Journal of Animal & Plant Sciences, 2010. Vol. 6, Issue 3: 653- 662.
Publication date: 28/04/2010, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

Evaluation of Sesame (*Sesamum indicum*) production in Ghana.

*Ofosuhene Sintim H. and Yeboah-Badu V. I.
Department of General Agriculture, Sunyani Polytechnic, P.O. Box 206, Sunyani, Ghana

**Corresponding author's e-mail address:* henlace@yahoo.co.uk

Key words: Sesame, yield, yield components, Ghana

1 SUMMARY
There is lack of information on sesame agronomy and constraints to production including its soil preferences in Ghana. This is a key constraint to its commercial cultivation. This study evaluated sesame performance and generated agronomic data for the transitional agro ecological zone of Ghana. Yields obtained using three adopted Asian varieties averaged 688kg ha^{-1}, which was higher than 383kg ha^{-1} reported in commercial production elsewhere. Although there were significant differences in yields between one site and the others, seed weight per ten capsules or per five plants were similar indicating that our varied soil properties and cropping histories had no influence. The key factor in yield differences among the sites is thus attributed to seedling emergence and establishment. Sites that were sandy within the 10cm upper soil depth and with a good nutrient status between the 10-30cm soil depth were superior in yield (1176kg ha^{-1}) as it aided seedling emergence optimizing plant population density (250,000 plants ha^{-1}) and supported good plant growth. The results of this study have demonstrated that sesame can be profitably produced in Ghana and other areas with similar agro ecologies. However, further research is recommended in plant-pest interactions and farmer scale production that can influence the productivity of sesame.

2 INTRODUCTION
Sesamum indicum (sesame) is a broadleaf crop that belongs to the Pedaliaceae plant family which has bell-shaped flowers and opposite leaves. It is a crop that hardly sheds its leaves during its vegetative phenology but terminates and self-defoliates after capsule formation. Sesame has geographical plasticity as it is cultivated in all continents of the world. The precise natural origin of the species (indicum) is unknown, although numerous wild relatives occur in Africa and a smaller number in India (Jefferson, 2003; Desai, 2004). The crop is widely naturalized in tropical regions around the world where it is cultivated for its edible seeds (Weiss, 2000) and oil which has high behenic acid content. The traditional agro-ecozone of sesame cultivation is between latitudes 6° and 10°N (Agboola, 1979) with the highest producing countries being found in Asia (FAOSTAT, 2000), perhaps due to its relatively diverse uses in these areas. In the South East Asian countries including Japan, hardly is rice eaten without some sprinkles of sesame seeds. Sesame contains the lignan called sesamin (Watt & Breyer-Brandwijk, 1962) which has antioxidant properties, and phytosterols, which block cholesterol production. With the growing consciousness of healthy lifestyles, natural products with health inducing properties are becoming popular. *Moringa oleifera* for example has gained astronomical importance in Ghana within the last decade (Fuglie, 1999) due to its phytochemical properties.

According to the FAO, in 2003, the reserved area for sesame planting in the world was 6.57 million ha; with a production rate of 3,096 million tones per year and an average yield of 471.2kg ha^{-1} (FAO, 2004). Sesame is grown and documented in most African countries including all the three countries that border Ghana, i.e. Burkina Faso, Togo and Cote d'Ivoire. Information on the cultivation or use of sesame in Ghana has been scanty until recently. It is not grown in commercial quantities in the country and it is considered as an exotic crop (FAOSTAT, 2000). With the ever increasing acceptance of traditional medicine and other folklore products in Ghana, one of the introductions has been roasted white sesame seeds, packed as 200g sachets and sold as a health promoting condiment. Although Ghanaian farmers, out of skepticism or experience will normally devote only marginal portions of their farmlands for introduced exotic crops of which sunflower has been a vivid example, it is anticipated that commercial sesame cultivation will increase in Ghana. For now it is grown as a subsistence crop in the northern parts of the country either for its leaves or seeds, which are roasted for food.

The objective of this study was to document the field dynamics of sesame production in Ghana by measuring the growth attributes including yield and interactions with soil.

3 MATERIALS AND METHODS

3.1 Study site: The study was carried out at the Experimental farm of the Sunyani Polytechnic, Ghana, (Figure 1) during the growing season between April and August 2009. This area lies at 9° 42N; 0° 55W and 180m above sea level, in the Brong Ahafo region of Ghana which falls within the Guinea savanna which has an average annual rainfall of 1000mm is suitable for sesame cultivation (Agboola, 1979). The rainfall requirements of sesame is about 50% of that needed for cotton, 25% of that needed for maize and 33% of that for sorghum cultivation (Smith, 2008). It also does well under temperatures of 20-37° C. The study site has an annual temperature range of 22-35° C and a bimodal rainfall regime consisting of a major dry season (November - February) and a major wet season (April-July).

