime were the reverse of the protein content of Chichele Balgu in particular.

The result indicates that seed quality traits of Bambara groundnut could vary under different moisture regimes and in low soil moisture, seeds obtained are small, low in protein and high in tannic acids. Since protein and tannin levels of cultivars at each moisture regime do not depend on definite seed colour patterns, knowledge of moisture conditions under which crops are grown is necessary for the overall selection of good quality seeds.

While soil water may not have significant effect on the proximate composition of Bambara groundnut seeds (Brough and Azam-Ali, 1992), the significant differences in protein and tannin contents of Bambara groundnut seeds at different soil water conditions in this study suggests that large scale environmental and soil moisture conditions may determine chemical composition of seeds (Deetz *et al*., 1996; Jarillo *et al*., 1998). The reports of Ofori *et al*. (2001) on Bambara groundnut accessions collected from various parts of Ghana with varied rainfall and climatic conditions might have contributed to the wide range of differences in protein and tannin contents within similar seed-coat coloured accessions.

Jabajaba (cream-seeded) recorded average protein content of 20.8% with low tannic acid content of 0.4% whilst Chichele Balgu (red-seeded) recorded average protein content of 17.3% with high tannic acid content of 1.4% and this may be an indication of nutritional superiority (Papadopoulos *et al*., 1985) of Jabajaba over Chichele Balgu. Though optimum cooking could enhance nutritive value of Bambara groundnut seeds (Omoikhoje, 2008), seeds with high concentrations of anti-nutritional factors like tannins may affect protein digestibility when consumed (Bressani *et al*., 1982; Plahar *et al*., 1997) and may not be suitable for formulating weaning foods (Nti and Plahar, 1995).

In this study, protein content has higher variation than seed sizes and tannin contents under varying soil moisture; whilst the tannin concentration seems to increase in seeds of cultivars grown under water stress condition of 30-40% soil moisture. Though cream-seeded cultivar (Jabajaba) has higher yield potential and better seed quality than Red-seeded cultivar (Chichele Balgu), the

moderate soil moisture content of 50-60% can increase seed yield and protein content and drastically reduce tannic acid levels of Bambara groundnut seeds.

Selecting predominantly cream-seed coated cultivars and growing them under conditions that favor 50-60% soil moisture, will improve Bambara groundnut seed yield and seed quality. Therefore, soil moisture status of growth should be integrated in research towards selection and improving both seed yield and seed quality of Bambara groundnut.

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