EFFECT OF DROUGHT ON MORPHO-PHYSIOLOGICAL TRAITS OF CHICKPEA (*Cicer arietinum* L.) UNDER NON-IRRIGATED CONDITION.

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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF DROUGHT ON MORPHO-PHYSIOLOGICAL TRAITS OF CHICKPEA (*Cicer arietinum* L.) UNDER NON-IRRIGATED CONDITION** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **AGRICULTURAL BOTANY,** embodies the result of a piece of bona fide research work carried out by **MD. JAHIRUL ISLAM,** Registration No. **17-08264** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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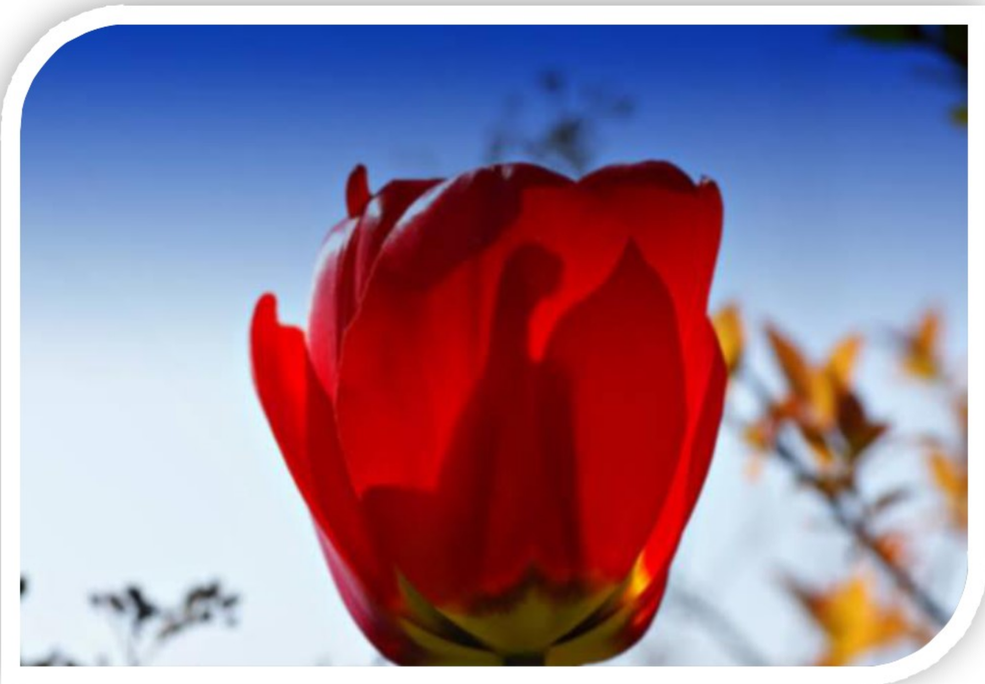
DEDICATED TO

MY FAMILY



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Abstract

The present experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh during rabi season (from October 2018 to March 2019) to study the effect of drought on morpho-physiological traits of chickpea (*Cicer arietinum* L.). The experiment was laid out in a Randomized Complete Block Design with three replications and treatment comprised of seven chickpea varieties evaluated on drought situation under non-irrigated conditions. The collected data were statistically analyzed for evaluation of the treatment effect. BARI Chola-9 (V4) produced the highest plant height, BARI Chola-3 (V1) produced the highest number of branches, Binasola-4 (V7) produced the highest number of pods (32.20) per plant, highest number of filled pods and BARI Chola-3 (V1) produced highest number of unfilled pods. BARI Chola-4 (V2) produced the highest (14.60 g) 100-seed weight which was statistically similar with BARI Chola-10 (V5) and BARI Chola-9 (V4). Binasola-4 (V7) produced the highest (334.33 kg ha^{-1}) seed yield which was statistically similar with BARI Chola-7(V3). The highest root length and the highest shoot length were observed from the genotype BARI Chola-3 (V1) respectively 17.01 cm and 61.79 cm. The highest plant fresh weight can be observed from the genotype BARI Chola-9 (V4) 3116.67 kg ha^{-1} and the highest plant dry weight BARI Chola-9 (V4) 317.1 k ha^{-1}. Binasola-4 (V7) produced the highest (2523.1 kg ha^{-1}) biological yield and Binasola-3 (V6) produced the highest (91%) harvest index. The highest (49.50%) and the lowest (44.16%) SPAD value of leaf produced respectively from BARI Chola-10 (V5) and Binasola-4 (V7) at 60 DAP. BARI Chola-4 (V2) produced the highest (55.37%) membrane stability at 80 DAP while Binasola-4 (V7) produced the lowest (48.88%). BARI Chola-3 (V1) produced the highest (375.67 mmol $m^{-2}s^{-1}$) and stomatal conductance at 80 DAP while Binasola-4 (V7) produced the lowest (169.90 mmol m-2s-1). BARI chola-3 (V1) was considered as drought tolerant varieties as they perform better to drought situation under non-irrigated condition.

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ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BINA	=	Bangladesh Institute of Nuclear Agriculture
BARC	=	Bangladesh Agriculture Research Council
FAOSTAT	=	Food and Agriculture Organization Statistics
AIS	=	Agriculture Information Service
ICRISAT	=	International Crops Research Institute for the Semi-Arid Tropics
SPAD	=	Soil Plant Analysis Development
MAS	=	Marker Assisted Selection
BBS	=	Bangladesh Bureau of Statistics
N	=	Nitrogen
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
t ha^{-1}	=	ton per hectare
Cm	=	centimeter
Mg	=	milligram
Mmol	=	millimol
G	=	gram
Kg	=	Kilogram
DAS	=	Day After Sowing
DAP	=	Day After Planting
SAU	=	Sher-e-Bangla Agricultural University
BAU	=	Bangladesh Agricultural University
SRDI	=	Soil Resources and Development Institute
Wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Co-efficient of Variance

CHAPTER 1

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops under the family Fabaceae and subfamily Faboideae. Chickpea ranks third in terms of area contributing around 1.61% of total pulse production of Bangladesh. The area of chickpea is 14,615 hectares with total production of 6,237 metric tons per year (BBS, 2018). The total area and production of chickpeas in Bangladesh are respectively 8445 hectares and 9402 hg/ha (FAO-STAT, 2016). The total area and production of chickpeas in Bangladesh are respectively 0.047 million hectare and 0.055 lakh metric ton (BBS, 2018). Chickpea seeds contain 20.6% protein, 2.2% fat and 61.2% carbohydrates (Gupta, 1987). Chickpeas have a protein digestibility corrected amino acid score of about 76 percent which is higher than fruits, vegetables, many other legumes and cereals, it is able to drive more than 70% of nitrogen from symbiotic dinitrogen fixation which makes it a promising crop for “alternative agriculture” that is now attracting a considerable attention in the industrialized world. The heavy demand created by the pressure of increasing population in the developing world requires a tremendous scientific effort to meet the requirements of food, fiber, fuel and other necessities of life. In Bangladesh, there is an increase of about 25% in per capita availability of pulses in 2018 (56 g/capita/day) compared to 2005 level (45 g/capita/day). In Bangladesh pulses are generally called as poor’s men protein. But in these days, we cannot fulfill our demand of pulse. We should give more attention to this protein source as the demand is close to 2 million tons but the country generates only 0.53 million tons comparing with total demand (Razzaque, 2000). Bangladesh produces more than 500,000 tons of pulses every year and imports a further 100,000 tons. Many people of our country, especially those who live in the coastal areas, are suffering from malnutrition. The demand of chickpea rises manifold in Bangladesh during the fasting month of Ramadan as most Muslims prefer chickpea as a delicious item to break the daylong fast.

Many approaches have been advocated for much needed chickpea productivity enhancement which can create additional genetic variation especially for traits of economic importance and enable effective utilization of available germplasm in chickpea improvement programs for enhanced and sustained chickpea production across the continents. Approximately, 90% of world chickpea is grown under rain fed condition, where terminal drought is one of the major constraints to chickpea production as they are grown during post-rainy season on residual soil moisture. In Chickpea flowering or pod filling stage are most sensitive to drought stress (Khanna *et al.* 1987). This leads to severe yield losses leading to yield losses, ranging from 30-100% depending on the genotype (Toker *et al.* 2007). The extent of drought stress depends upon previous rainfall, atmospheric evaporative demand and soil characters such as depth, texture and structure. Efforts to breed drought tolerant varieties have been difficult due to poor understanding of drought tolerance mechanisms. Drought is an important and complex phenomenon and extensive research efforts have been made at national and international levels on identification of morphological and physiological traits associated with drought tolerance. Several factors such as biotic and abiotic stresses reduce yield of chickpea. Among the abiotic stress factors, drought stress is relatively important in chickpea which causes a 40–50% reduction in yield globally (Millan *et al.* 2006). As the economy of Bangladesh is mainly agriculture oriented, crop failure comes as significant strain to its socio-economic structure. The narrow genetic base among cultivated chickpea accessions is limiting genetic improvement of chickpea through breeding efforts.