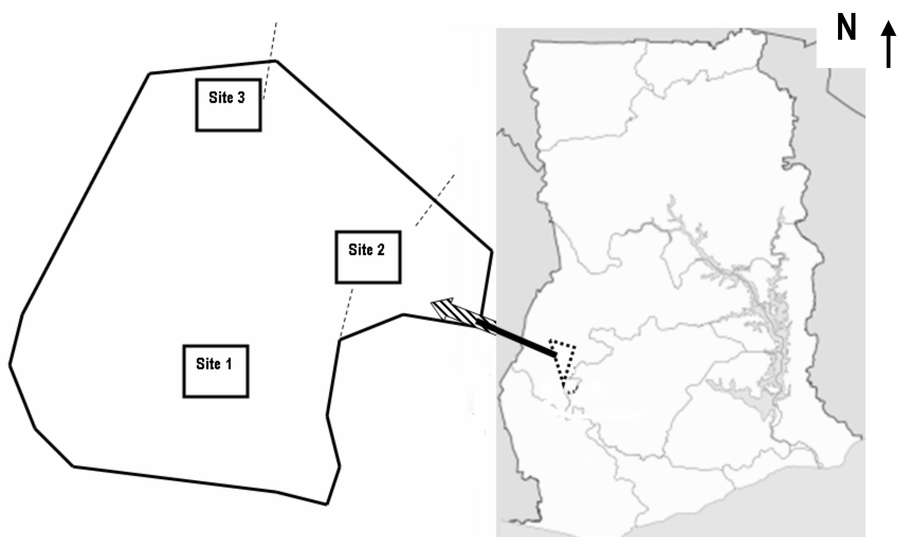

Figure 1: Location in Ghana and spatial distribution of the experimental sites on the ten hectare site. (The experimental area lies in the transitional zone of Ghana. To the north is the Guinea savanna with a unimodal rainfall pattern and to the south is the tropical rainforest with a bimodal rainfall. Distance between the sites are as follows; Site 1- Site 2 =155m, Site 1- Site 3 =250m and Site 2 -Site 3 =180m).

3.2 Trial establishment and plant material: Three plots each measuring 10 x 10m within a 10 hectare experimental farm (Figure 1) were set up. The plots were labeled as Site 1, Site 2 and Site 3 and will be referred to as such. Site 1 had been under fallow for 6 months, Site 2 was under cassava cultivation during the previous season and Site 3 had been under fallow but its soil has more gravel. Three sesame cultivars that mature within 14 weeks, each having a different pericarp colour (white, black or golden) and have the base descriptor of one capsule per node were obtained from the Faculty of Horticulture, Chiba University, Japan. Individual plots consisted of 7 blocks (0.8 x 10m) with an interblock distance of 0.8m. Each block had three rows consisting of one cultivar per row. The seeds were drilled at 0.2 x 0.4m in a triangular fashion with 5 seeds per hill. This was later thinned to two plants per stand after three weeks from emergence giving 250,000 plants ha^{-1}. Other agronomic practices such as weed control were done throughout the experiment. There was no soil amendment or other pest control measures. The seedlings were irrigated once in the first week to guarantee seedling establishment and afterwards resorted to the usual rainfall pattern in this agroecozone for which the study seek to target.

3.3 Soil sampling and analysis: Soil samples from the three stratified sites (Figure 1) based on cropping history were collected for chemical and physical analysis before planting. Soil was taken at three depths: 0-10, 10-20 and 20-30cm using an auger (diameter 5cm). For each plot, six samples of each depth were collected ($784cm^3$) and bulked. The physical and chemical properties of the sieved soils were determined for the three sites.

The soil texture was determined by the hydrometer method. Soil pH was measured in a 1:1 soil-water (v/w) using a digital H19017 microprocessor pH meter as described by Wilde et al. (1972). Soil organic carbon (OC) was determined by the method of Walkey & Black (1934). Percent organic matter (OM) was determined after Hesse (1975). Nitrogen was measured by the macro Kjeldahl digestion method (Cottenie, 1980) and Phosphorus (P) was measured by the Bray No. 1 method (Bray & Kurtz, 1945) using a spectrophotometer. Calcium (Ca) and Magnesium (Mg) were measured as described by Radov et al. (1985); Potassium (K) was determined by flame photometry.

3.4 Plant growth characteristics: The number of leaves, number of branches and the plant height of 75 random plants per site was recorded at weekly intervals for 10 consecutive weeks. The height was measured from the soil surface to the tip of the terminal leaf. Fifteen plants per site were tagged at flowering for yield components determination. The yield characters were measured as; the number of capsules/15 plants, the seed weight of 10 capsules and seed weight of 5 plants. This was used to compute the seed yield per area.

