

Original Research Article

Evaluation of Pearl millet Varieties for Adaptation to the Semi-Arid Agro-Ecology in Northern Ghana

ABSTRACT

Field trials were conducted at the Manga Agricultural Research Station near Bawku in the Upper East Region of Ghana to evaluate nine genotypes of Pearl millet [*Pennisetum glaucum* (L.) R. Br.] for adaptation to the Sudan Savanna agro-ecology of northern Ghana. The varieties are: Arrow, Bongo Short Head, Bristled millet, Sox Sat, Tongo Yellow and a local check (farmers' variety). ~~The hybrids included are: GB 8735, ICTP 8203 and TABI-B9.~~ The experiment was established as a randomized complete block design with 4 replicates. All standard agronomic practices and data as recommended for Pearl millet production in Ghana were adhered to. The results indicate highly significant ($P < 0.001$) differences among years and genotypes for all the traits recorded. The landrace variety Manga Nara was the earliest to attain 50% flowering; whilst Sox Sat was the latest. Downy mildew incidence at 30 days after sowing was least on Sox Sat and ICTP 8203, and highest on the farmers' variety and TABI-B9. At maturity downy mildew incidence was least on Sox Sat and highest on Tongo Yellow. ~~TABI-B9 Bristled millet and Sox Sat-C88~~ produced the tallest plants whilst Manga Nara, Bongo Short Head and GB 8735 produced the shortest plants. Bongo Short Head produced the broadest spikes whilst TABI-B9 the longest spikes. Pearl millet harvest indices were generally low with Arrow; and ICTP 8203 producing the highest and GB 8735; Bongo Short Head and the farmers' variety the lowest. ICTP 8203, Sox Sat and Bristled millet recorded superior grain yields compared to the other genotypes evaluated. ~~However, the farmers' variety, GB 8735 and TABI-B9~~ recorded the lowest grain yields compared to the trial mean. Sox Sat and TABI-B9 produced superior straw yield compared to the other genotypes whilst Tongo Yellow; the farmers' variety, Arrow and GB 8735 produced appreciably lower straw yields. ICTP 8203, Sox Sat and Bristled millet were the most efficient whilst the farmers' variety was the least in rainwater capture and use.

29
30 **Key words:** *bio-fortified hybrids, early millet, improved varieties, Sudan savanna agro-*
31 *ecological zone.*

32 33 **ABBREVIATIONS**

34 *ANOVA – Analysis of variance*

35 *Arrow –(AR)*

36 *Bongo Short Head – BSH*

37 *Bristled millet – BM*

38 *Days after sowing--DAS*

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40 *Downy mildew incidence--DMI*

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42 *Manga Nara--MN*

43 *Randomized complete block design--RCBD*

44 ~~*Sox Sat-C88 – Sox Sat*~~

45 *Tongo Yellow --TY*

46 *Upper East Region --UER*

47 48 **1. INTRODUCTION**

49 The importance of Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is most pronounced in the
50 Upper East Region of Ghana, where it serves as a hunger-breaker immediately after the long dry
51 season. Most farm-families would have exhausted their scanty harvest and even have difficulties
52 purchasing seed for the cropping season [1]. Pearl millet is the only cereal that reliably provides

grain and fodder under dry land conditions on shallow and sandy soils with low fertility and low water holding capacity [2, 3].

While Pearl millet farmers have managed to feed their families under harsh environmental conditions of the Sudan Savanna for centuries, high population pressure in recent times is outstripping their capacity to meet new demands of food, fuel wood and an occasional additional income using current farmers' agronomic practices and severely challenged landraces. The only cereal crop that can be sowed and harvested within 3 months in the UER of Ghana is Pearl millet. Regrettably there have not been any improved Pearl millet ~~crop~~ varieties since Ghana's independence from colonial rule in the mid 1950s.

The most important characteristic of Pearl millet is the crop's unique ability to tolerate and survive under adverse conditions of continuous or intermittent drought as compared to most other cereals like maize and sorghum [4]. Pearl millet is characterized by the C4-cycle photosynthetic pathway and has a very high rate of biomass production, despite being a crop adapted to the drier parts of the semi-arid tropics. Its northern limit in West Africa is the ~~zone~~ ~~with~~ about 250 mm annual rainfall, where cultivars requiring only 55-65 days to mature are grown [5].

