ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 14 (4): 272-278, 2015
ISSN 1812-5379

RESEARCH ARTICLE OPEN ACCESS

DOI: 10.3923/ja.2015.272.278

Graphical Determination of Leaf Area Index and its Relationship with Growth and Yield Parameters of *Sorghum* (*Sorghum bicolor* L. Moench) as Affected by Fertilizer Application

I.K. Addai and M. Alimiyawo
Department of Agronomy, University for Development Studies, P.O. Box TL 1882, Nyankpala, Tamale, Ghana

ARTICLE INFO
Article History:
Received: August 28, 2015
Accepted: October 21, 2015

Corresponding Author:
I.K. Addai
Department of Agronomy,
University for Development Studies,
P.O. Box TL 1882,
Nyankpala, Tamale, Ghana

ABSTRACT

Studies were conducted during the 2013 and 2014 cropping seasons at the University for Development Studies, Nyankpala, Ghana to determine leaf area indices of three *Sorghum* (*Sorghum bicolor* (L.) Moench) varieties using the graphical approach. Three varieties viz., Kapala, Kadaga and Dorado were planted and applied with three rates: 0-0-0, 45-30-30, 35-20-20 and 45:30:30 of N, P and K, respectively. Treatment combinations were replicated three times in RCBD. Results indicated that the application of N, P and K at 45:30:30 or 35-20-20 to variety Dorado or Kadaga significantly increased leaf number, seed weight, grain yield and LAI of *Sorghum*. The data also showed that LAI correlated positively with panicle length and number of leaves. The relationships between LAI and 100 seed weight and LAI and grain yield were also high but negative. The leaf area constants for *Sorghum* have been developed and were found to be 0.723, 0.661 and 0.545, respectively, for varieties Kadaga, Kapala and Dorado. They can be used by researchers in computing LAI to predict growth and development of *Sorghum*. Farmers in the study area who cultivate Dorado or Kadaga should apply N, P and K at 45:30:30 to increase growth and yield of *Sorghum*.

Key words: *Sorghum* varieties, leaf area constants, LAI, growth, components of yield

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is an annual crop belonging to the family Poaceae, tribe Andropogoneae, genus *Sorghum* and species *bicolor*. *Sorghum* originated in Africa and it is uniquely adapted to Africa's climate (Taylor, 2011). It is the fifth most economically important crop among cereals in the world (Tigabu *et al*., 2013). It is an important crop grown commonly by subsistence farmers with little or no added agricultural input, primarily for lack of capital and information on appropriate recommendation rates (Buah *et al*., 2012). In Ghana, *Sorghum* is cultivated on 243.482 ha of land for its grain and forage depending on the variety. A total of 287.069 t of the crop was produced in 2011 but production dropped to 256.736 t in the year 2013 (FAOSTAT., 2013). The crop is consumed directly as human food in the form of stiff porridge (tuo zaafi), thin porridge (kooko) and fried dumping (maasa). The leaves provide fodder for farm animals whiles the stalks are used in fencing, weaving baskets, mats and fuel wood but the crop is mainly used in brewing an opaque beer known as 'Pito' in Ghana (Atokple, 1993). The crop can be processed into syrup or *Sorghum* molasses and can also be used for the production of alcoholic beverages as well as biofuels (Mutegi *et al*., 2010). Presently, *Sorghum* has assumed greater commercial proportions throughout the country especially in Northern Ghana due to an increase in the number of people consuming it in the form of 'Pito'. 'Pito' mash, the residues from brewing is the main stay of the pig industry in northern Ghana (Bruce and Karbo, 1997).