Generally, morphological variability is taken as a measure of genetic diversity by most researchers. Biometrics tries to discern this variability with greater precision. However, it is well known that phenotype is the outcome of genotype, environment and thus phenotypic diversity may not be a true estimate of genetic diversity. It is important to characterize the genetic diversity in plant species since they serve as a resource base for as yet unidentified genetic information. Germplasm collections needs to be analyzed using for estimating the genetic variability both at molecular level and for morpho-physiological traits for terminal drought tolerance for increasing the genetic base and for breeding for higher productivity under limiting environments in chickpea.

To minimize the yield losses caused by terminal drought, there is a need to identify genotypes possessing terminal drought tolerance. This will greatly aid in development of chickpea cultivars with tolerance to drought. Drought tolerance as evidenced from review of literature is low in heritability and hence morphological and physiological parameters that are tightly linked to this trait needs to be identified so as to be able to select and breed for superior genotypes possessing drought tolerance. In Bangladesh, no research has not done yet on effect of drought on chickpea and that's why the present experiment was undertaken with the following objectives:

Objectives

1. To identify tolerant drought chickpea variety based on morphological and physiological characteristics.
2. To quantify the yield and yield attributes of chickpea in drought situation.

CHAPTER 2

REVIEW OF LITERATURE

Chickpea is an important legume crop in Bangladesh which can contribute to a large scale in the national economy. But the research works done on this crop with respect to recognizing the drought tolerance verity are inadequate. Only some limited studies have so far been done in respect of management practices of the crop. Drought is the most common abiotic stress limiting chickpea production in different parts of the world. Ninety percent of the world's chickpea was produced in areas relying upon conserved, receding soil moisture. Chickpea frequently suffers from drought stress towards the end of the growing season in rainfed condition. The extent of terminal drought stress varies depending on previous rainfall, atmospheric evaporative demand, and soil characteristics such as type, depth, structure, and texture. Terminal drought is globally the most serious constraint to chickpea productivity. It is estimated that if the soil water stress is alleviated, chickpea production could be improved up to 50% that is equivalent to approximately 900 million US dollars (Ryan 1997). Therefore, crop productivity is largely dependent on efficient utilization of available soil moisture (Kumar and Van Rheenen, 2000). Although chickpea is well adapted to growing on conserved moisture in drought prone environment, still drought is a major yield reducer.

2.1 Morphological ,yield contributing and yield characters

Drought can be defined as below normal precipitation that limits plant productivity. A drought situation can be classified as either terminal or intermittent. During terminal drought, the availability of soil water decreases progressively and this leads to severe drought stress at the later period of crop growth and development. Intermittent drought is the result of finite periods of inadequate rain or irrigation occurring at one or more intervals during the growing seasons and is not necessarily lethal.

Yaqoob *et al.* (2011) suggested that moisture stress at pre-flowering stage being harmful and detrimental is the, most critical for screening chickpea germplasm under drought prone conditions.

Ganjeali *et al.* (2010) evaluated 150 genotypes of chickpea (Kabuli type) using Augmented Designs for Preliminary Yield Trials under stress (Rainfed) and nonstress (Irrigated) conditions based on the obtained results, four candidate genotypes for drought tolerance and two susceptible ones were evaluated in a pot experiment at open door situation in stressed (25% Field Capacity) and non-stressed (Field Capacity) conditions based on a factorial trial in Randomized Complete Block Design They found out that there were positive and highly significant correlations between quantitative drought resistance indices such as MP, GMP, STI and HM with yield in stress and non-stress conditions. Also, there were positive and high significant correlations for SSI and DRI with yield in non-stress and stress conditions, respectively.

Leport *et al.* (2006) reported that the drought tolerance in chickpea was found to be directly proportional to deep system and high leaf water potential (LWP) and he also reported that the multipennate chickpea lines reduce amount of energy stored in leaf due to high level of reflection. Moisture stress to chickpea is more important at pre-flowering stage, because it is the most damaging stage to yield and yield parameters and plant need abundant availability of moisture in the root zone at this stage. Therefore, artificial stress at this stage will lead to screening for drought resistant genotypes in chickpea.

Anyia and Herzy (2004) reported that the high temperature stress to chickpea also causes yield losses because of damage to reproductive organs.

Drought is the most economically important abiotic constraint to crop production in the world (Araus *et al.* 2002).

Mitra (2001) explained various morphological, physiological and biochemical characters confer drought resistance. Morphological and physiological characters show different types of inheritance pattern (monogenic and polygenic) and gene actions (additive and non-additive). For agricultural context, drought escape and drought avoidance mechanisms are important for productivity.

Kumar and Van Rheenen (2000) reported that infertile pods, earlier phenology stages, declining seed filling duration and lower harvest index are the results of drought stresses in these regions. The significance of early flowering in reducing duration of crop maturity period has been recognized in semi-arid regions as an important trait to escape drought stress in chickpea.

2.1.1 Plant height

Roy *et al.* (2016) studied the effect of supplementary nitrogen, irrigation and hormones on growth and reproductive behavior of chickpea. Chickpea varieties showed significant variation on plant height at different DAS. The plant height was recorded from BARI Chola-9 with supplemental irrigation along with aqueous N before flowering while the shortest plant was observed from BARI Chola-8.

Variety and sowing time on the growth and yield of chickpea (*Cicer arietinum* L.) in southern region of Bangladesh was investigated by Sikdar *et al.* (2015) with two varieties (BARI Chola-2 and BARI Chola-4) and three sowing time (10 November, 20 November, and 30 November) with four replications and found that the tallest plant (38.54 cm) was obtained from BARI chola-4.

Sardar (2009) at Dharwad (Karnataka) observed that the plant height among differed chickpea varieties differed significantly at 30 DAS, 60 DAS and at harvest. Cultivar KAK-2 exhibited significantly greater plant height of 29.3 cm, 45.8 cm and 48.3 cm at 30 DAS, 60 DAS and at harvest, respectively as compared to other cultivars. However, cultivars ICCV-2 and Bheema were found not significant with each other.

Das (2006) investigated the effects of applied phosphorus on the growth, nutrient uptake and yield in chickpea (*Cicer arietinum* L.). He found that BARI

Chola-7 produced the tallest plant while shortest plant was produced from BU Chola-1.

2.1.2 No. of branch per plant

Kumar *et al.* (2003) conducted during the Rabi season of 2013-14 at the Crop Research Farm, Department of Agronomy, Allahabad School of Agriculture, SHIATS, Allahabad, Uttar Pradesh. The treatments consisted of three phosphorus levels (40, 60 and 80 kg/ha), 3 levels of Sulphur (15, 20 and 25 kg/ha) and two cultivars (Pusa-362 and Radhey) with plot size of 3 x 3 m (9 m2). The results revealed that treatment comprising Pusa-362 + P_2O_5 60 kg/ha + Sulphur 25 kg/ha recorded highest plant height (48.60 cm), number of branches per plant (7.66).

Sardar (2009) at Dharwad (Karnataka) observed that cv. KAK-2 recorded significantly a greater number of branches i.e., 8.05, 17.1 and 18.3 branches plant-1 at 30 DAS, 60 DAS and at harvest, respectively as compared to other cultivars.

Kabir (2009) at Gazipur (Bangladesh) reported that chickpea cv. BARI Chola-6 exhibited higher TDM (24.3 g m-2) as compared to cvs. BARI Chola-2 (21.0 g m-2) and BARI Chola-4 (20.8 g m-2). Sardar (2009) at Dharwad

Das (2006) showed that BARI Chola-6 produced the highest number of branches plant^{-1} and BARI Chola-7 produced the lowest number of branches plant^{-1}.

Kumar *et al.* (2003) noticed that number branches plant^{-1} were significantly higher in chickpea genotype H 96-99 than genotypes H 92 -69 and HC-1.

2.1.3 Days to first flowering

Kanouni *et al.* (2012) observed significant ($P<0.05$) positive relationships of days to flowering, seed yield per plant with pods per plant, 100-seed weight and plant height.

Babbar *et al.* (2012) observed that seed yield per plant had significant positive correlation with total number of seeds per plant, total number of pods per plant, biological yield, plant height and 100-seed weight. They emphasized use of pods per plant, 100-seed weight and seed yield per plant as selection criteria while selecting superior genotypes under late condition.

Correlation studies by Ali *et al.* (2010) revealed that both at genotypic and phenotypic levels, seed yield per plant had significant positive association with days for flowering, days to maturity, primary branches per plant, and secondary branches per plant while, plant height had negative and non-significant association.

2.1.4 No. of pod per plant

Raky and Liey (2017) studied the effect of irrigation on chickpea in Egypt and reported that irrigation at flowering and pod development stage exhibited higher seed yield, number of pods, branches, seed yield/plant, and seed weight over control.

Bandyopadhyay *et al.* (2001), reported that highest growth, yield, consumptive use and coefficient were recorded from chickpea plants subjected to two irrigation applied at branching and pod development. One irrigation during branching also produced an appreciably higher grain yield compared with no irrigation and one irrigation during the pod development stage.

Haqqani *et al.* (2000) reported that yield of chickpea was highest with irrigation at flowering (110 days after sowing) over control and pod formation stages.

Malik *et al.* (2005) documented highly significant positive correlation for seed yield with biological yield, secondary branches and number of pods/plants. Secondary branches were positively correlated with number of pods per plant and seed yield per plant, whereas it was negatively associated with 100-seed weight. Cluster diagram based on Euclidean dissimilarity placed all the genotypes in three clusters at 50% linkage distance.

