GROWTH AND YIELD VARIATIONS IN CHICKPEA AS INFLUENCED BY PLANTING GEOMETRY

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Dedicated

To

My Beloved Parents and Younger Brother

DEPARTMENT OF AGRONOMY
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CERTIFICATE

This is to certify that the thesis entitled **"GROWTH AND YIELD VARIATIONS IN CHICKPEA AS INFLUENCED BY PLANTING GEOMETRY"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRONOMY,** embodies the results of a piece of bona fide research work carried out by **MST. NAZMUN NAHAR** Registration. No. 10-04193, under my supervision and guidance. No part of this 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.

Dated:

Dhaka, Bangladesh

(Prof. Dr. Md. Fazlul Karim)

Supervisor

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GROWTH AND YIELD VARIATIONS IN CHICKPEA AS INFLUENCED BY PLANTING GEOMETRY

ABSTRACT

A field experiment was conducted at the Agronomy field laboratory of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November, 2015 to April, 2016 in rabi season with a view to study the growth and yield variations in chickpea as influenced by planting geometry. The experiment was carried out in split plot design considering three variety's *i.e*. BARI Chola-5, BARI Chola-6 and BARI Chola-9 in the main plot and five spacing viz. Sp_1 = 40 cm × 10 cm, Sp_2 = 30 cm × 30 cm, Sp_3 = 40 cm × 40 cm, Sp_4 = 50 cm × 50 cm and Sp_5 = 60 cm × 60 cm. The recommended dose of N, P_2O_5, K_2O, B at the rate of 20, 40, 20, 1 kg ha^{-1}, respectively were added to the soil of experimental field. Results indicated that among the varieties BARI Chola-5 performed well and gave maximum number of branches $plant^{-1}$ (46.93), leaves $plant^{-1}$ (344.8), above ground dry weight $plant^{-1}$ (22.92 g), pods $plant^{-1}$ (50.43), seed yield (0.78 t ha^{-1}); stover yield (1.09 t ha^{-1}) and biological yield (1.87 t ha^{-1}). In case of different spacing treatment 40 cm × 40 cm gave maximum branches $plant^{-1}$ (49.62), leaves $plant^{-1}$ (353.6), above ground dry weight $plant^{-1}$ (24.06 g), pods $plant^{-1}$ (47.49). Wider spacing had 33.67 % and 54.14 % value advantages over low yielder spacing regarding above ground dry weight $plant^{-1}$ and pods $plant^{-1}$. Narrower spacing (40 cm × 10 cm) gave more yield than wider spacing due to more number of plants per unit area. In combination treatment BARI Chola-5 along with spacing of 40 cm × 40 cm gave maximum branches $plant^{-1}$ (60.22), leaves $plant^{-1}$ (450.2), above ground dry weight $plant^{-1}$ (26.89 g), pods $plant^{-1}$ (66.00). Seed yield (1.82 t ha^{-1}) was recorded maximum from treatment BARI Chola-5 combined with 40 cm × 10 cm and the minimum 0.23 t ha^{-1} with BARI Chola-6 combined with 60 cm × 60 cm. From the results of present study it can be concluded that wider spacing influenced individual plant with vigorous growth and development but failed to show optimum seed yield due to lower number of plant per unit area.

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BINA	=	Bangladesh Institute of Nuclear Agriculture
SRI	=	System of Rice Intensification
SCI	=	System of Crop Intensification
SSI	=	System of Sugarcane Intensification
BBS	=	Bangladesh Bureau of Statistics
DAS	=	Days after sowing
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MoP	=	Muriate of Potash
Ca	=	Calcium
Mg	=	Magnesium
K	=	Potassium
P	=	Phosphorous
Fe	=	Iron
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
g	=	Gram
kg	=	Kilogram
mm	=	Millimeter
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
HI	=	Harvest Index
No.	=	Number
Wt.	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Non-significant
%	=	Percent
CV%	=	Percentage of coefficient of variance
T	=	Ton
viz.	=	Videlicet (namely)

CHAPTER I

INTRODUCTION

Global population is predicted to double by 2050 (http://www.fao.org), imposing an increasing demand for balanced food that comes together with an increasing concern on environment and food security. A second green revolution is needed to ensure food and nutritional security for the steadily growing people inside the face of global climate change. Grain legumes offer an unparalleled solution to this problem because of their low production cost with inbuilt capacity of symbiotic nitrogen fixation.

Chickpea (*Cicer arietinum* L.) belongs to the family Fabaceae is an important food legume grown in the world. It is an annual cool season crop and extensively used for human consumption. Chickpea is thought to be originated in south-eastern Turkey adjoining Syria (Ladizinsky, 1975) and subsequently spread to the west & south through silk route (Singh *et al.*, 1997). Two types of chickpea i.e. Deshi and Kabuli chickpeas are cultivated throughout the world. Among the temperate pulses, chickpea is the most tolerant crop to heat and drought stress and is fit for cultivation in low fertility soils. It is normally sown in the post monsoon i.e., during rabi season. In Bangladesh, chickpea is grown on well drained alluvial to clay loam soils having pH ranging from 6.0 to 7.0.