Traditionally, *Sorghum* has been known for its nutrient use efficiency and is managed with low fertilizer rates in Ghana but yield can be increased with the application of higher fertilizer rates. There has been an increase in grain yields of the crop following the application of N, P or K based fertilizers to the crop (Kaizzi *et al*., 2007). In crop production, leaf area index, defined as the total leaf area per unit ground area, is commonly used to quantify vegetative canopy structures (Welles and Norman, 1991). Leaf area index influences photon capture, photosynthesis, assimilate partitioning as well as growth and yield formation (Rosenthal and Vanderlip, 2004; Tsialtas and Maslaris, 2008). This quantity is used to predict the photosynthetic capacity of a crop and serves as a reference tool for crop growth. The relationship between leaf area and plant biomass was found to be non-linear and variable depending on carbon partitioning (Weraduwage *et al*., 2015). But from a micrometeorological perspective, an increase in leaf area index increases light interception and the source/sink strength for heat, water and CO_2 exchange. Accurate quantification of LAI is therefore important for crop growth and development. Early attempts to determine the leaf area of *Sorghum* used the relationship between the area of a single leaf and the total leaf area of the whole plant (Bueno and Atkins, 1981). This approach may largely be influenced by factors such as location and plant density and may not sufficiently estimate the leaf area with the development of yield components. There is the need to determine the relationships, if any, that exist between the LAI and yield components of *Sorghum*. These days, LAI estimation is by the use of devices such as leaf area meters. These instruments are either non-existent in most institutions in northern Ghana or simply cannot be afforded by most people in the area. The use of simple tools and methodologies for determining LAI would save the present but unpleasant situation of non-availability and unaffordability of leaf area meters in Northern Ghana. Moreso, the method used for LAI determination should be very simple and must predict plant growth and yield of crops. Analyzing growth using Leaf Area Index (LAI) and knowing the relationship among growth and yield parameters especially when fertilizer is applied will enhance a good understanding about the physiology and yield of such crops. The objectives of this study were to determine the LA constants of three *Sorghum* varieties popularly cultivated in Northern Ghana, determine the LAI using very simple methodologies and establish the relationship between the LAI and growth/components of yield of *Sorghum*.

MATERIALS AND METHODS

Site description: The experiments were conducted during the 2013 and 2014 cropping seasons at the University for Development Studies, Nyankpala, Ghana. The experimental site is located on an altitude of 183 m and latitude 09°25’ N and longitude 0°58’ W. Rainfall in the study area is evenly distributed from May to October with a peak in August or September in each year. The total annual rainfall is about 1022 mm. The average minimum temperature is 25°C whilst the maximum average temperature is 35°C (Lawson *et al*., 2013). The area lies within the interior Guinea Savannah of Ghana and is characterized with natural vegetation dominated by grasses with few shrubs. Soils of the area are moderately drained and are free from concretions; they are shallow with hardpan under the top few centimeters and were derived from Voltaian sandstone. The soils, according to FAO (1988), are classified as Nyankpala series or Plinthic Acrisol. The area has grassland vegetation and it is interspersed with short trees such as *Parkia biglobosa* and *Azadirachta indica* and weed species such as *Centrosema pubescens*, *Cyperus difformis* and *Striga hermontheca.* Weather conditions (Table 1) and soil physical and chemical properties of the study sites for the 2 years were not significantly different and the mean values (Table 2) are as shown.

Field preparation, experimental design and cultural practices: The experimental field was ploughed with tractor and harrowed during the first week of July for the 2 years. The layout of the field was done using pegs, lines and measuring tapes. Each plot measured 0.2×0.2 m with a distance of 1.5 and 1 m between blocks and plot, respectively. The study made use of 3×3 factorial experiment in each year for the two years. Three varieties of *Sorghum* namely Kadaga, Kapala and Dorado and three levels of fertilizer application viz., 0-0-0, 45-30-30 and 35-20-20 were used. Treatment combinations were replicated three times in randomized complete block design. The seeds were obtained from Seeds Inspection Unit of the Savannah Agricultural Research Institute (SARI), Nyankpala. Eight to nine seeds were sown per hill during the second week of July of each year, at a spacing of 0.75 m

