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Identifying Morpho-Physiological Characteristics Associated with Drought Tolerance in Selected Chikpea Germ Plasm in Nakuru and Baringo Counties, Kenya

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ABSTRACT

This paper examines the morpho-physiological characteristics of chickpea associated with drought tolerance based on a study of selected chickpea lines under field conditions in Nakuru and Baringo counties in Kenya. Drought has been spreading to more land in Kenya over the years due to climatic change attributed to global warming. Chickpea being drought resistant can act as a cereal-legume relay crop in dry highlands during the short rains as it improves soil fertility and conserves moisture. But currently there are no lines released for commercial production in Kenya, hence there is need to introduce and evaluate several lines to identify those that can do well in dry lands of Kenya. This study therefore screened several chickpea genotypes to identify and select drought tolerant lines with associated morpho-physiological characteristics under field conditions and determined their heritability. The study was conducted in two sites, at Koibatek-Farmers Training Centre for two seasons (during the short and long rains) and in KEPHIS-Lanet for one season (long rains). A mini core collection of 30 lines from ICRISAT was evaluated in the two sites in a Randomised Complete Block Design (RCBD), replicated twice. Parameters that were measured included phenological growth stages, yield (Kg/ha) and its components which included number of pods/plant, plant height (cm), plant spread (cm), biomass (Kg/ha), harvest index (HI). All data collected were analyzed using Analysis of Variance (ANOVA) using Genstat and means separated by Duncan Multiple Range Test (DMRT) at (P=0.05). The morphological traits associated with drought tolerance due to their direct contribution to yield included biological mass, days to physiological maturity, days to 50% flowering and % DTE. These traits could be of interest in improving chickpea since they could be genetically manipulated or improved due to their high genetic contribution to their phenotypic traits. There is need for further screening and breeding of the selected lines for drought tolerance.

Introduction

Chickpea (*Cicer arietinum* L.), commonly known as gram or garbanzo bean, is the most common legume crop in the world after common bean (*Phaseolus vulgaris L.*) and field pea (*Pisum sativum L.*) (FAO, 2009). Chickpea is an important crop for the resource poor farmers mainly living in sub-Saharan Africa (SSA), especially in eastern and southern Africa. This is because it is able to utilize the low amounts of rainfall, can complete its lifecycle early and require minimum amounts of input (FAO, 2009). Moreover, this crop is a key component in the diets of resource-poor people who cannot afford to supplement their diets with meat (ICRISAT, 2009). They also play an important role in improving soil fertility due to their ability to fix nitrogen in the symbiotic association with *Rhizobium* bacteria (Saraf *et al*., 1998). In addition, chickpeas adds Nitrogen to the soil (up to 140 Kg/ha) (Saraf *et al.*, 1998) by virtue of its leaves having substantial amount of residual dry matter. This is important for subsequent crops and also adds much needed organic matter to maintain and improve soil health, long term fertility and sustainability of the ecosystem.

Botany of Chickpea
Chickpea seeds have two cotyledons, an embryo and a seed coat. The seed coat consists of two layers the outer testa and the inner tegmen and a hilum which is the point of attachment of the seed to the pod. There is a minute opening above the hilum called micropyle and ridge formed funicle called rampha. The pointed end of the axis is the radicle and feathery end is the plumule (Cubero, 1987).

Chickpea plants have a strong taproot system with 3 or 4 rows of lateral roots. The parenchymatous tissues of the roots are rich in starch. All the peripheral tissue disappears at plant maturity and is substituted by a layer of cork (Cubero, 1987). The roots grow 1.5-2.0 m deep. Chickpea roots bear Rhizobium nodules and branched with laterally flattered ramifications, sometimes forming a fan like lobe (Corby, 1981). The chickpea stem is erect, branched, hairy, herbaceous green and solid. There are primary, secondary and tertiary branches (Cubero, 1987) (Plate 1).

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Plate 1: Chickpea plant showing the leaves branches, flowers and pods

Primary branches arise from the ground level as they develop from the plumular shoot as well as lateral branches of the seedling. They are strong and woody, and may range from one to eight in number. Secondary branches developed and buds located on the primary branches. Their number range from 2 to 12. The number of branches determines the total number of leaves and hence the total photosynthetic area. Tertiary branches arise from secondary branches. The primary branches form an angle with vertical axis ranging from almost a right angle (erect). Generally stems are incurred at the top, forming a spreading canopy. Chickpea leaves are petiolate, compound and pseudoimparipinnate and some lines have simple leaves. The rachis is 3-7cm long with grooves on its upper surface.

Leaflets each have a small pedical. The leaflets do not end at the true terminal position (the central vein continuing the rachis) but at the sub terminal position (central vein oblique to the ranches. This indicates the presence of two terminal leaflet buds, one of them being aborted and a micro or foliar shoot which is sometimes quite large (Cubero, 1987). The leaflets are 8-17 mm long and 5-14 mm wide, opposite or alternative with a terminal leaflet. They are serrated, the teeth covering about two thirds of the foliar blade. The shape of leaflets is oborate to elliptical with the basal and top portions cuneate or rounded. Leaves are pubescent. Chickpea is a self pollinated crop.

