Performance of Five Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) Landraces in the Transition Agroecology of Ghana under different Sowing Dates.

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Abstract

Drought associated with climate change is a potential threat to agriculture and food security in many sub-Saharan African countries. The need to promote drought tolerant crop cultivars acceptable to consumers cannot be overemphasized. Bambara groundnut is an underutilized and until lately, under researched crop. Its ability to produce some yields where other crops such as groundnut fail has been established. The balanced nutritional quality of the crop coupled with its tolerance to drought makes it a crop of choice to achieve food security especially in the dry areas of Africa. With the threat of climate change and its attendance drought coupled with the drying up of water bodies even when irrigation facilities are available, research on crops with inherently drought tolerant characteristics cannot be overemphasized. Sowing dates have been identified to affect the yield of the crop. Experiments were conducted in 2007 in Wenchi in the Transition agroecology of Ghana to determine the effect of sowing dates on the yield of bambara groundnut landraces namely; Burkina, NAV 4, NAV Red, Black eye, Tom, Mottled Red and Ada. Sowings were done in a factorial arrangement in a randomized complete block design with three replications. Pod and seed yields ranged between 600 kg/ha to 5.5 t/ha and 420 kg/ha to 3.8 t/ha, respectively for the various sowing dates. Pod yield of over 5 t/ha was produced by Burkina and Black eye. Pod harvest indices ranged from 0.12-0.53. Minor rainy season sowing of bambara groundnut in Ghana produced more pod yield than major rainy season sowing as shown by the August sowing. Tom was a highly vegetative landrace. Where irrigation is available, sowing bambara groundnut just before the rains in February in the Transition agro-ecology of Ghana produce high pod yields. Crop growth rate was highest for NAV Red (0.089 t/ha/d) and least with Tom (0.059 t/ha/d).

Keywords: Bambara groundnut, Transition agro-ecology, landraces, sowing date

Résumé

La sécheresse associée au changement climatique est une menace potentielle pour l'agriculture et la sécurité alimentaire dans de nombreux pays d'Afrique sub-saharienne. La nécessité de promouvoir les cultures tolérantes à la sécheresse, acceptables pour les consommateurs ne peuvent pas être sur estimée. L'arachide de Bambara est un sous-utilisé et jusqu'à ce que ces derniers temps, sous recherché. Sa capacité à produire des rendements où d'autres cultures comme l'arachide échouent a été établi. La qualité nutritionnelle équilibrée *de la culture associée à sa tolérance à la sécheresse, donne une culture de choix pour assurer la sécurité alimentaire, en particulier dans les zones sèches d'Afrique. Avec la menace du changement climatique et de sa sécheresse de présence associée à l'assèchement des masses d'eau, même lorsque les installations d'irrigation sont disponibles, la recherche sur les cultures ayant des caractéristiques résistantes à la sécheresse en soi ne peut pas être sur estimée. Dates de semis ont été identifiés pour affecter le rendement de la récolte. Des expériences ont été menées en 2007 à Wenchi dans la transition agro-écologie du Ghana pour déterminer l'effet des dates sur le rendement des variétés locales d'arachide de bambara à savoir; 'Burkina', 'NAV 4', 'NAV Red', 'Black eye', 'Tom', 'Mottled Red' et 'Ada'. Les semis ont été effectués dans un arrangement factoriel dans un bloc complet randomisé avec trois répétitions. La gousse et le rendement en graines se situaient entre 600 kg / ha à 5,5 t / ha et 420 kg / ha à 3,8 t / ha respectivement pour les différentes dates de semis. Le rendement de la gousse de plus de 5 t/ha a été produit par le 'Burkina' et le 'Black eye'. Les indices de la cosse de récolte allaient de 0,12 à 0,53. La saison des pluies mineure de semis d'arachide de bambara au Ghana a produit plus de rendement des gousses que la saison majeur des pluies de semis comme montre le semis du mois Août. La variétéTom était une variété locale très végétative. Là où l'irrigation est disponible, les semailles d'arachide de bambara juste avant les pluies en Février dans la transition agro-écologie du Ghana produisent des rendements élevés des gousses. Le taux de croissance des cultures était le plus élevé pour la variété 'NAV Red' (0,089 t/ ha/j) et moins pour la variété 'Tom' (0,059 t / ha / j).*