Table 1: Meteorological data for the experimental area during the study period

Year/month	Total monthly rainfall (mm)	Mean monthly maximum temperature (°C)	Mean monthly minimum temperature (°C)
2013			
July	143.4	32.3	26.8
August	252.6	34.5	25.3
September	212.3	31.4	23.5
October	104.5	33.2	25.7
2014			
July	195.5	32.6	26.4
August	79.3	34.5	25.5
September	202.6	31.3	23.8
October	148.1	35.6	24.7

Source: Council for Scientific and Industrial Research (CSIR)-SARI, Nyankpala between rows and 0.20 m within rows. After emergence seeds were replaced for those that did emerge. Plants were thinned to three seedlings per hill 7 days after emergence. Weeding was done at three weeks intervals, that is, at 3, 6 and 9 WAP to control weeds. NPK 15:15:15 fertilizers were applied to the crops 2 weeks after planting at a distance of 5 cm away from the plants and at 4 cm planting depth. Experiments were terminated in October ending each year.

Data collection and analysis: Leaf area index constants, plant height, chlorophyll content and number of leaves were measured and studied during the 2013 experimental season. Plant height was measured from the soil surface to the top of last two leaves. The chlorophyll content of the plants was recorded using the chlorophyll meter (the minolta) on tagged plants. Three leaves: the upper, middle and lower parts from the canopy were used and their average readings recorded. In the year 2014, leaf width (measured as the widest portion/distance at the middle section of the leaf), leaf length (measured as the distance from the leaf node to the tip), number of leaves, hundred seeds weight and panicle length were measured. The length of the panicle was taken from five tagged plants using a measuring tape from the base to the tip. The leaves for five tagged plants were counted and recorded per plot. Data collected was subjected to Genstat statistical software for analysis of variance and means separated using LSD at 5% probability level.

Table 2: Some physical and chemical properties of the soil at the experimental site

Soil properties	Values
Sand (%)	52.20
Silt (%)	43.40
Clay (%)	4.40
pH	5.04
Organic carbon (%)	0.78
Available nitrogen (%)	0.12
Available phosphorus (mg kg^{-1})	2.61
Potassium (mg kg^{-1})	8.60
CEC (cmol kg^{-1})	2.76

CEC: Cation exchange capacity

Determination of leaf area index: Constants for leaf area index were computed during the 2013 experimental period according to the method adopted by Addai and Scott (2011). In this method, fifty leaf samples from each of the three varieties were selected. The length of the leaves and the width of the leaves were recorded using a meter rule. Leaf length and width obtained were multiplied to get a parameter termed 'Measured Leaf Area' (MLA). Outlines of the fifty leaves were traced on A4 sheets. The weight of each A4 sheet used was recorded. The average weight and area of three such A4 papers were computed. The outlines (shape) of each leaf made on the paper were cut using a pair of scissors and were weighed. Using the average weight of the A4 paper, the weight and area of each piece of paper cut was determined by proportion because the weight and area of the A4 from which the leaf shapes were traced are already known. The area estimated for each piece of paper is the 'true Leaf Area' (tLA) for that leaf. Each MLA value obtained from the product of leaf length and width has a corresponding tLA value. Therefore coefficients of regression lines (β) were obtained by plotting values of tLA against those of MLA in scatter diagrams (Fig. 1) as leaf area constants. Thus the leaf area