The only Pearl millet variety that was bred during the colonial era and released was Manga Nara, which is currently being cultivated extensively in the UER. This is because Pearl millet for a long time period has not officially received the recognition it deserves as a strategic crop with almost unrivalled potential in respect of exceptional nutrition capacities [6, 7, 23]. The Council for Scientific and Industrial Research, Savanna Agricultural ~~research~~ Institute (CSIR-SARI) initiated a millet breeding program in the latter part of the 1990s. Scientists ~~bred for~~ early maturing, pest and disease resistant Pearl millet varieties, which have been widely evaluated with farmers through on-farm adaptive trials and demonstrations and are now ~~been~~ presented to the National Variety and technical Committee for consideration for release to increased Pearl millet productivity and ~~for mass~~ production in Ghana on a sustainable basis.

Adoption of improved Pearl millet varieties tends to be slow in some regions due a complex of factors such as seed availability, variety performance or household preferences [8]. The ability of Pearl millet to reliably produce on marginal lands and under low rainfall makes it an attractive choice for sandy, low

fertility and acidic soils [9]. There are two schools of thought in plant breeding: one is of the view that selecting for broad adaptation has greater gains and stability whilst the second school believes that in developing crops such as Pearl millet that are grown as landraces and also produced in marginal areas site-specific breeding is of essence [10, 11]. Either way, the importance of Pearl millet hybrids for enhanced yields cannot be over emphasized. Indeed earlier works have shown the benefits of heterozygosity and hybrid vigor in Pearl millet and sorghum in Africa [12, 13, 14,15] .

The introduction of five promising Pearl millet varieties together with three additional biofortified new hybrids is therefore welcome news to the anxious small-holder farmers of the Upper East Region, who over the years have always ranked the lack of early maturing and pest & disease resistant or tolerant crops as the second most important constraint rated only after low soil fertility to enhanced crop productivity in the area [16]. The inclusion of biofortified hybrids in the study was to help address the problem of malnutrition among children and nursing mothers in the Region. The objective of the study is to test the performance of these Pearl millet varieties for adaptation to the agro-ecological and socio-economic conditions of the Upper East Region of Ghana.

2. MATERIALS AND METHODS

2.1 The Experimental site

Field trials were established in 2012 and 2013 at the Manga Agricultural Research Station near Bawku (11°01' N, 0°16' W, 249 m above sea level) in the Sudan savanna agro-ecological zone of Ghana. The annual mean rainfall of the experimental site is approximately 950 mm. It is monomodal and has a characteristic erratic distribution pattern. The rains usually start in April and end in October with a short dry spell in July with a peak in August.

The soils in Sudan savanna zone of Ghana are developed over granites and stones. The topsoils are light varying in texture from coarse sands to loams. The texture of the soils varies from loamy sand, sandy loam to loam with the pH ranging from 5.4 to 6.1. Plant nutrient status is generally below average [21, Table 1]

The study evaluated nine Pearl millet varieties/hybrids comprising of three biofortified hybrids, four improved millet varieties from the [16]. Pearl millet breeding program and a local landrace



111 called Manga Nara. The land on which the trial was established had been used for seed maize
 112 multiplication for the past four years. **Cow dung** was applied to the field just before disc
 113 harrowing with a tractor. ~~Seedbeds were prepared using a non-adjustable animal drawn ridger~~
 114 ~~with a width of 0.75 m.~~ The experiment was established in a RCBD with four replicates. Plot
 115 dimensions were 4.5 m x 5 m. ~~planting~~ was done on ridges constructed by bullock traction with a
 116 spacing of 0.75 m. Seeds were sown on the middle of ridges with 0.30m spacing between hills.
 117 Pearl millet was ~~planted~~ 3 to 4 seeds per hill and ~~thinned out~~ to 2 plants per hill at 2 weeks after
 118 sowing (WAS). First weeding was done 2 WAS prior to the first (basal) fertilizer application.
 119 The second fertilizer application was ~~carried out~~ 2 weeks after the basal fertilizer application.
 120 Fertilization was at the following rates: basal - 80 kg N/ha and 40 kg/ha each of P₂O₅ and K₂O
 121 immediately after thinning using compound fertilizer (NPK 15-15-15) and top-dressing using
 122 ammonium sulphate. ~~Half the N (40 kg N/ha) and all the P₂O₅ and K₂O was applied at basal in the~~
 123 ~~form of compound fertilizer.~~ Re-shaping of ridges (using bullocks) was done after top-dressing to
 124 prevent root lodging as recommended for cereal for cultivation in Sudan Savanna agro-
 125 ecological zone [4, 16].

