Towards Sustainable Sorghum Production, Utilization, and Commercialization in West and Central Africa

Vers une production, utilisation et commercialisation durables du sorgho en Afrique occidentale et centrale

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Evaluation of Agronomic and Nutritional Characteristics of Released/Recommended Sorghum Varieties in Ghana

J.T. Manful, I.D.K Atokple, and J. Gayin[1]

Abstract

Seven sorghum (*Sorghum bicolor* (L) Moench) varieties were characterized according to their agronomic, nutritional, and anti-nutritional properties. These varieties included three early maturing (Naga White, Kadaga, and Kapaala), two medium-duration (NSV 1 and NSV 2), and two late-duration (Local 29 and Mankaraga).

This study essentially revealed that these varieties were either from the Caudatum or Guinea races of sorghum plant heights. Specifically, they ranged from 190 cm to 280 cm for the short-duration varieties; 400 cm to 410 cm for the medium-duration varieties; and over 500 cm for the long-duration varieties. With respect to growth cycle, days to maturity ranged between 95 and 110 days for the short-, 140 and 150 days for the medium-, and 160 and 170 days for the long-duration varieties. Potentially, these varieties had yields that varied from 3.0 to 5.0 t ha^{-1}. There were in addition marked differences among the varieties in terms of photoperiod sensitivity. Indeed all the three early varieties performed as photoperiod neutral whereas the medium- and the long-duration varieties on the other hand appeared quite similar to photoperiod sensitive crops.

Proximate analysis further showed that the NSV 1 had the highest protein and mineral contents, hence suggesting its likely higher suitability for infant food formulation among all the varieties being evaluated. Kapaala and Naga White could also be useful for malting and brewing trials, owing to their relatively low protein content but high carbohydrate levels. Finally, the analysis revealed that Kadaga as well as Naga White and NSV 2 had much higher anti-nutritional characteristics or tannin contents compared to all the remaining varieties under consideration.

Introduction

Sorghum (*Sorghum bicolor* (L) Moench) is one of the most important staple crops in northern Ghana. It is cultivated throughout the savannah agroecological zone of northern Ghana, covering about 41% of the total land area of the country. The crop is consumed in the form of stiff porridge (tuo zaafi), thin porridge (koko) or fried dumpling (maasa). It is used

1. Savanna Agricultural Research Institute (SARI), P.O. Box 52, Tamale, Ghana.
2. Food Research Institute (FRI), P.O. Box M. 20, Accra, Ghana.

in brewing local opaque beer (pito) while the leaves provide fodder for farm animals and the stalks used in fencing, roofing, weaving baskets, and mats and as fuel wood (Obilana 1995).

The major breeding objective of the sorghum improvement program in Savanna Agricultural Research Institute (SARI) is to produce varieties with specific characteristics or traits that can be of widespread use in their natural milieu or environment. Some of these characteristics include their ability to adapt and produce, high yields as well as ability to respond to a wide spectrum of management practices and resistance to major diseases and pests. Such varieties should add to already existing improved varieties, so that the farmer can grow them in whichever farming or crop systems he/she chooses to. From the farmer's standpoint, consistency in yields and quality are usually more important in the face of frequent unpredictable vagaries of the environment than quantity per se. On the other hand, varieties of past releases, such as Naga White and Kadaga in 1971 and Framida in 1989 were selected for earliness, improved harvest index, and high productivity. Since farmer preferences depend upon the consumption value of the grain and its market price, grain deterioration and inherent food quality problems have become crucial for the extension of those released high-yielding genotypes. The current research thrust in sorghum genetic enhancement program emphasizes acceptable grain qualities in association with other desirable agronomic traits. From 1970 to the present, about seven sorghum varieties have been developed and either released or recommended for release.

Though a number of products could be prepared from sorghum, the appearance, texture, taste, shelf life, digestibility, and overall acceptability of the food are greatly affected by the variety of the sorghum. It is, therefore, important to screen both the traditional and improved varieties for their agronomic, physical, and chemical properties to ascertain the grain quality and its suitability for certain specific uses as well as their performance in the field.

Specifically, this study was designed to:

- determine the agronomic and nutritional properties of released/recommended sorghum varieties; and
- use available information to assist in determining the best possible uses that can be made of these varieties

Materials and Methods

Field Evaluation

The seven-released/recommended sorghum varieties, namely Kadaga, Naga White, Kapaala, Mankaraga, NSV 1, NSV 2, and Local 29 went through multi-locational trials and on-farm evaluations for several years. For the on-station trial, randomized complete block designs with four replications were used and this was modified with the on-farm evaluations where the individual farmers constituted the replications. While Kapaala was a crossbreed introduced from ICRISAT, the other six varieties were improved local germplasm, which were released or recommended for release based on their performance. To characterize the sorghum germplasm, data were collected on various agronomic traits. Analytical tests were also carried out on them.