The solitary flowers are borne in axillary's raceme. Sometimes there are 2 or 3 flowers on the same node such flowers possess both a peduncule and a pedicel. The race mouse is 6-30 mm in length. At flowering, the floral and racemal portions of the peduncle form a straight line, giving the appearance that the flowers are placed on the leafy axil by a single peduncle. After fecundation the raceme becomes incurved. The bracts are 1-5 mm in length. Chickpea flowers are complete bisexual, and have papilionaceous corolla. They are white, pink blue or purple in colour. In coloured flowers, the peduncule may be different colours, the floral part purplish and the racemal green. The auxiliary inflorescence is shorter than the subtending leaf (Cubero, 1987). The calyx is dorsally gibbous at the base. There are five sepals with deep lanceolate teeth. The teeth are longer (5-6mm) than the tube (3-4mm) and prominent midribs. The five sepals are closer to each other than they are to the two lateral ones in ventral position. The fifth calyx tooth is separate from the others. The peduncles and calyx are glabrous the calyx tube is oblique.

Chickpea flowers have five petals which are generally ceteste and purplish red or light pink in colour depending on the type. The petals are polypetalous, i.e. consisting of standard (vexillum), wings and keel. The vexilum is obarate 8-11 mm long, 7-10 mm wide and either glabrous or pubescent with no glandular hair on its external surface. The wings are also obarate with short pedicels (nails). They are 6-9 mm long and about 4 mm wide with auriculate base. The auricular are over the pedical and form a pocket in the basal upper part, which is covered by vexillum. The keel is 6-8mm long, rhomboid, with a pedicel 2-3 mm long, two-thirds of the frontal side of its ventral face is adnate. The wings do not show concrescence with the keel. There are 10 stamens in diadelphous (91) +1 condition.

The filaments of nine of the stamens are fused, forming and roecial sheath, the tenth stamen is free. The stamina column is persisted. The fused part of the filament is 4-5 mm long dilated at the top. The apex of the sheath is oblique the stamens facing the petals are little longer than others. The anthers of the stamens are bicelled, base fixed and round. The other anthers burst longitudinally. The pollen grains are orange. The ovary is mono carpellary, unilocular and superior with marginal placentation it is ovate with pubescent (glandular hairs predominate) surface. The ovary is 2-3 mm long linear, upturned and glabrous except at the bottom. The stigma is globose and capitate. Sometimes it may be of the same size as the style (Cubero, 1987).

Statement of the Problem

Drought is a common phenomenon in Kenya because approximately 83% of total land area falls under arid semi-arid lands (ASAL). This is because there has been expansion of subtropical deserts due to global warming (Alguo, 2011). Rainfall in these areas is highly unpredictable in quantity and distribution, leading to frequent crop failures. There is, therefore, a need to develop crop cultivars that are resistant/tolerant to drought; such cultivars may contribute to food security amongst communities living in these areas. However, because of the erratic nature of rainfall, ideal cultivars targeted for such marginal areas should be able to grow well under a wide range of moisture conditions and produce high yields in the presence and/or absence of drought. People living in these areas experience food shortage leading to hunger and famine due to crop failure caused by lack of drought resistant crops.

The high agricultural potential areas covering approximately 17% of total land in Kenya cannot supply sufficient food for the country since they are highly populated. This means increase in infrastructural development and expansion of cities, human settlement leaving very little land for farming. Possible remedial measures include irrigation but there is insufficient amount of water in those areas since most rivers are seasonal. In addition, establishment of irrigation system will be expensive to most farmers and will cover a small area. There is therefore need for alternative cheap way of producing crops in these regions. Common legumes like beans and peas grown in Kenya only do well in areas receiving high amount of rain. Hence alternative legume like pigeon peas, cowpeas and chickpeas that do well in drought prone regions areas is recommended if food sufficiency is to be realized (ICRISAT, 2008). Production of drought tolerant crops is the best option for dry areas and a cheap way of producing crops in this region, since there is no additional cost to a farmer once he gets one more legume as alternative food security.

Morpho-physiological and Genetic basis of Drought Resistance and Tolerance

Drought is a meteorological event which implies the absence of rainfall for a period of time, long enough to cause moisture-depletion in soil and water deficit with a decrease of water potential in plant tissues (Abbo, 2002b). Drought has become a common, especially in the subtropical regions of the world, due to global warming (Alguo, 2011). Global warming is the rise in the average temperature due to in the increasing concentration of greenhouse gases caused by human activities such as deforestation and the burning of fossil fuel (Alguo, 2011).

From the agricultural point of view, drought causes inadequacy of water availability, including precipitation and soil-moisture storage capacity, in quantity and distribution during the life cycle of a crop plant, which restricts the expression of full genetic potential of the plant (Singh, 1986). Drought is the most significant constraint to yield in chickpea accounting for 40-50% yield reduction globally. The other constraint is low temperature. Most chickpea cultivars are susceptible to chilling temperature at flowering (Crosser, 2003a). It is more serious in flowering and pod setting. However, Singh and Kamath (1990) list several advantages of winter chickpea in comparison to spring chickpea including higher germination rate, less incidence of Fusarium wilt, increased nitrogen fixation, better utilization of available moisture and increased protein and grain yield per hectare.