126 All recommended data for Pearl millet production [4] was collected including Days to 50%
 127 bloom, Plant height at maturity, Spike length, Spike girth, Downy mildew at 30 days after
 128 germination, Downy mildew at maturity and Harvest index. Rainwater use efficiency (kg mm⁻¹
 129 ha⁻¹) was determined as the ratio of rain water received in the season to crop yield. The data
 130 obtained was subjected to statistical analysis using *GenStat* 9th Edition software [20]. Where
 131 statistical significance was measured, means were separated using the standard error or standard
 132 error of a difference between means.

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s/no	Improved varieties	Bio-fortified	Local/landrace
		Varieties	
1	Arrow (AR)	GB 8735	Manga Nara (MN)



2	Bongo Short Head (BSH)	ICTP 8203
3	Bristled millet (BM)	TABL B9.
4	SOX SAT	C88
5	Tongo Yellow (TY)	

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Figure 1. Improve Pearl millet varieties evaluated

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Table 1. Some physical and chemical properties of the surface (0-15 cm) soil at the experimental

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site at Manga Agricultural Research Station, 2012

	Soil physical and chemical properties	value
139	Sand (%)	80.4
140	Silt (%)	16
141	Clay (%)	3.6
142	Soil texture	Loamy sand
143	Soil pH	4.64
144	Organic carbon (%)	0.35
145	Total nitrogen (%)	0.06
146	Available P (mg kg ⁻¹)	13.58
147	Exchangeable cations $\mu\text{mol (+) kg}^{-1}$	
148	Ca	0.07

149	Mg	0.05
150	K	65.70
151	CEC [cmol (+) kg ⁻¹]	3.28

Economic Analyses

Economic analysis was carried out to compare the profitability of producing different varieties and hybrids of millet in the semi-arid agro-ecology of northern Ghana using the same inputs. The crop enterprise budget technique developed by [21] where the benefit-cost ratio of millet varieties/hybrids were used to assess the economic feasibility of the different varieties. The cost of all recommended variable inputs used in the study were considered. Crop prices and all input prices were surveyed in the study area using seasonal averages that prevailed in the study area during the cropping seasons.

The value of the millet crop was taken at harvesting periods and therefore there was no cost borne for storage. Variable costs were the actual prices paid by farmers each year which included the different types of fertilizers. Net returns per hectare were then calculated as the difference between the gross income and total variables costs. The benefit-cost ratio was therefore calculated by dividing the benefits by the total variable costs as:

$$B/C = \frac{TB}{TVC}$$

Where B/C- Benefit Cost Ratio

TB- Total Benefit

TVC- Total Variable Cost

When B/C ratio is = 1.8, it implies that for each 1 GHC invested in an enterprise, the farmer will recover his 1 GHC, plus an extra 0.8 GHC as net benefit. All other things been equal, farmers should be willing to accept a variety if the B/C ratio of that variety is greater than the minimum acceptable B/C rate of 1 (B/C >1). An enterprise with a ratio greater than 1 (B/C >1) is economically viable.

152 3. RESULTS

153 The soils of the experimental site are mainly sandy, and also acidic with high levels of
154 potassium. However, all the other plant growth requirements are below average for enhanced
155 cereal production [22; Table 1].