Mots-clés: Arachide de Bambara, transition agro-écologie,les variétés locales, date de semis

Introduction

The transition agro-ecology is one of the major bambara groundnut cultivation zones in Ghana. Unfortunately, not much effort has gone into evaluating the performance of the bambara groundnut landraces at different sowing dates in Ghana. Working on the effect of planting time on growth, flowering and seed yield of nine bambara groundnut landraces, Kumaga *et al.* (2002) observed that moderate rainfall, coupled with relatively high temperatures over the entire growing period, may be required for high pod and seed yield. The yield per plant was generally higher in the minor season than the major (Kumaga *et al.* 2002). Sesay *et al.* (2008) observed that the variation in pod yield across sowing dates was closely associated with variation in pod number per plant, seed size, harvest index and dry matter production.

Sesay *et al.* (2004) noted that the time of planting of bambara groundnut in Swaziland varies from October to January. Within this period however, they observed that changes in the environmental conditions notably daylength and temperature may affect the yield of the crop. Shegro *et al.* (2010) observed that delayed planting of soybean in the Metekel Zone, North Western Ethiopia resulted in short plants, reduced leaf area and leaf area index. They observed that May and June plantings produced significantly greater grain yields compared to July sowing. Akmal (2011) reported that each week delay of wheat sowing reduces length of vegetative and reproductive stages resulting in reduction in yield. Ichi *et al.* (2013) observed that planting cowpea in mid-March significantly increased the number of days to 50% flowering but sowing in February resulted in significant increase in grain yield per hactare. Changes in the environmental factors such as temperature, rainfall, daylength, may greatly affect the growth, reproductive development and the eventual pod yield of the crop. This preliminary study was undertaken to determine whether differences in sowing dates could affect the performance of five bambara groundnut landraces in the Transition agro-ecology of Ghana.

Materials and methods

Plant material

Five bambara groundnut landraces were used for the experiment except in the August, 2007 minor season sowing where six landraces were used. Landraces were used because there were no released improved varieties in Ghana. The names of the landraces were given by the author taking into consideration the colour and the source of the material where local names did not exist. The landraces used and their brief descriptions are as follows;

Navrongo 4 (NAV 4):
Cream coloured seed with ash coloured eye. The grain size is big originating from Navrongo in the Upper East Region of Ghana with 100 seed dry weight ranging between 70 - 80 g

S*ummoligu (NAV Red):*
Local name meaning red bambara. Local landrace from the Upper East Region of Ghana with 100 seed dry weight ranging between 70 - 80 g.

Sumpiligu: (Black-eye):
Local name meaning white bambara. Cream coloured seed with conspicuous black eye and medium grain size with 100 seed weight ranging between 60 - 70 g.

Tom:
Brownish cream coloured bambara from Tom, Nkoranza in the Brong-Ahafo (Transition) Region of Ghana with big grain size 100 seed weight ranging between 80 - 90 g.

Burkina:
White coloured bambara from Burkina Faso with medium grain size 100 seed weight of 50 60 g.

Experimental design

Plants were sown on six different sowing dates in a factorial arrangement in a Randomised Complete Block Design (RCBD) with three replications at Wenchi in the Transition agro-ecology. The different sowing dates were to simulate changes in duration of day length if any and environmental changes over the growing periods. The six planting dates were; 13th February, 27th February, 12th March, 26th March and 9th April 2007 and a minor season sowing on 6th August, 2007

Cultural practices

Land preparation, planting and fertilizer application

The land was ploughed and harrowed. Soil samples were taken to determine the NPK levels at the Soil Research Institute of the Council for Scientific and Industrial Research (CSIR-SRI) at Kwadaso-Kumasi, Ghana. The soil nutrient level was maintained at 50 kg ha^{-1} of N, 25 kg ha^{-1} of P and 25 kg ha^{-1} of K. The field was fallowed with elephant grass as the dominant vegetation. Weeds were controlled using hand-hoeing. Plots were weeded as and when necessary.