According to Crosser (2003a), drought delays formation of sugars, lowers energy exchange and destroys the entire biochemical processes. Drought is manifested in three main ways: soil, atmospheric or combination of both. Soil drought is associated with less water in the root area and the plant reacts by producing few branches, delays growth and minimizes transpiration. It however has an advantage of allowing economic use of available water to form seed. Atmospheric drought is worse than soil drought. It lessens humidity to 18-20% when atmospheric temperature rises to 38-40^{0}C. This causes the greatest loss during flowering, and leads to dropping of seed. In agriculture, drought resistance refers to the ability of a crop plant to produce its economic product with minimum loss in a water-deficit environment relative to the water-constraint-free management (Gaff & Slinkard, 1980). An understanding of genetic basis of drought resistance in crop plants is a pre-requisite for a geneticist to develop superior genotype through either conventional breeding methodology or biotechnological approaches.

Mechanisms of drought resistance can be grouped into three categories, viz. drought escape, drought avoidance and drought tolerance (Leviit, 1972). However, crop plants use more than one mechanism at a time to resist drought (Gaff & Slinkard, 1980). Drought escape is defined as the ability of a plant to complete its life cycle before serious soil and plant water deficits develop. This mechanism involves rapid phenological development (early flowering and early maturity), developmental plasticity (variation in duration of growth period depending on the extent of water-deficit) and remobilization of pre-anthesis assimilates to grain (Turner, 1979). Drought avoidance is the ability of plants to maintain relatively high tissue water potential despite a shortage of soil-moisture, whereas drought tolerance is the ability to withstand water-deficit with low tissue water potential. Mechanisms for improving water uptake, storing in plant cell and reducing water loss confer drought avoidance. The responses of plants to tissue water-deficit determine their level of drought tolerance.

Agriculture Science Developments, 2(11) November 2013

Drought avoidance is performed by maintenance of turgor through increased rooting depth, efficient root system and increased hydraulic conductance and by reduction of water loss through reduced epidermal (stomatal and lenticular) conductance, reduced absorption of radiation by leaf rolling or folding (O'Toole *et al.,* 1997; Begg, 1980) and reduced evaporation surface (leaf area) (Passioura, 1976; Turner, 1986).

In chickpea, high root mass has been of interest because the more the roots, the more their efficiency in absorption of water (O'Toole *et al*., 1997; Begg, 1980). This gives a plant more advantage in times when less moisture is available in the soil. A positive correlation between root system sizes and resistance to water stress has been found in several crops and many breeding attempts have focused on obtaining cultivars with larger root systems (Tuberosa *et al*., 2002). For example, Saxena (2003) has developed a chickpea cultivar with a greater degree of drought tolerance from combining large root traits of ICC4958. Similarly, Krishnamurthy (2003) has reported that large root biomass in a minicore collection of ICRISAT chickpea germplasm had high correlation with drought tolerance. Root system size is a complex trait since it is determined by intrinsic genetic factors and modulated by numerous environmental cues like nutrient and moisture availability in the soil (Davies & Zhang 1991). He also noted that smaller leaf surface was also a desirable trait related to drought tolerance. Plants with small leaf surface (pinnules) have shown to experience reduced water loss (Saxena, 2003).

Similarly, early maturing crops tend to escape drought i.e. they establish and mature before rains stop. ICRISAT has placed high emphasis on development of short duration lines chickpea as this can escape terminal drought. The first breakthrough was the development of an extra short duration Kabuli lines ICCV2, from a multiple cross involving five parents (2 Kabuli and 3 desi) which has helped the expansion of Kabuli chickpea cultivation to tropical environment (ICRISAT, 2009). Currently, ICRISAT has developed super early chickpea lines (e.g. ICCV 96029 and 96030) in desi chickpea and is being used extensively in crossing programmes by NARS in India, Africa and Canada to develop early varieties (ICRISAT, 2009).

Plants under drought condition survive by doing a balancing act between maintenance of turgor and reduction of water loss (Shashidhar *et al.,* 2000). The mechanisms of drought tolerance are maintenance of turgor through osmotic adjustment (a process which induces solute accumulation in cell), increase in elasticity in cell and decrease in cell size and desiccation tolerance by protoplasmic resistance (Ugherughe, 1986; Sullivan *et al.,* 1986). Most of these adaptations to drought have disadvantages since a genotype with short life cycle usually yields less compared to that of normal duration. The mechanisms that confer drought resistance by reducing water loss (such as stomatal closure and reduced leaf area) usually result in reduced assimilation of carbon dioxide. Osmotic adjustment increases drought resistance by maintaining plant turgor, but the increased solute concentration responsible for osmotic adjustment may have detrimental effect in addition to energy requirement for osmotic adjustment (Turner, 1979). Consequently, crop adaptation must reflect a balance among escape, avoidance and tolerance while maintaining adequate productivity. Use of these traits as indirect selection for grain yield has been reported to be easier in breeding programmes than selection based on direct grain yields (Saxena, 2003).