2.1.5 Hundred seed weight

A study was carried out by Aliloo *et al.* (2012) to analyze the response of chickpea (*Cicer arietinum* L.) varieties (Azad and ILC-482) to nitrogen applications at vegetative and reproductive stages under rainfed condition and reported that 100-seeds weight was significantly affected by varieties.

Research was carried out by BINA (2012) to determine the optimum irrigation water requirement of chickpea developed at BINA during the Rabi season of 2010-2011. Results revealed that highest 1000 seeds weight (148.05 g) was produced form BINA Chola-6.

2.1.6 Seed yield

Sethi *et al.* (2016) conducted field experiments during two consecutive Rabi seasons 2012-13 and 2013-14 at Pulse Research Area of CCS Haryana Agricultural University, Hisar to study the yield response of four chickpea varieties (H09-23, H08-18, C-235 and HC-1) as influenced by two dates of sowing (1st fortnight of November and December) and three seed rates (40, 50 and 60 kg ha^{-1}). The results indicated that variety H09-23 and H08-18 produced significantly higher grain yield than other varieties.

Nawab *et al.* (2015) examined the effect of irrigation (no irrigation, pre-sowing irrigation and irrigation at flowering stage) on chickpea varieties (Karak-1, Karak-2, Sheenghar and KC-98) sown on different dates (Oct. 1, Oct. 15, Nov. 1, and Nov. 15) on irrigated fields of Bannu, Khyber Pakhtunkhwa, Pakistan. The results of the above experiment indicated that Chickpea variety Karak-I produced significantly higher grain yield followed by Karak-II.

Variety and sowing time on the growth and yield of chickpea (*Cicer arietinum* L.) in southern region of Bangladesh, investigated by Sikdar *et al.* (2015) with two varieties (BARI Chola-2 and BARI Chola-4) and three sowing time (10

November, 20 November, and 30 November) with four replications and found that the highest seed yield (1719.41 kg ha^{-1}) and Stover yield (2365.77 kg ha^{-1}) were obtained from BARI Chola-4.

Islam *et al.* (2013) investigated the effect of date of sowing on the yield and yield contributing characters of chickpea varieties. The treatments of the experiment included four sowing dates (November 1, November 15, December 1 and December 15) and three varieties (BINA sola-4, BINA sola-3 and Hyprosola). The results showed that Binasola-4 produced higher seed yield (2085 kg ha^{-1}) followed by BINA sola-3 (2036 kg ha^{-1}) in November 15 sowing.

Results of an experiment conducted by Khatun *et al.* (2010) revealed that different varieties of chickpea varied significantly in terms of seed yield. The highest seed yield was observed in BARI Chola-5 and the lowest in BARI Chola-8.

Bhuiyan *et al.* (2008) carried out two field experiments during two consecutive rabi seasons of 2002-03 and 2003-2004 to analyze the effect of Rhizobium inoculation on four varieties of chickpea viz., BARI Chola-3, BARI Chola-4, BARI Chola-5 and BARI Chola-6 and reported that among the varieties studied BARI Chola-3 gave significantly higher Stover yield.

2.1.7 Root length and Shoot length

Miyahara *et al.* (2011) has been reported that the number of lateral and fine roots increase under drought stress in several crop species which not only increases root surface area for water absorption but also increases root hydraulic conductivity

Franco *et al.* (2011) showed root traits, such as rooting depth and root biomass, have been identified as the most promising plant traits in chickpea for terminal drought tolerance. Roots are much more exposed to drought stress than the upper plant parts. So, the root system is more affected than the aerial part of the plant for drought stress Root development is strongly influenced by growing conditions such as drought stress. However, root growth is usually less affected by drought stress than shoot growth, since more severe water deficit conditions possibly developed in the transpiring shoots. Other root characteristics like root length, fresh weight, dry weight, diameter and surface area, deep rooting and cortex thickness are also strongly affected by drought.

Franco *et al.* (2011) also observed that deep rooting is a critical factor influencing the ability of the plant to absorb water from the deeper layers of the soil. Also, a greater percentage of fine roots, capable of penetrating smaller soil pores, presumably optimizes the exploratory capabilities of the root system as a whole, and may have an important role for survival of plants to drought stress.

2.1.8 Biological yield

Falah (2017) reported that supplemental irrigation has significant effects on yield and yield component, also suitable plant densities and correct adjustment of row spacing lead to optimum uses of soil and environment factors that produce high yield and yield component in chickpea.

Sharma *et al.* (1988) reported that two irrigation at pre-flowering and pod formation stages of chickpea and irrigation at pod formation stage of chickpea being at par with each other recorded significantly highest yield over the irrigation at per flowering stage of chickpea and no irrigation.

Patel *et al.* (1991) Evaluated to improve chickpea production and to enhance water productivity in Bansagar commond area of Madhya Pradesh four water management treatments. Consisting two farmers‟ practices treatments, i.e. two irrigation by flooding method and two improved practices i.e. two irrigation at flowering and pod formation stage with border strip method were studied. Under improved practices water was applied twice each of 40 cm depth at flowering and pod formation stage by border strip method. It was researched that improved irrigation management practices gave significantly higher number of nodules (119/plant), and seed yield (1237 kg/ha) of chickpea. An increase of 11.32 % chickpea yield was noticed as compared to farmers practices.

2.1.9 Harvest index

Ali (2017) was conducted at BINA sub-station Magura, to evaluate the yield potential of new cultivars of chickpea under different irrigation regimes. The experimental design was RCBD (with split-plot) having irrigation treatments in the main plots and chickpea varieties in the sub-plots. The irrigation treatments comprised of: control (no irrigation), irrigation at vegetative state (25-30 DAS), irrigation at flowering stage (45- 50 DAS), and irrigation at vegetative state (25-30 DAS) and flowering stage (45-50 DAS). Irrigation water was applied up to field capacity as per treatment. The results revealed that irrigation treatments had detrimental effect on all yield attributes (plant height, seed per pod, branch per plant) and seed yield. The seed yield gradually reduced when irrigation was applied. The highest seed yield (1.87 t ha^{-1}) was obtained from control treatment which received no irrigation. The varieties had also significant effect on all yield attributes and seed yield. The cultivar BINA sola-5 produced the highest yield (1.20 t ha^{-1}). The highest water use efficiency (263.01 kg ha^{-1} cm-

1) was also found in control treatmet, which received no irrigation. From the results of the study, it is revealed that under the prevailing climatic and soil condition, the chickpea cultivars do not need any irrigation at Magura, rather it reduces yield.

2.2 Physiological Characters

2.2.1 SPAD value of leaf

In peanut, Arunyanark *et al.* (2009) demonstrated that the variation in TE was closely correlated with genotypic variation in chlorophyll density and hence with photosynthetic capacity, such that chlorophyll density could be used as a potential indicator of TE in peanut. The chlorophyll meter (SPAD-502 Minolta, Tokyo, Japan), also known as SPAD (soil plant analysis development) meter, can quickly and reliably assess the N status of a crop based on leaf area. In addition, a SPAD chlorophyll meter reading (SCMR) is an indicator of the photo-synthetically active light-transmittance characteristics of the leaf, which is dependent on the unit amount of chlorophyll per unit leaf area (chlorophyll density).

Significant and positive correlations between SCMR and chlorophyll content, and chlorophyll densities have been reported (Arunyanark *et al.* 2009).

Nageswara Rao *et al.* (2001) reported significant and high interrelationship among SLA, SLN, and SCMR. A direct close relationship of TE with SPAD chlorophyll meter readings (SCMR) was reported in groundnut (Nageswara Rao *et al.* 2001; Bindu-Madhava *et al.* 2003) and SCMR is a direct linear relationship through extracted leaf chlorophyll (Yadava 1986) and also related leaf nitrogen concentration.

SCMR and SLA are negatively correlated and genetic variation for SCMR has also been reported in chickpea (Nageswara Rao *et al.* 2001). As a noninvasive surrogate of TE, SCMR is easy to operate, reliable, fairly stable and low cost. The SCMR is reported to be more stable than SLA. A significant positive relationship was observed between seed yield and SCMR in many crops; black gram, green gram, groundnut, cereals and maize. The advantages such as easy and rapid measurement, nondestructive method and light weight made SPAD meters the best choice for use in the trait-based breeding program to improve the drought tolerance of groundnut and chickpea at the International Crops Research Institute for the Semi- Arid Tropics.

2.2.2 Membrane stability

Crop water use efficiency will also be influenced by the ability of the plant to maintain growth during periods of water stress. Osmotic adjustment is one trait that helps plants maintain turgor during periods of water deficit and hence sustain growth under increasingly dry conditions. Among the cool-season grain legumes, chickpea is considered to be relatively drought-tolerant, and there is evidence of significant levels of osmotic adjustment in chickpea during periods of moisture stress (Leport *et al.*, 1998,).

Sharma *et al.* (1988) showed that zinc deficiency reduced the osmotic potential in leaves of cabbage when plants were well watered. This reduction in the osmotic potential is probably associated with the increase in the concentration of sugars and soluble nitrogen compounds which can result from zinc deficiency, but there are no data describing how zinc deficiency may affect a plant's capacity for osmotic adjustment as water stress increases.