Plot size and plant population

Plot size was 6 m x 6 m (13 rows and 31 hills). Seeds were sown at two seeds per hill at inter row spacing of 50 cm and intra row spacing of 20 cm. Plots were thinned at 20 days after sowing (DAS) to one plant/hill giving a plant population of 10 plants/m^2

Pest and disease control

No spraying was done against pests and diseases because the crop was relatively tolerant to pests and diseases. Generally the crop is free from pests and diseases in Ghana.

Farmers also do not spray bambara groundnut fields in Ghana.

Growth analysis

The sampling sequence for growth analysis was pre-determined on the row/plant matrix to avoid bias in selecting plants. Ten plants within the final harvest area were not removed. They were used for the final harvest data. Ten plants were removed at each sampling date at 20 DAS, 45 DAS, 60 DAS, 105 DAS and 120 DAS which represented the vegetative flowering, initiation of podding, physiological maturity of some pods and harvesting stages of pods respectively. Dry weights were obtained at the different sampling dates by drying samples in ovens maintained at 80°C for 48 hours and weighing with electronic scales.

Crop growth rate (CGR)

Crop growth rate (CGR) at maturity was determined for the five landraces. Thermal time from sowing to flowering, podding and maturity were also determined for the five landraces. Crop growth rate was calculated as:

Crop growth rate (CGR) in t ha^{-1} d^{-1} was calculated as:

CGR = Haulm yield + pod yield/Tt

Where Tt is the number of days from sowing to maturity.

Thermal time

Thermal time was obtained as follows:

i= n

Θ= ? (T Tb)

i=1

Where

Θ=Thermal time in degree days (°Cd)

n= The number of days taken for the developmental stage

T= Mean daily temperature (°C)

Tb = Base temperature (10°C)

The base temperature for bambara groundnut has been quoted as 10°C (Collinson *et al.* 1996, Harris and Azam-Ali, 1993)

Data collected

Days to 50% emergence: This was recorded as the number of days 50% of seedlings on a plot emerged. Seedlings were considered to have emerged when the first true leaf had broken through the soil and was visible. The day of sowing was considered as Day 0 in all the phenological data taken.

Days to 50% flowering: This was recorded as the number of days 50% of the plants on a plot showed fully opened flower with visible corolla colouration.

Days to podding: This was recorded as the number of days 50% of sampled plants on a plot started to produce pods. Ten days after 50% flowering and at 5-day interval some plants within the border rows of each landrace were dug to determine the onset of podding to complement information from the scheduled growth analysis where 10 plants were harvested.

Days to maturity: This was recorded as the number of days at least 50% of sampled plants on a plot took to reach physiological maturity. Plants were considered mature when the leaves turned yellow and majority of the pods had hard shells and ripe seeds.

Plants harvested for each growth analysis were separated into component parts: leaves, petiole, stem, roots and pods as when they appeared. The plant parts were oven dried at 80°C for 48 hours and weighed with a weighing scale.

Leaf dry weight: the weight of the oven-dried leaves measured in grams.

Stem dry weight: the weight of oven-dried stems measured in grams.

Root dry weight: the weight of oven-dried roots measured in grams.

100 pod dry weight: the weight of 100 randomly selected oven-dried pods weighed in grams.

100 pod seed weight: the weight of seeds extracted from 100 randomly selected oven-dried pods and measured in grams.

100 seed dry weight: the weight of 100 randomly selected oven-dried seeds measured in grams.

Immature pod dry weight: the weight of oven-dried immature pods harvested from sampled plants measured in grams.

Mature pod dry weight: the weight of oven-dried mature pods harvested from sampled plants measured in grams.

Total pod yield: the total weight of oven-dried pods harvested from sampled plants measured in grams.

Harvest index

Pod and seed harvest indices were calculated as follows;

Pod harvest index (PHI) = Total pod yield /Total biomass yield

Seed harvest index (SHI) = Total seed yield/Total biomass yield

Meteorological data

Meteorological data on temperature, rainfall, humidity, evaporation and sunshine hours were obtained from the Ghana Meteorological Services Department at Navrongo and Wenchi. The data was used to calculate sunshine hours and determine the thermal time for the different developmental stages.