Materials and methods

The study was carried out in two sites, namely Koibatek Agricultural Training College (ATC) and KEPHIS Lanet between April 2008 and August 2009. Koibatek (latitude $1^0$35'S, longitude $36^0$66'E) has an altitude of 1890 m above sea level. It lies in UM4 agro-zone, with low agricultural potential. The average annual rainfall range between 500-800 mm with mean rainfall of 767 mm, mean annual minimum and maximum temperatures are 10.9^0C and 28.8^0C respectively. The soils are vitric endosols with moderate to high soil fertility, well drained deep loam to sandy loam soil (Jaetzold & Schimdt, 1983). Lanet lies under agro-ecological zone – UM3, the altitude is 1600-1830 M above sea level with annual rainfall of 936 mm. The mean minimum and maximum temperatures are 18.6^0C and 21.0^0C respectively. The soil is well drained deep loam to sandy loam (Jaetzold & Schimdt, 1983).

Between the two sites, Lanet is relatively high potential and has highest amount of seasonal rainfall, because it is located in the higher altitude cool areas. Koibatek is the driest site with very low rainfall which is poorly distributed hence crops were planted during long and short rains. The two sites therefore fit the recommendation of testing lines in both agrozones within the varied conditions in ASALS of Kenya.

Plant Materials

Thirty chickpea lines were selected based on preliminary drought tolerance screening of population from ICRISAT gene bank. They included 17 Kabuli and 13 Desi types with varied yield and phenological phases. Table 1 shows lines used in the experiment.

Agriculture Science Developments, 2(11) November 2013

Table 1: The Chickpea lines evaluated for Drought Tolerance

LINES	TYPE	ORIGIN
ICC 10018	Kabuli	ICRISAT
ICC 1098	Kabuli	ICRISAT
ICC 11378	Desi	ICRISAT
ICC 11819	Kabuli	ICRISAT
ICC 13523	Desi	ICRISAT
ICC 14098	Desi	ICRISAT
ICC1422	Kabuli	ICRISAT
ICC 16487	Kabuli	ICRISAT
ICC 1923	Desi	ICRISAT
ICC 2850	Desi	ICRISAT
ICC 2629	Kabuli	ICRISAT
ICC 2679	Desi	ICRISAT
ICC 3391	Kabuli	ICRISAT
ICC 3631	Kabuli	ICRISAT
ICC 4363	Desi	ICRISAT
ICC 6294	Kabuli	ICRISAT
ICC 6537	Desi	ICRISAT
ICC 7315	Kabuli	ICRISAT
ICC 7571	Kabuli	ICRISAT
ICC 7819	Desi	ICRISAT
ICC 8384	Kabuli	ICRISAT
ICC 9002	Kabuli	ICRISAT
ICC 9895	Kabuli	ICRISAT
ICCV 10	Desi	ICRISAT
ICCV 92311	Desi	ICRISAT
ICCV 95311	Kabuli	ICRISAT
IG 10500	Desi	ICRISAT
IG 10701	Kabuli	ICRISAT
IG 6905	Kabuli	ICRISAT
IG 74036	Desi	ICRISAT

Experimental Design

The experimental design was Randomized Complete Block Design (RCBD) of 3 blocks with two replicates. The dimension of each block was 4m x 1m. Each block had 10 lines which represented plots. In total there were 30 plots in the 3 blocks in each replication. In between each block was a pathway of 1m. There was a pathway between the two replicates. Spacing of the plants was 40cm x 10cm.

Plate 2: Field screening at Koibatek FTC

The seeds were sown and double super phosphate (DSP) was applied at the rate of 50 kg/ha. After establishment management practices were carried out. This included manual weeding by uprooting and cultivation using jembes. Disease were managemed using chemicals (Rindomil) to mainly control fussarium wilt while pests were controlled using pesticides (actara) mainly against pod borer (*Helicoparva ammigera*). Harvesting was done when over 75% of the pods had dried by uprooting the whole plant and packaging each line separately. The crop was dried in an oven, and then seeds were removed, threshed and weighed each line separate. The rest of the plant without seeds and roots was weighed to obtain the biomass.

Data Collection

In order to screen different lines for drought tolerance both quantitative and qualitative data were collected, during the growing period and after harvesting. Data collected were phenological phases at vegetative stage period, days to 50% flowering, days to podding and physiological maturity. Most quantitative data was collected in the field which included plant height (cm), plant diameter at maturity (cm), and number of pods per plant (pieces), while biomass without seed (g) and seed yield per plant (g) was done in the laboratory using an electronic weighing machine. Measurement of plant height and diameter were taken in the field just after podding using a ruler.

The height of the plant in the experiment was considered to be the height above the ground as suggested by Moles *et al.* (2009). Diameter was considered to be the extent of the spread of the plant branches. Biomass and yield were taken after harvesting using an electronic weighing scale. Biomass was considered to be above ground productivity less the seed weight as suggested by Gill *et al.* (2008). Plant vigour was taken just before flowering where 1- was very poor, 2- poor, 3-fair, 4-good and 5-very good. Drought index was measured at 75% maturity where 1-was no wilting, 2-moderate wilting, 3-high wilting/leaf drop, 4-very high wilting and 5-death. Resistance to pests and diseases was also noted. Drought tolerance was determined using grain yield in the two seasons. The experiments were done in two seasons in Koibatek (main experimental site) and once in Lanet.