3.5 Data collection and analysis: Agronomic data at the vegetative and reproductive stages of sesame were measured from sowing to 50% flowering and afterwards at physiological maturity (Mulkey *et al*., 1987). Data recorded included number of days to 50% flowering (when at least half of the plants on a site had fully flowered) and physiological maturity (when at least 90% of the capsules on a plant have matured), height at 50% flowering and physiological maturity, number of capsules per plant and seed yield. According to Tewolde *et al.* (1994), a sesame capsule is mature when the subtending leaf defoliates due to normal senescence. The 15 earlier tagged plants were harvested separately at maturity (i.e. when over 95% of the capsules were mature) and used for yield component analysis.

All data were subjected to analysis of variance (XLSTAT, 2010). The plant growth and yield data were subjected to correlation analysis. Simple correlation analysis was also carried out to determine the relationship between height at 50% flowering and physiological maturity, number of capsules per plant, seed weight per plant or grain yield. Means of treatments with significant differences were compared using the standard error of means with the Bonferroni correction. Soil properties were related to the yield and growth characteristics.

4 RESULTS

The soil physical properties of the experimental site were generally classified by mechanical analysis as loams (Table 1). The sites were at most 250m apart. The respective sand-silt-clay percentages for the

Journal of Animal & Plant Sciences, 2010. Vol. 6, Issue 3: 653- 662.
Publication date: 28/04/2010, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

three sites at depths 0-30cm was a minimum of 39-34-14 and a maximum of 50-40-26. Sand and silt, unlike clay generally decreases with depth. The aqueous soil pH was generally neutral (6.9) at the top soil layer and became slightly alkaline (5.4) with depth. The organic matter content of the soil was 3.81-5.18% in the topmost soil and 2.02-2.16% at 20-30cm depth. The organic Carbon or Nitrogen and Organic matter content were related with an R^2 of 100 and 95%, respectively. The total Nitrogen was 0.11-0.29% increasing towards the top soil. All the measured exchangeable minerals; Calcium, Magnesium and Potassium had a general pattern that decreased from the top soil towards the 20-30cm depth in Sites 1 and 3. The exchangeable Mg and K recorded in Site 2 (Table 1) had no consistent pattern since the exchangeable K in the middle soil sampling depth, (10-20cm) was as low as 0.30 me/100g but 0.43 me/100g at the 20-30cm soil depth below. Again the exchangeable Mg at the top soil layer of Site 2 was lower than at the deeper layers (Table 1). The available Phosphorus and Potassium contents in all the sites decreased with depth. The soils tested had a Carbon-Nitrogen (C-N) ratio between 9.5 and 11.6.

The agronomic attributes of sesame were assessed for the three sites. Seed germination and emergence (number of stands) was 80.7±14.0% (Site 1- 85%, Site 2- 92% and Site 3- 65%). Seedlings that survived after two weeks were 75.6±15.9% (Site 1- 70%, Site 2- 89% and Site 3-58%, Table 2) and the number of plants remained the same till harvest except for a few plants that lodged due to wind or rain, but had harvestable fruits. The height of plants at 50% flowering and at physiological maturity was 97±3cm and 128±7cm, respectively. Except for yield per unit area, all the other agronomic attributes evaluated (Table 2) were not significantly different between the tested sites, $P>0.05$. Plant height at 50% flowering could only predict 25% certainty of the height at physiological maturity ($P=0.17$).

The number of branches/plant at 50% flowering was 6±1 whilst the number of leaves/plant at the same period was 87±13 (Table 2). The number of branches was positively correlated to all the growth or yield characteristics (Table 3) and was significantly correlated to plant height at 50% flowering (R^2=47%; $P=0.041$), and plant height at maturity (R^2=48%; $P=0.04$). The number of capsules per plant at maturity was 74±10 (Table 2) and was positively correlated to the number of plant branches (R^2=78%; $P=0.002$), number of leaves per plant (R^2=84%; $P=0.001$), weight of seed yield per plant (R^2=96%; $P<0.0001$) and had a correlation (R^2=73%; $P=0.003$) with plant height at maturity.

Table 1: Soil properties of the experimental sites before planting.

Sites(2)	Depth	Sand	Silt	Clay	pH(3)	Organic		Total N	Exchangeable Cations me/100g			E.C.E.C	Available-Brays	
	(cm)	%				Carbon	Matter	%	Ca	Mg	K	me/100g	ppm P	ppm K
Site 1	0-10	46.0	39.9	14.0	5.9	2.47	4.26	0.26	5.07	3.60	0.43	9.47	3.19	93.74
	10-20	44.4	39.5	16.0	5.6	1.56	2.69	0.14	4.54	2.00	0.30	7.28	0.88	46.87
	20-30	44.4	34.5	22.0	5.4	1.17	2.02	0.11	4.27	1.60	0.24	6.59	Trace	33.48
Site 2	0-10	49.6	36.3	14.0	6.5	2.21	3.81	0.19	8.28	1.97	0.83	11.33	2.63	133.91
	10-20	43.5	34.4	22.0	6.4	1.68	2.90	0.15	6.41	4.27	0.30	11.24	1.12	83.70
	20-30	39.8	34.1	26.0	6.1	1.29	2.22	0.13	6.14	2.94	0.43	9.80	Trace	63.61
Site 3	0-10	50.0	40.0	10.0	6.9	2.99	5.15	0.29	10.41	6.14	0.78	17.59	3.75	113.83
	10-20	49.0	34.9	16.0	6.3	1.72	2.97	0.15	6.68	2.94	0.43	10.28	0.72	60.26
	20-3o	43.9	35.9	20.0	6.3	1.25	2.16	0.13	4.54	3.47	0.36	8.60	Trace	50.22

