ASSESSMENT OF SELECTED LANDRACE AND IMPROVED GROUNDNUT (*Arachis hypogaea* L.) GENOTYPES UNDER STRESSED AND NON-STRESSED CONDITIONS

ABSTRACT

Drought is one of the most essential and critical abiotic restraints to groundnut production and yields in the Northern Region of Ghana. A field experiment was conducted to assess selected landrace and improved groundnut genotypes for agronomic performance in the 2017 and 2018 minor seasons. Groundnut genotypes were treated under normal irrigation (W/W) and water-stressed (W/S) conditions. A Randomized Completely Block Design (RCBD) with four replications was adopted. Total experimental area was 23.4m x 2.4 m with a planting distance of 40 cm x 20 cm for both environments. Data collected include; days to 50% emergence and flowering, plant height at maturity (cm), growth appearance, days to maturity, number of pods/plot, number of seeds/plot, pod weight (g), seed weight (g), fresh and dry biomass weights (g), SPAD chlorophyll meter reading at 60 and 80 days after planting, harvest index (HI) and drought tolerance index (DTI). The data were subjected to analysis of variance (ANOVA) using GenStat, version 12.0, Exploratory Analysis, descriptive Statistics (mean comparison of plant characteristics by varieties at 5% level using Tukey's groups) was conducted; Correlation Analysis and Multivariate Analyses were performed using the Wilk's Lambda to test for significant difference at 5% and 1% levels respectively. Means were separated using S.E.D. of means at 95% confidence level. Results from the growth features indicated a higher percentage of the groundnut varieties sprouted earlier under well-watered conditions. There was no significant difference among the groundnuts regarding the numbers of days to flowering. The groundnuts took approximately 104 days after planting to mature under both water conditions. Chlorophyll content and distribution in the groundnut leaves was high the well-watered plants. The chlorophyll content among the groundnut crops showed no significant difference between the chlorophyll content at 60-days after planting and 80-days after planting under the water-stressed condition. However, chlorophyll content of leaves at the 60-days after planting was 2.94 lower than that under 80 days after planting. Maturity and flowering (0.768), as well as plant height and seed yield (0.501) were highly significantly and highly positively correlated. The seed characteristics were also highly, significantly and positively correlated with the pod characteristics of the crop. The biomass measure also correlated with the pod and seed traits. Groundnuts genotypes under well-watered environment generally performed better in terms of yield than those under water-stressed environment.

Keywords: Groundnut, jute sack, landraces, postharvest, P.R.A., questionnaire

1. INTRODUCTION

Groundnut (*Arachis hypogaea L.*) belongs to the family Leguminosae and sub-family Papilionoideae (Waele and Swanevelder, 2001). The name groundnut is derived from the Greek word 'arachis' meaning 'legume' and hypogaea meaning 'below ground', referring to the formation of pods in the soil (Waele and Swanevelder, 2001).

Groundnut originated from South America, Mexico, and Central America (Tweneboah, 2000).

According to Tweneboah (2000), groundnut is an annual herb whose main and remarkable characteristic is the production of fruits underground. He reported that it is unique in that, after fertilization, the aerial flowers grow downwards and the ovary, at the end of the elongated stalk 'peg', enters the soil in a positive geotropic manner where the ovary at the tip of the peg grows into the pod containing seeds (Tweneboah, 2000).

The groundnut plants has a tap root with abundantly branched, lateral roots on which globular, often dark brown nodules are usually present but branching and floral axis patterns are two discriminating characters (Gregory, 1986).

Groundnut is an important food and cash crop for resource poor farmers in Asia and Africa (FAOSTAT, 2010).

The world average yield of groundnut production is around 13,000 kg ha^{-1} and about 70% of the world groundnut production occurs in the semi-arid tropics where the average yield is around 800 kg ha^{-1} (FAOSTAT, 2010).

The Guinea Savannah ecology of Ghana accounts for over 70% of total groundnut produced in the country, making it the most important groundnut region in the country FAOSTST (2010).

Groundnut provides highly nutritious meals and protein substitutes for households (Thamaga-Chilja *et al*., 2004).

Due to its high mono-saturated content, it is considered healthier than saturated oils and is resistant to rancidity (Thamaga-Chilja *et al*., 2004).

Groundnut is particularly valued for its protein content (26%). In addition to protein and oil, groundnut is good source of calcium (Ca), phosphorus (P), iron (Fe), zinc (Zn), and boron (B) (Shilling, 2002).

Groundnut is cultivated predominantly in the tropics and subtropics on sandy soils, where the availability of water is a major constraint on yield (Shilling, 2002). During the entire season the crop is subjected to water deficit stress at one stage or another leading to drastic reduction in productivity. This necessitates development of cultivars which can withstand water stress and still can be productive. Reduction in groundnut yield resulting from drought has been well documented (Reddy *et al*., 2007).

In breeding programs, grain yield is the primary trait for selection under drought prone conditions. Some drought resistant groundnut cultivars have been developed by Savannah Agriculture Research Institute (SARI) for farmers in the Northern part of Ghana. However, this is not enough. Improvement of the crop in terms of yield and other agronomic characteristics, especially in drought prone environments, to serve as a first step among others at improving the crop in future for adoption by farmers for higher productivity and enhanced incomes is thus necessary.

1.2 Problem statement

Production of groundnut in Ghana has since been at the subsistence level and mainly carried out by small-scale resource-poor farmers (Thamaga-Chija *et al*., 2004). The commonly cultivated varieties are the Virginia and the Spanish or Valencia types (Thamaga-Chilja *et al*., 2004). In rural areas of Northern Ghana where improved varieties have not yet been fully adopted, the predominant cultivars are the Virginia variety (Thamaga-Chilja *et al*., 2004) The production level of groundnut in Ghana have not been consistent in the Upper East Region. There is limited information about drought-tolerant groundnut varieties in the region.

Due to the complex nature of drought, as well as genotype by environmental effect, it is difficult to predict drought (Solomon and Labuschagne, 2003). However, identification of drought-tolerant and drought susceptible genotypes based on yield under stress alone is compounded by the genotype's yield potential and phenology.

1.3 Significance of the study

Groundnut production is a profitable and viable enterprise that is easily practiced by small-scale farmers. Groundnut production is easy to start because it requires little initial investment. Some drought resistant groundnut cultivars have been developed by Savannah Agriculture Research Institute (SARI) for farmers in the Northern part of Ghana. Yield losses due to drought are highly variable in nature depending on timing, intensity and duration, coupled with other location-specific environmental stress factors such as high irradiance and temperature and salinity (Graciano *et al*., 2011). Breeding for drought tolerance has been an important and cheaper strategy and alternative adopted by researchers to alleviate the water stress problems and to ensure higher productivity in environments prone to drought (Songsri *et al.*, 2008). Assessing performance of groundnut genotypes in terms of yield and other characteristics especially in drought prone environment in the current study is imperative and timely.

The development of improved groundnut genotypes would augment groundnut production and yields in the Upper East Region, in particular and Ghana at large, and would increase farmers' incomes.

The present study sought to evaluate the growth and yield performance of landrace and improved groundnut genotypes under two water regimes/ environments (well-watered and water-stressed).

MATERIALS AND METHODS

Source of genetic materials

The genetic materials used for the present study consisted of thirteen (13) groundnut genotypes, both improved and landrace varieties. Six (6) improved groundnut varieties were obtained from Savannah Agriculture Research Institute (SARI), Tamale in the Northern Region of Ghana and seven (7) popular groundnut landraces were obtained from farmers.

Experimental site

The study was carried out at the experimental field of the Department of Ecological Agriculture, Bolgatanga Polytechnic, in the Upper East Region of Ghana, between January and May, 2018 dry season. Soil samples were drawn at random from 0 to 30 cm depth from the experimental field. The composite soil samples were analysed for various physico-chemical properties. The soil was sandy-loam in texture, neutral in soil reaction, medium in organic carbon and available nitrogen, medium in available phosphorus and potassium

Land preparation

The field which was selected for the experiment was cleared of stumps, trees, and grasses. The land was ploughed, harrowed and levelled in order to have a uniform tilt before sowing. After final preparation of the land, sunken beds were prepared for each environment. Total experimental area was 23.4m x 2.4m (56.16m^2) for both environment one (I) and two (II).

Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with two replications and involving thirteen genotypes per each of the two environments, well-watered (W/W) and water-stressed (W/S).

Sowing and management

The seeds were sown on 10th January, 2018 with planting spacing of 40 cm x 20 cm for both environment I (well-watered) and environment II (water-stressed).

One seed was sown per hill and filling in was done one week after germination.

Weeds were controlled manually two weeks after germination and as and when necessary.

Water treatment for environment I (well-watered, WW)

Plants/plots in environment I (WW) were irrigated morning and evening until harvest stage. Eight (8 ml) of water per plant per day was applied (4 ml/plant in the morning, 4 ml per plant in the evening) (Garcia *et al*., 2007; Aydinsakir *et al*., 2016)

Water treatment for environment II (water-stressed, WS)

Plants were irrigated (8ml/plant) twice a week up to 30 days after planting**.** Then twice a day from 30 days after planting to 50 days after planting. From 50 days after planting, plants were not irrigation for 14 days, then irrigated on the 15th day. Plants were not irrigation for 10 days and then irrigation resumed on the 11th day**.** Water was again withdrawn for 7 days and then irrigation resumed until harvest stage**.**

Both experiments were laid out in RCBD on a total experimental area of 23.4m x 2.4m and at a spacing of 40 cm x 20 cm for both environments and water regimes.

Data collection

The following growth and yield and yield component data were recorded for the earliness as well as for the drought tolerance screening for both environments one (well-watered) and environment two (water-stressed) regimes.

Growth Parameters

Days to 50% Emergence

The percentage of seedlings or plants emerged was recorded from 3 to 7 days after sowing. A plot attains 50% emergence when half the number of seeds sown emerges.