Chickpea due to its high protein contents (26%) and high digestibility (70-90%) is considered a good substitute of animal protein (Williams & Singh, 1987; Kaul, 1982). It plays a unique role in the diets of resource poor people majority of which cannot manage to pay for animal protein for balanced nutrition. According to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) chickpea seeds contain on average 64% total carbohydrates (47% starch, 6% soluble sugar), 5% fat, 6% crude fiber and 3% ash. Chickpea nutrition is a potent package of protein, vitamins and minerals and thus are often included in many healing diets**.** Its seeds contain essential amino acids like leucine, lysine, isoleucine, phenylalanine and valine (Karim & Fattah, 2006).

Moreover, it can be considered as a good source of vitamins such as riboflavin, niacin, thiamine, folate and the vitamin A precursor of β-carotene and additionally an incredible source of absorbable minerals like Ca, Mg, K, P and Fe (Chavan *et al.*, 1986;

Christodoulou, 2005). Chickpea provides a range of specific health benefits. It has been cited by lowering cholesterol level in the bloodstream, increasing satiety, boosting digestion, protecting cancer in particular colon cancer and keeping blood sugar levels stable.

Being a leguminous crop, it is capable of fixing atmospheric nitrogen in root which is used for crop growth and development and also for soil nitrogen increase. Chickpea plant improves soil with organic matter and nodule nitrogen which is very beneficial in our cropping system. It is also good for livestock feeding. Therefore, the inclusion of chickpea in an exhaustive crop rotation is very effective. Considering the nutritional value along with environmental benefit there is huge potentiality to cultivate chickpea in our country.

In Bangladesh chickpea is the third major pulse crop after grasspea (*Lathyrus sativus*) & lentil (*Lens culinaris*). It contributes 1.68% to total pulse production of Bangladesh (BBS, 2016). Chickpea occupied 7074 hectare of land producing 6672 metric ton (BBS, 2016). The average yield of chickpea in Bangladesh is lower than the other chickpea producing countries in the world (BBS, 2016).

A number of factors are responsible for lower yield of chickpea. Of different factors, the crucial one for determining yield is spacing. Normal physiological activities of crops are directly affected by spacing. Improper spacing cause a considerable reduction in yield which is because of competition for light, space, water, nutrient etc. among the plants or want of desired plant population per unit area. On the contrary, optimum spacing assures better growth and ultimately higher yield through better utilization of natural resources without any competition between plants.

Variety is undoubtedly an important factor in generating better yield of a crop. But good yields even from the high yielding varieties cannot be achieved without the adoption of improved package of technology. The promising technologies generated by researchers can play a pivotal role in increasing productivity and in this regard the square geometry used in system of rice intensification was put to use.

System of rice intensification, SRI is claimed to be a novel and promising approach to rice cultivation that is both more productive and more sustainable than conventional methods (Dominic, 2011).

It was developed in 1980s in Madagascar (Laulanie, 1993) and rice yields have been improving in many countries showing plant more resilience to the hazards of climate change (Thakur *et al*., 2009; Zhao *et al*., 2009). It is a system of agronomic manipulation (Uphoff *et al*., 2002) which optimize growing conditions for plants particularly in the root zone. In this method crops are planted singly in a square grid pattern which provide plant wider space to encourage greater root and canopy growth. This system facilitates aeration and light penetration in to plant canopy for optimizing rate of photosynthesis. By adopting these principles the production of rice has been reported to increase from 50 to 100 per cent (Uphoff, 2002) and reduced seed cost by 80-90% and water savings up to 25-50%.

It is such a method which produces more from much less, using fewer seeds and less water, but cautiously managing the connection between plant and soil. The reduced want of inputs like seed, water and fertilizer makes SRI less expensive to poor smallholders, and its successes decorate its potential for replication. In recent years, the adaptation of SRI experience and principles to other crops (wheat, mustard, sugarcane, finger millet, pulses etc.) showing increased productivity over conventional planting practices (http:// sri.cals.cornell.edu, 2015; Khadka *et al*., 2012), is being referred as the system of Crop Intensification (SCI). Similar to SRI, the SCI practices also proved to increase the yield levels of crops more than two times (Uphoff *et al*., 2011). In pursuit of extending the beneficial effect of SCI, the present study was programmed in Chickpea.

Research work on planting geometry of chickpea is very limited in Bangladesh. In view of this fact it is thought that this new technique could improve chickpea yield exploring food security options for Bangladesh. Considering the above facts the present research was designed with the following objectives-

1) To study the response of different varieties on the growth and yield of chickpea,

2) To evaluate the effect of spacing on the growth and yield of chickpea, and

3) To determine the combined effect of variety and spacing on the growth and yield of chickpea

CHAPTER II

REVIEW OF LITERATURE

Chickpea is an important pulse crop grown and consumed throughout the world. Farmers in our country usually cultivate chickpea using traditional methods. No research work has been conducted regarding planting geometry in chickpea in our country. So research findings in this regard is almost zero. However some relevant works on these have been reviewed in this chapter under the following headings.

2.1. Effect of Variety on growth and yield of chickpea

2.1.1. Plant height

Roy *et al*. (2016) studied the effect of supplementary nitrogen, irrigation and hormones on growth and reproductive behaviour of chickpea. Chickpea varieties showed significant variation on plant height at different DAS. The tallest plant 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.

To evaluate the performance of three chickpea varieties (Flip-1, Flip-2 and Flip-3) under rainfed condition Tahir *et al*. (2015) conducted a study at Bakrajo, Sulaimani in Iraq. Results revealed that the effect of varieties on plant height was significant. Flip-1 produced the tallest plants (11.94 cm) being closely followed by Flip-3 (11.82 cm). The shortest plants (7.54 cm) were found in Flip-2. Variation among the varieties in respect of plant height appears due to genotype variation.