1) Soil was sieved through a wire mesh (25 holes/cm^2) before analysis; Site 1 had been under fallow for a season,
2) Site 2 was under cassava cultivation during the previous season and Site 3 has been under fallow but it is generally gravelly; 3) Soil pH was measured in aqueous solution at 1:1 (w/v).

Seed yield was 688 kg/ha^{-1} with a wide range of 387-1176 kg/ha^{-1} between the sites which were significantly different ($P<0.05$). The seed yield/plant and plant height had a significant relationship ($R^2=62\%$; $P=0.012$). Seed yield per five plants (58±10g) or seed yield per ten capsules (1.6±0.1g) were not significantly different between the sites ($P>0.05$). Other attributes such as number of leaves per plant at 50% flowering had a significant correlation with yield ($R^2=60\%$; $P=0.014$). The average height of the first capsule from the ground was 43.4cm. Plant branching was a fairly accurate index of seed yield as it could predict correctly by 75% ($P=0.003$) of harvested grain. Internode length of the main stem at maturity was 2.43±0.23 (Table 2).

Of the three growth parameters evaluated over time (Figure 2), growth rates were not significantly different among the sites ($P>0.05$). Plant growth rate measured as height, number of leaves and number of capsules did not respond to the variations in the soil properties of the three tested sites. Plant growth rate after the 9th week from emergence was static. The rate of leaf initiation was rapid up to the 8th week when capsule formation started. Amongst the three growth indices, capsule initiation rate was the most static. There was virtually little or no change in the number of capsules within the five weeks that capsule formation data was taken.

5 DISCUSSION

The origin of sesame is said to be Sudan but it thrives with its numerous land races in most places in the southern hemisphere (Agboola, 1979; Desai, 2004; FAO, 2004) hence comparisons between authors working on sesame are often difficult due to normal biological variations relating to cultivar, season, environment and agronomic practices. Sesame's seed and oil contains abundant lignans primarily sesamin (Kato *et al.*, 1998). Comparatively, sesame has either been underexploited (Olowe *et al*, 2009) or not been given adequate recognition globally as an important oilseed crop (IPGRI and NBPGR, 2004; Weiss, 2000). Its research had been scarce in the past, but since recently it has received renewed interest due to its potential effects on human health (Laurentin & Karlovsky, 2006).

The position of sesame as a cash crop is not well understood in the global trade, and a significantly clearer interpretation of opportunities it presents is essential (Chemonics, 2002). The bulk of sesame in the world is produced in semiarid regions where rainfall is relatively limiting. This confirms the attribute of sesame as a drought tolerant crop that could be widely cultivated in areas where most grain crops cannot survive. Towards the north of the transitional zone of Ghana it is a unimodal rainfall ecozone with a long dry spell of seven months between October and April. Sesame being drought tolerant could be cultivated during this dry period if seedling establishment could be guaranteed using the latest rains in October. Soils form a key component to sesame yield in terms of seedling emergence. The crop also does well on soils within a pH range 5.5-8.0 (Weiss, 2000). Soils tested from our sites falls within this optimum condition for sesame culture with a pH of 5.4-6.9. Although sesame is adaptable to many soil types, it thrives best on well-drained, fertile soils of medium texture and neutral pH.

Fertility requirements for sesame are 89kg N ha^{-1}, 22kg P_2O_5 ha^{-1} and 22kg K_2O ha^{-1} (Olowe & Busari, 2000). The mineral contents of our experimental soils are comparable to most tropical sandy loams which characteristically have a C: N ratio just above 10. The reported root feeding zone of sesame is within 10-30 cm deep. At this depth, from our tested soils, Ca, Mg, K and P were adequate for optimum plant growth. One of the experimental sites had a better nutrient status at this root feeding zone. For example whilst potassium at the 10-20cm depth of this site was 84ppm it was 47 and 60ppm for the other sites. Incremental application of NPK fertilizer up to 150 kgha^{-1} (Ojikpong *et al.*, 2009) significantly increased the average sesame seed yield and this seems to be the optimum level as further additions reduced yield, perhaps due to an increase in vegetative growth (Taylor et al., 1986). Increasing N with P levels to 90kg N ha^{-1} and 60kg P_2O_5 ha^{-1} respectively, reduced grain yield (Olowe & Busari, 2000). Data from our experiments indicate that soil conditions could significantly influence yield as the differences within our three experimental sites led to yield differences of 387 and 1176 kg ha^{-1}.