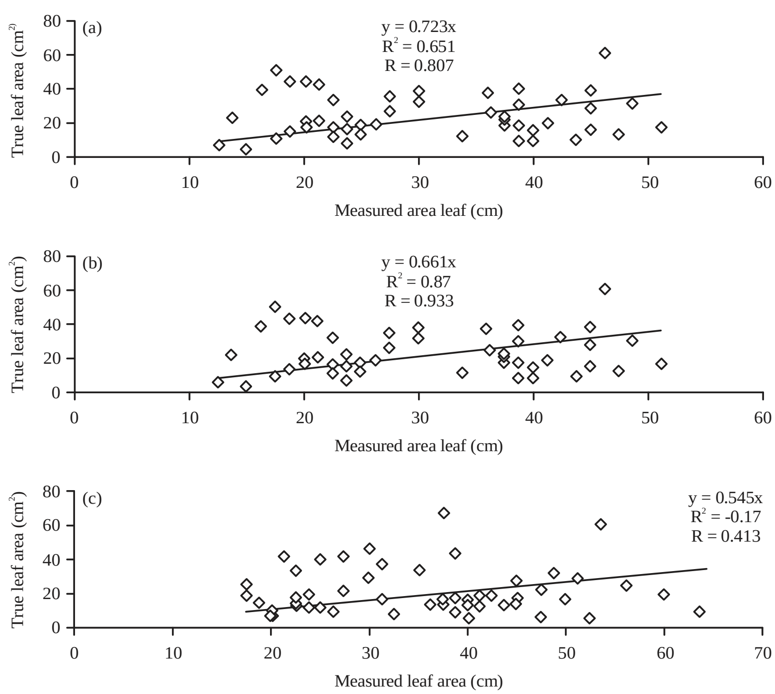

Fig. 1(a-c): Determination of leaf area constants for the various varieties of *Sorghum* used in the study (a) Kadaga, (b) Kapala and (c) Dorado constants for the varieties Kadaga, Kapala and Dorado were 0.723, 0.661 and 0.545, respectively (Fig. 1a-c). Thus in year 2014, leaf lengths and widths were measured of the varieties at each data collection time and the product of these two quantities gave MLA. The β already developed for each variety of *Sorghum* in 2013 experimental period was multiplied by the total number of leaves counted of each variety and MLA obtained from the product of leaf length and width to obtain the total true leaf area of the variety at that time. The results obtained were divided by the product of the intra and inter row spacings (planting distance) to get the leaf area indices.

RESULTS

Vegetative growth: The varieties behaved differently in terms of plant height and number of leaves depending on the fertilizer rate applied. Both the main and interaction effects for the two traits were significant ($p<0.05$). Kapala at 35-20-20 rate of application recorded the highest height whilst Dorado and Kadaga plants which received no fertilizer application were the shortest (Fig. 2a). Also Dorado and Kadaga at 45-30-30 and 35-20-20, respectively recorded significantly the same and highest chlorophyll content whilst unfertilized plants from Kapala gave the least chlorophyll content (Fig. 2b). Also Dorado at either 35-20-20 or 45-30-30 and Kadaga at 45-30-30 recorded the highest number of leaves. Similarly plants from the same two varieties that were not fertilized had the least number of leaves (Fig. 2c).

Yield and components of yield: For panicle length, the main effect of fertilizer was not significant ($p>0.05$) but both the main effect of crops and the interaction for the two factors were significant ($p<0.05$). Unfertilized plants from variety Kadaga and Kapala recorded the highest and lowest panicle length, respectively (Table 3). For 100 seed weight, however, the main effect of either fertilizer or crops was not significant ($p>0.05$) whilst the interaction effect was significant ($p<0.05$). Variety Dorado at 45-30-30 produced the highest seed weight whilst unfertilized plants from Kadaga recorded the least seed weight (Table 4). The trend in grain yield was similar to that of 100 seed weight (Table 5).

Leaf area indices: Leaf area index was computed at three stages of growth: 3, 6 and 9 WAP. In general, LAI increased

Table 3: Effects of fertilizer application and variety on panicle length of *Sorghum* (cm)

Fertilizers	Dorado	Kadaga	Kapala
0-0-0	27.67	30.99	22.29
35-20-20	25.46	30.27	24.43
45-30-30	27.01	26.59	22.85
Mean	26.71	29.28	23.19

LSD (0.05) Crops = 2.36, LSD (0.05) Crop×fertilizer = 4.09

Table 4: Effects of fertilizer application and variety on 100 seed weight of *Sorghum* (g)

Fertilizers	Dorado	Kadaga	Kapala
0-0-0	2.83	2.50	2.83
35-20-20	2.67	2.60	2.90
45-30-30	3.03	2.63	2.60