Days to 50% Flowering

Plots were regularly monitored to record the date at which 50% of the plants by plot flowered. A plot achieves 50% flowering when half of the plants develop flowers.

Plant Height (cm)

Four plants selected at random were used to record plant height after sowing. Heights of the four tagged plants were measured with a meter rule. Heights were measured from soil level to the primordial leaf node. The heights of each of the four were averaged for a plot.

Growth Habit (general appearance)

Plant growth habit were scored as either the bunch (or erect or semi-erect) types and the runner (or trailing) types. A groundnut plant has a central, upright stem and numerous horizontal branches.

Days to Plant Maturity

Number of days from planting to maturity (before harvesting) was recorded. The plots were harvested when at least 75% of the developed pods were mature as determined by the blackening of the internal shell wall (Williams and Drexler, 1981).

Yield and Yield Components Data

Biomass Weight

Above ground, biomass (Haulm) weight was calculated from four (4) plants harvested from the middle of each plot. Haulm weight was taken by weighing the harvest using a Top Pan Balance after 3 weeks air drying.

Pod Yield

Number of Mature (dry) Pods per Plot was determined from four (4) plants harvested from middle of each plot, after air drying to constant weight for two weeks.

Pod Weight

Fresh weight of filled pods per harvestable area of each plot was taken; the pods were sun and/or air dried to constant moisture content and their dry weights taken.

Seed Weight

Pods were shelled by hand at moisture level of 10% to 13% and seed weight per harvestable area of each plot recorded.

Harvest Index (HI)

Harvest Index was calculated by adopting the following formula:

HI= Total Dry Pod Weight (g) (i.e. Economic yield)/Total Biomass (haulm) Weight (Girdthai *et al*., 2010).

Drought Tolerance Index (DTI)

Drought Tolerance Index was calculated for each trait as the ratio of the trait (e.g. pod yield) under Water-Stress (WS) treatment to that under Well-Watered (WW) condition as suggested by Nautiyal *et al*. (2002).

SPAD Chlorophyll Meter Reading (SCMR)

Plants were sampled at random and the second fully expanded leaf from the top of the main stem was used for SCMR assessment during the morning period (0900±1200h) as proposed by Nageswara *et al*. (2001). The chlorophyll content was recorded on each of the four leaflets of the tetrafoliate leaf. An average SCMR for each plot was derived from 20 single observations (four leaflets x 5 plants per plot) (Arunyanark *et al*., 2008). Care was taken to ensure that the SPAD meter sensor fully covered the leaf lamina in order to avoid interference from veins and midribs during the SCMRs (Nageswara *et al*., 2001). The SCMR was measured at 60 and 80 days after planting.

Data analysis

The data collected were subjected to analysis of variance (ANOVA) using GenStat, version 12.0; Exploratory analysis, descriptive statistics (mean comparison of plant characteristics by varieties at 5% level using Tukey's groups), correlation analysis and multivariate analysis using the Wilk's Lambda to test for significant difference at 5% and 1% level were performed.

RESULTS AND DISCUSSION

Exploratory Analysis

The results as presented in Figure 1 shows the sprouting and growth characteristics of the groundnut varieties under the two water conditions (well-watered and water-stressed). The visualisation of the growth features indicates that a higher percentage of the groundnut varieties sprouted earlier under well-watered conditions as compared to water-stressed environments; however, the numbers of days that it took the different varieties to flower were very similar under both water conditions. Comparing the maturity level of the crop, there was no significant difference as it took approximately 104 days after planting for the groundnut crops to mature under both water conditions. Jadhav *et al.* (2000) studied the response of groundnut genotypes differing in growth habit, emergence, flowering and maturity to plant density under well-watered and water-stressed environment and indicated that 50% of groundnut varieties under well-watered environment sprouted earlier as compared to those under water-stressed. There was no significant difference in maturity level of the groundnut varieties under both environments.

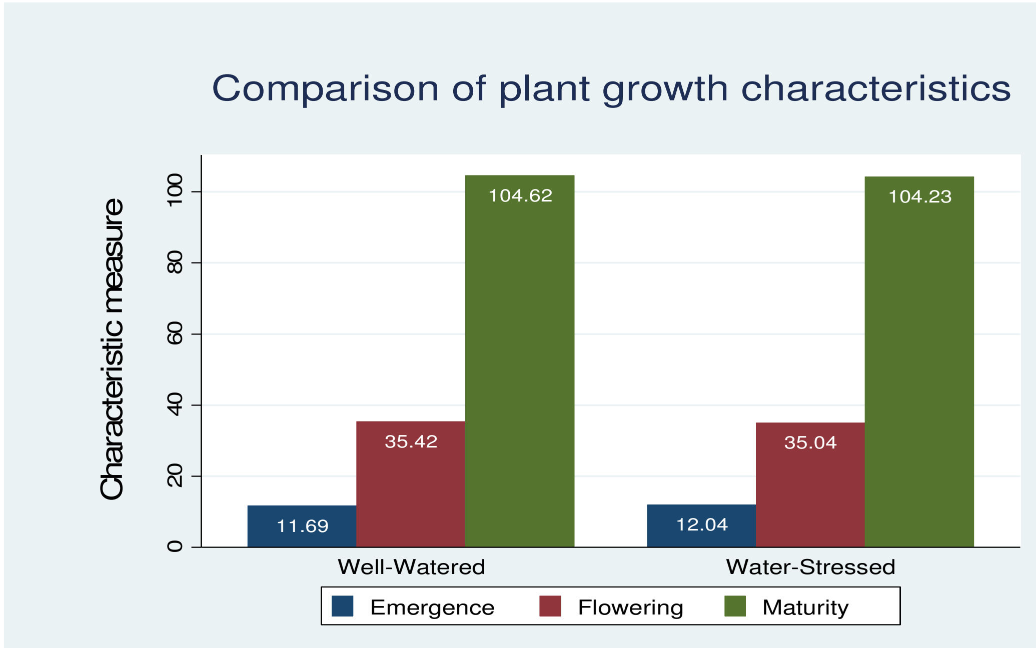

Figure 1: Germination and Growth characteristics of groundnut varieties

SPAD Chlorophyll Meter Reading

The chlorophyll meter readings of the groundnut crops as shown in Figure 2 indicates no significant difference between the chlorophyll content at 60-days after planting and 80-days after planting under the water-stressed condition. However, a slight difference was observed under the well-watered environment as the SPAD chlorophyll meter reading at the 60-days after planting was 2.94 lower than the 80-days after planting. With groundnut crops planted under the well- watered conditions, the chlorophyll content and distribution in the leaves increased whereas it remained the same in groundnut crops planted under water- stressed conditions. This result is similar to those reported by Acquaah (2007), that groundnut varieties under well-watered conditions increases in chlorophyll content whereas in water-stressed conditions, it does not increase in chlorophyll content (Bindu-Madhava *et al.*, 2003; Songsri *et al.*, 2009).

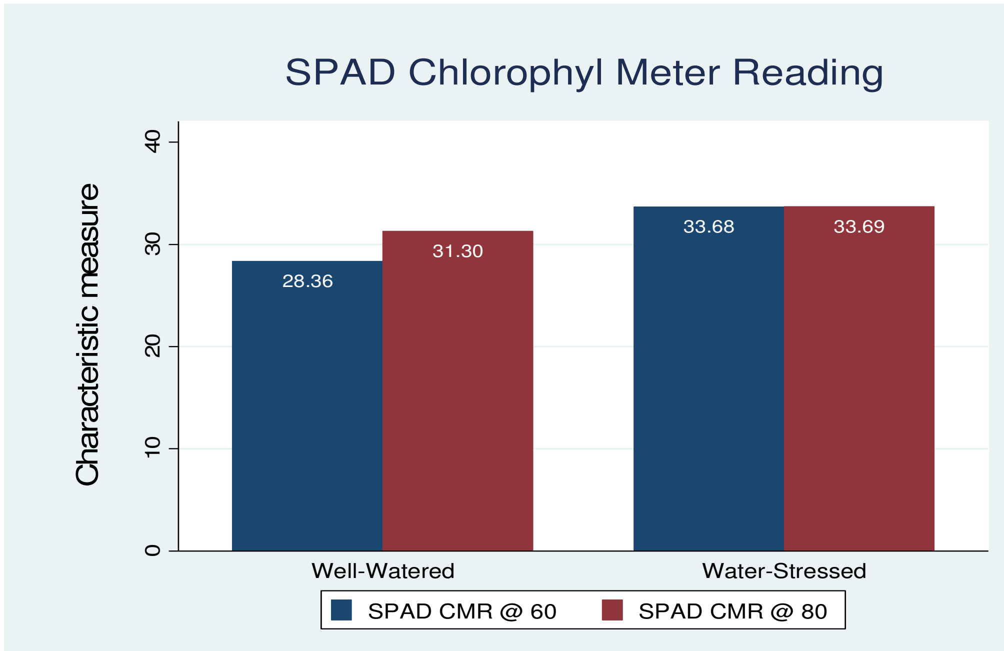

Figure 2: Chlorophyll Meter Reading

Groundnut Biomass

The results revealed that the groundnut crops produced higher biomass content under the well-watered environment as compared to the water-stressed environment. It is however, obvious as the biomass content of the crop is largely dependent on water content of the environment. The difference between the fresh biomass under the well-watered and water-stressed environments was higher than the difference between their dry biomass content (Figure 3). It therefore suggests that the biomass content of crops under water-stressed conditions shrinks more quickly than does under well-watered conditions, probably due to the much water content of the biomass produced under the well-watered environments. Nageswara Rao *et al.* (1994) reported that the productivities of groundnut varieties differences between the fresh biomass under water-stressed and well-watered conditions was higher than the difference between their dry biomass content. These differences according to Patel *et al.* (2005) are influenced more by genetic factors than by the environment since the varieties were grown in different environments under different water regimes.