Kabir *et al.* (2009) carried out a study to determine the effect of sowing time and varieties on the growth and yield performance of chickpea under rainfed condition. The varieties used were BARI Chola-2, BARI Chola-4, and BARI Chloa-6. The tallest plants (32.30 cm) were observed in BARI Chola-4 which was statistically in line with BARI Chola-2 (30.9 cm) while the shortest plant (29.26 cm) were found in BARI Chola-6.

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. Branches plant^{-1}

Sikdar *et al*. (2015) conducted an experiment on variety and sowing time on the growth and yield of chickpea (*Cicer arietinum* L.) in southern region of Bangladesh 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 number of branches per plant (20.32) were obtained from BARI Chola-4.
Shamsi *et al.* (2011) stated that the number of branches of chickpea was not affected by variety.

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. Total dry weight plant^{-1}

Field experiment was conducted by Rani and Krishna (2016) at Regional Agricultural Research Station, Nandyal (Andhra Pradesh) to study the response of chickpea varieties to nutrients levels on a calcareous vertisols. The experiment comprised of four varieties i.e., NBeG-3, NBeG-28, JG-11 and KAK-2 and with four nitrogen levels i.e., 0, 20, 30 and 40 kg/ha. Among the varieties significantly higher dry matter production at harvest was recorded with JG-11 while it was lowest with KAK-2.

2.1.4. Nodule dry weight

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 BARI Chola-3 gave significantly higher nodule weight.
Solaiman *et al.* (2007) studied the response of five chickpea (*Cicer arietinum* L) varieties to *Rhizobium* inoculant and mineral nitrogen on nodulation, nitrogen fixation,

dry matter production, nitrogen (N) uptake, yield and quality of the crop and found that BARI Chola-5 performed best in recording number and dry weight of nodules.

A study conducted by Eusuf Zai *et al.* (1999) showed that significantly higher nodules were found in variety BARI Chola-6.

Gupta and Namdeo (1986) in India from their study reported that nodulation and yield of chickpea varied significantly due to use of different varieties.

2.1.5 Pods plant^{-1}

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 recorded highest number of pods per plant in 2012-13 and variety H08-18 in 2013-14.

An experiment was completed by Sikdar *et al*. (2015) to find out the Effect of variety and sowing time on the growth and yield of chickpea (*Cicer arietinum* L.) in southern region of Bangladesh 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 number of pods per plant (62.57) were obtained from BARI Chola-4.

2.1.6 Seeds pod^{-1}

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 highest number of seeds pod^{-1} (1.35) were obtained from BARI Chola-4.

To investigate the effects of autumn and spring sowing dates on yield and yield components of chickpea varieties a field experiment was carried out in Shahre-Rey region, in south of Tehran, Iran by Sadeghipour and Aghaei (2012) with five chickpea varieties (Arman, Azad, Hashem, ILC1799 and ILC482) and five sowing dates

(October 12, November 02 and November 22 as autumn sowing dates and March 16 and April 06 as spring sowing dates). Data from their investigation indicated that number of seeds pod^{-1} varied significantly due to different varieties. Hashem variety produced maximum seeds pod^{-1} (1.06) while ILC482 produced minimum seeds pod^{-1} (0.95).

2.1.7. 1000-seeds 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.

Karasu *et al.* (1990) investigated the effect of bacterial inoculation and different nitrogen doses on yield and yield components of some chickpea genotypes (*Cicer arietinum* L.) and found significant variation in 1000 seeds weight due to different genotypes of chickpea.

2.1.8. Seed yield and stover yield

Experiment was conducted by Harikesh *et al.* (2016) to determine the effect of integrated nutrient management modules on growth and yield of high yielding varieties of chickpea (*Cicer arietinum* L.) under late sown condition by taking twelve treatments viz. three varieties (Uday, Avarodhi and Push362) and four nutrient management modules viz. Control, RDF (20 kg N + 50 kg P_2O_5 + 0 kg K_2O)+ RC (Rhizobium culture), RDF (20 kg N + 50 kg P_2O_5 + 0 kg K_2O)+ PSB (Phosphorus solubilizing bacteria), RDF (20 kg N + 50 kg P_2O_5 + 0 kg K_2O)+RC +PSB. The result showed that grain and straw yields of chickpea was significantly affected due to different varieties. The chickpea variety PUSA-362 produced maximum grain and straw yields, which was significantly superior over Uday variety and found at par with Avarodhi.

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 (Binasola-4, Binasola-3 and Hyprosola). The results showed that Binasola-4 produced higher seed yield (2085 kg ha^{-1}) followed by Binasola-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.

Hasanuzzaman *et al.* (2007) carried out an experiment during the period from November, 2005 to March, 2006. Three varieties viz. BARI chola-1, BARI chola-4 and

BARI chola-5 were given foliar spray of water spraying and 1500 ppm KNap as treatment variables to study the response of chickpea varieties to the application of growth regulator. Among the varieties, BARI chola-5 with 1500 KNap gave the maximum seed yield (1.81 t ha $^{-1}$) which was 36.09% more over BARI chola-1 which produced the lowest seed yield (1.33 t ha $^{-1}$).