LSD (0.05): Crop×Fertilizer = 0.34

Table 5: Effects of fertilizer application and variety on grain yield of *Sorghum* (kg ha^{-1})

Fertilizers	Dorado	Kadaga	Kapala
0-0-0	1491.89	1317.93	1491.89
35-20-20	1487.64	1448.64	1615.79
45-30-30	1779.13	1544.26	1526.64

LSD (0.05): Crop×Fertilizer = 169.24

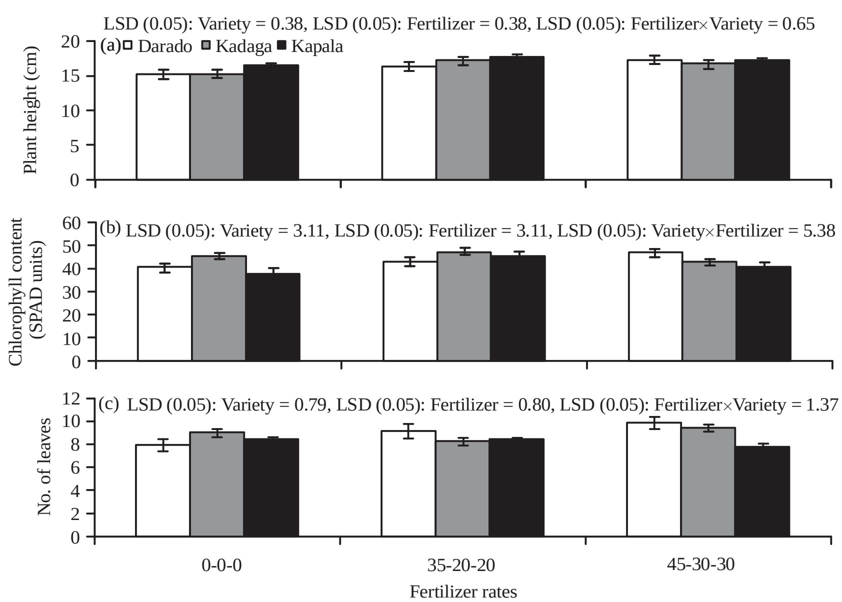

Fig. 2(a-c): Effects of treatment combinations on (a) Plant height, (b) Chlorophyll content and (c) No. of leaves of *Sorghum*. Measurements were made at 9 WAP