Table 2: Plant growth and yield characteristics of sesame grown on three tested soils.

Parameter	Site 1	Site 2	Site 3	Mean±SD	(1)p-value
Percent Seedling emergence	85	92	65	81 ±14	-
Percent seedling survival after two weeks	70	89	58	76 ±16	-
Plant height at 50% flowering (cm)	97	99	95	97 ±2.4	0.56
Number of branching at 50% flowering	5	6	7	6 ±1. 2	0.73
Number of leaves at 50% flowering	63	72	87	74 ±12.7	0.43
Plant height at physiological maturity (cm)	125	137	127	129 ±6.7	0.73
Number of capsules/plant at physiological maturity	62	79	80	74 ±10.3	0.07
(2)Seed yield (kg/ha)	387[a]	1176[b]	501[a]	688 ±128	0.05
Weight of ten capsule seed (g)	1.53	1.59	1.62	1.58±0.05	0.68
Weight of five plant seed (g)	47.0	63.0	65.0	58 ±9.6	0.26
Height of first capsule (cm)	47	44	40	43 ±3.5	0.15
Internode length at physiological maturity (cm)	2.52	2.59	2.17	2.43± 0.23	0.56

[1]The p-value is the probability above which there is no difference between the sites; [2]The superscripts in the seed yield data indicate significant difference if the letters within a row are different with the Bonferroni correction.

Soils that are relatively sandy, e.g. our study site tend to aid seedling emergence. The rates of emergence in the field also vary depending on planting method and the seed type. Our results compare well to the emergence rates of up to 84% reported by Tuna *et al.* (2005) in Turkish cultivars. Although there was an average of 81% emergence rate, another crucial factor that we considered was also early survival. Sesame seedlings are very tender and one needs to compute emergence rates with care. In our experiments there was a 6% loss of emerged seedlings by the second week due to damage by sporadic insects or inadequate soil moisture. This seedling loss was suspected to be due to cutworm *(Agrotis sp.*), which characteristically cuts seedlings at the ground level. During hand weeding, one each of the last instar cutworm was collected from sites 1 and 2. The 4-leaf seedling stage would appear to be a better index of future plant stand density since there was no plant stand loss after this stage. The small sized sesame seeds are not able to penetrate capped soils (less porous at the top soil) especially when soils are watered before emergence or seeds are sown too deep.

Soil moisture is not a limiting factor in sesame production in the major sesame growing areas in West Africa. Literature suggests that sesame prefers relatively dry, light and well drained soils (Jefferson, 2003) which are reminiscent of soils found in West Africa (Van Rheenen, 1979). Sesame has a very low salt tolerance. The plant is deep rooting and well adapted to withstand dry conditions. Its drought-tolerance is due in part to an extensive root system that also improves soil structure. However, it requires adequate moisture for germination and early growth but cannot tolerate wet conditions. It will grow on relatively poor soils in climates generally unsuitable for other crops, and so it is widely valued for its nutritional and financial yield from otherwise inclement (limited suitability) areas. It is well suited to smallholder farming with a relatively short harvest cycle of 90-140 days allowing other crops to be grown in the same field, though it is also often intercropped with other grains. The mean plant density has been calculated as 673,000 plants ha^{-1} (Oplinger *et al.*, 1990) leading to yields of 1028kg ha^{-1} but our experiments with 250,000 plants ha^{-1} compared well in terms of yield. Research on sesame revealed that yield per hectare increases with increasing plant population until a level is reached which is hardly exceeded as density increased further (Gupta, 1982).