Nagarajaiah *et al.* (2005) studied the response of chickpea (*Cicer arietinum* L.) varieties to seed rate and time of sowing under late sown conditions at Water Management Research Centre, Belvatagi (Karnataka) and recorded significantly higher seed yield (1408 kg ha^{-1}) in chickpea variety Annigeri-1 over ICCV-2 (1332 kg ha^{-1}).

2.1.9. Biological yield

Experiment was conducted by Harikesh *et al.* (2016) to determine the effect of integrated nutrient management modules on growth and yield of high yielding varieties of chickpea (*Cicer arietinum* L.) under late sown condition by taking twelve treatments viz. three varieties (Uday, Avarodhi and Push 362) and four nutrient management modules viz. Control, RDF (20 kg N + 50 kg P_2O_5 + 0 kg K_2O)+ RC (*Rhizobium* culture), RDF (20 kg N + 50 kg P_2O_5 + 0 kg K_2O)+ PSB (Phosphorus solubilizing bacteria), RDF(20 kg N + 50 kg P_2O_5 + 0 kg K_2O)+RC +PSB. The results showed that the chickpea variety PUSA-362 produced maximum biological yield, which was significantly superior over Uday variety and found at par with Avarodhi.

To investigate the effects of autumn and spring sowing dates on yield and yield components of chickpea varieties a field experiment was carried out in Shahre-Rey region, in south of Tehran, Iran by Sadeghipour and Aghaei, (2012) with five chickpea varieties (Arman, Azad, Hashem, ILC1799 and ILC482) and five sowing dates (October 12, November 02 and November 22 as autumn sowing dates and March 16 and April 06 as spring sowing dates). Data from their investigation indicated that varieties had significant effects on biological yield. Variety ILC1799 gave the highest biological yield (691.2 g m^{-2}) while the lowest biological yield (515.4 g m^{-2}) was produced in variety ILC482.

2.1.10 Harvest index

To find out the effect of variety and sowing time on the growth and yield of chickpea (*Cicer arietinum* L.) in southern region of Bangladesh, Sikdar *et al.* (2015) conducted an experiment 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 harvest index (41.89%) was obtained from BARI Chola-4.

Sadeghipour and Aghaei (2012) investigated the effects of autumn and spring sowing dates on yield and yield components of chickpea varieties with five chickpea varieties (Arman, Azad, Hashem, ILC1799 and ILC482) and five sowing dates (October 12, November 02 and November 22 as autumn sowing dates and March 16 and April 06 as spring sowing dates) and found significant variation in HI among different varieties of chickpea. Arman variety produced maximum harvest index (40.34%) against Hashem variety.

2.2 Effect of Spacing on plant characters of chickpea

2.2.1 Plant height

Bavalgave *et al*. (2009) conducted an experiment on growth and yield of Kabuli chickpea varieties (ICCV - 2, Virat, Vihar, and KAK - 2) as influenced by different spacing **(**30 cm × 10 cm, 30 cm × 15 cm, 45 cm x 10 cm and 45 cm x 15 cm). The results revealed that the tallest plants were observed at a closer spacing of 30 cm × 10 cm followed by rest of spacing.

Ali *et al*. (1999) carried out an investigation to evaluate the effect of intra and inter row spacing on the yield and yield components of chickpea. The treatments of the experiment included three inter (10, 20, 30 cm) and intra (5, 10, 15 cm) row spacing. The results indicated that planted height was significantly increased with an increase in intra and inter row spacing.

Fleton *et al*. (1996) and Sharar *et al*. (2001) reported tallest plant of chickpea in higher plant population treatments due to more competition for light.

2.2.2. Branches plant^{-1}

To study the effect of different inter row (20, 30, 40, 50 cm) and intra row spacing (5, 10, 15 cm) on growth parameters, yield components and yield of Desi chickpea Agajie (2013) conducted an experiment in Assosa Woreda of western Ethiopia and reported that interaction of 50 cm inter and 15 cm intra-row spacing resulted in the highest number of primary branches plant^{-1} which was statistically at par with the interaction of 50 cm inter- and 10 cm intra-row spacing. While the lowest number of branches per plant was obtained from interaction of 20 cm inter- and 5 cm intra-row spacing.

Togay *et al*. (2005) and Bakry *et al*. (2011) noticed decreased number of primary branches with the increase in density of chickpea.

Sarwar (1998) from his study reported that the number of branches plant^{-1} in chickpea were significantly influenced by row spacing.

2.2.3. Total dry weight plant^{-1}

Agajie (2013) conducted an experiment to determine the effect of different inter row (20, 30, 40, 50 cm) and intra row spacing (5, 10, 15 cm) on growth parameters, yield components and yield of Desi chickpea in Assosa Woreda of western Ethiopia. The results revealed that intra and inter row spacing and their interaction significantly influenced total dry biomass production. The highest dry matter (10650.27 kg ha^{-1}) was obtained from 20 cm × 5 cm spacing combination and the lowest dry matter content (2186.69 kg ha^{-1}) from 50 cm ×15 cm spacing.

Beech and Leach (1989) grew chickpea at row spacings of 18, 36, 53 and 71 cm with plant densities of 14, 28. 42 and 56 plants m^{-2} and reported that row spacing had a little effect on total dry matter production of chickpea.