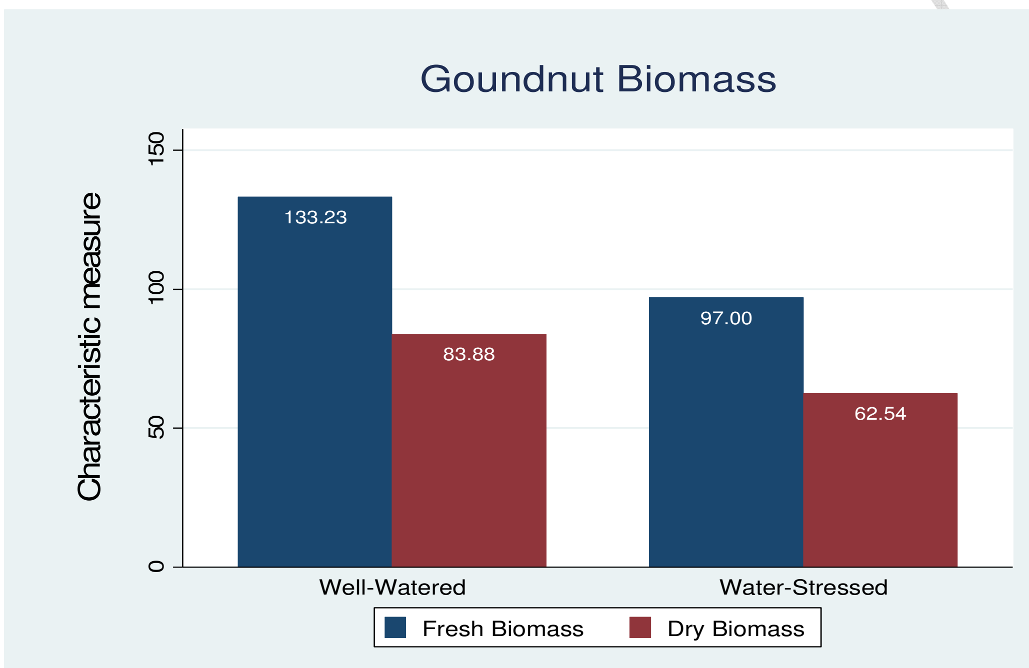

Figure 3: Biomass measure of the groundnut crops

Pod and seed features

The primary reason for the production of groundnut is largely to obtain good and sufficient seed for food. The phenotypic appearance of the pods is an indication of the seed weight and content of the crops. The weight and yield of the pods and seeds of the different varieties of the groundnut crops was measured.

From the results, all the pod and seed characteristics of the crops were much higher under the well-watered environment as compared to the crops that were planted under the water-stressed conditions. Though the visual analysis is not enough to conclude on the significant difference between the weights and yields of the crop under both water conditions, it gives a clear indication of the importance of water in the production groundnut. Also, it can be speculated that the yield and weight of the pods are different relates or associates with the yield and weight of the seeds. Challinor *et al.* (2003) reported that pod and seed yield of groundnuts accounts for over 50% in yield under well-watered environment than water-stressed. Water-stressed drastically reduced pods and seed weight of groundnut varieties (Shinde *et al.,* 2010b). Water-stressed at flowering stage reduced seed number significantly in groundnut varieties in the current study, as reported by Nautiyal *et al*. (1991).

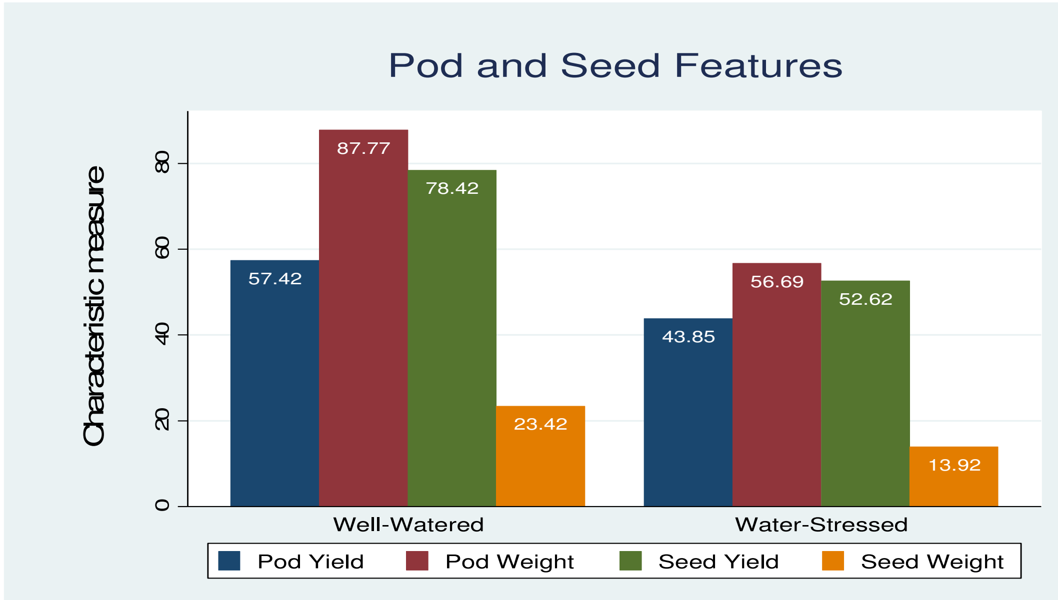

Figure 4: Pod and seed characteristics of groundnut produced under WS and WW conditions

Comparison of plant growth characteristics

Most of the groundnut varieties as captured in the study produced similar characteristics as the results suggest in Figure 5. In terms of days to 50% mergence, it was observed that the average number of days to sprouting was between 9 and 15 days with a peak at approximately 12 days. Also, the number of days to 50% flowering of most of the varieties was within 30 to 40 days except Bugla variety which took to 41 days to flower. Considering the weather conditions of the Upper Regions, the Bugla variety would be less advantageous to be used by farmers from the results of the study. Instead, groundnut varieties such as Seedje would be more preferred since they have the lowest number of days to emergence, mature and flower as compared with others. In terms of days to maturity, it was observed that groundnut varieties that took longer days to mature also took longer periods of days to flower. The present results are in conformity with the findings of Kaul (1999) and Kathirvelan and Kalaiselvan (2006), who observed in their study that groundnut varieties that took longer days to mature also took longer period of days to flower.

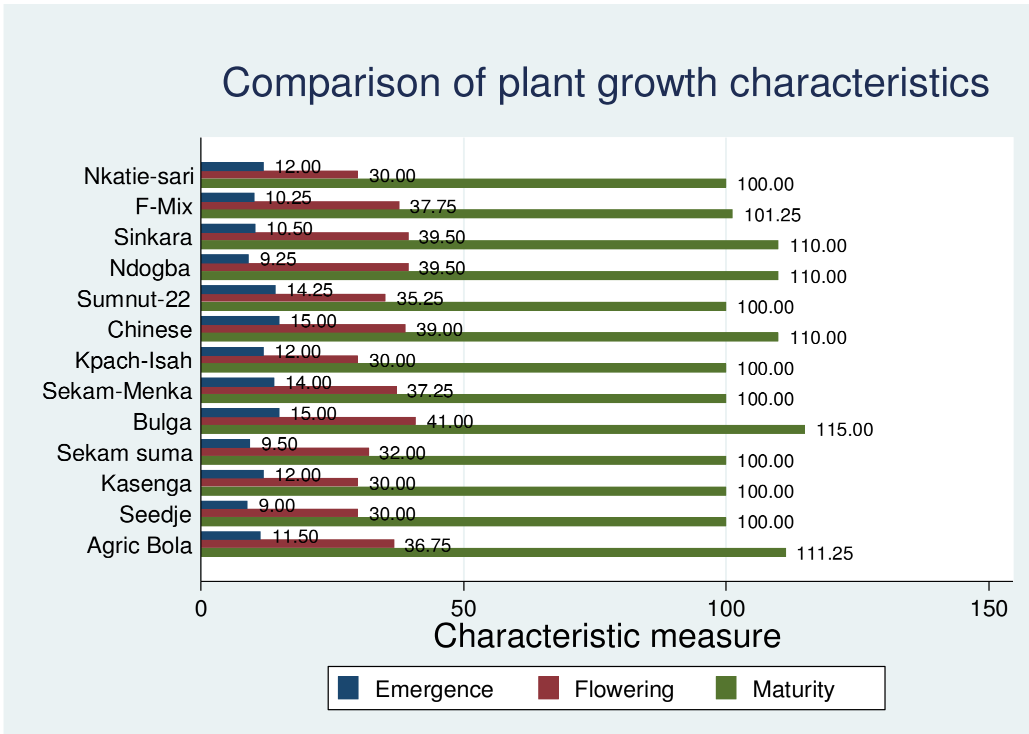

Figure 5: Sprouting and growth characteristics of groundnut varieties

SPAD Chlorophyll Meter Reading

The SPAD chlorophyll meter readings measures the leaf transmittance which does not depend only on the content of the chlorophyll but also on their distribution in the leaves. As visualised in Figure 6, the SPAD chlorophyll meter readings varied across all the groundnut varieties. The chlorophyll content of groundnut varieties such as Nkatie-SARI, Sinkara, Sumnut-22, Kpach-Isah, Bugla, Sekam-Suma, Kasenga, Seedje and Agric-Bola increased with increasing number of days, though not at the same rate but the reverse was the case of the other groundnut varieties. It is also reported by Veeraputhiran (2001), that the chlorophyll content of groundnut varieties increased with increasing number of days. SPAD chlorophyll meter reading has been associated with drought tolerance in groundnut varieties (Paungbut, 2011).