Analytical Tests

The 1000-grain mass as well as other physical characteristics were determined using the methods outlined by Gomez et. al. (1997). Proximate composition was determined using the AACC (1986) Standard Methods of analysis. The tannin contents of the varieties were determined using the procedure of Burns (1963), Maxon and Rooney (1972), and Prince et al. (1978).

Results and Discussion

Table 1 shows some taxonomic and agronomic characteristics of the seven sorghum varieties. While Naga White and Kapaala belong to the Caudatum race, the other five are of the Guinean race. Surveys have shown that the latter race dominates in Ghana. The seven varieties also show differences in plant color.

While Kapaala has the tan color, Naga White and Kadaga are red and NSV 1, NSV 2, Mankaraga, and Local 29 have brown stalks. Genetically, red is dominant to brown and this is also dominant to tan; a phenomenon that makes a rather easy identification of hybrids. The tan color also serves as a gene-marker for resistance to many leaf diseases. Naga White and Kapaala have erect and semi-compact heads and this is a distinguishing characteristic of the Caudatum race. The loose and drooping head of the other five varieties is also unique to the Guinean race. The compact head creates a humid microclimate, which is conducive for headbug infestation and associated grain molds. On the other hand, the loose and drooping heads are quite dry, thus conferring some resistance in the Guinean sorghums to panicle insects and diseases.

Apparently, plant height tends to be positively related to maturity. Unlike maize, the grain yield in sorghum is negatively related to maturity. This probably explains why the short-duration varieties like Naga White, Kadaga, and Kapaala tend to have higher yield potentials than the medium- and late-duration varieties, which are taller. The geographical area in which a cultivar or species is productive can be limited by the day length required for its floral initiation (Fehr 1987). This photoperiod requirement can vary between and within species. There were marked differences among the varieties in terms of photoperiod sensitivity. While all the three early varieties are photoperiod neutral, the medium- and the long-duration varieties are quite photoperiod-sensitive. The implication is that the photoperiod-insensitive varieties have wider adaptability than the sensitive ones.

Table 2 shows some of the physical quality characteristics of the sorghum varieties. The cultivars of sorghum evaluated showed some variations for the selected parameters. The 1000-grain mass is a measure of grain size and density. The mean 1000-grain mass was 28.0 g. Local 29 variety recorded the highest value of 32.7 g indicating that out of the seven varieties, it had the largest grain. Kadaga and Mankaraga followed with 31.1 g and 30.8 g respectively. NSV 1 had the smallest grain size with a 1000-grain mass of 23.6 g.

Seed coat color is important because it influences the color of any product made from that grain. For instance, if the grain is to be milled and used for porridge meal, a white to light color is generally preferred and in some communities of northern Ghana a reddish seed color is preferred in brewing the local alcoholic beverage, pito.

Color is therefore an important attribute of local preparations, such as *koko* and *tuo zaafi*. Four of the improved varieties were comparable to the white color of the Local 29 variety. These were Mankaraga, NSV 1, Kapaala and Naga White.

Even though they were all bi-colored, the white color dominated making them closer to the white Local 29. Kadaga and NSV 2 had dark grain colors of red and brown respectively. This means that these varieties would not be the most sought after ones in the preparation of foods like koko and tuo since white to cream appearance is an important parameter with respect to consumer acceptability of these foods.

Pericarp thickness affects dehulling loss and milling yields. Grains with thin pericarps need a shorter dehulling time than thick pericarp grain. NSV 1 and Local 29 had pericarps of medium thickness. The pericarps of the remaining varieties were thin. This means Mankaraga, Kadaga, NSV 2, Naga White, and Kapaala may have a relatively shorter dehulling time than NSV 1 and Local 29.

Of all the varieties evaluated, only NSV 2 and Naga White showed the presence of a testa. Endosperm color, like testa affects the color of milled products while endosperm texture affects hardness, hence the milling yield. The endosperm color was white to translucent for all the varieties but the endosperm texture showed differences. NSV 2, Mankaraga, and Local 29 had about 80% of the endosperm being vitreous with a 20% floury inner part. NSV 1 and Kapaala showed an almost totally vitreous endosperm texture. Kadaga had a very floury endosperm of about 80% with about 20% vitrosity.

The proximate compositions of the varieties are shown in Table 3. The nutritional status of all the varieties fall within the generally expected range for sorghum (McCance and Widdowson 1992). Kadaga and Local 29 had the highest ash contents of 1.6% with the others ranging between 1.3% and 1.5%. The mean fat content of the varieties was 3.97%. Kapaala and Kadaga had high values of 4.8% and 4.7% respectively with Naga White having the least of 3.0%. Kadaga, Mankaraga, NSV 1, and NSV 2 showed higher protein content than Local 29 variety. NSV 1 had the highest protein content of 12.1%. Naga White and Kapaala had lower values of 9.5% and 9.2% respectively.