Data analysis

Data were analysed using the Genstat statistical package. Means separation were done using the Least Significance Different (LSD) method at 95% level of probability

Results

Days to 50% emergence

There was a highly significant difference among the landraces ($p<0.001$), planting dates ($p<0.001$) and landrace and planting dates interaction ($p<0.001$) with respect to days to 50% emergence. Black eye used the least mean number of days to 50% emergence over all planting dates (9.7 days) whilst Burkina used the greatest mean number of days to 50% emergence over all planting dates (10.9 days) (Table 1). Mean days to 50% emergence for all the landraces were significantly lower ($p<0.001$) for the 26/03/07 and 9/04/07 sowings (8.5 days) and highest (14.1 days) for the 13/02/07 sowing (Table 1).

Days to 50% flowering

There was a highly significant difference among landraces ($p<0.001$), planting dates ($p<0.001$) and landrace and planting dates interaction ($p<0.001$) with respect to days to 50% flowering. Burkina took the least mean number of days to 50% flowering (33.5 days) and Tom took the greatest mean number of days (38.9 days) to 50% flowering (Table 1). Plants sown on 9/04/07 gave the least number of days to 50% flowering (31.8 days). Those planted on the 13/02/07 took a longer duration to 50% flowering (38.7days) (Table 1).

Days to podding

There was a highly significant difference ($P< 0.001$) among the landraces, and landrace and planting date interaction with respect to days to podding. Burkina took the least mean number of days to podding for all the sowing dates (53.2 days) with Tom taking the greatest mean number of days to pod production (73.6 days) (Table 1).

Significant difference was also observed for the different sowing dates ($P<0.001$) in days to podding. The 9/04/07 sowing had the least number of days to podding (53.7 days) with 13/02/07 sowing producing the greatest mean number of days to podding (70.5 days) (Table 1).

Days to maturity
There was a highly significant difference (p< 0.001) among landraces, planting dates and landrace by planting dates interaction with respect to days to maturity. Burkina was the earliest maturing landrace (106.4 days) with Tom being a late maturing landrace (117.5 days) (Table 1).

Table 1: Days to 50% emergence, 50% flowering, podding and maturity as affected by landraces and sowing dates

	Days to 50% Emergence	*Days to 50% Flowering*	*Days to 50% Podding*	*Days to 50% Maturity*
Landraces				
Black eye	9.7	36.3	67.6	109.2
Burkina	10.9	33.5	53.2	106.4
NAV4	10.4	35.9	54.7	108.9
NAV Red	10.5	35.4	55.0	108.9
Tom	10.4	38.9	73.6	117.5
Mean	10.4	36.0	60.8	110.1
CV%	7.3	1.7	3.7	0.7
LSD (0.05%)	0.3	0.4	0.7	0.5
P value	<0.001	<0.001	<0.001	<0.001
Sowing Dates				
13/02/07	14.1	38.7	70.5	118.1
27/02/07	9.2	35.0	57.6	111.9
12/03/07	8.7	35.4	55.9	111.0
26/03/07	8.5	34.8	55.6	111.0
9/04/07	8.5	31.8	53.7	97.0
Mean	9.8	35.1	58.7	109.8
CV (%)	7.3	1.7	3.7	0.7
LSD (0.05)	0.5	0.4	1.6	0.5
P value	<0.001	<0.001	<0.001	<0.001

Pod maturity was significantly earliest ($p<0.001$) for the 9/04/07 sowing (97.0 days) and latest for the 13/02/07 sowing (118.1 days) (Table 1).

Immature/mature pod dry weight
The immature pod weight was taken to determine which of the landraces produced the greatest number of immature pods at maturity. There was a highly significant difference ($p<0.001$) among the landraces and planting dates. There was however, no significant landraces and planting dates interaction. Among the landraces, Black eye produced the highest number of immature pods (57.9) and Tom the least (30.2) (Table 2). With planting dates, the 13/02/07 sowing produced the highest mean number of immature pods (50.8) whilst the 27/02/09 sowing produced the least mean number of immature pods (34.7) (Table 2). Mature pod yield was significantly greatest in NAV Red (351.1 g m^{-2}) and least in Tom (56.8 g m^{-2}) ($p<0.001$). The 26/03/07 sowing produced the greatest mature pod yield (331.3 g m^{-2}) with the 9/04/07 sowing producing the least mature pod yield (183.3 g m^{-2}) (Table 2).
Total pod dry weight