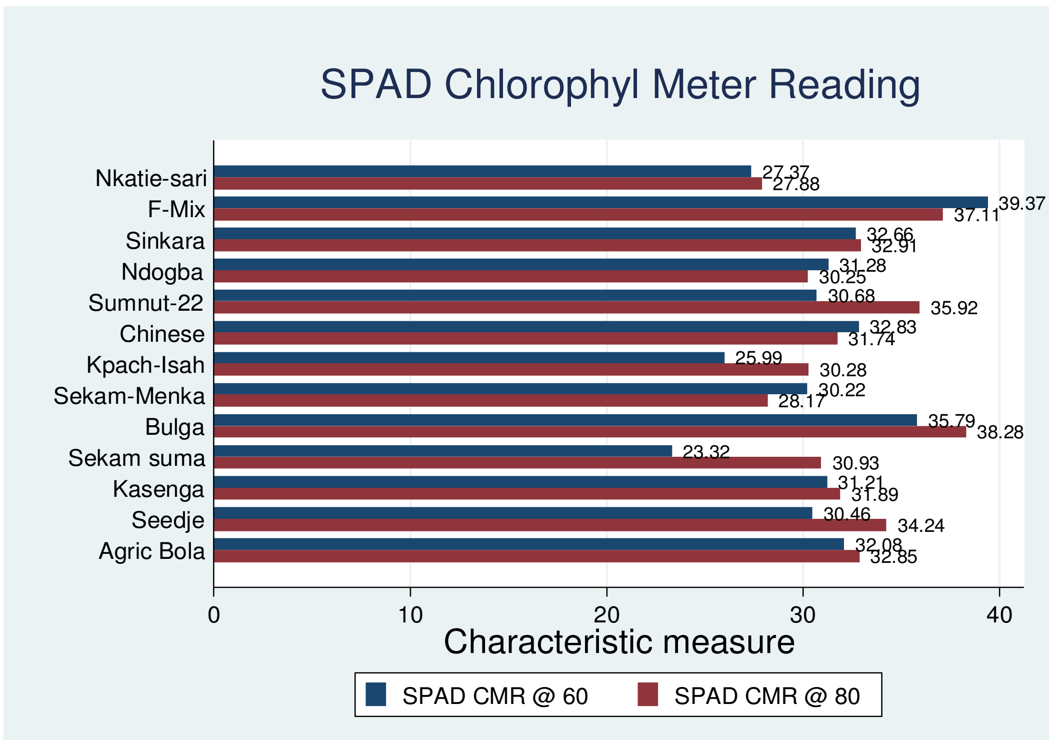

Figure 6: Chlorophyll Meter Readings

Groundnut Biomass

Biomass is an important waste product in groundnut that is desired for feeding livestock. In as much as the primary purpose of cultivating groundnut is for its seeds for consumption, the biomass generated from it is considered valuable and nutritious for livestock. For this purpose, the focus of the study was not only on the food aspect of the crop but also to investigate the variety that produced enough biomass to be used as animal feed. As presented in the visual analysis (Figure 7), Sinkara and Kasenga produced the highest amount of both fresh and dry biomass in terms of weight. For the purpose of this study, much importance was focused on the dry biomass since groundnut biomass can only be preserved in a dry state for longer periods of time in areas such as the Upper East Region.

As observed in Figure 6, the amount of chlorophyll content present in the leaves of the groundnut crop was not an indication of the amount of biomass expected to be produced by the crop. The F-mix, Bugla, Sumnu-22 and other varieties that contained much chlorophyll content had less biomass content. This is in agreement with Patel (2005), who reported that varieties that contained much chlorophyll content had less biomass content than by the environment since the varieties were grown in the same environment.

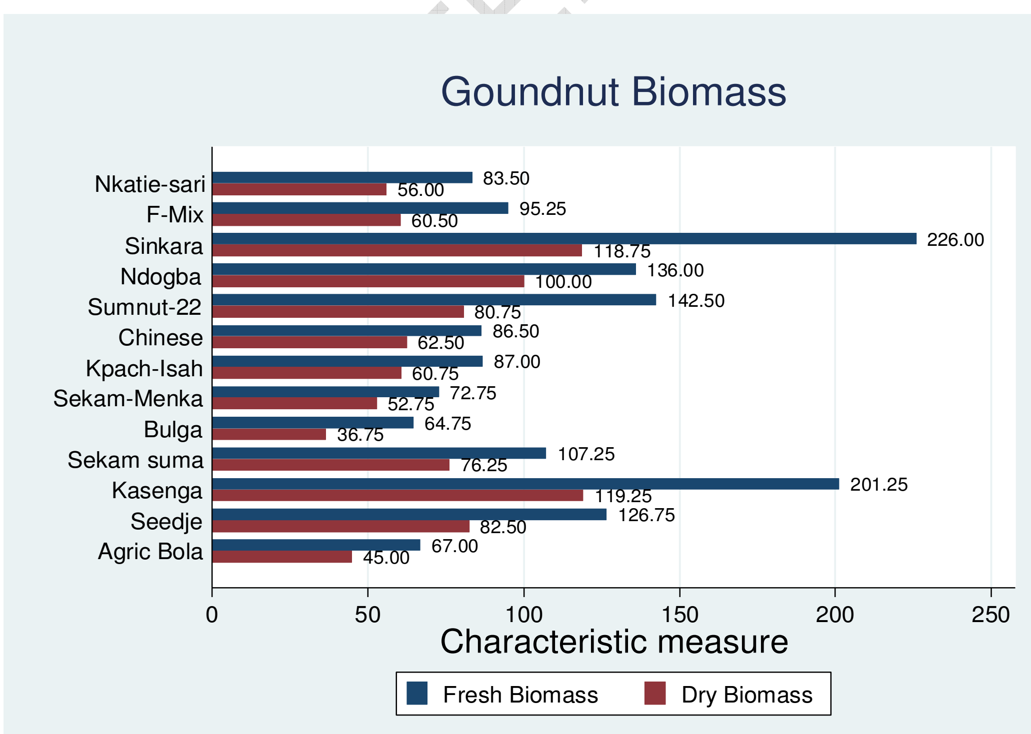

Figure 7: Biomass content of groundnut varieties

Pod and Seed Features

The result as presented in Figure 8 indicates that all the varieties exhibited similar characteristics. Whereas the pod weight for all the varieties exceeded the seed weight, the same was not the case for the number of pods/plot and number of seeds/plot. However, Sinkara, Kpach-Isah, Kasenga and Seedje produced more seeds as compared to the other varieties. Though the pod yield is as important as the seed yield, the focus was on the discovering varieties that have the tendency of producing more seed yield. This is a further confirmation of a study by Gaikpa *et al.* (2015) who showed the superiority of landrace genotypes to the other varieties in terms of yield. This implies that landrace groundnut genotypes perform higher than improved genotypes.

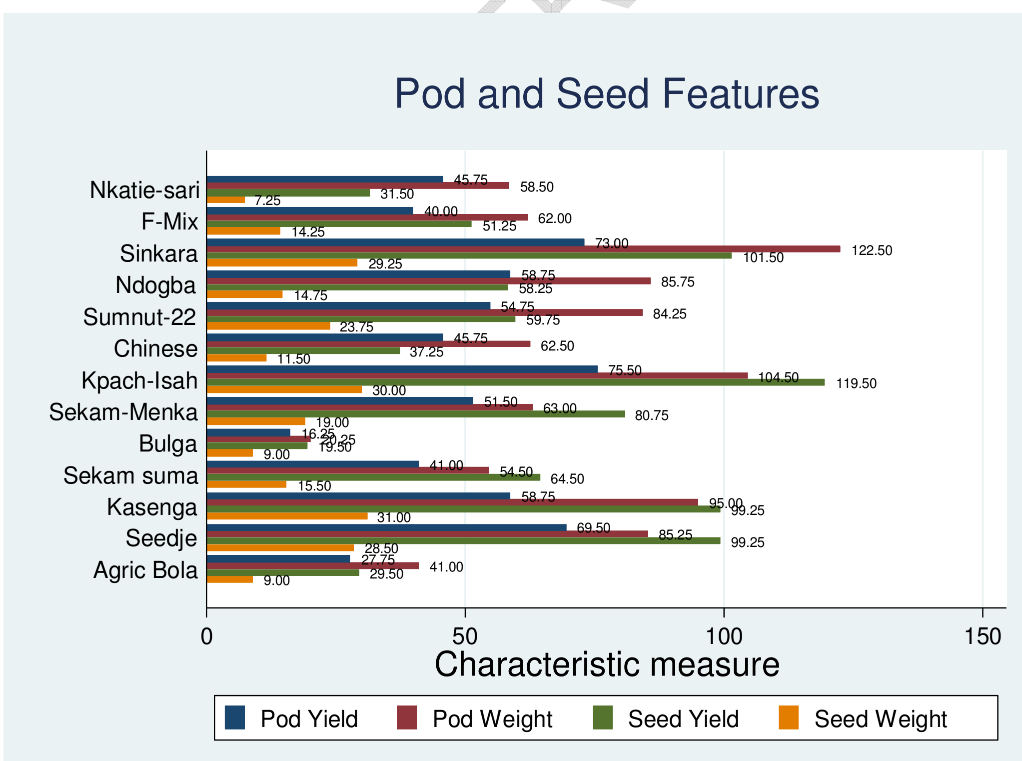

Figure 8: Pod and Seed characteristics of groundnut varieties

Comparison of plant growth characteristics

Results of the study indicate that there was no significant difference (Figure 9). Though the improved varieties had approximately longer days to emerge as well as flower, they took shorter days to mature as compare with the landraces (Figure 9). According to Salasya *et al.* (2007), improved groundnut varieties took longer days to emerge and flower due the poor adaptation to the environmental, but the landrace varieties may be well-adapted to the environment.