2.2.3 Stomatal conductance

Pushpavalli *et al.* (2015) showed physiological processes of plants in drying soil do not begin to decrease immediately after water is withheld, but there is a threshold soil water content at which transpiration and other physiological processes begin to decrease. In chickpea, studies on the threshold values when transpiration begins to decrease show large genotypic variation when drought stress was imposed during either the vegetative or the reproductive stage.

In grass pea (*Lathyrus sativus* L.), the threshold soil water content at which seed set was reduced coincided with that at which the leaf stomatal conductance and photosynthetic rate began to decrease (Kong *et al.*, 2015). To date, no studies on the threshold values of soil water content at which the development of reproductive organs (flowers, pods, and seeds) ceases have been undertaken in chickpea, and their association with plant water status, photosynthetic characteristics, and phytohormone production is unknown.

CHAPTER 3

MATERIALS AND METHODS

This chapter has been written on different resources, cultural managements, data collection and statistical analysis required in this experiment. The experiment was conducted during the period from October 2018 to March 2019 to study the response of chickpea varieties to drought situation. The details materials and methods of this experiment are presented below under the following headings:

3.1. Experimental site

The present research work conducted at the agricultural farm field of Sher-e-Bangla Agricultural University, Dhaka. The experimental area was situated at (90°33´E longitude and 23°77´N latitude at an altitude of 8.6 meter above the sea level.

3.2. Soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment.

3.3. Climate

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October.

3.4. Planting materials

The crop used in this study was cultivars of chickpea viz., BARI Chola-3, BARI Chola-4, BARI Chola-7, BARI Chola-9 and BARI Chola-10 varieties and also Binasola-3, Binasola-4 have been developed by the Bangladesh

Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) for cultivation in this country. The seeds were collected from BARI, Joydebpur, Gazipur and BINA, BAU campus, Mymensingh. The seeds were healthy, pulpy, well matured and free from mixture of other seeds, weed seeds and extraneous materials.

3.5. Land preparation

Power tiller was used for the preparation of the experimental field. Then it was exposed to the sunshine for 5/6 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed and deep ploughing was done to obtain good tilth, which was necessary to get better yield of this crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubble were removed from the experimental field. The plots were spaded one day before planting and the fertilizers were incorporated thoroughly as per treatment before planting according to fertilizers recommendation guide (BARC, 2012).

3.6. Fertilizers application

Urea, Triple super phosphate (TSP) and Muriate of potash (MoP) were used as a source of nitrogen, phosphorous and potassium, respectively in the experimental plot. The applied fertilizers were mixed properly with soil in the plot using a spade. (Source: BARC, 2012.)

Fertilizer	**Dose (kg ha^{-1})**
N	32
P	28
K	48
S	24
Zn	3.0
B	1.5
MoP	0.6

During land preparation TSP, MoP and half of urea used as basal dose, rest of urea applied in two splits. The micro nutrients were applied according to treatment.

3.7. Treatments of the experiment

The experiment consisted of 7 varieties as follows:

V_1 = BARI Chola-3

V_2 = BARI Chola-4

V_3 = BARI Chola-7

V_4 = BARI Chola-9

V_5 = BARI Chola-10

V_6 = Binasola-3

V_7 = Binasola-4

3.8. Experimental design and layout

The experiment will be laid out in a Randomized Complete Block Design (RCBD) with three (3) replications.

Number of treatments: 7

Number of replications: 3

Total Number of plots: 21

Plot size: 2.5 × 1.5

3.9. Sowing of seeds in the field

Seeds were sown on 17th October 2018. Row to row and plant to plant distances were 40 cm and 10 cm, respectively. Seeds were placed at about 2-3 cm depth from the soil surface.

3.10. Intercultural operations

3.10.1. Thinning

Emergence of seedling was completed within 10 days after sowing. Overcrowded seedling was thinned out two times. First thinning was done after 15 days of sowing which was done to remove unhealthy and lineless seedlings. The second thinning was done 10 days after first thinning.

3.10.2. Weeding

First weeding was done at 20 DAS and then second weeding at 40 DAS.

3.10.3. Disease and pest management

The research field looked nice with normal green plants. The field was observed time to time to detect visual difference among the treatments and any kind of infestation. The experimental crop was not infected with any disease and no fungicide was used. Hairy caterpillars attacked the young plants and accumulated on the lower surface of leaves where they usually sucked juice of green leaves. Borers also attacked the pods. To control these pests, the infected leaves were removed from the stem and destroyed together with insects by hand picking. Besides, spraying Pyriphos to control these insects. The insecticide was sprayed two times at seven days interval.

3.11. Harvesting and threshing

Harvesting of the crop was done after 120 days of sowing for data collection when about 80% of the pods attained maturity. After germination 2.5m×1.5m area from middle portion of each plot was marked for harvest at maturity. The harvested plants of 2.5m×1.5m of each treatment were brought to the cleaned threshing floor and separated pods from plants by hand and allowed them for drying well under bright sunlight.

3.12. Sampling and data collection

The data of the different parameters of chickpea were collected from randomly selected ten plant samples which were collected from each plot excluding border lines. The sample plants were uprooted carefully from the soil. Plant height (cm) at 30,45 and 60 days, no. of branch per plant at 30,45 and 60 days, days to first flowering, no. of pod per plant, no. of filled pod per plant, no. of unfilled pod per plant, hundred seed weight (g), seed yield (kg ha^{-1}) up to harvest. Yield and yield contributing parameters were recorded from the remarked plants from the central part of the plots. A brief outline of the data recording on morpho-physiological and yield contributing characters are given below.

Data was collected on the following parameters:

A. Morphological and Yield response of plant to drought :

i. Plant height (cm) at 30,45 and 60 days

ii. No. of branch per plant at 30,45 and 60 days

iii. Days to first flowering

iv. No. of pod per plant

v. No. of filled pod per plant

vi. No. of unfilled pod per plant

vii. Hundred seed weight (g)

viii. Seed yield (kg ha^{-1})

ix. Root length (cm)

x. Shoot length (cm)

xi. Fresh weight of plant (kg ha^{-1})

xii. Dry weight of plant (kg ha^{-1})

xiii. Biological yield (kg ha^{-1})

xiv. Harvest index (%)

B. Physiological response of plants to drought

i. SPAD value (%) of leaf at 60 DAP

ii. Membrane stability (%) at 80 DAP

iii. Stomatal conductance (m mol m^{-2} s^{-1}) at 80 DAP

A. Morphological and Yield Contributing Characters

3.12.1. Plant height (cm)

Plant height at 30,45 and 60 days was measured in centimeter by a meter scale at harvest period from the ground surface to the top of the main shoot and the mean height was expressed in cm.

3.12.2. No. of branches $plant^{-1}$

Number of branches per plant at 30,45 and 60 days was counted from selected plants. The average number of branches per plant was determined.

3.12.3 Days to first flowering

Days to 1st flowering were recorded by counting the number of days required to start flower initiation of chickpea plant in each plot.

3.12.4 No. of pod $plant^{-1}$

The number of pods per plant was observed and counted from each plot and average number of pods per plant was recorded as per treatment.

3.12.5 No. of filled pod plant^{-1}

The number of filled pods per plant was recorded randomly from selected pods at the time of harvest. Data were recorded as the average of 5 pods from each plot.

3.12.6 No. of unfilled pod plant^{-1}

The number of unfilled pods per plant was recorded randomly from selected pods at the time of harvest. Data were recorded as the average of 5 pods from each plot.

3.12.7 Hundred seed weight (g)

One hundred cleaned, dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and expressed in gram (g).

3.12.8 Seed yield (kg ha^{-1})

The seeds collected from 3.75 (2.5 m × 1.5 m) square meter of each plot were sun dried properly. The weight of seeds was taken and converted the yield in kg/ha.

3.12.9 Root length (cm)

Root were collected from five randomly selected plants. The root length was calculated from their mean values.

3.12.10 Shoot length (cm)

Shoot were collected from five randomly selected plants. The shoot length was calculated from their mean values.

3.12.11 Fresh weight of plant (kg ha^{-1})

The plant was harvested and taken weight of plants including roots, stem and leaves.

3.12.12 Dry weight of plant (kg ha^{-1})

The plant dry matter was taken by oven dry method. Collected plants including roots, stem and leaves was oven dried at 70˚ C for 72 hours then transferred into desiccator and allowed to cool down to the room temperature and final weight was taken and converted into total dry matter per plant.

3.12.13 Biological yield (kg ha^{-1})

The summation of economic yield (grain yield) and biomass yield (Stover yield) was considered as biological yield. Biological yield was calculated by using the following formula:

Biological yield= Grain yield + Stover yield (dry weight basis)

3.12.14. Harvest index (%)

It is the ratio of economic yield (grain yield) to biological yield and was calculated with the following formula:

% Harvest index (HI) = (Economic yield/Biological yield) ×100

B. Physiological Characters

3.12.15 SPAD value of leaf at 60 DAP

SPAD value of leaf was significantly affected at different stages of crop growth were recorded at 60 days. Data were recorded from 5 plants from each plot.