There was a highly significant difference ($p < 0.001$) for landrace and planting date with respect to total pod weight. Landrace by planting date interaction was also significant. Tom produced the lowest mean total pod yield 87.0 g m^{-2} among the landraces whilst NAV Red gave the greatest total pod yield of 416.0 g m^{-2} (Table 2). The 13/02/ 2007 sowing gave the highest pod yield (421.6 g m^{-2}) followed by the 26/03/07 sowing (378.0 g m^{-2}) (Table 2).

Table 3 gives the 100 pod dry weight, seed weight of 100 pods, 100 seed dry weight and total pod dry weight for August sown Bambara groundnut. Significant differences were observed for the 100 pod dry weight, seed weight of 100 pods, 100 seed dry weight and total pod weight ($p = 0.05$).

Crop growth rate and thermal time

Table 4 shows the crop growth rate at maturity and thermal time for different stages of the crops growth for the 13/02/07 sowing. Crop growth rate was significantly different

Table 2: Immature, mature and total pod dry weight (g m^{-2}) as affected by landraces and sowing dates, grown at Wenchi in 2007

	Immature pod dry weight (g m^{-2})	*Mature pod dry weight (g m^{-2})*	*Total pod dry weight (g m^{-2})*
Landraces			
Black eye	57.9	333.9	386.3
Burkina	42.1	325.5	365.6
NAV4	53.9	327.8	380.6
NAV Red	59.3	351.1	416.0
Tom	30.2	56.8	87.0
Mean	48.7	279.0	327.0
CV%	31.1	21.7	19.0
LSD (0.05%)	10.1	40.3	41.4
P value	<0.001	<0.001	0.005
Sowing Dates			
13/02/07	50.8	374.1	421.6
27/02/07	34.7	220.0	248.0
121/03/07	46.0	256.7	308.0
26/03/07	46.7	331.3	378.0
9/04/07	45.3	183.3	228.7
Mean	44.7	273.1	316.9
CV (%)	31.1	21.7	19.0
LSD (0.05)	10.1	44.2	45.3
P value	<0.001	<0.001	0.005

($p<0.05$) and ranged between 0.056 to 0.089 t ha^{-1} d^{-1} with a mean of 0.080 t ha^{-1} d^{-1}. Crop growth rate was highest for NAV Red (0.089 t/ha/d) even though this was not significantly different from Burkina and Black eye. Tom had the lowest crop growth rate (0.059 t/ha/d).

Thermal time to maturity was significantly different ($P<0.05$) among the landraces with Tom having the highest thermal time of 2109.0 °Cd.

Discussion

Interaction effect

Even though sowing date by landrace interaction were observed in some results of this study, Clewer and Scarisbrick (2001,1991) reported that it is debatable whether different sowing dates can be regarded as a factor. Little and Hills (1977) also observed that several years results involving several harvests each year may be combined as a split plot analysis with varieties as main plots, years as split plots and harvest as split-split plots, however, the interactions of varieties x years x harvests usually is not of primary importance.

Table 3: 100 pod dry weight, 100 pod seed weight, 100 seed dry weight and total pod yield (August 2007 sowing).

Landraces	*100 pod dry weight (g)*	*100 pod seed weight (g)*	*100 seed dry weight (g)*	*total pod yield (kg ha^{-1})*
Ada	82.7b	62.7b	56.0b	4000.0b
Black eye	82.7b	62.7b	56.3b	4570.0a
Burkina	83.3b	63.3b	56.3b	4100.0b
NAV4	82.7b	65.0b	58.0b	3897.0b
NAV Red	86.3b	65.3b	58.0b	4537.0a
Tom	116.7a	98.7a	94.7a	2260.0c
CV%	3.6	2.0	3.1	5.2

Figures in a column bearing the same letters are not significantly different (p=0.05) by Duncan's Multiple Range Test.

Table 4. Crop growth rate (sowing to harvest) and thermal time for bambara groundnut landraces for 13/02/07 sowing at Wenchi.