The varieties had a mean carbohydrate content of 73.88%. Naga White had the highest carbohydrate content of 76.3% and Mankaraga, the least value of 72.0%. The mineral contents of the cultivars also were within the levels stated by Hulse et. al. (1980) and McCance and Widdowson (1992). For the major minerals (calcium, phosphorus, and iron), there was little variability among the varieties. However, Naga White had higher calcium content of 11.8 mg per 100 g. Kadaga, NSV 1, and NSV 2 had greater amounts of phosphorus than the Local 29. The mean iron content of the varieties was 1.96 mg per 100 g. Kadaga had the highest amount of 2.5 mg per 100 g.

In sorghum, tannins are predominantly found in the pericarp and pigmented testa layer. Therefore, generally red and brown sorghums that have testa are usually high in tannins. Tannins in sorghum have agronomic advantages such as protecting the seed from attack by molds, insects, and birds and from pre-harvest germination. They also have anti-nutritional effects. For instance, they are usually bound to and precipitate proteins thereby reducing their availability to the body (Hahn et al. 1984). Kadaga had the highest tannin content of 9.10 mg-catechin equivalent (CE) per gram of sample (Table 4). Other varieties with high tannin contents were Naga White and NSV 2 with 5.45 mg CE per g and 3.38 mg CE per g

respectively. The remaining varieties all had tannin level of less than 1.0 mg CE per g of sample. This means that with the exception of Kadaga, Naga White, and NSV 2, the other recommended varieties have tolerable levels of the anti-nutritional factor, tannin.

It could be concluded that NSV 1, which is rich in protein, high in energy with good amounts of minerals, would be suitable for infant food formulation. Kapaala and Naga White are high in carbohydrate with low levels of protein. This makes them good candidates for malting and brewing trials. Traditionally they may be useful for the brewing of pito, an alcoholic beverage. The levels of tannins in all the varieties apart from Kadaga, Naga White, and NSV 2 were within tolerable limits.

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Table 1. Some taxonomic and agronomic characteristics of seven sorghum varieties.

Variety	Race	Plant color	Panicle shape	Plant height (cm)	Maturity (days)	Potential yield (t ha^{-1})	Photo-periodism
Naga White	Caudatum	Red	Erect and semi-compact	190-200	95-100	5.0	Insensitive
Kadaga	Guinea	Red	Drooping and loose	270-280	100-105	3-4	Insensitive
Kapaala	Caudatum	Tan	Erect and semi-compact	200-210	100-110	4-5	Insensitive
NSV-1	Guinea	Brown	Drooping and loose	400-410	140-150	3-4	Sensitive
NSV-2	Guinea	Brown	Drooping and loose	400-410	140-150	3.0	Sensitive
Mankaraga	Guinea	Brown	Drooping and loose	>500	160-170	3.4	Sensitive
Local 29	Guinea	Brown	Drooping and loose	>500	160-170	3-4	Sensitive

Table 2. Physical quality characteristics of seven sorghum varieties.

Variety	Seed Color	Pericarp Thickness	Testa	Endosperm Color	Endosperm Texture	100 Grain Mass (g)
Mankaraga	Yellow and White	Thin	Absent	White	Vitreous	0.8
Kadaga	Red	Thin	Absent	White	Floury	31.1
NSV 1	Yellow and Gray	Medium	Absent	White	Vitreous	23.6
NSV 2	Gray and Brown	Thin	Present	White	Vitreous	24.2
Local 29	Gray and Brown	Medium	Absent	White	Vitreous	32.7
Naga White	White and Brown	Thin	Present	White	Floury	27.5
Kapaala	Yellow	Thin	Absent	White	Vitreous	26.1

Table 3. Proximate composition of some sorghum varieties.

Variety	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbo-hydrate (%)	Energy
Local 29	10.2	1.6	4.4	9.6	74.2	423
Kadaga	9.8	1.6	4.7	11.5	72.4	378
Naga White	9.7	1.5	3.0	9.5	76.3	370
Kapaala	9.5	1.4	4.8	9.2	95.1	380
Mankaraga	11.6	1.5	4.1	10.8	72.0	368
NSV 1	8.8	1.3	3.6	12.1	74.2	378
NSV 2	11.3	1.4	3.2	11.1	73.0	365
Mean	10.12	1.47	3.97	10.54	73.88	380.28
LSD	0.92	0.10	0.66	0.85	1.41	18.21

Table 4. Mineral and tannin contents of recommended sorghum varieties.

Variety	Calcium (mg per 100 g)	Phosphorus (mg per 100 g)	Iron (mg per 100 g)	Tannin (mg CE per g)
Local 29	11.7	61	2.0	0.30
Kadaga	9.5	78	2.5	9.10
Naga White	11.8	60	2.0	5.45
Kapaala	11.1	51	1.5	0.14
Mankraga	11.5	60	2.0	0.59
NSV 1	10.1	75	2.0	0.62
NSV 2	11.0	67	1.7	3.38