3.12.16 Membrane stability (%) at 80 DAP

Membrane Stability Index (MSI) was calculated by taking 100 mg fresh leaf sample in Petridis and immersing it in 10 ml of distilled water. This Petridis was kept in water bath at 45°C for 30 min. It was allowed to cool at room temperature and then water conductivity of sample (C1) was measured using Electrical Conductivity Meter. Again, the Petridis was kept in water bath at 100°C for 10 min. and subsequently cooled to room temperature and the final conductivity meter reading of the sample(C2) was measured. The Membrane Stability Index (MSI) was calculated using following formula.

$$MSI = [1- C1/ C2] X 100$$

3.12.17 Stomatal conductance (mmol $m^{-2}s^{-1}$) at 80 DAP

Stomatal conductance (mmol $m^{-2}s^{-1}$) was determined on both abaxial and adaxial surfaces of the terminal leaflet of the upper-most fully expanded leaf of the main stem or one of the basal branches 10 d after induction of water stress using a porometer (Model AP4, Delta-T Devices, Cambridge, UK). Measurements were taken between 12:00 and 14:00 h.

3.13. Statistical analysis

The data obtained from the experiment on various parameters were statistically analyzed in MSTAT-C computer program. The mean values for all the parameters were analyzed by analysis of variance (ANOVA) performed by the 'F' (variance ratio) test and the Least Significant difference (LSD) at 5% level of probability.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprised presentation and discussion of the results obtained from the study on the tolerant chickpea genotype under drought conditions based on morphological and physiological characteristics and to quantify the yield and yield attributes in drought situation. The analyses of variance (ANOVA) of the data on different morpho-physiological parameters and yield of chickpea are presented in Appendix III- VIII. The results have been presented and discussed in the different tables and graphs and possible interpretations are given under the following headings.

4.1 Plant height (cm)

Plant height varied significantly due to variety treatments (table 1). Plant height (cm) increased with days after sowing. It was observed that at 30 DAS BARI Chola-9 (V_4) produced the highest plant height of 9.60 cm which was followed by V_7 ((9.46 cm) and V_1 (8.66 cm) and they are statistically similar. BARI Chola-7 (V_3) produced the lowest plant height of 6.9 cm. At 45 DAS BARI Chola-9 (V_4) produced the highest plant height of 13.4 cm which was followed by V_4 (12.61 cm) and V_2 (12.21 cm) and they are statistically similar. BARI Chola-7 (V_3) produced the lowest plant height of 10.2 cm. At 60 DAS BARI Chola-3 (V_1) produced the highest plant height of 15.8 cm and BARI Chola-7 (V_3) produced the lowest plant height of 12.1 cm. Result shows that the BARI Chola-9 (V_4) shows statistically similar data compared to Binasola-4 (V_7) for the highest plant height at 30, 45 and 60 DAS. (Table 1)

Table 1: Plant height (cm) at different days after planting of different chickpea varieties under rainfed condition.

Varieties	Plant height (cm)		
	30 DAS	45 DAS	60 DAS
V_1	8.66 ab	13.43 a	15.80 a
V_2	7.53 ab	12.21 ab	14.37 a
V_3	6.99 b	10.25 b	12.18 a
V_4	9.60 a	12.61 ab	15.15 a
V_5	7.14 ab	10.83 b	13.95 a
V_6	8.39 ab	11.52 ab	12.51 a
V_7	9.46 ab	11.59 ab	12.89 a
CV (%)	17.62	12.45	16.42
LSD	2.5458	2.5669	3.9782

(CV=Coefficient of variance; In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance. V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

4.2 No. of branches per plant

Number of branches of chickpea varied significantly due to variety treatments. Number of branches of chickpea increased with days advancement of time. It was observed that BARI Chola-3 (V_1) produced the highest number of branches at 30 DAS (7) and BARI Chola-10 (V_5) produced the lowest number of branches at 30 DAS (3). BARI Chola-3 (V_1) produced the highest number of branches at 45 DAS (8) which was followed by V_2 (7.07) and V_6 (6.80). BARI Chola-10

(V_5) produced the lowest number of branches at 45 DAS (5). BARI Chola-3 (V_1) produced the highest number of branches at 60 DAS (14) and BARI Chola-10 (V_5) produced the lowest number of branches at 60 DAS (9).

Table 2: No. of branches per plant at different days after planting of different chickpea varieties under rainfed condition.

Varieties	No. of branches per plant		
	30 DAS	**45 DAS**	**60 DAS**
V_1	7.27 a	8.40 a	14.40 a
V_2	3.40 b	7.07 ab	11.53 b
V_3	3.33 b	6.13 b	10.27 b
V_4	3.40 b	6.73 b	9.80 b
V_5	3.20 b	5.53 b	9.60 b
V_6	3.47 b	6.80 ab	11.33 b
V_7	3.60 b	6.47 b	9.93 b
CV (%)	34.37	13.83	10.63
LSD	2.3791	1.6303	2.0437

(CV=Coefficient of variance; In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance. V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

4.3 Days to first flowering

Number of days to first flowering of chickpea varied significantly due to variety treatments (Figure 01). Result shows that the BARI Chola-7 (V_3) shows statistically similar data compared to BARI Chola-10 (V_5) and Binasola-3 (V_6) for the no. of days to first flowering.

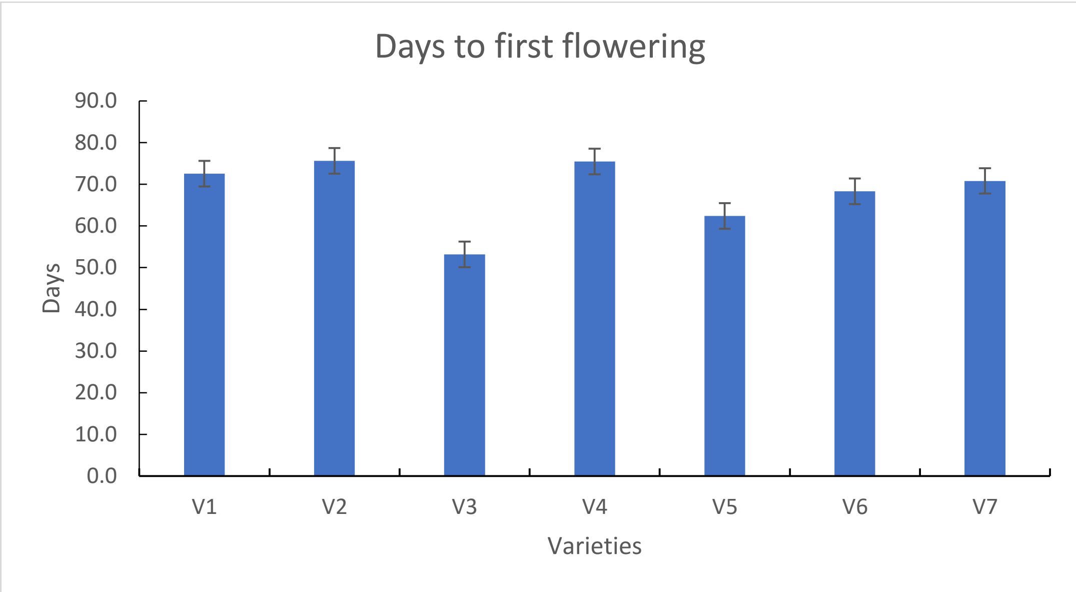

Figure 01: Effect of Chickpea varieties on no. of days for first flowering.

(V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

4.4 No. of pods per plant, no. of filled pods per plant and no. of unfilled pods per plant

Number of pods per plant, no. of filled pod per plant and no. of unfilled pod per plant of chickpea varied significantly due to variety treatments. It was observed that Binasola-4 (V_6) produced the highest number of pods (32.20) per plant which was followed by V_1 (29.47) and V_4 (25.40) However, Binasola-3 (V_6) produced the lowest number of (19.87) pods plant at harvest. (Table 3)

The significant variation between the chickpea varieties on no, of filled and unfilled pods per plant where the highest no, of filled pods were calculated from Binasola-4 (V_7) and the lowest no. of unfilled pods from BARI Chola-7 (V_3) which is statistically similar to Binasola-4 (V_7). For the lowest no. of filled pods was from Binasola-3 (V6) and highest no. of unfilled pods was on BARI Chola-3 (V_1). (Table 3)

Table 3: Effect of Chickpea varieties on no. of pods per plant, no. of filled and unfilled pods per plant.

Varieties	**No. of pods per plant**	**no. of filled pods per plant**	**no. of unfilled pods per plant**
V_1	29.47 ab	28.67 a	4.07 a
V_2	24.40 ab	21.60 a	3.33 ab
V_3	23.00 ab	19.87 a	3.13 b
V_4	25.40 ab	21.87 a	3.93 ab
V_5	20.40 ab	17.93 a	3.47 ab
V_6	19.87 b	17.07 a	3.67 Ab
V_7	32.20 a	29.13 a	3.60 Ab
CV (%) LSD	26.95 11.822	32.98 12.880	14.55 0.9171

(CV=Coefficient of variance; In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance. V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

4.5 Hundred seed weight (g)

100-seed weight of chickpea varied significantly due to variety treatment (Table 4). It was observed that BARI Chola-4 (V_2) produced the highest (14.60 g) 100-seed weight which was statistically similar with BARI Chola-10 (V_5) and BARI Chola-9 (V_4). BARI Chola-7 (V_3) produced the lowest (13.91 g) 100-seed weight.