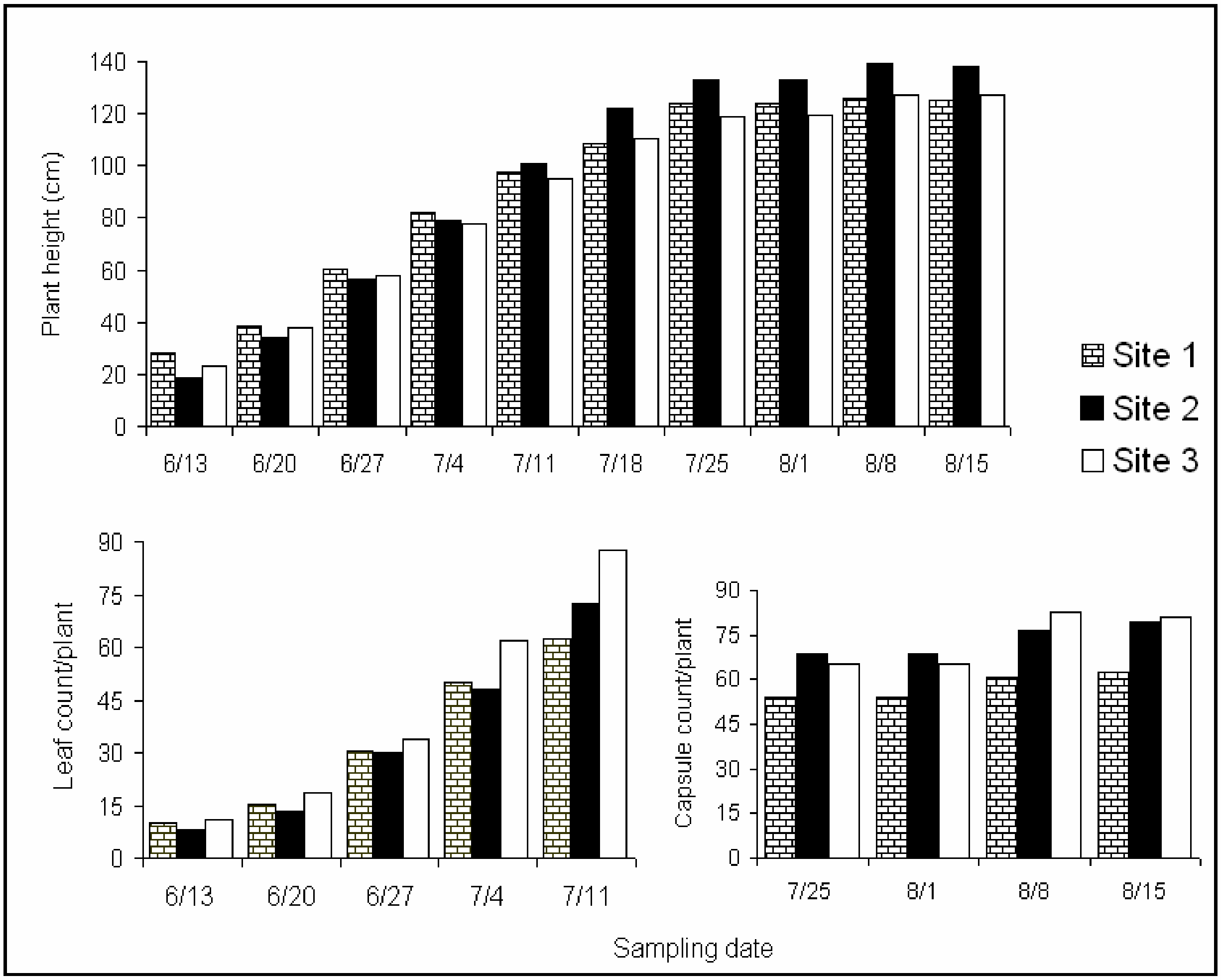

Figure 2: Some agronomic characteristics of sesame evaluated over time in Ghana. (Data was collected between June 13th and August 15th 2009; Data is the average of 25 plants from each of the three experimental sites; Plant height was measured from the soil surface to the tip of the youngest terminal leaf or to the terminal capsule after senescence of the terminal leaf).

The positive relationships between grain yield and plant height at physiological maturity, number of stem branching and number of capsules per plant has also been reported by Delgado & Yermanos (1975) and Olowe (2007). According to Olowe and Busari (2000) the number of capsules per plant could only be increased from 31 to 42 with the application of 90kg N ha^{-1}. This is unlike the cultivars used in our experiments which had higher capsule numbers at organic conditions of up to 80 capsules per plant. Under our growing conditions, all the measured agronomic characteristics were positively related to grain yield. This is an indication that these traits concurrently increased grain yield of sesame (Delgado & Yermanos, 1975; Ogunremi & Ogunbodede, 1986).

The average yield of sesame from our experiment was 688kg ha^{-1} which is far higher than the quoted average of 383kg ha^{-1} (FAO, 2004). These FAO figures could also be only rough estimates of the situation as sesame is a smallholder crop and much of the harvest is consumed locally, without record of the internal trade and domestic processing. In northern Ghana for example, sesame cuisines abound apparently from locally produced sesame but there are no documented production figures. Olowe and Adeoniregun (2010) have also reported yields that were greater than 1000kg ha^{-1}, above which should be the targets for future

Journal of Animal & Plant Sciences, 2010. Vol. 6, Issue 3: 653- 662.
Publication date: 28/04/2010, http://www.biosciences.elewa.org/JAPS; **ISSN 2071 - 7024**

cultivar selections. Our results were however obtained from small plot experiments that had been irrigated during the early seedling growth. Nevertheless it is a good indication that sesame thrives in the transitional zone of Ghana and it is anticipated that economic returns can be realized in areas with similar agro ecological conditions.