2.2.4 Pods plant^{-1}

Agajie (2013) worked on the effect of different inter row (20, 30, 40, 50 cm) and intra row spacing (5, 10, 15 cm) on growth parameters, yield components and yield of Desi chickpea in Assosa Woreda of western Ethiopia and reported that intra and inter row spacing and their interaction significantly influenced number of pods per plant. The highest number of pods per plant (34.7) was obtained from 40 cm inter- and 10 cm intra- row spacing which was statistically in line with 50 cm ×10 cm and 50 cm ×15 cm spacings. The lowest number of pods per plant was obtained from the closest spacing of 20 cm ×5 cm.

Pooniya *et al*. (2009) conducted an experiment with different row spacings and weed control and reported that 40 cm row spacing produced significantly higher number of pods per plant as compared to 20 cm and 30 cm of row spacing.

Shamsi (2009) conducted an experiment at Kermanshah, Iran on the effects of sowing date and row spacing on yield and yield components of chickpea variety Hashem. The results showed significant differences between the planting date and planting density on number of pods per plant. The maximum number of pods per plant were found in plants spaced at 40 cm.

Ali *et al*. (1999) carried out an investigation to evaluate the effect of intra and inter row spacing on the yield and yield components of chickpea. The treatments of the experiment included three inter (10, 20, 30 cm) and intra (5, 10, 15 cm) row spacing. The results indicated that number of pods per plant differed significantly due to change in row spacing. Plants with wider spacing of 30 cm resulted in higher number of pods per plant (83.7) followed by 20 cm (73.1) and 10 cm (68.1) row spacing, respectively.

Singh *et al*. (1988) reported that, the number of grains per plant of chickpea decreases as the plant density increases.

2.2.5 Seeds pod^{-1}

Farjam *et al.* (2014) evaluated the effects of row spacing and a superabsorbent polymer on some agronomic traits of chickpea using 20, 25 and 30 cm row spacings and three doses of super absorbent polymer. They found that number of seeds per pod were increased with increasing row spacing.

Pooniya *et al*. (2009) conducted an experiment with different row spacings and weed control and reported that 40 cm row spacing produced significantly higher number of seeds per pod as compared to 20 cm and 30 cm of row spacing.

2.2.6. 1000 seeds weight

Agajie (2013) investigated the effect of different inter row (20, 30, 40, 50 cm) and intra row spacing (5, 10, 15 cm) on growth parameters, yield components and yield of Desi chickpea in Assosa Woreda of western Ethiopia and reported that interaction of inter and inter row spacing had no significant effect on hundred seed weight of chickpea.

Farjam *et al*. (2014) evaluated the effects of row spacing and a superabsorbent polymer on some agronomic traits of chickpea using 20, 25 and 30 cm row spacings and three doses of super absorbent polymer. They found that 30 cm row spacing recorded 100-seed weight compared to 20 and 25 cm spacing.

Sarwar (1998) found different row spacings had no influence on 1000 seeds weight.

2.2.7. Seed yield

Research was conducted by Agajie (2013) to determine the effect of different inter row (20, 30, 40, 50 cm) and intra row spacing (5, 10, 15 cm) on growth parameters, yield components and yield of Desi chickpea in Assosa Woreda of western Ethiopia and reported that intra and inter row spacing and their interaction significantly influenced seed yield. The highest seed yield (1219 kg ha^{-1}) was obtained from 30 cm × 5 cm spacing which was statistically similar with 40 cm × 5 cm, 30 cm × 15 cm and 20 cm × 15 cm spacing and the lowest seed yield (733 kg ha^{-1}) from 50 cm × 15 cm spacing combination being statistically at par with 50 cm × 15 cm spacing.

Biabani (2011) examined the effect of plant density on yield and yield components of chickpea (*Cicer arietinum* L.) grown under environmental condition of Golestan, Iran and reported that spacing combination of 45 cm × 7.5 cm produced maximum yield than that of 35 cm × 5 cm and 55 cm ×10 cm spacing.

Bavalgave *et al*. (2009) conducted an experiment on growth and yield of Kabuli chickpea varieties (ICCV - 2, Virat, Vihar, and KAK - 2) as influenced by different spacing **(**30 cm × 10 cm, 30 cm × 15 cm, 45 x 10 cm and 45 x 15 cm). The results revealed that the highest seed yield was observed at a closer spacing of 30 cm × 10 cm followed by rest of spacing.

Farjam *et al.* (2014) evaluated the effects of row spacing and a superabsorbent polymer on some agronomic traits of chickpea using 20, 25 and 30 cm row spacings and three doses of super absorbent polymer. They found that seed yield was increased with increasing row spacing. 30 cm row spacing produced 32.3% and 26.6% higher yield than 20 and 25 cm spacing respectively.

Verma and Pandey (2008) studied the effect of fertilizer doses and row spacings on growth and yield of chickpea (*Cicer arietinum* L.) at research farm of Brahmanand Mahavidyalaya in India during 2004-05 and found that 30 cm row spacing with application of 25 kg nitrogen performed better to harvest significantly higher production from chickpea while lower yield was found with control and 50 cm row spacing.

Barary *et al*. (2001) reported that seed yield did not differ significantly for row and plant spacing but varied significantly with the interaction between plant and row spacings.

Sharar *et al*. (2001) investigated growth and seed yield response of gram (*Cicer arietinum* L.) variety Paidar-91 to different seeding rates (40, 50, 60,70 and 80 kg ha^{-1}) and row spacings (30, 45 and 60 cm) and found no significant effect of row spacing on yield and yield attributes of gram varieties.

Panwar *et al*. (1980) from their study reported that 45 cm row spacing produced significantly higher yield compared to 30 cm and 50 cm row spacings.