4.6 Seed yield (kg ha^{-1})

Seed yield of chickpea varied significantly due to variety treatments (Table 4). It was observed that BARI Chola-3 (V_1) produced the highest (2262 kg ha^{-1}) seed yield which was statistically similar with BARI Chola-4 (V_2). Binasola-4 (V_7) produced the lowest (1618.7 kg ha^{-1}) seed yield. Khatun *et al.* (2010) and Bhuiyan *et al.* (2008) reported seed yield significantly influenced by chickpea variety.

Table 4: Effect of Chickpea varieties on 100-seed weight (g) and seed yield (kg ha^{-1}).

Varieties	Hundred seed weight (g)	Seed yield (kg ha^{-1})
V_1	14.34 a	2262 a
V_2	14.60 a	2205.4 ab
V_3	13.91 a	2172 abc
V_4	14.48 a	2082 abc
V_5	14.51 a	1868.7 d
V_6	14.40 a	1822 d
V_7	14.21 a	1618.7 e
CV (%)	3.40	15.15
LSD	0.8545	181.871

(CV=Coefficient of variance; In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance. V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

4.7 Root length (cm) and shoot length (cm)

Root length and shoot length of chickpea varied significantly due to variety treatments (Table 5). The highest root length can be observed from the variety BARI Chola-3 (V_1) 17.01 cm which was followed byV_3 (14.97cm) and they are statistically similar and the lowest from the genotype BARI Chola-10 (V_5) 13.51 cm. Whereas the highest shoot length was obtained from BARI Chola-3 (V_1) 61.79 cm which was folioed by V_7 (35.97 cm) and V_2 (34.75 cm) and they are statistically similar and the lowest from BARI Chola- 10 (V_5) 28.49 cm as well.

Table 5: Root and shoot length (cm) of different chickpea varieties under rainfed condition.

Varieties	Shoot length (cm)	Root length (cm)
V_1	61.79 a	17.01 a
V_2	34.75 ab	13.88 b
V_3	28.25 b	14.97 ab
V_4	34.91 ab	14.79 b
V_5	28.49 b	13.51 b
V_6	31.15 ab	14.80 b
V_7	35.97 ab	14.64 b
CV (%)	51.41	8.02
LSD	32.835	2.0793

(CV=Coefficient of variance; In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance. V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

4.8 Fresh weight (kg ha^{-1}) of plant and dry weight (kg ha^{-1}) of plant

Fresh weight and dry weight of chickpea varied significantly due to variety treatments (Figure 2). The highest fresh plant weight can be observed from the variety BARI Chola-9 (V_4) 3116.67 kg ha^{-1} and the lowest from the variety Binasola-3 (V_6) 1943.33 kg ha^{-1}. Whereas the highest dry weight was obtained from BARI Chola-9 (V_4) 317.1 kg ha^{-1} and the lowest from Binasola-3 (V_6) 197.7 kg ha^{-1} as well.

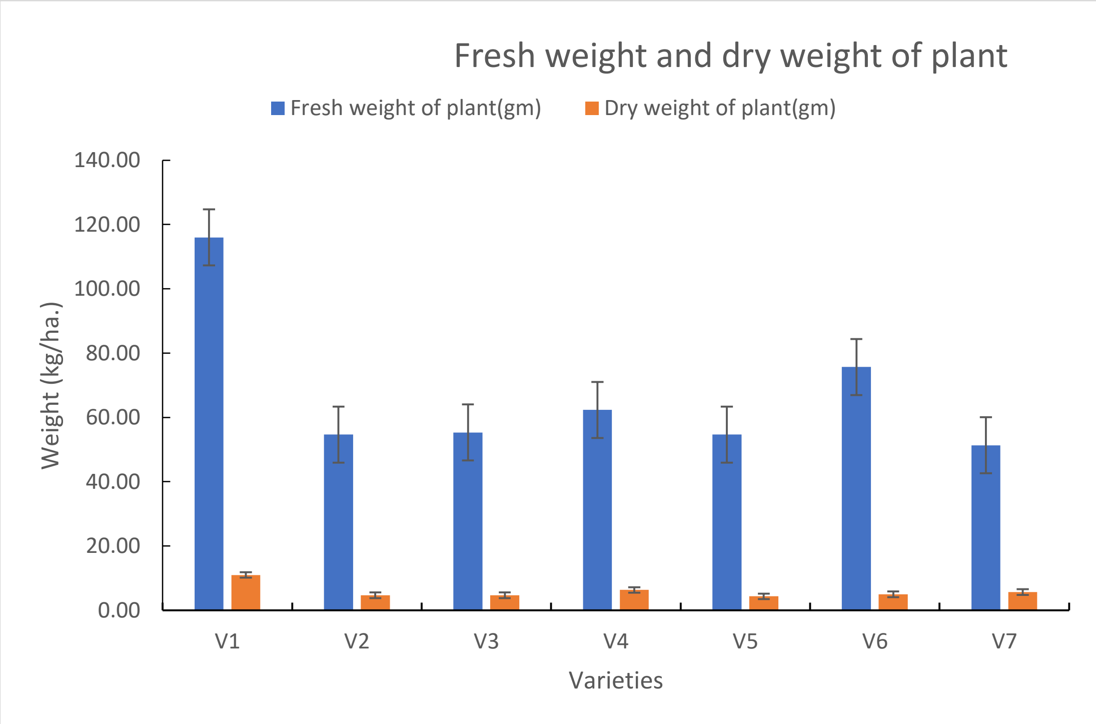

Figure 2: Effect of Chickpea varieties on fresh weight and dry weight of plant.

(V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

4.9 Biological yield (kg ha^{-1})

Biological yield also varied significantly due to variety treatments (Figure 3). It was observed that the Binasola-4 (V_7) produced the highest (2523.1 kg ha^{-1}) biological yield which was statistically similar to BARI Chola-7 (V_3) and BARI Chola-3 (V_1) and BARI Chola-10 (V_5) produced the lowest (1896.7

kg/ha) biological yield. Khatun *et al.* (2010) and Bhuiyan *et al.* (2008) also found significant variation of biological yield due to various chickpea variety.

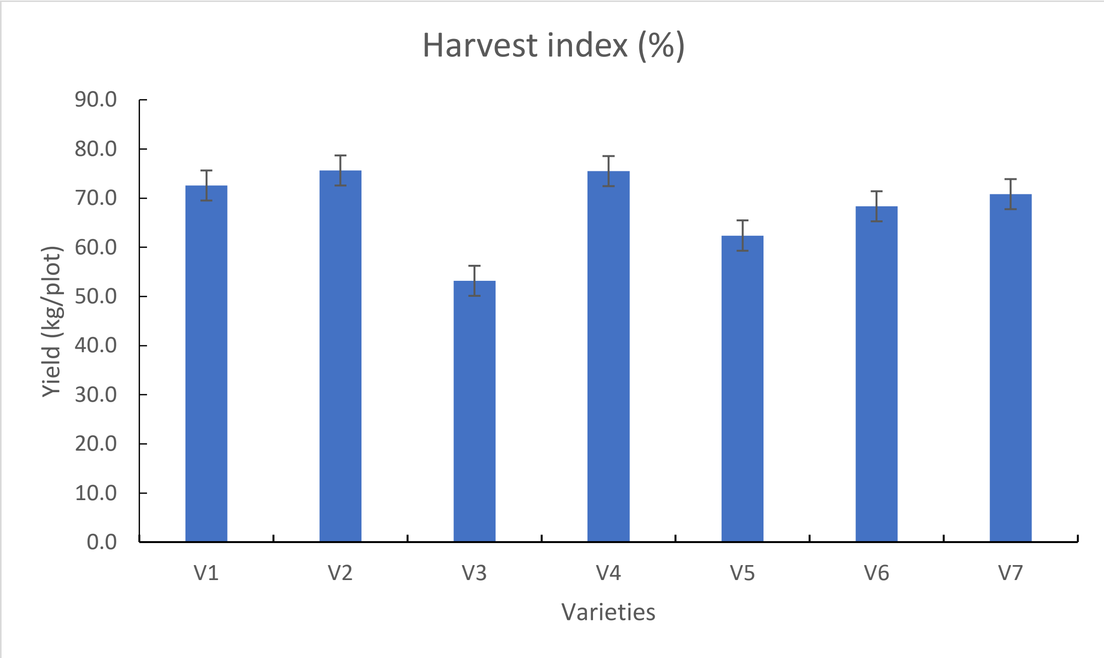

Figure 3: Effect of Chickpea varieties on biological yield.

(V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

4.10 Harvest index (%)

Harvest index vary significantly due to variety treatments (Figure 4). It was observed the Binasola-3 (V_6) produced the highest (91%) harvest index numerically which is statistically similar to BARI Chola-3 (V_1) with (90%) while BARI Chola-7 (V_3) produced the lowest (54%) harvest index numerically. However, Bhuiyan *et al.* (2008) reported significant variation of harvest index due to various chickpea variety.