Drought susceptibility index (DSI) was estimated from yield data after harvest. It was used to separate the effect of yield potential and drought resistance based on grain yield under drought (water stress season) as described by Fisher and Maurer (1978).

$$DSI = [1-(Yd/Yp)] / D$$

Where Yd was the mean grain yield in stress condition (season 2), Yp is mean grain yield in non-stress conditions (season 1) and D was the environmental stress intensity and is expressed as grand mean of genotypes under moisture stress conditions (Yd)/grand mean under non moisture stress conditions (Yp).

Drought tolerance efficiency (DTE) was used to determine the extent to which the lines were able to resist or tolerate drought as explained by Fischer and Wood (1981). The formula used was that: percentage DTE = (Yield under stress condition/Yield under non stress condition) x 100 (Fischer & Wood, 1981).

Data Analysis

All data collected was analyzed using Analysis of Variance (ANOVA) using Genstat programme (2009). Statistical differences among lines for all variables were separated using Duncan Multi Range Test (DMRT) P = (0.05). Data for each site was analysed separately and combined over the two seasons. Correlation analysis was done using Stata SE 10 to observe the contribution of yield elements to grain yields and also among themselves.

Results

The total rainfall in season I was 252.5 mm and the average temperatures were 17.8^{0}C. This amount of rainfall was higher compared to season 2 and Lanet but temperatures were lower. The high rainfall favoured high performance in most traits in the study.

The mean temperature in season II was 18^{0}C. The total amount of rainfall received was 163.5 mm. The season was characterized by very little rain that was poorly distributed. Just before the crop established the rains failed in December 2008. This finally affected yields and most traits in the study. The lines responded to this stressful condition in different ways depending on their level of tolerance to drought and the kind of drought mechanism employed by as suggested by Leviit (1972).

Days to Physiological Maturity

In Koibatek season 1, the mean number of days taken to physiological maturity was 91.1 days. Plants took between 75.5 days to 104.00 days in this season to mature. There was no significant difference among the lines in terms of days to physiological maturity (P = 0.3605). Early maturing lines in this season were; ICC 3391 (75.5 days), ICC 2679 (84.00 days) and ICCV 10 (84.00 days). Mean temperatures during season I were lower than Lanet, thus the days taken to maturity were longer than in season 2 and Lanet. Temperatures play a key role in determining the length of time a crop takes to mature (Craufurd & Wheeler, 2009). In the study, lower temperature delayed maturity relative to season 2. Despite this delay mean yield performance still remained relatively high in this season 663.00 Kg/ha. Early maturity is important in escaping the terminal drought and therefore it can be considered an appropriate parameter for earliness (Hedge, 2010).

Therefore, those chickpea lines that took the shortest time to mature had an advantage of escaping drought through rapid growth. Days to physiological maturity was recorded once the crop attained over 75% maturity.

The second season realized mean days to physiological maturity of 92.13 days compared to season 1 (91.1 days) and Lanet (91.2 days) in terms days to physiological maturity. Those chickpea lines that took the longest to mature included ICC 14098 (101.5 days), ICC 16487 (100.5 days) and ICC 9895 (99.00 days). Those that matured early during season II were ICC 13523 (86.50 days), ICCV 10 (87.00 days) and ICC 92311 (87.50 days). In season I, ICC 1098 took equal time amount to mature (101.5 days), whereas ICC 16487 took the longest time (104.5days). The two lines equally took a long time to mature in Lanet (95.5 days and 103.5 days respectively).

The lines took 91.2 days on average in Lanet to reach maturity. There was notably a long range of time taken between the early maturing (ICC 11819) and late maturing (IG 74036) (45.00 days to 112 days respectively). This could be attributed to difference in genetic difference that exists between the lines.

Height

Plant height was taken in the field just after podding. The height of the plant in the experiment was considered to be the height above the ground as suggested by Moles *et al.* (2009). The mean height recorded in Koibatek season I was 27.72 cm. The tallest lines in the season were IG 74036 (39.90 cm) and IG 10701 (32.65 cm). Plants in this season were taller compared to season 2 since the season received more rainfall (252.5 mm) (than season II (163.5mm).

Due to higher amount of rainfall received in Koibatek season I (252.5 cm) which was experienced mainly during the growing period of the crop, the chickpea lines there had a higher mean height as indicated by their means, Koibatek season I (27.72cm) and Lanet (24.70 cm). It was also indicated by the significant difference between the sites ($P \leq 0.001$).

The lines in season II had a very high significant difference amongst themselves in terms of height at $P \leq 0.05$. The range of height among chickpea lines in the study was from 12.05 cm (ICC 8384) to 34.50 cm (ICC 13523). The mean height of lines in the study was 23.3 cm which was lower than in season I since rainfall in Koibatek season I as earlier reported having been more than in season II. Plant height, as reported by Moles *et al*. (2009), is mainly influenced by the environment, since biologically height depends on growth, and growth requires water. Plant height of even potentially tall lines like IG 10701 (32.35 cm) was limited in this season therefore yielding lowest (13.65 cm). The most constraining factor to height was rainfall. Bhambota *et al.* (1994) have reported that chickpea height differ from one environment to another due to differences in environmental factors particularly rainfall.

The lines in Lanet site were generally shorter, their heights ranged from 14.53 cm (ICC 8384) and 33.25 cm (ICC 13523). The mean height in the site was 24.70 cm. The heights in this site were limited by the earlier reported poor establishment as result of poor rains at the site after which agrees with the findings of Moles *et al.* (2009).