2.2.8. Biological yield

Pooniya *et al*. (2009) conducted an experiment with different row spacings and weed control and reported that 30 cm row spacing produced significantly highest biological yield than 20 cm and 30 cm of row spacing.

2.2.9 Harvest index

Khan *et al.* (2010) examined the effect of row spacing and seeding rates on growth, yield and yield components of chickpea at Arid Zone Research Institute Bhakkar and reported that the highest row spacing (45 cm) produced maximum harvest index (41.66%) than 15 cm row spacing.

Barary *et al*. (2001) reported that harvest index differed significantly due to plant and row spacings and their interaction and harvest index increased with increase in plant and row spacing.

Hussain *et al.* (1998) and Sarwar *et al.* (1998) found no significant effects of seeding densities and row spacings on harvest index.

2.3 Effect of SRI technique on different crops

The growth analysis and yield of rice as affected by different system of rice intensification (SRI) practices was examined at Pandit Jawaharlal Nehru College of Agriculture and Research Institute in India. The results of their investigation showed that crops grown under SRI principles enhanced the growth parameters which in turn improved the grain yield by 68.25 per cent over the traditional practice (Sridevi & Chellamuthu, 2015)

Production potential and economics of hybrid rice under system of rice intensification and its manipulation was evaluated at Indira Gandhi Krishi Vishwa vidyalaya, Chhattisgarh. The results revealed that manipulated SRI gave 13.52% higher grain yield and 16.80% higher net income over recommended practices of hybrid rice (Verma *et al.,* 2014).

Two experiments were conducted at rice research farm of Punjab Agricultural University, Ludhiana during 2006 and 2007 to evaluate the performance of SRI against conventional transplanting method. The results revealed that SRI transplanting (10 days old seedling) resulted 11.8 and 27.9 per cent increase in yield over conventional transplanting method and SRI direct seeding method during 2006 and 2007 respectively (Mahajan and Sarao, 2009).

System of Rice Intensification (SRI) produced 78% (3.3 t/ha) more yield with a 40% reduction in water use and 50% in fertilizer applications, with 20% lower costs of production over the conventional farmer practices (Sato and Uphoff, 2007)

At Purulia in West Bengal, India paddy yields with SRI were increased by 32% than those of conventional paddy cultivation and net incomes were increased by 67% with 8% reduction in labour input (Sinha and Jyesh, 2007).

SRI (System of Rice Intensification) method gave rice yields of 7 to 8 t ha^{-1} against the normal 3 to 4 tons (Devarajan, 2005).

In Tamil Nadu in India the rice production with SRI was increased by 28 percent with 53 percent less water and in Sri Lanka the income with SRI was increased by 44 percent. Similarly, the harvest increased by 35 to 50 percent in China and 41 percent in Cambodia (Dixit, 2005).

SRI, System of Rice Intensification was proved to give 37% higher yield than the average with improved practices, and 85% higher than the average with farmers' practices in Nepal in 2002 (Mae Wan Ho, 2005)

Sichuan Provincial Department of Agriculture, in China reported that the use of SRI methods has expanded from 1133 ha in 2004 to over 300,000 ha in 2010. It calculated an average yield increase of 1.7 t ha^{-1} from using SRI ideas and methods during this period. This gave farmers 1.6 million tons of additional paddy rice, worth over $300 million, while reducing their water requirements by one-quarter in a province that has growing water constraints (Zheng *et al.*, 2004)

Ethiopia's Agricultural Transformation Agency applied SCI concepts and practices for raising production of that country's main staple grain, tef referred to as the system of tef intensification (STI) is being promoted and assessed in two versions. In the 2012–13 season, 160,000 Ethiopian farmers who participated in on-farm trials with the less-intensive, direct-seeded version got an average yield increase of 70%, while another 7,000 farmers who used the recommended, more-intensive methods that involved transplanting had yield increases of 200% to 300%, with 50% to 90% reductions in seed (Abraham *et al.*, 2014).

In Trigary Province of Ethiopia, one woman farmer observed the response of finger millet crop to SCI technique and obtained a yield equivalent to 7.8 tons/ha in 2003, compared to usual finger millet yields of 1.4 tons/ha with broadcasting, or 2.8 tons ha^{-1} with generous use of compost (Araya *et al*., 2013).

System of Wheat Intensification (SWI) practices showed better yield and economic returns at Shindhuli district in Nepal in 2011-12. Pre-germinated seed of Bhirkuti variety sown at 20 cm x 20 cm spacing gave 54% more yield than the available 'best practices' used under similar conditions of irrigation and fertilization. 6.5 tons ha^{-1} wheat was obtained from SWI, compared to 3.7 tons ha^{-1} with conventional broadcasting, and 5 tons ha^{-1} with row sowing (Adhikari, 2012).

In Jharkhand state of India in 2005, farmers working with the NGO PRADAN experimented SRI methods for their rain-fed finger millet cultivation in the name System of finger millet intensification (SFMI). With conventional broadcasting practices the usual yields of finger millet were around 1 ton ha^{-1} whereas yields with transplanted SFMI had averaged 3-4 ton ha^{-1}. Costs of production per kg of grain were reduced by 60% with SFMI management, from Rs. 34.00 to Rs. 13.50 (Pradan, 2012a).