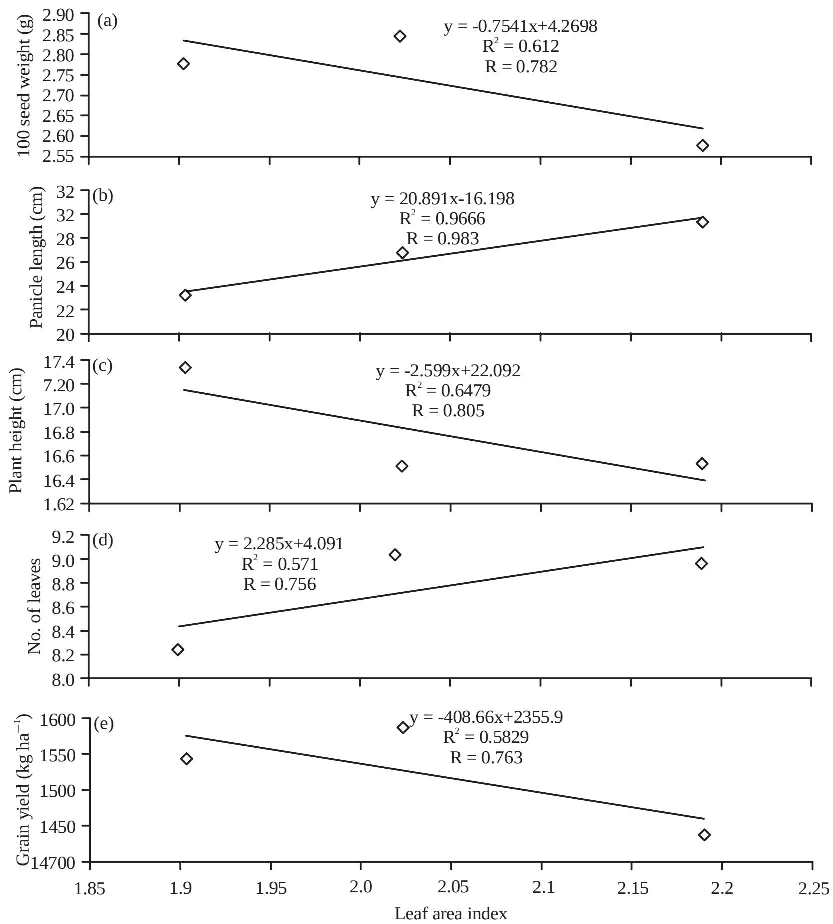

Fig. 3(a-e): Relationship between (a) 100 seed weight, (b) Panicle length, (c) Plant height (d) No. of leaves and (e) Grain yield and LAI of *Sorghum*

Table 6: Effects of treatment combinations on Leaf area index at 3 and 6 WAP

Fertilizers	Dorado	Kadaga	Kapala
3 WAP			
0-0-0	0.045	0.055	0.050
35-20-20	0.059	0.059	0.076
45-30-30	0.058	0.066	0.041
Mean	0.054	0.060	0.056
6 WAP			
0-0-0	1.07	1.59	1.05
35-20-20	1.00	1.50	1.65
45-30-30	1.41	1.42	1.47
Mean	1.16	1.50	1.39

LSD (0.05): Crop, Fertilizer and Crop×Fertilizer = NS, WAP: Week after planting

from 3-9 WAP. For 3 and 6 WAP, there were no significant differences (p>0.05) among values of LAI for the main and interaction effects (Table 6). At 9 WAP, however, the interaction between the two factors had a significant effect on LAI. The overall highest and lowest values of LAI at 9 WAP were plants from Dorado at 45-30-30 and the unfertilized plants from same variety, respectively (Table 7).

Table 7: Effects of treatment combinations on leaf area index at 9 WAP

Fertilizer	Dorado	Kadaga	Kapala
0-0-0	1.45	2.38	1.82
35-20-20	1.90	2.06	2.11
45-30-30	2.72	2.13	1.78

LSD (0.05): Crop×Fertilizer = 0.69

Correlation between leaf area index and components of yield: There were high positive correlations between LAI and panicle length (Fig. 3b) and LAI and number of leaves (Fig. 3d) (R = 0.983 and 0.756, respectively). The relationships between LAI and 100 seed weight (Fig. 3a); LAI and plant height (Fig. 3c) and LAI and grain yield (Fig. 3e) were also high but negative (R = 0.782, 0.805 and 0.763).

DISCUSSION

Plants treated with the fertilizer recorded higher growth than the unfertilized control. This is because the application of the fertilizer supplied the plants with N, P and K. These elements are the basic nutrient elements needed by plants for successful growth (Nino *et al*., 2012). The results obtained in this study confirms the observation made by Dauda *et al*. (2008), who reported that *Sorghum*, like other cereals, requires adequate supply of nutrients particularly nitrogen, phosphorus and potassium for growth and for high photosynthetic activities to promote roots and vegetative growth. Plants from Kapala fertilized with 35-20-20 rate of application recorded the highest growth in terms of plant height whilst unfertilized plants from Dorado or Kadaga grew the shortest. The result of the study revealed that varieties may differ in their response to a number of factors as reported by Zhang *et al*. (2012). In the present study, the three varieties used for the study varied differently in terms of plant height depending on the fertilizer rate applied. The application of 35-20-20 and 45-30-30 rates of the fertilizer generally gave similar responses in vegetative growth. As for example, in terms of number of leaves and chlorophyll content, both 35-20-20 and 45-30-30 gave similar performances. This observation is in accordance with the findings of Zeng *et al*. (2015), who suggested that in sunflower both moderate and high rates of fertlizer application would support growth and yield of the crop. Also, the single effects of fertilizer and variety as well as their interaction were significantly ($p<0.05$) different implying that variation in plant growth was not only due to fertilizer application but probably the genetic makeup of plants. The result presented here is in support of Taylor (2011), who also made a similar observation.