156 The tallest plants were produced by TABI-B9 followed closely by Bristled head with the
157 farmers' variety producing the shortest plants followed by Bongo Short Head (BSH) and GB
158 8735 (Table 2). ~~The tallest plants were produced by TABI-B9 followed closely by Bristled~~
~~159 millet and then Sox Sat, whilst the shortest plants were recorded by the farmers' variety, BSH~~
~~160 and GB 8735 (Table 2).~~ TABI-B9, Bristled millet and Sox Sat produced significantly ($P<0.001$)
161 taller plants compared to the rest of the genotypes evaluated in the study.

162 The farmers' variety, Manga Nara (MN) was the earliest to attain 50% flowering whilst Sox Sat
163 was the latest to attain this stage. MN attained 50% flowering significantly earlier than the rest of
164 the varieties/hybrids tested. Similarly Tongo Yellow, GB 8735, BSH and Arrow all attained 50%
165 flowering significantly earlier than Sox Sat and TABI-B9 (Table 2). There however, were no
166 significant differences among treatments with regards to the number of heads harvested.
167 Nonetheless, ICTP recorded the highest number of heads at harvest followed by TABI-B9 and
168 Sox Sat. GB 8735 recorded the least number of heads at harvest. Only ICTP 8703 and TABI-B9
169 recorded heads that were above the trial mean.

170 Downy mildew incidence (DMI) at 30 days after sowing was highest on GB 8735 and on the
171 farmers' variety, whilst Sox Sat recorded the least level of infection followed by ICTP 8703. The
172 local improved varieties (Fig. 1) had lower levels of infection as compared to that recorded for
173 the trial mean. At maturity the level of downy mildew incidence was similar to that observed at
174 50 days after sowing, with GB 8735 recording the highest level of incidence followed by Tongo
175 Yellow; whilst Sox Sat and ICTP 8703 again recorded the least levels of infection (Table 2).
176 Significant ($P<0.001$) differences were noted among the varieties with regards to DMI or the
177 number of chaffy heads recorded at harvest with the farmers' variety recording significantly the
178 highest chaffy heads whilst TABI-B9 and Sox Sat recorded the lowest numbers of chaffy heads.
179 TABI-B9; Sox Sat and CTP 8703 all recorded significantly fewer numbers of chaffy heads
180 compared to that recorded by the farmers' variety (Table 2).

181 **Table 2. Days to 50% flower; plant height at harvest and downy mildew incidence as**
 182 **affected by Pearl millet genotype in 2012-13 cropping seasons**

Millet genotype	Days to 50% flowering		Plant height at harvest (cm)		Downy mildew at 30 days		Downy mildew at maturity	
	2012	2013	2012	2013	2012	2013	2012	2013
Arrow	50	45	202.5	210	6.75	0.25	23.3	1.0
Bongo Short head	49	46	189.6	195	7.25	0.0	29.3	1.75
Bristled millet	53	52	243.8	234	5.75	1.0	21.3	1.25
GB 8735	48	46	191.3	198	17.25	1.8	34.0	6.25
ICTP 8203	51	56	215.6	199	4.0	0.0	9.5	2.50
Sox Sat	58	58	228.5	210	0.25	0.0	1.75	0.50
TABL-B9	55	65	246.7	221	11.0	0.0	23.3	0.0
Tongo Yellow	46	46	212.4	204	9.25	0.0	30.3	3.75
Farmers variety	43	41	185.7	176	11.75	1.0	23.1	6.75
Mean	50.3	51	212.9	205	8.14	0.44	22.3	2.64
LSD (0.01)	2.90	3.61	13.64	14.77	4.14	1.20	4.52	2.14
C.V. (%)	3.9	4.90	4.40	4.9	25.60	18.47	13.9	56.4

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 184
 185 There were significant ($P < 0.001$) differences among genotypes with regards to spike length with
 186 TABL-B9 producing the longest spikes (heads) followed closely by Bristled millet whilst BSH
 187 and the farmers' variety produced the smallest heads at harvest. The spikes produced by all the
 188 varieties/hybrids were significantly longer than those produced by BSH and the farmers' variety
 189 (Table 3). Spike girth however, followed a different trend compared to Spike length; with the
 190 Bongo Short Head producing the broadest spikes and TABL-B9 the smallest. BSH produced
 191 significantly broader spikes than the rest of the varieties/hybrids tested. Similarly, Sox Sat, MN,
 192 TY and GB 8735 also produced significantly broader spikes as compared to those produced by
 193 TABL-B9, ICTP 8203, Bristled millet and Arrow (Table 3).