Biomass

The mean biomass in season I was 6637 Kg/ha. The lines were significantly different from each other ($P \leq 0.001$) in biomass in Koibatek season I. The biomass was higher than season II and the difference was brought about by the difference in the amount of rainfall received during the growing season (Moles *et al.,* 2009). The lines that yielded high biomass in this season were ICC 7315 (8942 Kg/ha) and ICC 11378 (8791 Kg/ha). The lowest recorded in the study was IG 6905 (3343 Kg/ha).

The mean biomass in season 2 was 2179 Kg/ha way below that of season I (6637 Kg/ha). The chickpea line that recorded the highest biomass this season was ICC 13 523 (3335 Kg/ha) and the lowest was ICC7819 (1380 Kg/ha). The difference was brought about by the difference in rainfall amount and distribution. Rains were consistent in season I but erratic in season II. Low rainfall reduces biomass greatly and this is in line with conclusion reached by Leport *et al.* (2006).

Discussion

Days to Physiological Maturity (DPM)

The grand mean of DPM Koibatek and Lanet on the number of days to physiological maturity combined was 91.2 days. There was completely no much difference in DPM in Koibatek and Lanet as seen in their mean of 91.1 days and 91.2 days respectively. The lowest DPM in the study was 45.00 days recorded for lines ICC 11819 in Lanet and the one that took the longest was ICC 9895 (109.00 days). The lowest and highest 5 chickpea lines in terms of DPM sites combined were as shown on Table 2. Days to physiological maturity had high positive significant correlation with the biological mass ($r = 0.580^{**}$), and days to 50% flowering ($r = 0.966^{**}$). However, there was a negative significant correlation with days to first podding, drought index and harvest index ($r = -0.736^{**}$, $r = -0.753^{**}$ and $r = -0.760^{**}$ respectively).

Table 2: The Highest and Lowest DPM in Koibatek and Lanet Sites combined

Shortest DPM		Longest DPM	
LINE	**No. of Days**	**LINE**	**No. of Days**
ICC 11819	44.9	ICC 9895	108.9
IG 4363	59.9	ICC 9002	103.9
IG 74036	84.4	ICC 16487	103.4
ICCV 92311	84.9	ICC 11378	102.9
ICCV 10	86.9	ICC 1923	101.4

The correlation of yield and days to physiological maturity was positive even though not significant (r = 0.138).

The study revealed that DPM had positive correlation with yield which contradicted the findings of Jens (2003), that days taken to maturity were negatively associated with seed yield in chickpea. However, Neterpal *et al*. (2001) has established similar results as that of the findings. Similarly, Quarbun *et al*. (2011), in their analysis of correlation for quantitative traits in chickpea came up with the conclusion that DPM had high positive and significant correlation with yield. Generally, early maturity results in low yield through poor formation of pods and seed (Leport *et al.*, 2006). This goes in agreement with the study that, with longer days to maturity the yield increased (r = 0.138). Even though water deficit decreases yield of chickpea and shortens the vegetative period, it is a mechanism of drought escape as reported by Leviit (1972) and Boyer (1996). If a line is able to complete its lifecycle before serious onset of soil water deficit, then it is considered tolerant to drought (Gaff & Slinkard, 1980). Days to physiological maturity can therefore form the basis in selection for drought tolerance in chickpea as is also reported by Arora (1991).

Biological Mass

In sites and seasons combined, there was no significant difference in biomass among the chickpea lines between the seasons (P = 0.133) and also among the lines (P = 0.761). The lines which recorded the highest biological mass when sites were combined with their respective yield are as shown in Table 3.

Table 3: The Biological Mass of the Best Five Lines together with their yields

Lines	Biological mass, Kg/ha	Yield, Kg/ha
ICC 10018	7979	474
ICC 1923	7873	757
ICC 16487	7793	773
IG 74036	7542	694
ICC 2850	7511	541

The lines on Table 3 due to their highest biological mass could therefore be recommended for use as fodder crop. However, it requires further screening for nutritional, palatability and digestibility factors as recommended of a good fodder crop (Ngugi & Karau, 1978). The least biological mass sites combined were recorded in ICC 1098. There was a direct negative correlation between biomass and drought index as well as harvest index (r = -0.445** and = -0458**) respectively. However, there was a significant positive correlation with days to 50% flowering and days to physiological maturity (r = 0.585** and r = 0.580). Biological mass had some insignificant positive correlation with yield (r = 0.160).

During the first season when there was high mean rainfall (252.5 mm), it favoured high vegetative growth but reduced amount of rainfall resulted to low biomass. It has also been reported by Leport *et al*. (2006) that the water deficit conditions decreases yield of chickpea shortens the vegetative period and reduces the produced biomass. Biomass in most crops has a direct positive relationship with the yield as reported by Mishra *et al.* (1988) and Sohell and Keyvan (2010) which agrees with the finding of this study. High biomass means there is a high surface area of the plant expected above the ground and so it follows that the area exposed for photosynthesis is quite large. High photosynthesis increases yield although it may mean low drought resistance in terms of surface area exposed to environmental factors (Omar & Singh, 1986). Biomass can form basis for selection for high yield in chickpea as also suggested by Raza and Farzad (2007).