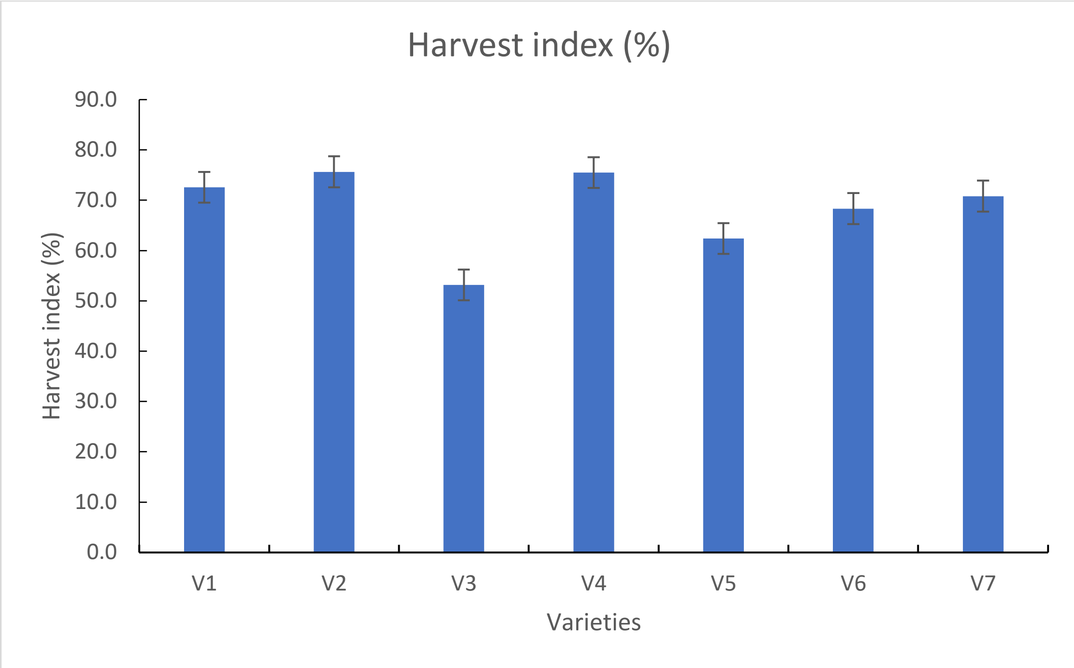

Figure 4: Effect of Chickpea varieties on harvest index (%)

(V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

4.11 SPAD Value (%) of leaf at 60 DAP

SPAD value (%) of leaf at 60 DAP don't show significant variance due to variety treatments (Table 6). However, it was observed the BARI Chola-10 (V_5) produced the SPAD value of leaf at 60 DAP (49.50%) while Binasola-4 (V_7) produced the lowest (44.16 %) SPAD of leaf at 60 DAP.

4.12 Membrane stability (%) at 80 DAP

Membrane stability at 80 DAP don't show significant variance due to variety treatments (Table 6). It was observed the BARI Chola-4 (V_2) produced the highest (55.37%) Membrane stability at 80 DAP which is statistically similar to BARI Chola-9 (V_4) with (54.69%) Membrane stability at 80 DAP while Binasola-4 (V_7) produced the lowest (48.88%) Membrane stability at 80 DAP.

4.13 Stomatal conductance (mmol $m^{-2}s^{-1}$) at 80 DAP

Stomatal conductance at 80 DAP show significant variance due to variety treatments (Table 6). It was observed the BARI Chola-3 (V_1) produced the highest (375.67 mmol $m^{-2}s^{-1}$) Stomatal conductance at 80 DAP while Binasola-4 (V_7) produced the lowest (169.90 mmol $m^{-2}s^{-1}$) Stomatal conductance at 80 DAP.

Table 6: SPAD value of leaf at 60 DAP, membrane stability (%) at 80 DAP and stomatal conductance (mmol $m^{-2}s^{-1}$) at 80 DAP of different chickpea varieties under rainfed condition.

Varieties	SPAD value of leaf at 60 DAP	Membrane stability (%) at 80 DAP	Stomatal conductance (mmol $m^{-2}s^{-1}$) at 80 DAP
V_1	45.21 a	49.21 a	375.67 A
V_2	46.76 a	55.37 a	320.40 B
V_3	47.91 a	50.44 a	231.80 D
V_4	45.95 a	54.69 a	329.40 B
V_5	49.50 a	50.48 a	339.87 B
V_6	47.04 a	54.08 a	263.50 C
V_7	44.16 a	48.88 a	169.90 E
CV (%)	6.61	11.52	15.09
LSD	5.4000	10.469	279.87

(CV=Coefficient of variance; In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of significance. V_1 = BARI Chola-3, V_2 = BARI Chola-4, V_3 = BARI Chola-7, V_4 = BARI Chola-9, V_5 = BARI Chola-10, V_6 = Binasola-3 and V_7 = Binasola-4.)

CHAPTER 5

SUMMARY AND CONCLUSION

The present experiment was conducted in the Agricultural farm field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during rabi season (from October 2018 to March 2019) determine to study the response of chickpea varieties to drought situation. The experiment was laid out in a Randomized Complete Block Design with three replications. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the varieties in respect majority of the observed parameters.

Plant height (cm) increased with days after sowing. It was observed that BARI Chola-9 (V_4) produced the highest plant height at 30, 60 and 90 DAS. BARI Chola-3 (V_1) produced the highest number of branches at 30, 45 and at 60 DAS. BARI Chola-7 (V_3) shows statistically similar data compared to BARI Chola-10 (V_5) and Binasola-3(V_6) for the no. of days to first flowering. It was observed that Binasola-4 (V_7) produced the highest number of pods (32.20) per plant. highest no, of filled pods were calculated from Binasola-4 (V_7) and highest no. of unfilled pods was on BARI Chola-3 (V_1). It was observed that BARI Chola-4 (V_2) produced the highest (14.60 g) 100-seed weight which was statistically similar with BARI Chola-3 (V_3) and BARI Chola-9 (V_4). BARI Chola-3 (V_1) produced the highest (2262 kg ha^{-1}) seed yield which was statistically similar with BARI Chola-4 (V_2). The highest root length can be observed from the genotype BARI Chola-3 (V_1) 17.01 cm and the highest shoot length was obtained from BARI Chola-3 (V_1) 61.79 cm. The highest fresh plant weight can be observed from the genotype BARI Chola-9 (V_4) 3116.67 kg ha^{-1} and the highest dry plant weight BARI Chola-9 (V_4) 317.1 kg ha^{-1}. It was observed that the Binsola-4 (V_7) produced the highest (2523.1 kg ha^{-1}) biological yield. Binasola-3 (V_6) produced the highest (91%) harvest index numerically which is statistically similar to Binasola-3 (V_6) with (75.5%). BARI Chola-10 (V_5) produced the SPAD value (%) of leaf at 60 DAP (49.50 %) while Binasola-4 (V_7) produced the lowest (44.16%) SPAD value of leaf at 60 DAP. BARI Chola-4 (V_2) produced the highest (55.37%)

Membrane stability at 80 DAP which is statistically similar to BARI Chola-9 (V_4) with (54.69%) Membrane stability at 80 DAP while Binasola-4 (V_7) produced the lowest (48.88%) Membrane stability at 80 DAP. BARI Chola-3 (V_1) produced the highest (375.67 mmol m^{-2} s^{-1}) stomatal conductance at 80 DAP while Binasola-4 (V_7) produced the lowest (169.90 mmol $m^{-2}s^{-1}$) stomatal conductance at 80 DAP.

Considering the above results, it may be summarized that growth, seed yield contributing parameters of chickpea are positively correlated with variety and experimental results suggest that the BARI chola-3 would be suggested as drought tolerant varieties as they perform better to drought situation.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. The results are required to substantiate further with different varieties of chickpea.
3. It needs to conduct more experiments with drought situation whether can regulate the growth, yield and seed quality of BARI chola-3 and BARI chola-4.