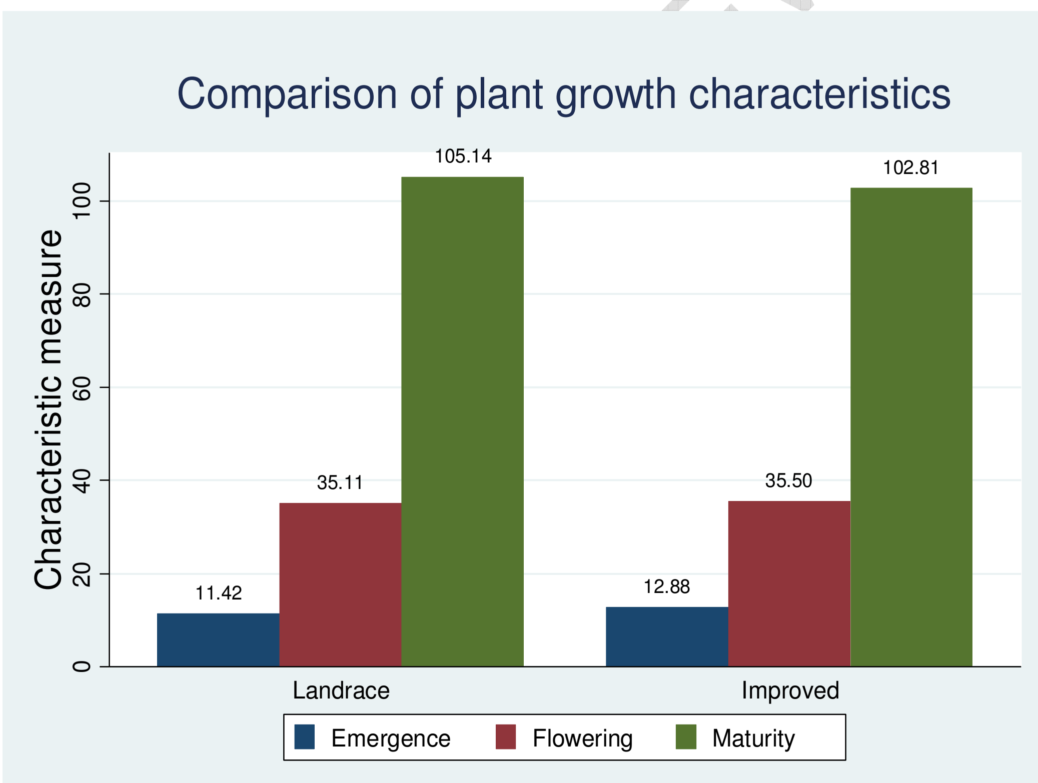

Figure 9: Sprout and growth characteristics between the landraces and improved varieties

SPAD Chlorophyll Meter Reading

In terms of SPAD Chlorophyll level of the two categories of groundnut genotypes, the improved versions had more chlorophyll content as compared to the landraces (Figure 10). However, they both had a slight increase with increasing number of days. Veeraputhiran *et al.* (2001) reported in their research that improved groundnut varieties produced more chlorophyll content as compared to landrace varieties. This assertion is also supported by Bindu-Madhava *et al*. (2003).

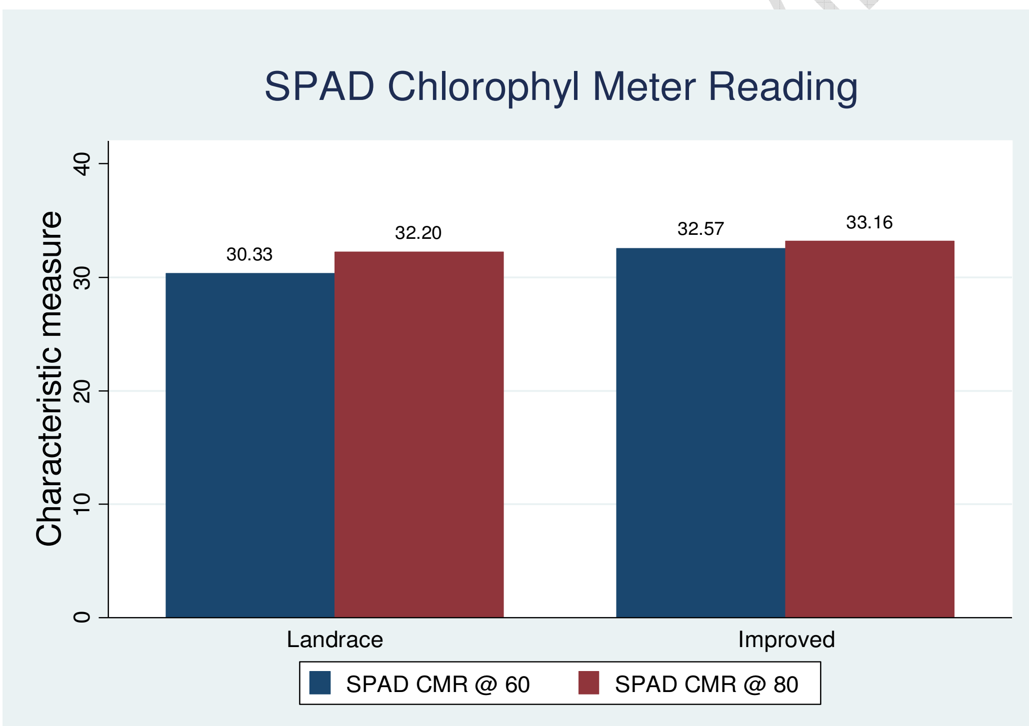

Figure 10: SPAD Chlorophyll level between landraces and improved varieties

Groundnut Biomass

According to the results of the present study as shown in Figure 11, the landraces produced more biomass than the improved ones. Based on the opinion of the researchers, this transformation difference is not enough for the improved varieties to be preferred if biomass is the primary selection criteria for the varieties. This agrees with the findings of Gouri *et al.* (2005) and Patel *et al*. (2005) who suggested physiological differences as the source for the difference in biomass weight among groundnut varieties.

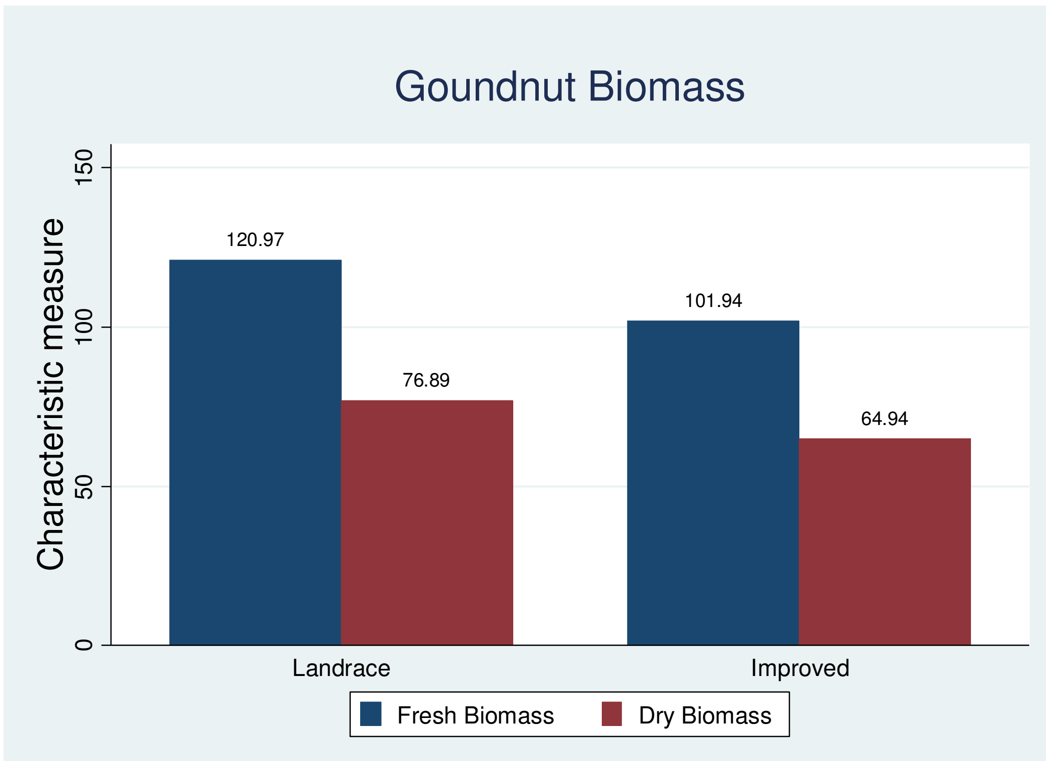

Figure 11: Biomass measure between the landraces and improved groundnut

Varieties

Pod and Seed Features

There was clear difference in performance between the landraces and the improved varieties. As reported in Figure 12, the amount of yield and weight of the pods and seeds of the improved groundnut varieties were much lower when compared with those of the landraces. This result is supported by the findings of McCann (2005), in their research on groundnuts. They reported that improved groundnuts varieties generally have higher yields than landraces ones.