Conclusion and recommendations

The study concluded that the days to physiological maturity have high positive significant correlation with the biological mass and days to flowering. However, there is a negative significant correlation with days to first podding, drought index and harvest index in chickpea germplasm. Studies have shown that if a line is able to complete its lifecycle before serious onset of soil water deficit, then it is considered tolerant to drought. As such, days to physiological maturity can therefore form the basis in selection for drought tolerance in chickpea.

Moreover, in sites and seasons combined, there was no significant difference in biomass among the chickpea lines between the seasons and also among the lines. There is a direct negative correlation between biomass and drought index as well as harvest index. High biomass means there is a high surface area of the plant expected above the ground and so it follows that the area exposed for photosynthesis is quite large. High photosynthesis increases yield although it may mean low drought resistance in terms of surface area exposed to environmental factors. As such, biomass can form basis for selection for high yield in chickpea.

According to Mishra *et al.* (1988), those factors that contributed directly and indirectly to yield should also form a basis for selection for drought tolerance. Raza and Farzad (2007) concluded that these factors included biological mass and harvest index. The study did not find any strong contribution either directly or indirectly of biological mass and harvest index (r = 0.16 and r = -0.051 respectively) to yield or even to DTE (r = 0.161 and r =0.015 respectively). Therefore, through ranking it was concluded that the traits that were more positively correlated to yield were days to flowering (r = 0.121), days to physiological maturity (r = 0.138), biological mass (r = 0.160) and percentage DTE (r = 0.177). These therefore are concluded to be the morphological traits associated with drought tolerance in chickpea under study since they contributed directly to yield. Field observation however confirmed that early flowering and pod formation led to early maturity which was a notable feature to drought escape during drought stress conditions. Falconer (1960), used heritability index (H^2) to conclude on characters that could be used in indirect selection for yield. They included those whose H^2 were greater than that of yield. The traits whose H^2 were higher than the yield in the study included plant diameter, days to first podding, days to 50% flowering, drought index, and or spread. These traits could be of use in breeding programmes of the selected lines.

In general, there was no single morphological or physiological trait which alone was responsible for drought tolerance. Thus in the developing of drought tolerance, lines pyramiding approach (bringing genes together in one line) is recommended.

References

Abbo S. (2002b). Breeding for osmotic adjustment in Chickpea. *Australian Journal of plant breeding association,* p. 463.

Alguo, D. (2011). *Drought under global warming; a review of 2010 study by national atmospheric research (NCAR),* 2: 45-65.

Arora, P. P. (1991). Genetic variability and its relevance in chickpea improvement. *International Chickpea Newsletter,* 25: 9.

Bhambota, S. K., Sood, B. C., & Gartan, S. L. (1994). *Association of yield and its components in chickpea*. Department of plant breeding and genetics, pp 203-218.

Begg, S. T. (1980). Planting date temperature effects on germination and seed yield of chickpea. *Agronomy Journal,* 80: 909-914.

Boyer, J. S. (1996). Advances in drought tolerance in plants. *Advance in agronomy*, 56: 187-218.

Craufurd, P. Q., & Wheeler, T. R. (2009). Climate change and annual crops. *Oxford University Journal – Life Sciences*, 60: 2529-2539.

Corby, R. (1981). Seeds of Leguminosae. In R. M. Polhill, & P. H. Raven, (Eds.). *Advances in legumes Systemics*. *Part 2* (pp 913-915). Kew, UK: Royal Botanic Gardens.

Crosser, J. S. (2003a). Utilisation of wild *circer* in chickpea improvement - progress, constraints, and prospects. *Australian J. Agricultural Res*, 54: 429.

Cubero, J. I. (1987). Morphology of chickpea. In M. C. Saxena, & K. B. Singh, *The chickpea* (pp 35-66). Wallingford, Oxon, UK: CAB International.

Davies, W., & Zhang, J. (1991). Root signals and the regulation of growth and development of plants in dry soil. *Annual review of plant physiology and plant molecular Biology,* June, 42: 55-76.

FAO (2009). *Carbohydrates in Human Nutrition; Report of joint FAO/WHO Expert consultation in FAO Food and Nutrition paper*. Food and Agricultural Organization and WHO Rome, p. 1-95.

Fisher, R. A., & Maurer, R. (1978). Drought resistance in spring wheat cultivars, Australian yield responses in spring wheat. *Australian J. Agric Sci.* 29: 892-912.

Fischer, K. S., & Wood, G. (1981). Breeding and selection for drought tolerance in tropical maize In *Proc. Symp. On principles and methods in crop improvement for drought resistance with emphasis on Rice* (pp 31-46). IRRI Philippines.

Gill, S., Abid, M., & Azam, E. (2008). Mixed cropping effects on growth of wheat and chickpea. UNIV of Idaho (2009), www.cnr.idhaho.educ (module) - principle vegetative measurement and assessment, University of Idhao, pp 106-112.

Gaff, P. M., & Slinkard, A. E. (1980). Broad few outwardly curved wings; Two new mutant chickpea. *Plant Breeding*, 122: 192-203.

Hedge, V. S. (2010). *Plant Breeding: Genetics for flowering time in chickpea in a semi arid environment*, 129: 683-687.