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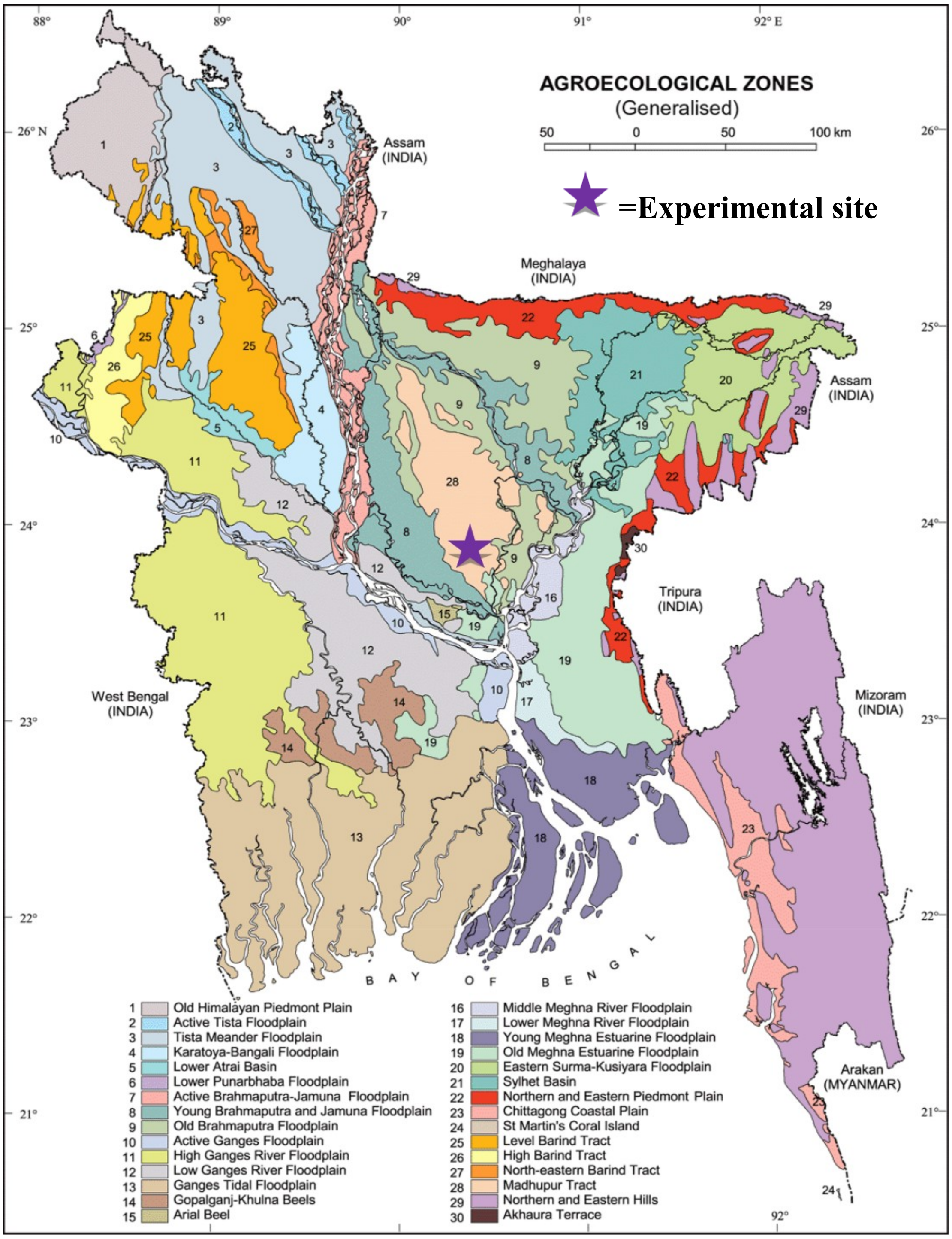
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University farm field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical characteristics

Soil characters	Value
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix III. Monthly meteorological information during the period from October, 2018 to April, 2019

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2018	October	29.05	17.56	56.23	18
	November	28.10	11.83	58.18	12
	December	25.00	9.46	69.53	00
2019	January	25.2	12.8	69	00
	February	27.3	16.9	66	39
	March	31.7	19.2	57	23
	April	33.50	25.90	64.50	119

Source : Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data on plant height of Chickpea as influenced by different variety

Source of variation	df	Mean square of plant height at different days after transplanting		
		30 DAS	45 DAS	60 DAS
Treatment	6	3.37095*	3.51381*	5.69333*
Error	14	2.11333	2.14857	5.16048
Total	20	5.4812	5.6623	10.8537
CV		17.62	12.45	16.42
Grand mean		8.2524	11.771	13.833

*Significant at 5% level of significance

^{NS} Non significant

Appendix V. Analysis of variance of the data on no. of branches plant⁻ Chickpea as influenced by different variety

Source of variation	Df	Mean square of no. of branches plant^{-1} at different days after transplanting		
		30 DAS	45 DAS	60 DAS
Treatment	6	6.45206*	2.38222*	8.51429*
Error	14	1.84571	0.86667	1.36190
Total	20	8.2977	3.24889	9.87619
CV		34.37	13.83	10.63
Grand mean		3.9524	6.7333	10.981

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on Interaction effect of fresh weigh, dry weight, seed yield/pot and harvest index of Chickpea as influenced by different variety

Source of variation	df	Mean square of			
		Fresh weight	Dry weight	Seed yield/plot	Harvest Index
Treatment	6	1591.76*	16.2698*	1706.63*	197.070*
Error	14	2047.71	25.5238	2185.67	175.224
Total	20	3639.47	41.7936	3892.3	372.294
CV		67.40	84.88	15.15	19.37
Grand mean		67.143	5.9524	308.57	68.347

*Significant at 5% level of significance

^{NS} Non significant

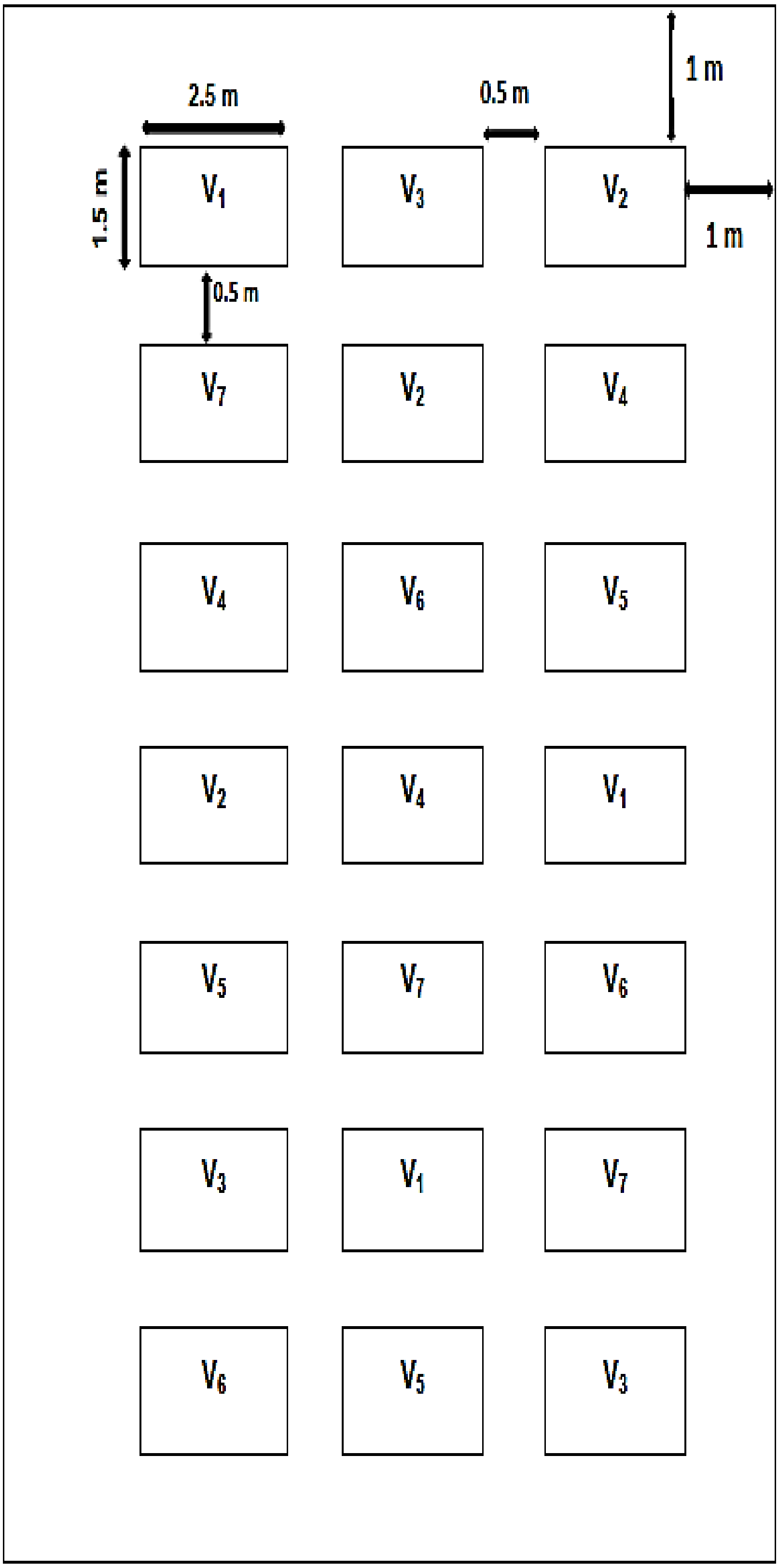
Appendix VII. Analysis of variance of the data on Interaction effect of fresh weigh, dry weight, seed yield/pot and harvest index of Chickpea as influenced by different variety

Source of variation	df	Mean square of		
		SPAD value of leaf (%) at 60 DAP	Membrane stability (%) at 80 DAP	Stomatal conductance (mmol $m^{-2}s^{-1}$) at 80 DAP
Treatment	6	9.33256*	22.5772*	15407.7*
Error	14	9.50860	35.7366	25541.6
Total	20	18.8411	58.3138	40.949.3
CV		6.61	11.52	55.09
Grand mean		46.646	290.08	51.879

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Layout of the experiment



PLATES

Plate 1. Experimental plot preparation

Plate 2. Collected chickpea seed

Plate 3. Fertilization in experimental plot

Plate 4. Intercultural operation

Plate 5. Multipennate formation in chickpea to reduce energy

Plate 6. Pod formation in chickpea