Table 3: Correlation matrices among some sesame growth and yield characteristics.

Traits	Plant height at 50% flowering	Plant height at physiological maturity	Number of capsules/plant at physiological maturity	Number of leaves/plant at 50% flowering	Number of branching/plant at physiological maturity	Yield per plant
Plant height at 50% flowering		0.50	0.51	0.63	0.69*	0.51
Plant height at physiological maturity			0.86**	0.48	0.69*	0.78*
Number of capsules/plant at physiological maturity				0.74*	0.88**	0.98***
Number of leaves/plant at 50% flowering					0.92***	0.78*
Number of branching/plant at physiological maturity						0.87**
Yield per plant						

1. Data is the correlation matrix (Pearson) of nine independent sampling means for each variable
2. Values indicated by * indicate significance at p=0.05, ** indicate significance at p=0.01 and *** indicate significance at p=0.001

The annual exports of sesame from neighbouring Nigeria for example are valued at about US$20 million which is the primary supplier of sesame seed to the world's largest importer, Japan (Chemonics, 2002). Japan dominates the purchasing side of the trade for sesame seed with an annual requirement of up to 165,000 tonnes which increases annually due to increased consumer concern for healthy eating. Currently sesame is traded on the world market at a price of $1500/tonne. This relatively high price reflects a worldwide shortage (Vimukt, 2009). The data obtained shows that since the number of capsules per plant, grain yield per plant or per capsule was not significantly different among the sites, indicating that the different soil physical and chemical properties as well as cropping histories did not influence individual plant agronomic characters. It is highly suspected that plant stand density below or above the optimum could be the limiting factor in yield per area as also reported by Adebesi et al. (2005) and Ssekabembe (2007) that when plant population density exceeds an optimum of 270,000 plants ha^{-1} there is yield reduction. This indicates that "mean plant stand density" as reported by Oplinger *et al.*, (1990) may be in reference to spatial capacity. In this experiment the seeds were sown to target 250,000 plants ha^{-1} but our yield was eventually calculated from a seedling survival of 76 % due to early plant life losses. Again since our cultivars have the base descriptor of one capsule per node (IPGRI & NBPGR, 2004), the yield per area component could be increased if we introduce other cultivars obtained from Asia that have eight or more capsules per node. Numbers of capsules are a consistent contributor of variation between quoted yield differences worldwide (Adebesi *et al*., 2005). For us, in the absence of soil or plant density variations, quantitative traits with wider variations like the numbers of capsules per plant or per node are crucial or are a better yield variable than the number or weight of seeds which are inconsistent even within sesame cultivars.

This experiment was done in the transitional zone of Ghana and as such reflects the ecological conditions towards both the north and south. The results obtained indicate that there is a potential for sesame production in Ghana. This experiment should be considered as a simulation of a farmer' field condition where they practice organic agriculture by default. However we would need to verify the plant-arthropod interactions within sesame fields especially if there are large sesame monocrop scenarios. Most farmers in Ghana are smallholders and since sesame presents a relative advantage in that seed yields under mechanization and traditional systems are comparable, it is a crop that smallholder farmers will remain relevant.

ACKNOWLEDGEMENTS: This work was sponsored by a grant from Ograsoa Bookshop, Ghana. Soil samples were analysed by the Soil Research Institute, Kumasi, Ghana with funds from the Sunyani Polytechnic. We are grateful to Mr. Francis Barnes (MOFA-FC, Ghana) and the other anonymous reviewers. Many thanks to the Polytechnic technician-Dominic Amo, my students and the local farmhands.

6 REFERENCES

Adebisi MA, Ajala MO, Ojo DK. and Salau AW: 2005. Influence of population density and season on seed yield and its components in Nigerian sesame genotypes. Journal of Tropical Agriculture 43:13-18.

Agboola SA: 1979. The Agricultural Atlas of Nigeria. Oxford University Press, Oxford.

Bray RH. and Kurtz LT: 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Science 59: 39-45.

Chemonics International Inc: 2002. Overview of the Nigerian sesame industry. USAID PCE-I-00-99-00003-00.

Cotteine A: 1980. Soil and plant testing as a basis of fertilizer recommendation. F.A.O. Soil Bulletin 6. F.A.O. Rome, Italy. 100pp.

Delgado M. and Yermanos DM: 1975. Yield components of sesame (*Sesamum indicum* L.) under different population densities. Economic Botany 29: 69-78.

Desai BB: 2004. Seeds handbook: biology, production, processing, and storage, Science 787pp.

FAO: 2004. www.apps.fao/faostat/form06/2009

FAOSTAT: 2000. Sesame. Eleven-year global sesame seed production and productivity: www.ecoport.org 12/2005.

Fuglie L: 1999. The miracle tree. *Moringa oleifera*: natural nutrition for the tropics. Church World Service, Dakar, Senegal 68pp.