Farmers in Bihar state of India adopted SRI methods for growing mustard (aka rapeseed or canola). 7 women farmers in Gaya district working with Pradan and the government's ATMA agency started applying SRI practices to their mustard crop in 2009-10. This gave them an average grain yield of 3 tons/ha, three times their usual 1 ton ha^{-1}. In 2011-12, 1,636 farmers practiced SMI with an average yield of 3.5 tons/ha. Those who used all of the practices as recommended averaged 4 tons ha^{-1}, and one reached a yield of 4.92 tons ha^{-1} as measured by government technicians. With SMI, farmers' costs of production were reduced by half, from Rs. 50 per kg of grain to just Rs. 25 per kilogram (Pradan, 2012b).

Farmer trials with SWI methods were started in the Timbuktu region of Mali In 2008-09, where it was learned that transplanting young seedlings was not as effective as direct seeding, while direct seeded SWI with spacing of 25cm x 25cm proved to be too great. Still, obtaining a 13% higher yield with a 94% reduction in seed (10 kg/ha vs. 170 kg/ha), a 40% reduction in labor, and a 30% reduction in water requirements encouraged farmers to continue their experiments in this system (Styger and Ibrahim, 2009).

Farmers working with the People's Science Institute (PSI) first tested the System of Wheat Intensification (SWI) technique in northern India in 2006. First-year trials near Dehradun, using several varieties, showed average increases of 18% to 67% in grain yield and 9% to 27% higher straw yields (important for subsistence farmers as fodder) compared to traditional broadcast methods for crop establishment. Impressed with these results, PSI began promoting SWI in the states of Uttarakhand and Himachal Pradesh (Prasad, 2008).

Being introduced to SRI methods in 2004, farmers in Andhra Pradesh state of India started adoption of these ideas and practices to their sugarcane production and some farmers got as much as three times more yield, cutting their planting materials by 80-90%. By 2009 there had been enough testing, demonstration and modification of these initial practices that the joint Dialogue Project on Food, Water and Environment of the World Wide Fund for Nature (WWF) and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) in Hyderabad launched a 'sustainable sugarcane initiative' (SSI). The project published a manual that described and explained the suite of methods derived from SRI experience that could raise cane yields by 30% or more, with reduced requirements for both water and chemical fertilizer (ICRISAT/WWF, 2009).

The Tamil Nadu Agricultural University having launched an SSI promotion campaign reported that using this SSI sugarcane yield could be raised up to 225 tons ha^{-1}, from present yields of 100 tons by reducing the seed rate by 90% (Anon, 2013).

A World Bank evaluation of project effect in Bihar state reported yield increases as 86% for rice, 72% for wheat, 56% for pulses, 50% for oilseeds, and 20% for vegetables. The profitability increases for these different crops were calculated, as averaging 250%, 86% 67%, 93%, and 47% (Behera *et al.,* 2013).

The Agriculture-Man-Environment Foundation (AMEF) based in Bangalore reported that with SRI practices, pigeon pea yields were increased by 70%, from a usual yield of 875 kg/ha to 1.5 tons/ha (AMEF, 2009).

The Aga Khan Rural Support Programme started application of SCI principles to Soya bean in central India's Madhya Pradesh state in 2013. Analysis of initial harvest results showed the yield with adapted SCI methods to be as much as 86% higher. The phonotypical improvements in the soya plants that supported such yield increase were having: 4.2 times more branches per plant, 3.7 times more pods per plant, as many as 4.3 times more seeds per plant and 4% higher weight (grams per 100 seeds). Average dry matter per plant was 2.75 times greater. From calculations of the cost of production and revenue per acre, the increase in benefit-cost ratio with these alternative methods compared with farmers' traditional practice was 75-100% greater (AKRSP-I, 2013)

In eastern India, the Bihar rural livelihood support program has reported a tripling of yields from mungbean when using SCI methods. Usual yields are about 625 kg/ha, whereas with SCI management, the average is 1.875 tons/ha on farmer's fields. In northern India, Proteomics Society of India (PSI) reported that with adaptations of SRI practices to the cultivation of various legumes, small farmers in Uttarakhand and Himachal Pradesh states obtained higher yields (Abraham *et al.*, 2014). They obtained increased yield by 65% in lentil, 50% in soybean, 67% in kidney bean and 42% in pea.

SCI technique is also applicable for vegetables. By using SCI method instead of conventional practice chilies, tomato and eggplant yield were increased by 170%, 270% and 100%, respectively. (BRLPS, 2011).

From the review, it can be concluded that chickpea yield is possible to increase using modern variety and optimum spacing.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207 during November, 2015 to April, 2016 to study the growth and yield variations in chickpea as influenced by planting geometry. In this chapter the materials and method used in conducting this experiment has been described in brief.

3.1 Description of the experimental site

3.1.1 Geographical location

The experimental field is situated between 23° 74´ N latitude and 90º 35´ E longitude and at an elevation of 8.4 m from sea level (Anon., 1989).

3.1.2 Agro-ecological Region

The study area belongs to the Agro-ecological zone 28, “The Modhupur Tract” (Anon, 1988). This is region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon, 1988). The experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.1.3 Soil

The soil of the study area is Deep Red Brown Terrace soil having a sandy loam texture under the Tejgaon series. The chosen plot was medium high land having a pH range of 5.7-6.0. The field was flat with appropriate drainage and irrigation facilities and above the flood level. Morphological characteristics of the soil of experimental field are presented in Appendix-II.