ICRISAT (2009). The international efforts in chickpea improvement. *Staff research on improvement of legumes in the Topics,* 3: 359-377.

ICRISAT (2008). *International Crop Research Institute for Semi-Arid Tropics annual report*. Nairobi, Kenya, pp 45-53.

Jaetzold, R., & Schmidt, H. (1983). *Farm Management Handbook of Kenya –Natural Conditions and Farm Management Information*, vol. II/B: Central Kenya (Rift Valley and Central Provinces). Ministry of Agricultural, vol. 121, pp 37- 404.

Krishnamurthy, L. (2003). Genetic diversity of drought- avoidance root traits in the mini-core germplasm collection of chickpea. *International Chickpea and Pigeon pea News*, vol. 10, p. 21.

Leport L.N., Turner S., Davis L. and Siddique K. H. M. (2006). Variation in pod production and abortion among chickpea cultivars under terminal drought. *European Journal of Agronomy*, 65: 87.

Levitt, (1972). Mechanisms of heat and drought resistance in grain yield in chickpea. *Journal of characteristization and molecular mapping of drought tolerance in chickpea,* 98: 148.

Mishra, R., Rao, S. K., & Koatal, G. K. (1988). Genetic variability correlation studies and their implication in selection of high yielding genotypes of chick pea. *Indian Journal of Agric Resources,* 15-57.

Moles, A. T., Warton, D., Warman, L., Swenson, N. G., Laffan, S. W., Zane, A. E., Hemmings, F. A., & Leishman, M. R. (2009). Global patterns of plant height. *Journal of Ecology School of Biological Earth and Environmental Science*, University of South Whales, Sydney Australia, 95(5): 923-932.

Neterpal, S., Krishna, R., & Kumar, (2001). An assay effect of different traits on chickpea grain yield. *Ann. Agriculture Resource News*, Series 22: 564-569.

Ngugi, D. N., & Karau, P. K. (1978). *East African Agriculture.* London: Macmillan publishers, pp 116-124.

Omar, M., & Singh, K. B. (1986). *Increasing seed yield in chickpea by increased biomass yield*. ICRISAT-Andhra-India, vol. 4, p. 78.

O'Toole, N., Stoddard, F. L., & O'Brien, L. (1997). Screening for chickpeas for adaptation to autumn sowing. *Journal of agronomy and crop science,* 186(3): 193-207.

Passioura, J. B. (1976). Physiology of grain yield in wheat growing on stored water. *Australian Journal of physiology*, 3: 559-565.

Quarbun, A., Mohammad, H., Saeed, A., Amjad, I., & Muhammad, A. (2011). Genetic variability and correlation for quantitative traits in chickpea genotypes (*Cicer arietinum* L.). *Journal of bacteriology research,* 3(1): 6-9.

Raza, T., & Farzad, F. (2007). Correlation and path analysis of yield and yield components of chickpea in dry land conditions west Iran. *Asian Journal of plant Science,* 6: 1151-1154.

Saraf, C. S., Rupella, O. P., Yadav, R. L., Shivkumar, B. G., & Bhattarai, S. (1998). *Biological Nitrogen fixation and residual effects of winter grain legumes in rice and wheat cropping system of Indo – Gangetic plain.* Oxford and IHB Publishing New Delhi India, pp 14-30.

Saxena, M. C. (2003). *Recent advances in chickpea agronomy*. Proceeding of the International Workshop on chickpea improvement, 28th Feb.-3rd Mar. 1979, ICRISAT Centre, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi – Arid Tropics p. 29-31.

Shashidar, R., Saroj, S. D., Harjare, S., Dhokane, V., Sharma, A., & Bandekar, J. R. (2000). Tropics. Inheritance of flower colour in chickpea. *Journal of heredity*, 91: 5.

Singh, S., & Kamath, M. B. (1990). Soil and fertilizer phosphorous utilization from full basal, split and foliar application of phosphate by chickpea (Cicer arietinum L.) using isotope tracer. *Indian Journal of plant Physiology,* 32(2): 110-114.

Sohell, K., & Keyvan, S. (2010). Investigation of correlation analysis and relationships between grain yield and other quantitative traits in chickpeas. *African journal of biotechnology*, 19: 2342-2348.

Sullivan, P. A., Donovan, J. T., & Sharma, A. K. (1986). Influence of the relative time of emergence of wild oats on yield loss of barley and wheat. *Weed science,* 33: 498-503.

Tuberosa, R., Sanguinet, M. C., Landi P., Guiliani, M. M., Salvi, S., & Conti, S. (2002). Identification of QTLs for root characteristics of maize hydroponics analysis of their overlap with QTLs for grain yield in field at water regimes. *Plant mol. Biology*, 48: 697-712.

Turner, N. C. (1986). Adaptation of water deficits – A changing perspective. *Australian Journal of plant physiology*, 13: 175-190.

Turner, N. C. (1979). Drought resistance and adaptation to water deficit in crop plants. In H. Mussell, & R. C. Staples, (Eds.), *Stress physiology in crop plants* (pp 343-367). New York.

Ugherughe, P. O. (1986). Relationship between digestibility of *Bromus inermis* plant parts. *Journal of agronomy and crop science*, 157: 136-143.