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Harvest index of millet was generally very low as compared to those reported for other cereals such as maize, rice and sorghum, with Arrow, ICTP 8203 and Tongo Yellow recording the highest harvest indices whilst GB 8735 recorded the lowest. Arrow, ICTP 8203 and TY recorded significantly ($P<0.001$) greater harvest indices compared to those recorded by GB 8735. 1000-grain weight of Pearl millet was similarly very low as compared to its dry cereal counterparts with Bristled millet and Tongo Yellow recording the heaviest grain than those produced by TABI-B9 and Arrow. Grain yield of Pearl millet was significantly ($P<0.01$) influenced by variety/hybrid with ICTP 8203 producing the highest grain yield and followed closely by Sox Sat and Bristled millet whilst the farmers' variety and GB 8735 produced the lowest grain yield. ICTP 8203 produced significantly greater grain yield than all the treatments except Sox Sat and Bristled millet. Sox Sat also significantly out-yielded the farmers' variety, GB 8735 and TABI-B9. Bristled millet significantly out-performed the farmers' variety and GB 8735. All the varieties/hybrids evaluated produced grain yield greater than trial mean of 1 metric ton with the exception of GB 8735, TABI-B9 and MN. Sox Sat produced the highest straw yield followed closely by TABI-B9 whilst Tongo Yellow (TY) produced the lowest (Table 3). Sox Sat produced superior straw yield than the rest of the treatments except TABI-B9. All the varieties/hybrids significantly out-yielded the TY. All the varieties/hybrids with the exception of TY Arrow, MN and GB 8735 produced lower straw yield compared to the trial mean yield.

Rainfall use efficiency (RUE), is a measure of how efficiently the genotype uses rain water. RUE was significantly ($P<0.01$) affected by genotype with ICTP 8203 recording the highest RUE followed closely by Sox Sat and Bristled millet. ICTP 8203 recorded significantly greater RUE than that recorded for the farmers' variety, GB 8735, Tongo Yellow and Arrow (Table 3). Only ICTP 8203, Sox Sat and Bristled millet recorded RUE values greater than the trial mean.

Table 3. Days to 50% flower; plant height at harvest and downy mildew incidence as affected by Pearl millet genotype in 2012-13 cropping seasons

Millet genotype	Spike length (cm)	Spike girth (mm)	Harvest index
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	2012	2013	2012	2013	2012	2013	
Arrow	21.3	26.9	73.5	74.5	0.09	0.12	
Bongo Short Head	13.6	13.4	114.5	77.0	0.07	0.09	
Bristled ~~millet~~	30.5	33.1	77.0	113.0	0.08	0.10	
GB 8735	24.3	24.6	90.0	98.0	0.06	0.10	
ICTP 8203	26.2	27.3	77.0	79.0	0.09	0.08	
~~Sox-Sat~~	22.6	22.3	98.5	97.0	0.07	0.08	
~~TABI-B9~~	33.9	29.4	68.5	67.0	0.07	0.05	
Tongo Yellow	20.5	21.0	91.0	90.5	0.09	0.12	
~~Farmers variety~~	15.9	18.7	96.5	100.0	0.07	0.09	
Mean	23.8	24.02	87.4	88.4	0.08	0.092	
LSD _(0.01)	4.35	4.36	7.43	0.95	0.01	0.034	
C.V. (%)	12.5	12.4	5.81	7.30	21.30	25.30	

Table 4. Days to 50% flower; plant height at harvest and downy mildew incidence as affected by Pearl millet genotype in 2012-13 cropping seasons