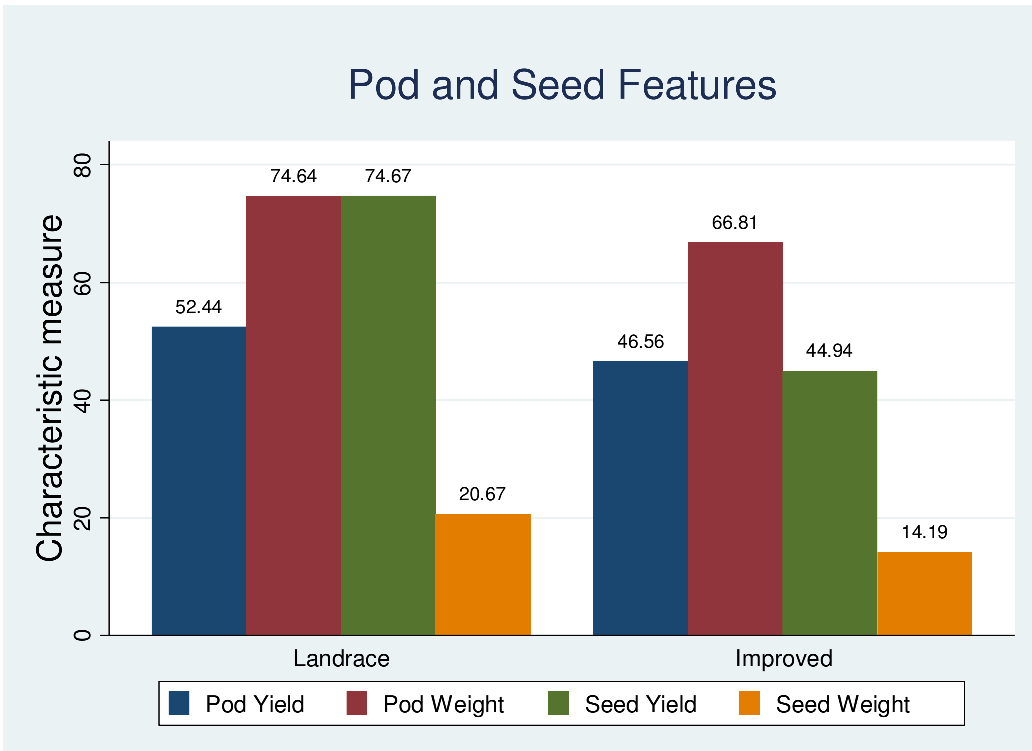

Figure 12: Pod and seed features of the two categories

Fresh and Dry Harvest Indices

A scatter plot of the fresh and dry harvest indices shows great differences among the groundnuts as shown in (Figure 13). It was observed that the fresh biomass measure was generally higher than the total pod weight whereas the dry pod weights of majority of the groundnut varieties were more than that of the dry biomass which accounted for the high harvest indexes in most cases. However, a few of the varieties had both fresh and dry harvest indexes closer to 1, which is an indication of the equivalence in weights of the pod weight and total biomass of the crops. Dharanguttikar and Borkar (2014), reported similar results, thus the performance of different groundnut varieties in respect of dry and fresh harvest index showed that fresh biomass measured was higher than the total pod weight as well as dry pod weight.

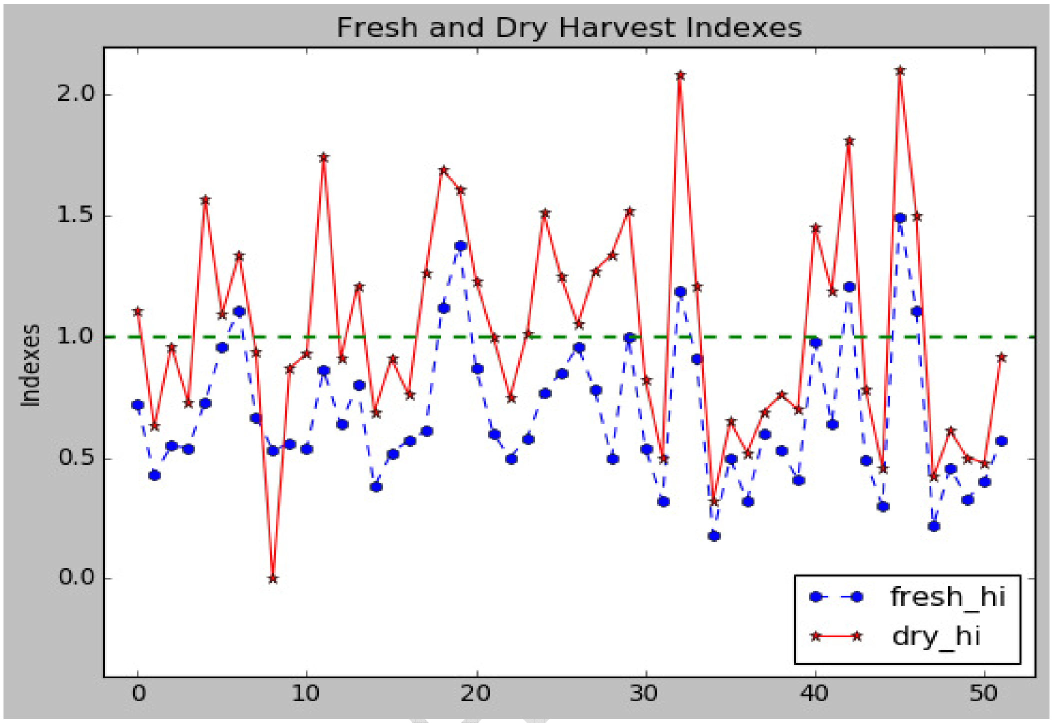

Figure 13: Harvest index comparison

Descriptive Statistics

Besides the analysis explored in the last section, the numerical descriptive statistics as presented in this section is aimed at further exploring the differences in the performance of the different groundnut varieties as assessed in the study. The results in (Table 1) display the mean, standard deviation (**σ)** and the coefficient of variation (CV).

Comparing the features of the groundnut varieties between the different water regimes, the coefficient of variation was included in the analysis to be used as a more informed comparison tool since it is measured on a single scale.

The result in (Table 1) clearly shows that the variability of the groundnut varieties lied heavily on the pod, seed and biomass measures which varied significantly between the two water regimes. However, the number of days to 50% emergence, flowering and maturity had similar variability between the two water environments. This suggests that the water condition did not affect the distribution of emergence and growth characteristics of the groundnuts.

In general, distribution of the sprout and growth characteristics did not vary as much as the pod and seed features. Also, a CV of 0.52 (52%) and 0.55 (55%) is high, indicating a high variability between the biomass levels of the groundnut varieties in the study. The results of this study were closely in line with previous works published by Sio-Se *et al*. (2006) and Golbashy *et al.* (2010).

Table 1: Descriptive statistics of groundnut varieties by water condition

	Well-watered (WW)		Water-stressed (WS)		Total	
Plant characteristics (Trait)	**μ ± σ**	**Cv**	**μ ± σ**	**Cv**	**μ ± σ**	**Cv**
Days to 50% flowering	35.00 ± 4.40	0.13	35.00 ± 4.50	0.13	35.00 ± 4.50	0.13
Plant height	6.00 ± 1.10	0.19	5.30 ± 0.89	0.17	5.60 ± 1.10	0.19
Maturity	105.0 ± 6.20	0.06	104.0 ± 5.80	0.06	104.0 ± 5.90	0.06
SPAD 60	28.00 ± 4.70	0.17	34.00 ± 6.40	0.19	31.00 ± 6.20	0.20
SPAD 80	31.00 ± 5.20	0.17	34.00 ± 6.60	0.20	32.00 ± 6.00	0.19
Pod yield	57.00 ± 27.00	0.47	44.00 ± 23.0	0.53	51.00 ± 26.0	0.51
Pod weight	88.00 ± 42.00	0.48	57.00 ± 26.0	0.45	72.00 ± 38.0	0.52
Seed yield	78.00 ± 45.00	0.57	53.00 ± 23.0	0.44	66.00 ± 38.0	0.58
Seed weight	23.00 ± 13.00	0.57	14.00 ± 5.80	0.42	19.00 ± 11.0	0.60
Days to 50% emergence	12.00 ± 3.40	0.29	12.00 ± 3.50	0.29	12.00 ± 3.40	0.29
Fresh biomass	133.0 ± 77.00	0.58	97.00 ± 39.0	0.40	115.0 ± 63.0	0.55
Dry biomass	84.00 ± 48.00	0.57	63.00 ± 22.0	0.36	73.00 ± 38.0	0.52
Fresh harvest index	0.71 ± 0.24	0.33	0.65 ± 0.35	0.54	0.68 ± 0.30	0.44
Dry harvest index	1.10 ± 0.38	0.36	0.99 ± 0.52	0.53	1.00 ± 0.45	0.44

Cv = Coefficient of Variation, μ = Mean , σ = Standard Deviation

The results in Table 2 and 3 show the mean comparison of plant characteristics by varieties measured at the 5% level of significance using the Tukey's groups. The superscripts show the varieties that are similar or are not significantly difference at the 5% level. The results in (Table 2 and 3) show a complex web of similarities and significant difference. For example, much difference was not observed on the sprout and growth characteristics as compared to the pod and seed characteristics. In terms of the number of days to 50% flowering, three set of group differences were observed. Thus, whereas the mean difference between Nkatie-Sari, Kpach-Isah, Sekam-Suma, Kasenga and Seedje were not significantly difference from each other, Sumnut-22, Sekam-Suma and Agric-Bola also exhibited similar mean characteristics. These results are in accordance with the findings of John *et al.* (2005).