Landrace	*Crop growth rate tons/ ha/day*	*Thermal time (°Cd) to 50% flowering*	*Thermal time (°Cd) to podding*	*Thermal time (°Cd) to maturity*
Burkina	0.088	620.0	986.5	1817.5
Black eye	0.086	686.0	1224.7	1863.7
NAV4	0.076	680.0	1012.5	1857.2
NAV Red	0.089	680.0	1021.4	1857.2
Tom	0.059	707.0	1338.7	2109.0
Mean	0.080	674.4	1116.8	1901.0
LSD (0.05%)	0.003	14.5	210.0	158.1

Days to 50% emergence and flowering

Sesay (2005) working on time of sowing in Swaziland reported that the longer period from sowing to flowering for the October 13 sowing was due to the delay in seedling emergence caused by the late rains. A similar observation was made in the days to 50% emergence and eventually days to 50% flowering in this study. February falls within the dry season at Wenchi. Problems with the irrigation system at the experimental site affected the days to emergence for the plants sown in February. It is possible the dry nature of the soil affected the imbibition of moisture needed for rapid seedling emergence. Squire (1990) reported that severe drought can prevent seeds from germinating.

Days to maturity

Moisture availability in April when the rains have set in could have translated into early seedling emergence which could have facilitated the early maturity of the April sown crops. The landrace Burkina is from Burkina-Faso a Sahelian country with low rainfall. The landrace might have adapted to drought stress by maturing early to escape the drought. Photoperiod in this study ranged between 12.3 h and 12.7 h with a mean of 12.5 h within the growing period. Photoperiod could therefore not have affected crop growth and development and final days to maturity since bambara groundnut is a short day crop. This result is in agreement with Kumaga *et al.* (2002) who reported that differences in light hours between the minor and major season in Ghana were too small to significantly influence flowering dates. Berchie *et al.* (2011) evaluating the performance of three early maturing bambara groundnut landraces observed that Burkina relative to Zebra Coloured and Mottled Cream is a medium maturing landrace.

Immature and total pod dry weight

For any crop improvement on bambara groundnut towards determinacy it is anticipated that a high ratio of mature to immature pods at maturity is favourable. The 13/02/07 treatment produced the highest number of immature pods. This was in the dry season where soil moisture level was low. Practically this has an implication in water management if more mature pods are to be obtained. Low sink strength and source capacity could have resulted in more pods not being filled under moisture stress conditions. Tom produced the least number of immature pods (Table 2). However, when the immature pods were expressed as a percentage of mature pods at maturity, the following values were obtained; Black eye, 17.3%; Burkina, 13.0%; NAV 4, 16.4%; NAV Red, 16.9% and Tom 53.2%. Burkina therefore produced the least percentage immature pods relative to mature pods at maturity. This may give it a potential for improvement if obtaining a determinate crop is to be considered. Monthly mean sunshine hours between February and June for the 13/02/07 sowing (866.2 hrs) from emergence to harvest was higher compared to the other sowings dates. This period felt within the dry season and the mid-part of the rainy season when cloud cover was minimal and sunshine hours were greater. This study showed that where irrigation is available and soil conditions are favourable for bambara groundnut production, dry season cultivation of bambara groundnut in the transition agro-ecology of Ghana can result in high pod yield. Total mean pod yield for 13/02/07 planting under irrigation was 421.6 g m^{-2} (Table 2). The April planting gave the least total pod yield of 228.7 g m^{-2} (Table 2). Total sunshine hours from emergence to harvest for the April sowing was 576.5 hrs and this was as a result of cloud cover during the major rainfall. Despite the shorter days to podding (53.73 days) for the 09/04/07 sowing compared to 70 days for the 13/02/07 sowing, the longer duration of pod filling (50 days) for the 13th February sowing relative to 43 days for the 9th April sowing could have also accounted for the higher pod yield of the 13/02/07 sowing relative to the 09/04/07 sowing. Witzenberger *et al.* (1988) attributed pod yield in groundnut to shoot growth rate, partitioning factor and effective pod filling period. Decreased partitioning to grain competitively favours partitioning towards organs that continue vegetative growth, hence increasing dry matter production and leaf area (Wallace and Yan, 1998). This was observed in Tom which partitioned more dry matter to vegetative organs at the expense of pod formation.