Gupta TA: 1982. Effect of plant density on yield components in sesame (*Sesamum indicum* L). Madras Agriculture Journal 69: 569-572.

Hesse PR: 1975. A textbook of soil chemical analysis. Chemical Publishing Co., Inc. New York. 520pp.

IPGRI. and NBPGR: 2004. Descriptors for Sesame (*Sesamum spp*.). International Plant Genetic Resources Institute, Rome, Italy; and National Bureau of Plant Genetic Resources, New Delhi, India.

Jefferson T: 2003. Sesame is an ancient oilseed. www.jeffersoninstitute.org/pubs/sesame.shtml06/2009

Kato MJ, Chu A, Davin LB. and Lewis NG: 1998. Biosynthesis of antioxidant lignans in *Sesamum indicum* seeds. Phytochemistry 47: 583-591.

Laurentin H. and Karlovsky P: 2006. Genetic relationship and diversity in sesame (*Sesamum indicum* L.) germplasm collection using amplified fragment length polymorphism (AFLP). BMC Genetics 2006, 7:10.

Mulkey JR, Drawe HJ. and Elledge RE Jr: 1987. Planting date effects on plant growth and development in sesame. Agronomy Journal 79: 701-703.

Ogunremi EA. and Ogunbodede BA: 1986: Path coefficient analysis of seed yield in early season sesame (*Sesamum indicum* L.). Ife Journal of Science 1: 27-32.

Ojikpong TO, Okpara DA. and Muoneke CO: 2009. Effect of time of introducing sesame and Nitrogen, Phosphorus, Potassium (15:15:15) fertilizer on sesame/soybean intercropping in the southeastern rain forest belt of Nigeria. Journal of Plant Nutrition 32: 367-381.

Olowe VI. and Adeoniregun OA: 2010. Seed yield, yield attributes and oil content of newly released sesame (*Sesamum indicum* L.) varieties. Archives of Agronomy and Soil Science 56: 201-210.

Olowe VIO, Adeyemo YA and Adeniregun OO: 2009. Sesame: the underexploited organic oilseed crop. In: Proceedings of the 1st African Organic Agriculture Conference, Kampala, Uganda www.unep-unctad.org/cbtf/index.htm4/2010

Olowe VIO: 2007. Optimum planting date for sesame (*sesamum indicum* L) in the transition zone of south west Nigeria. Agricultura Tropica et Subtropica 40: 156-164.

Olowe VIO. and Busari LD: 2000. Response of sesame (*Sesamum indicum* L.) to Nitrogen and Phosphorous application in southern Guinea savanna of Nigeria. Tropical Oilseed Journal 5: 30-37.

Radov AS, Pustova LV. and Korolkov AV: 1985. Practicals in agriculture chemistry Agropromizdat, Moscow. 312pp.

Ssekabembe CK: 2007. Comparison of research on sesame (*Sesamum indicum*) and nakati (*Solanum aethiopicum*) at Makerere University. African Crop Science Conference Proceedings, African Crop Science Society. 8: 2063-2069.

Smith R: 2008. Sesame fills gap in failed cotton fields. South West Farm Press www.southwestfarmpress.com/news/sesame-crop-1030/4/2010

Taylor BR, Lamboll D. and Kafirit E: 1986. Sesame agronomy in south-east Tanzania. III. The effect of Nitrogen and Phosphorus on seed yield and oil content. Experimental Agriculture 22: 263-268.

Tewolde H, Mulkey JR Jr. and Fernandez CJ: 1994. Recovery of sesame from defoliation and growth terminal clipping. Agronomy Journal 86: 1060-1065.

Tuna D, Erdem A, Tuvay NH. and Zeybek A: 2005. A study on pelleting sesame (*Sesamum indicum* L.) seeds. Asian Journal of Plant Sciences 4: 449-454.

Van Rheenen HA: 1979. Soil moisture and growth of sesame. Plant and Soil 53: 277-285.

Vimukt DV: 2009. High prices at home force India to import raw sesame. www.business-standard.com/india/news/high-prices-at-home-force-india-to-import-raw-sesame/353154/04/2010

Walkey A. and Black AA: 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science 37: 29-38.

Watt JM. and Breyer-Brandwijk MG: 1962. The medicinal and poisonous plants of southern and eastern Africa. Being an account of their medicinal and other uses, chemical composition, pharmacological effects and toxicology in man and animal, 2nd edn. E & S Livingstone Ltd. Edinburgh, UK.1457pp.

Weiss EA: 2000. Oilseed crops. 2nd ed. Oxford: Blackwell Science. Oxford, U.K. 131-164pp

Wilde SA, Voigt GK. and Iyer JC: 1972. Soils and plant analysis for tree culture. Oxford and IBH Publishing Co. New Delhi, India. 209pp.

XLSTAT: 2010. *Addinsoft™ version 2010.* www.xlstat.com/02/2010