Table 2: Mean comparison of plant characteristics by varieties at 5% level using

Variety	Flowering	Height	Maturity	SPAD 60	SPAD 80	Pod yield	Pod weight
Nkatie-SARI	30.00^{c}	4.60^{ab}	100.0^{a}	27.00^{ab}	28.00^{a}	46.00^{ab}	58.00^{abc}
F-Mix	38.00^{ab}	5.40^{ab}	101.0^{a}	39.00^{b}	37.00^{a}	40.00^{ab}	62.00^{abc}
Sinkara	40.00^{ab}	5.60^{ab}	110.0^{b}	33.00^{ab}	33.00^{a}	73.00^{a}	123.0^{c}
Ndogba	40.00^{ab}	6.50^{a}	110.0^{b}	31.00^{ab}	30.00^{a}	59.00^{ab}	86.00^{abc}
Sumnut-22	35.00^{ad}	5.60^{ab}	100.0^{a}	31.00^{ab}	36.00^{a}	55.00^{ab}	84.00^{abc}
Chinese	39.00^{ab}	5.80^{ab}	110.0^{b}	33.00^{ab}	32.00^{a}	46.00^{ab}	63.00^{abc}
Kpach-Isah	30.00^{c}	6.20^{ab}	100.0^{a}	26.00^{ab}	30.00^{a}	76.00^{a}	105.0^{bc}
SekamMenka	37.00^{ab}	6.30^{ab}	100.0^{a}	30.00^{ab}	28.00^{a}	52.00^{ab}	63.00^{abc}
Bugla	41.00^{b}	4.00^{b}	115.0^{b}	36.00^{ab}	38.00^{a}	16.00^{b}	20.00^{a}
Sekam Suma	32.00^{cd}	5.70^{ab}	100.0^{a}	23.00^{a}	31.00^{a}	41.00^{ab}	55.00^{abc}
Kasenga	30.00^{c}	5.70^{ab}	100.0^{a}	31.00^{ab}	32.00^{a}	59.00^{ab}	95.00^{abc}
Seedje	30.00^{c}	6.30^{a}	100.0^{a}	30.00^{ab}	34.00^{a}	70.00^{ab}	85.00^{abc}
Agric-Bola	37.0^{abd}	5.60^{ab}	111.0^{b}	32.00^{ab}	33.00^{a}	28.00^{ab}	41.00^{ab}

Tukey's groups (a)

*Means sharing the same letter in the group label are not significantly different at the 5% level

Table 3: Mean comparison of plant characteristics by varieties at 5% level using Tukey's groups (b)

Variety	Seed yield	Seed weight	Days to 50% Emergence	Fresh biomass	Dry biomass	Fresh HI	Dry HI
Nkatie-SARI	32.00^{ab}	7.30^{c}	12.00^{a}	84.00^{a}	56.00^{ab}	0.72^{a}	1.00^{ab}
F-Mix	51.00^{abc}	14.00^{abc}	10.00^{a}	95.00^{ab}	61.00^{ab}	0.64^{a}	1.00^{ab}
Sinkara	102.0^{cd}	29.00^{ab}	11.00^{a}	226.0^{c}	119.0^{a}	0.55^{a}	1.10^{ab}
Ndogba	58.00^{abc}	15.00^{abc}	9.30^{a}	136.0^{abc}	100.0^{ab}	0.83^{ab}	1.20^{ab}
Sumnut-22	60.00^{abcd}	24.00^{abc}	14.00a	143.0^{abc}	81.00^{ab}	0.59^{a}	1.10^{ab}
Chinese	37.00^{ab}	11.00^{abc}	15.00^{a}	87.00^{a}	63.00^{ab}	0.67^{a}	0.94^{ab}
Kpach-Isah	120.0^{d}	30.00^{ab}	12.00^{a}	87.00^{a}	61.00^{ab}	1.30^{b}	1.80^{b}
Sekam-Menka	$81.00b^{cd}$	19.00^{abc}	14.00^{a}	73.00^{a}	53.00^{ab}	0.89^{ab}	1.20^{ab}
Bugla	20.00^{a}	9.00^{ac}	15.00^{a}	65.00^{a}	37.00^{b}	0.38^{a}	0.43^{a}
Sekam Suma	65.00^{abcd}	15.00^{abc}	9.50^{a}	107.0^{ab}	76.00^{ab}	0.51^{a}	0.72^{a}
Kasenga	99.00^{cd}	31.00^{b}	12.00^{a}	201.0^{bc}	119.0^{a}	0.44^{a}	0.74^{a}
Seedje	99.00^{cd}	28.00^{ab}	9.00^{a}	127.0^{abc}	83.00^{ab}	0.66^{a}	1.10^{ab}
Agric Bola	30.00^{ab}	9.00^{ac}	12.00^{a}	67.00^{a}	45.00^{ab}	0.65^{a}	0.96^{ab}

*Means sharing the same letter in the group label are not significantly different at the 5% level, HI =Harvest Index

Correlation Analysis

The correlation analysis as presented in Table 4 was performed to examine the relationship between the growth characteristics, pod and seed features as well as the biomass yield of the crops. This analysis will form the basis for further analysis based on the decisions made at the 5% level of significance.

It was observed from the study that the maturity and flowering (0.768), as well as plant height and seed yield (0.501) were highly significantly and highly positively correlated. The seed characteristics were also highly significantly positively correlated with the pod characteristics of the crop. This presupposes that the performance of the pods directly affects the performance of the seeds. The biomass measure was also correlated with the pod and seed features as shown in Table 4. These results are in accordance with the findings of Singh *et al.* (2008), who reporting similar positive correlation between plant height and seed yield. Antony (2000), reported a positive and significant correlation between flowering and maturity. Reddy *et al.* (2000) reported correlation between SCMR and total chlorophyll content and SCMR and seed yield were positively correlated in groundnut genotype.

Correlation Analysis

Table 4: Correlation among groundnut plant characteristics

	Flowering	Plant height	Maturity	SPAD 60	SPAD 80	Pod yield	Pod weight	Seed yield	Seed weight	Emergence	Fresh biomass
Plant height	-0.107										
Maturity	0.768*	-0.237									
SPAD 60	0.425*	-0.343*	0.334*								
SPAD 80	0.234	-0.300*	0.230	0.416*							
Pod yield	-0.237	0.415*	-0.290*	-0.250	-0.100						
Pod weight	-0.156	0.446*	-0.210	-0.277*	-0.194	0.890*					
Seed yield	0.352*	0.501*	-0.387*	-0.338*	-0.231	0.658*	0.801*				
Seed weight	-0.287*	0.444*	-0.313*	-0.272	-0.171	0.646*	0.818*	0.939*			
Emergence	0.172	-0.133	0.160	0.159	-0.010	-0.063	-0.069	-0.124	-0.017		
Fresh biomass	-0.064	0.289*	-0.085	-0.219	-0.104	0.653*	0.777*	0.548*	0.632*	-0.087	
Dry biomass	-0.101	0.337*	-0.119	-0.258	-0.136	0.671*	0.741*	0.482*	0.529*	-0.126	0.938*

Analysis of Variance (ANOVA)

The analysis of variance as presented in

Table and Table shows a significant difference in respect to most of the categorical variables. At the 5% level of significance, the sprout and growth characteristics of the crops significantly differed. Thus, the emergence, maturity and flowering of the crops varied from one variety to another. There was no significant difference between the water regimes and no interaction effect was also observed.

The biomass measure on the other hand showed significant difference among the 13 varieties of groundnuts and the two water regimes at the 5% level of significance. There was also an interaction effect observed. This implies that the effect of the varieties is different at the different levels of water regimes. Kadam *et al*. (2000) studied the significant variation in stability among genotype. Both well watered and water stressed effects of genotype and environment interaction was highly significant for both traits.

There was clear indication that all the pod and seed characteristics of the crops were significantly different among the different varieties and water conditions. However, the plant height and chlorophyll levels did not show any interaction effect.

Table 5: Effect of variety and water condition on plant characteristics (a)

	Mean Square					
Source	**Flowering**	**Height**	**Maturity**	**SPAD-CMR 60**	**SPAD-CMR 80**	**Pod yield**
Variety	**72.19****	**1.94***	**132.93****	**66.27****	**41.04**	**1194.48****
Water condition	**1.92**	**5.22***	**1.92**	**369.21****	**74.45**	**2396.33****
Interaction	**3.92**	**0.78**	**5.05**	**26.68**	**41.17**	**1304.12****

* p< 0.05, ** p < 0.01, SPAD: Soil Plant Analytical Development-Chlorophyll Meter Reading @ 60 and 80 Days after Planting

Table 6: Effect of variety and water condition on plant characteristics (b)

	Mean Square					
Source	**Pod weight**	**Seed yield**	**Seed weight**	**Emergence**	**Fresh biomass**	**Dry biomass**
Variety	**3016.10****	**4126.14****	**309.56****	**18.40***	**10249.32****	**2778.37****

Water condition	**12555.08****	**8658.48****	**1173.25****	**1.56**	**17064.69****	**5923****
Interaction	**1967.91****	**1107.61****	**110.67****	**15.35**	**4973.65****	**2858.77****

* $p < 0.05$, ** $p < 0.01$

Multivariate Analysis

The rationale behind the cross examination of the significant differences in the performance of the crops based on the different varieties and water regimes using the multivariate is that, all the plant characteristics were simultaneously affected by the variety and water regimes at the same time. For that reason, the comparisons are done in such a manner that will include all the dependent variables at the same time.

Using the Wilk's Lambda to test for significant difference, the results as shown in Table indicates clearly that the null hypothesis of no significant difference should be rejected at the 5% level. This suggests that the performance measures of the crops were statistically different among the different varieties and water regimes. Also, there was an interaction effect to the characteristic performance of the different varieties differed significantly across the different water regimes at the 1% level. However, the results confirmed those of Attarde *et al*. (2001) and Vijayakumar *et al.* (2003).

Table 7: Multivariate analysis of the effect of variety and water condition on plant characteristics using the Wilk's Lambda (Λ)

Source	Statistic	Df	df1	df2	F	p-value
Model	**0.000**	**14**	**196.0**	**276.6**	**4.73**	**0.000**
Variety	**0.000**	**12**	**168.0**	**252.0**	**4.29**	**0.000**

Water condition	**0.220**	**1**	**14.0**	**25.0**	**6.32**	**0.000**
Interaction	**0.351**	**1**	**14.0**	**25.0**	**3.31**	**0.005**

Breush-Pagan test of independence: chi (91) = 499.67, p-value = 0.000; DF-degree of freedom; P-probability

The regression estimates of the multivariate analysis of variance shown in (Table 8) further shows that the different plant characteristics as measured in the study all revealed significant differences at the 1% level of significance. The Coefficient of determination (R^2) for all the models equations were very high indicating that the variety and water condition as predictor variables explained a high amount (at least 80%) of the variability in the characteristic performance (dependent variables) of the crops. Similar results were observed in groundnut genotypes by several researchers (Ntare *et al*., 2001; Songsri *et al*., 2008a; Songsri *et al*., 2008b and Hamidou *et al*., 2012).