Pod yield for the various landraces were relatively high in the August sowing. Tom which had performed poorly in the same agro-ecology in earlier studies in terms of pod yield, yielded over 2 t ha^{-1} in the August sowing (Table 6). 100 pod dry weight, 100 pod seed weight and 100 seed dry weight were all significantly higher in Tom (p=0.05) than the other landraces. This confirms the fact that Tom is a big-seeded landrace and this could attest to farmers' preference for the landrace. Berchie *et al.* (2010) observed that farmers and consumers in the Transition and Guinea Savannah agro-ecologies of Ghana have a preference for white and big seeds. Begemann (1988) observed that pod length, number of pods per plant and one hundred seed weight were significantly positively correlated to the yield per plant of the crop. The low pod yield of Tom could be attributed to the few number of pods produced by the landrace. Generally the pod yield for all the landraces were higher for the August sowing and this result is in agreement with the findings of Kumaga *et al.* (2002) who reported that minor season planting of bambara groundnut in Ghana yields better than the major season. August falls within the minor season in these areas with bimodal rainfall in Ghana. This also justifies farmers' decision to sow the crop at this time even though considerations like bambara ground-nut being regarded as a minor crop compared to maize in the Transition may be a factor. Bambara groundnut has shown a potential of a high yielder by virtue of the following characteristics; almost vertical canopy architecture of the crop which enhances maximum interception of irradiance, low sink demand of the thin and much branched stem which offers little competition for assimilates relative to the developing pods (Doku, 1996). The crops ability to survive and produce some yield under high temperatures enables the crop to relatively overcome photorespiration and thus enhance net photosynthesis. Bambara groundnut has a potential of a high yielder because the low lipid content of the crop gives it a high product value of carbohydrate per gram glucose synthesised relative to soybean and groundnut which are high in lipids.

Harvest indices

NAV 4 and NAV Red had the highest mean pod harvest indices of 0.45 and 0.44 respectively. Even though Burkina did not have the highest mean harvest index, its shorter maturity period and its performance across the various sowing dates makes it a candidate to consider especially for the drier areas. Mkandawire and Sibuga (2002) reported pod harvest indices of 0.57 (flat seedbed) and 0.58. (ridge seedbed) in a study conducted at Morogoro in Tanzania. Pod yield and harvest index (HI) were highest with the 13/02/07 planting (Table 3). Pod harvest indices for Black eye, NAV Red and Burkina for the 13/02/07 sowing were 0.50, 0.53 and 0.51 respectively which are in agreement with values obtained by Mkandawire and Sibuga (2002).

Crop growth rate and thermal time

Crop growth rate was highest in NAV Red (0.089 t ha^{-1} d^{-1}) but this was not significantly different from that of Burkina and Black eye. Tom showed significantly low (p=0.05) crop growth rate (0.059 t ha^{-1} d^{-1}). The low crop growth rate in Tom reflected in the low pod and seed yields of the landraces. Sesay *et al.* (2006) obtained a mean crop growth rate of 0.081 t ha^{-1} d^{-1} with a range of 0.062 - 0.099 t ha^{-1} d^{-1} for groundnut cultivars grown under irrigated conditions. Mean crop growth rate for this study was 0.080 t ha^{-1} d^{-1} with a range of 0.059 - 0.089 t ha^{-1} d^{-1}.

Thermal time to crop maturity in this study ranged between 1817°Cd to 2109°Cd with a mean of 1901°Cd. Collinson *et al.* (1996) obtained mean thermal time of 2163° Cd to 2773 °Cd in Sierra Leone. Sesay *et al.* (2008) also observed mean thermal times of 1428°Cd in a study on bambara groundnut in Swaziland. Mehdi Dahmardeh (2012) observed that July sowing of maize cultivars accumulated the greatest thermal unit (1743) progressively reducing to a minimum with late planting (1252). Sowing dates affected grain yield and harvest index. Differences in thermal time could be due to differences in days to maturity of the various landraces and the environmental conditions under which they were cultivated.

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