The data showed that variety Dorado recorded the highest chlorophyll content, leaf number, LAI, seed weight and grain yield especially when either 35-20-20 or 45-30-30 rate of NPK were applied. The result is in conformity with the findings of Ahlrichs and baue (1983). According to these authors, LAI predicts the photosynthetic capacity of a crop and serves as a reference tool for crop growth and development. An increase in leaf area index increases light interception and the source/sink strength. Thus the higher the LAI, the higher the photosynthetic activity and the higher the growth and the crop yield. In general, the high LAI of plants from variety Dorado provided them with competitive advantage relative to the others in terms of acquisition of resources for growth and yield. This implies that Dorado is an excellent genotype for cultivation in the study area and its inclusion in the cropping system in the study area should be encouraged. An application rate of either 35-20-20 or 45-30-30 should be applied by farmers to enhance leaf growth and plant height development in order to achieve high grain production. In general, leaves are the major sources that supplies assimilates to sinks such as developing organs, young pods and seeds (Abdi *et al*., 2007; Barimavandi *et al*., 2010). An increase in vegetative growth particularly number of leaves coupled with the relatively high chlorophyll content of these genotypes might have enhanced the development of photosynthetic apparatus of this genotype resulting in increases in photo assimilates production. The high grain yield of variety Dorado was as a result of its high LAI. A similar observation was made by Rosenthal and Vanderlip (2004) and Tsialtas and Maslaris (2008), who stated that LAI influences plants to capture photon to increase photosynthetic rate and this enhances assimilate partitioning resulting in high growth and grain yield. The results on correlation studies in the present study also support the above observation. The data suggest that LAI correlated very well and positively with panicle length and number of leaves. The relationships between LAI and 100 seed weight and grain yield were also high but negative implying that high LAI is necessary for assimilate production but the photosynthetic products formed by the leaves will be channeled towards the development of seeds and grains at the expense of further leaf production.

CONCLUSION

The results obtained from this study revealed that the application of NPK 45:30:30 or 35-20-20 to Dorado significantly increased leaf number, seed weight, grain yield and LAI of *Sorghum*. The data suggest that LAI correlated very well and positively with panicle length and number of leaves. The relationships between LAI and 100 seed weight and grain yield were also high but negative. Dorado is an excellent genotype for cultivation in the study area and its inclusion in the cropping system in Northern Ghana should be encouraged but NPK 15:15:15 should be applied at a rate of either 35-20-20 or 45-30-30 for good vegetative growth and grain production.

ACKNOWLEDGMENT

The authors of this study are most grateful to the Faculty of Agriculture of UDS for providing funds for land preparation prior to planting.

REFERENCES

Abdi, S., M.A. Fayaz and M.G. Zade, 2007. Effect of different defoliation intensities at plant reproduction stages on seed yield and oil percentage of two sunflower hybrid cultivars. Water Soil Sci. (J. Sci. Technol. Agric. Nat. Resour.), 11: 245-255.

Addai, I.K. and P. Scott, 2011. Detrimental effects of below-ground herbivory to the growth and development of the common hyacinth and lily. Ghana J. Hortic., 9: 43-63.

Ahlrichs, J.S. and M.E. Baue, 1983. Relation of agronomic and multispectral reflectance characteristics of spring wheat canopies. Agron. J., 75: 987-993.

Atokple, I.D.K., 1993. Nyankpala Agricultural Experimental Station (NAES) annual report, 1993. *Sorghum* and Millet Section, NAES, Ghana, pp: 46-67.

Barimavandi, A.R., S. Sedaghathoor and R. Ansari, 2010. Effect of different defoliation treatments on yield and yield components in maize (*Zea mays* L.) cultivar of S.C704. Aust. J. Crop Sci., 4: 9-15.