Millet genotype	100-grain weight		Grain yield		Stover yield		Rainwater use efficiency (kg mm ⁻¹ ha ⁻¹)	
	(g)		(kg/ha)		(t/ha)			
	2012	2013	2012	2013	2012	2013	2012	2013
Arrow	9.2	13.1	1039	2131	15.8	15.8	1.84	3.3
Bongo short head	9.5	10.9	1046	1188	21.7	13.2	1.85	1.8
Bristled millet	11.5	15.1	1255	2022	22.9	10.9	2.22	3.1
GB 8735	9.8	13.6	756	1519	19.3	11.6	1.34	2.4
ICTP 8203	8.4	9.2	1492	1344	23.8	13.1	2.64	2.1
Sox Sat-C88	7.1	11.4	1307	2069	30.1	19.8	2.31	3.2
TABI-B9	6.2	7.7	922	972	28.3	16.8	1.63	1.5
Tongo Yellow	11.4	15.0	1027	1896	11.8	13.0	1.82	2.9
Farmers' variety	10.0	14.2	713	1296	15.1	11.20	1.26	2.0
Mean	9.21	12.3	1062	1604	21.5	13.9	1.88	2.5
LSD (0.01)	0.92	1.50	184.7	528.9	1.70	3.00	0.327	0.82
C.V. (%)	1.90	8.4	38.1	22.6	13.64	14.8	24.60	22.6

Organoleptic attributes which influenced the acceptability of bread made from millet-wheat composite flour is presented in Table 5. As shown, mouth-feel, taste and texture contributed significantly and correlated positively with overall acceptability. Even though they are essential attributes and may affect acceptability of other products, appearance, color, aroma and crust did not significantly influence panelist preference for bread made from millet-wheat composite flour. The performance of the different millet varieties in the final product, in respect of the key sensory attributes was quite promising, since a mean score of 5.8 (mouth-feel), 5.8 (taste), 5.7 (texture) were obtained for these attributes. Bread made from the 5 different varieties showed no significant differences ($p < 0.05$) for these sensory indices (Table 6). This gives an indication that

flour made from these millet varieties may be used in the production of bread with acceptable mouth-feel, taste and texture.

Table 5. Attributes affecting acceptability of bread

Parameter [†]	Acceptability estimates	SE of estimates	p-value
<i>Intercept</i>	-0.252	0.116	0.038
Mouth-feel	0.233	0.180	0.035*
Taste	0.372	0.118	0.004*
Texture	0.347	0.148	0.027*

*significant at $p \leq 0.05$. [†] Appearance, color, aroma and crust were excluded from the model because they were not influential predictors of bread acceptability

Table 6. Comparison between influential attributes from different Pearl millet varieties



Variety	Attribute		
	Mouth-feel	Taste	Texture
Arrow	6.4±0.6 ^a	6.3±0.6 ^a	6.3±0.5 ^a
Bristle millet	5.7±0.5 ^a	5.6±0.6 ^a	5.5±0.6 ^a
Bongo Short Head	5.4±0.7 ^a	5.4±0.7 ^a	5.4±0.7 ^a
Tongo Yellow	5.8±0.6 ^a	6.0±0.6 ^a	5.8±0.6 ^a
Sox Sat	5.7±0.7 ^a	5.7±0.7 ^a	5.7±0.7 ^a

252 ¹Table 7. Comparing the economic returns of Pearl millet varieties and hybrids for
253 adaptation to the semi-arid agro-ecology of northern Ghana

		Bongo	Bristle	GB	ICT			Tongo	Farmer
	Arro	Short	d	873	P	Sox	TAB	Yello	s'
Treatment	w	Head	millet	5	8203	Sat	I-B9	w	variety
				151					
Yield/Ha (Kg)	2131	1188	2022	9	1344	2069	972	1896	1296
Price/Kg (GH¢)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Gross Benefit (GH¢)	1917.9	1069.2	1819.8	1367.1	1209.6	1862.1	874.8	1706.4	1166.4
Cost/Ha (GH¢)									
Ploughing	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5
Cost of Seed	15	15	15	15	15	15	15	15	15
Cost of Herbicide	35	35	35	35	35	35	35	35	35
Fertilizer: NPK 15-15-15 (NPK)	357.5	357.5	357.5	357.5	357.5	357.5	357.5	357.5	357.5
Fertilizer: Sulphate of ammonia (S/A)	143	143	143	143	143	143	143	143	143
Harvesting	50	50	50	50	50	50	50	50	50
Carting	60	60	60	60	60	60	60	60	60
Shelling/Threshing	120	120	120	120	120	120	120	120	120
Winnowing and Bagging	50	50	50	50	50	50	50	50	50
Labour	150	150	150	150	150	150	150	150	150