Table 8: Parameter estimates

Equation	**RMSE**	**R^2 (%)**	**F**
Days to 50% Flowering	**9.64**	**94.61**	**47.68****
Plant height	**1.77**	**93.04**	**36.26****
Days to 50% Maturity	**31.40**	**93.41**	**38.49****
SPAD 60	**8.95**	**94.15**	**43.66****
SPAD 80	**10.17**	**93.07**	**36.46****
Pod Yield	**26.70**	**83.82**	**14.06****
Pod Weight	**33.85**	**87.37**	**18.77****
Seed Yield	**23.29**	**93.03**	**36.25****

Seed Weight	**6.79**	**92.90**	**35.49****
Days to 50% Emergence	**4.82**	**88.88**	**21.70****
Fresh Biomass	**51.60**	**88.67**	**21.24****
Dry Biomass	**37.00**	**85.30**	**15.75****

* $p < 0.05$, ** $p < 0.01$; RMSE = Coefficient of determination; R^2=Root Mean Square Error

SUMMARY

Thirteen (13) groundnut genotypes, both improved and landraces were assessed for drought tolerance under two environments; well-watered and water-stressed.

Results obtained from the assessment of the thirteen groundnut genotypes under the two water regimes (Well-Watered and Water-Stressed) indicated that the analysis of variance (ANOVA) proved significant difference in respect of most of the variables. At the 5% level of significance, the growth characteristics (emergence, maturity and flowering) differed significantly among the varieties. There was no significant difference between the water regimes, and no significant interaction effect was observed.

The biomass yield on the other hand showed significant difference among the 13 varieties of groundnuts and the two water regimes at the 5% level of significance. There was also an interaction effect observed. This implies that groundnut varieties performed differently at different levels of water regimes. There was indication that all the pod and seed characteristics of the crops were significantly different among the different varieties and water conditions. However, the plant height and chlorophyll levels did not show any significant interaction effect. The correlation analysis presented was performed to examine the relationship between the growth characteristics, pod and seed features as well as the biomass measure of the crops. It was observed from the study that the maturity and flowering, as well as plant height and seed yield were significantly and highly correlated positively. The seed characteristics were also highly and significantly and positively correlated with the pod characteristics of the crop. This presupposes that the performance of the pods directly affected the seeds yield. The biomass yield also correlated positively with the pod and seed characteristics.

Conclusions

Based on the results, groundnut varieties under well-watered environment performed better in terms of yield than the groundnut varieties under water-stressed environment.

Comparing the yield of landrace groundnut varieties and improved varieties, the results showed that improved varieties had approximately higher days to emerge as well as flower; however, the improved genotypes took shorter days to mature.

In terms of SPAD chlorophyll level (chlorophyll content in leaves) under the two water regimes, the improved varieties had more chlorophyll content as compared to the landraces.

According to the results, the landrace varieties produce more biomass than the improved varieties.

The amount of yield and weight of the pods and seeds of the improved groundnut varieties were much lower for the improved varieties than the landraces ones.

The drought tolerance of the selected groundnut varieties such as Sinkara, Kpach-Isah, Kasenga and Seedje recorded the highest yield as compared to the other varieties.

The drought tolerance of the selected groundnut varieties based on the SPAD-Chlorophyll Meter Reading; Nkatie-SARI, Sinkara, Sumnut-22, Kpach-Isah, Bugla, Sekam-Suma, Kasenga Seedje and Agric-Bola had the highest chlorophyll contents as compared to the other varieties.

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APPENDICES

Appendix 1:

Table 1: Source and Phenotypic Characteristics of Groundnut Genotypes Studied

№.	Genotype	*Sub-Species	Source	Days to Maturity, days	Phenotypic Characteristics and Other Trait ***Oil Content and Other Traits***
1.	Nkatie-sari	*Hypogaea (Virginia)*	CSIR-SARI, Ghana	100-115 (110)	Oil Content: 46%, Seed Colour: Light tan testa colour
2.	F – mix	*Hypogaea (Spanish)*	CSIR-SARI, Ghana	100-115 (120)	Oil Content: 49% Seed colour: Tan with red/brown shades Av. Yield: 2500kg/ha Highly Tolerant to Rosette and Rust
3.	Sinkara	*Hypogaea (Spanish)*	Landrace, Ghana	100-115 (120)	Oil Content: 45% Seed colour: Red Yield Potential: 2.2t/ha
4.	Ndogba	*Fastigiata*	Landrace, Ghana	85-90	Seed colour: Tan red

5.	Sumnut – 22	*Hypogaea*	CSIR-SARI, Ghana	100-115 (110-120)	Seed colour: Tan red Rosette disease Tolerant
6.	Chinese	*Hypogaea (Spanish)*	Landrace, Ghana	85-90 (100)	Oil Content: 35% Early maturing Use: Soup and Confectionery
7.	Kpach – Isah	*Fastigiata*	Landrace, Ghana	85-90	Seed colour: Light red
8.	Sekam Menka	*Hypogaea (Spanish)*	Landrace	100-115	Oil Content: 45% Seed colour: Red Yield Potential: 2.2t/ha
9.	Bugla	*Hypogaea*	Landrace	100-115	Seed colour: Tan red
10.	Sekam-Suma	*Fastigiata*	Landrace	100-115	Seed colour: tan red
11.	Kasenga	*Hypogaea*	Landrace	100-115	Seed colour: Red to whitish
12.	Seedje	*Fastigiata (Spanish)*	CSIR-CRI, Ghana	85-90 (90)	Oil content: 50% Resistant to Rust Seed colour: Dark red Yield Potential: 2700kg/ha Days to 50% flowering: 23DAP
13.	Agric-Bola	*Hypogaea (Spanish)*	Landrace, Ghana	100-115 (110-	Oil Content: 47% Seed colour: red

	120)	teste High yield potential

Sub-Species, *Oil Content and Other Traits are from CSIR-CRI and SARI published data

CSIR-Council for Scientific and Industrial Research, SARI – Savanna Agriculture Research Institute, Ghana, CRI – Crops Research Institute, 'Landrace'- Farmers' popular and locally adapted variety.

Plate 1: Pictures of the 13 groundnut varieties

Table 2: SUMMARIZED AGRONOMIC PERFORMANCE OF THIRTEEN (13) IMPROVED GROUNDNUT VARIETIES FOR WELL-WATERED (WW) UNDER ENVIRONMENT ONE (1)

Character/ Trait	No. of Sample	Mean±S.E	CV%	S.E.D.	F.pro	Significant
Days to 50% emergence	13	11.81±1.973	16.3	1.973	<0.001	Significant
Days to 50% flowering	13	35.42±1.979	5.6	1.979	<0.001	Significant
Plant height (cm)	13	5.78±0.736	13.3	0.736	<0.001	Significant
SPAD chlorophyll meter reading at 60 days after planting	13	28.36±4.342	14.0	4.342	0.004	Significant
SPAD chlorophyll meter reading at 80 days after planting	13	31.31±5.615	17.3	5.615	0.279	Not significant
Days to maturity	13	104.615±0.6934	0.7	0.6934	0.001	Significant
Number of seeds (seed yield)	13	78.42±6.984	10.7	6.984	<0.001	Significant
Number of pods (pod yield)	13	58.2±7.41	14.5	7.41	<0.001	Significant
Seed weight (g)	13	23.42±3.382	18.1	3.382	<0.001	Significant
Pod weight (g)	13	87.77±6.128	8.5	6.128	<0.001	Significant
Fresh biomass weight (g)	13	133.2±12.81	11.1	12.81	<0.001	Significant
Dry biomass	13	83.9±7.74	10.6	7.74	<0.001	Significant

weight (g)						
Harvest index (HI)	13	0.707±0.1954	30.1	0.1954	0.014	Significant
Drought tolerance index (DTI)	13	1.067±0.2010	19.6	0.2010	<0.001	Significant

S.E.: Standard Error, CV% Coefficient of Variation (percentage), S.E.D.: Standard Error of the Difference, F-pro.: F-Probability

Table 3: SUMMARIZED AGRONOMIC PERFORMANCE OF THIRTEEN (13) IMPROVED GROUNDNUT VARIETIES FOR WATER- STRESSED (WS) UNDER ENVIRONMENT TWO (2)

Trait	No. of Samples	Mean +S.E	F.pro	Significant/ Not Significant
Days to 50% emergence	13	12.35±1.973	<0.001	Significant
Days to 50% flowering	13	35.04±1.979	<0.001	Significant
Plant height (cm)	13	5.32±0.736	<0.001	Significant
SPAD chlorophyll meter reading 60 days after planting	13	33.68±4.342	0.004	Significant
SPAD chlorophyll meter reading 80 days after planting	13	33.69±5.615	0.279	Not significant
Days to maturity	13	104.808±0.6934	<0.001	Significant
Number of seeds (seed yield)	13	52.23±6.984	<0.001	Significant
Number of pods (pod yield)	13	43.8±7.41	<0.001	Significant
Seed weight (g)	13	13.92±3.382	<0.001	Significant
Pod weight (g)	13	56.69±6.128	<0.001	Significant
Fresh biomass weight (g)	13	97.0±12.81	<0.001	Significant
Dry biomass weight (g)		62.5±7.74	<0.001	Significant
Harvest index	13	0.590±0.1954	0.014	Significant
Drought tolerance index	13	0.987±0.2010	<0.001	Significant

S.E.: Standard Error, F-pro.: F-Probability