Bruce, J. and N. Karbo, 1997. *Sorghum* production in Northern Ghana. Proceedings of the 10th Annual Conference of the Ghana Society of Animal Production, August 13-16, 1997, University of Ghana, Legon, Ghana.

Buah, S.S.J., J.M. Kombiok and L. N. Abatania, 2012. Grain *Sorghum* response to NPK fertilizer in the Guinea Savanna of Ghana. J. Crop Improv., 26: 101-115.

Bueno, A. and R.E. Atkins 1981. Estimation of individual leaf area in grain *Sorghum*. Lowa State J. Res., 55: 341-349.

Dauda, S.N., F.A. Ajayi and E. Ndor, 2008. Growth and yield of water melon (*Citrullus lanatus*) as affected by poultry manure application. J. Agric. Social Sci., 4: 121-124.

FAO., 1988. Soil map of the world: Revised legend with corrections and updates. World Soil Resources Report 60, FAO, Rome, Italy.

FAOSTAT., 2013. Ghana: *Sorghum*, production quantity (tons). Food and Agricultural Organization of the United Nations, Rome, Italy.

Kaizzi, K.C., J. Byalebeka, C.S. Wortmann and M. Mamo, 2007. Low input approaches for soil fertility management in semiarid Eastern Uganda. Agron. J., 99: 847-853.

Lawson, I.Y.D., A. Issahaku, S.K. Acheampong, B. Adams and V. Tuffour, 2013. Time of planting and weed suppression abilities of some legumes intercropped with maize in the Guinea savanna zone of Ghana. Agric. Biol. J. North Am., 4: 358-363.

Mutegi, E., F. Sagnard, M. Muraya, B. Kanyenji and B. Rono *et al*., 2010. Ecogeographical distribution of wild, weedy and cultivated *Sorghum bicolor* (L.) Moench in Kenya: Implications for conservation and crop-to-wild gene flow. Genet. Resour. Crop Evol., 57: 243-253.

Nino, A., A. Rivera and A. Ramirez, 2012. Production of organic fertilizer with macro-micronutrients from the solid waste generated at home. Eur. J. Exp. Biol., 2: 199-205.

Rosenthal, W.D. and R.L. Vanderlip, 2004. Simulation of individual leaf areas in grain *Sorghum*. Agronomie, 24: 493-501.

Taylor, J.R.N., 2011. Importances of *Sorghum* in Africa. Department of Food Sciences, University of Pretoria, Pretoria, South Africa.

Tigabu, E., M. Andargie and K. Tesfaye, 2013. Genotypic variation for salinity tolerance in *Sorghum* (*Sorghum bicolor* (L.) Moench) genotypes at early growth stages. J. Stress Physiol. Biochem., 9: 253-262.

Tsialtas, J.T and N. Maslaris, 2008. Evaluation of a leaf area prediction model proposed for sunflower. Photosynthetica, 46: 294-297.

Welles, J.M. and J.M. Norman, 1991. Instrument for indirect measurement of canopy architecture. Agron. J., 83: 818-825.

Weraduwage, S.M., J. Chen, F.C. Anozie, A. Morales, S.E. Weise, T.D. Sharkey, 2015. The relationship between leaf area growth and biomass accumulation in *Arabidopsis thaliana*. Front Plant Sci. 10.3389/fpls. 2015. 00167

Zeng, W., C. Xu, J. Huang, J. Wu and T. Ma, 2015. Emergence rate, yield and nitrogen-use efficiency of sunflowers (*Helianthus annuus*) vary with soil salinity and amount of nitrogen applied. Commun. Soil Sci. Plant Anal., 46: 1006-1023.

Zhang, Y., S. Guo, Z. Liu and S.K. Chang, 2012. Off-flavor related volatiles in soymilk as affected by soybean variety, grinding and heat-processing methods. J. Agric. Food. Chem., 60: 7457-7462.