¹ Average of prices (GH¢) surveyed within the project area for (2013): price millet/kg (0.9); Price NPK-/kg (1.43); Price SA-/kg (0.96); Average daily wage rate (5.00 GH¢); price of shelling/threshing per 100kg bag (5.00); Price of winnowing/100kg bag (2.5); price of seed/kg (1.5)

1.0 US\$ = approx. 3.5 (GH¢) as at September 20, 2014

Total	Variable			106			106		
Cost (GHC)	1068	1068	1068	8	1068	1068	8	1068	1068
							-		
				299.		794.	193.		
Net Benefit	849.9	1.2	751.8	1	141.6	1	2	638.4	98.4
B/C Ratio	1.8	1.0	1.7	1.3	1.1	1.7	0.8	1.6	1.1

From Table 7 above almost all varieties are economically feasible with the exception of TABL-
B9 with a B/C ration of 0.8. The varieties Arrow, Bristled millet, and Sox Sat varieties have very
high B/C ratios of 1.8, 1.7, and 1.6 respectively. These three varieties will easily be accepted by
farmers to replace their current farmer variety which has a B/C ratio of 1.1.

4. DISCUSSIONS

There were strong positive correlations between plant height and spike length with Pearl millet
grain yield. Similar results were reported by [23] in an evaluation of Pearl millet varieties across
seven countries in West Africa. The low incidence of downy mildew on Sox Sat and ICTP 8203
could be ascribed to their resistance to the disease, whilst the farmers' variety and the other
locally improved varieties are highly susceptible to the disease. These findings are corroborated
with those of [23], who reported lower incidence of downy mildew on Sox Sat and higher level
of incidence on the local improved open-pollinated varieties.

50% flowering influenced Pearl millet grain yield with higher grain yield being associated longer
days to attainment of 50% flowering. This could be due to longer periods of utilization of plant
growth resources such as nutrients; soil moisture and solar radiation. Days to flowering had the
least consistent correlation with grain yield [3, 23]. The higher yields associate with ICTP 8203;
Sox Sat and Bristled millet was due to their low numbers of chaffy heads recorded for these
varieties as against the higher numbers of chaffy heads recorded for the farmers' variety, GB
8735, Bongo Short Head and Arrow. The higher yielding varieties recorded greater harvest
indices indicating their superior conversion of dry matter to generative at the expense of
vegetative organs as reflected in the greater harvest indices associated with the higher yielding
varieties compared to their lower yielding counterparts. The higher grain yields associated with
the top 4 high yielding varieties comprising ICTP 8203, Sox Sat, Bristled millet, Bongo Short



Head and Arrow could be attributed to their relatively higher rain water use efficiencies thereby resulting in better resource capture and use of nutrients and solar radiation with resultant higher rates dry matter accumulation. Straw yield followed a ~~similar~~ trend like grain yield with the better performers also producing superior straw yields compared to their lower yielding counterparts. ~~This could be ascribed to poor capture and use of plant growth factors by these varieties. Millets~~ are not only a great source of starch, making it a high-energy food. ~~It is also an excellent~~ source of protein, fiber and a rich source of phosphorus, which plays an important part in the structure of body cells. Many authors [24, 25] are of the mind that in the next decade or so, the greatest advances in agriculture in the warmer climatic regions of the world will come from the development of Pearl millet as a feed grain crop.

5. CONCLUSION/RECOMMENDATIONS

These preliminary results have clearly shown the superiority of ~~So x Sat~~ Bristled millet, Bongo Short Head, Arrow and Tongo Yellow. These varieties would be included as Inspection materials in the coming seasons for evaluation by the National Variety Release and Technical Committee for release to farmers in order to increase both yield and areas of cultivation of the crop, which has lost grounds to maize cultivation in recent times due to the lack of high yielding ~~and insect pests and disease resistant varieties.~~

There is also the need to breed for downy mildew resistance in the local improved varieties, which all have appreciably higher levels of the disease in the present study.

COMPETING INTERESTS

Authors have declared that no competing interests exist

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