3.1.4 Climatic condition

The research area was situated in the subtropical monsoon climatic zone which was set aparted by heavy rainfall during the months from April to September (kharif season) and scant of rainfall during rest of the year (Rabi season). There was plenty of sunshine and fairly low temperature throughout the growing season. The monthly average temperature, humidity and rainfall during the crop growing period were presented in Appendix III. The average maximum and minimum temperature were varied from

28.1ºC to 34.8ºC and 11ºC to 18.0ºC, respectively. The relative humidity varied from 60% to 79%. The month March was experienced with maximum total rainfall (41 mm).

3.2 Materials

a) Seeds- Three chickpea varieties namely BARI Chola-5, BARI Chola-6 and BARI Chola-9 were used as the test crops. The seeds were collected from Pulse research Centre of Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gazipur.

b) Fertilizers- Urea, Triple super phosphate (TSP), Muriate of potash (MoP) and Boric acid were used in the experimental field. All these fertilizers were provided by the farm of SAU, Dhaka-1207.

3.3 Description of the Variety

3.3.1 BARI Chola-5

BARI Chola-5 is a high yielding variety of chickpea developed by Pulse research Centre of Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gazipur. The variety was released in 1996. The plant is scattered type and light green in color. They attain a height of 40-50 cm at maturity and take 125-130 days to mature. Seeds are small in size, grey brown in color and hilum is clear. Thousands seed weight is 110-120 gm. The yield of the variety is 1.8-2.0 t ha^{-1}.

3.3.2 BARI Chola-6

BARI Chola-6 is also a high yielding variety of chickpea developed by Pulse research Centre of Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gazipur. The variety was released in 1996. The plant is scattered type and light green in color. They attain a height of 55-60 cm at maturity and take 125-130 days to mature. Seeds are almost rounded and bright brown yellow in color. The weight of thousands seed is 155-160 gm. The yield of the variety is almost 2.2 t ha^{-1}.

3.3.3 BARI Chola-9

BARI Chola-9 is also developed by Pulse research Centre of Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gazipur. The plants attain a height of 55-60 cm at maturity and take 125-130 days to mature. The weight of thousands seed is 180-220 gm. The yield of the variety is almost 2.3-2.7 t ha^{-1}.

3.4 The layout of the experiment

The experiment was laid out in split plot design with three replications having three chickpea varieties in the main plot and five spacing in the sub plot. There were 15 treatment combinations. So the total number of plots were 45. The individual plot size was 2.5 m x 2.0 m. Plot to plot and replication to replication distances were 0.5 m and 1.5 m, respectively.

3.5 Treatments of the experiment

The treatment of the experiment comprised of two factors i.e. variety and spacing. Two factors and treatment combinations are mentioned below:

Factor A: Variety (3)

V_1= BARI Chola-5

V_2= BARI Chola-6

V_3= BARI Chola-9

Factor B: Spacing (5)

Sp_1 = 40 cm × 10 cm

Sp_2 = 30 cm × 30 cm

Sp_3 = 40 cm × 40 cm

Sp_4 = 50cm × 50 cm

Sp_5 = 60 cm × 60 cm

Treatment combinations:

V_1Sp_1	V_2Sp_1	V_3Sp_1
V_1Sp_2	V_2Sp_2	V_3Sp_2
V_1Sp_3	V_2Sp_3	V_3Sp_3
V_1Sp_4	V_2Sp_4	V_3Sp_4
V_1Sp_5	V_2Sp_5	V_3Sp_5

3.6 Details of the experimental preparation

3.6.1 Land preparation

The chosen plot for the experiment was irrigated before ploughing. After ‘zoe’ condition the land was first opened using a power tiller. The first ploughing was done on 21 November, 2015. Ploughed soil was then brought into Desirable fine tilth by 3 ploughing and cross-ploughing, harrowing and laddering. Weeds and stubbles were removed from the sphere. The land was finally prepared for experiment on 28 November, 2015. Experimental land was divided into unit plots following the experimental Design.

3.6.2 Fertilizer application

Fertilization in the experiment field was completed on 29 November, 2015.The recommended dose of N, P_2O_5, K_2O, B used for chickpea varieties was at the rate of 20, 40, 20, 1 kg ha^{-1}, respectively which was common for all treatments.

3.6.3 Seed sowing

Seeds of 3 varieties of chickpea **(**BARI Chola-5, BARI Chola-6 and BARI Chola-9) were sown at the rate of 60 kg ha^{-1} on 30 November, 2015. Seeds were sown at a depth of 2-3 cm from the soil surface. Row to row and plant to plant distances were maintained as per treatments of the experiment.

3.7. Intercultural operations

3.7.1. Thinning

Emergence of seedling was completed within 10 days after sowing (DAS). Thinning was done two times, first at 14 DAS and second at 20 DAS to maintain proper spacing as per treatment.

3.7.2 Irrigation and drainage

Pre-sowing irrigation was given to assure the maximum germination percentage. After emergence of seedling 3 irrigations were given at 20 DAS, 55 DAS and 75 DAS to optimize the vegetative growth, flowering and pod development of chickpea for all experimental plots equally. Irrigations were given depending on the soil moisture content after soil moisture testing by hand. Before harvesting a last irrigation was given to facilitate harvesting. Though it was rabi season, proper drainage was made on 15 DAS to drain out of excess water from irrigation and also rainfall. At the last stage there was heavy rainfall and excess water was drained out.

3.7.3 Weeding and mulching

The experimental field was weeded as per necessary. After irrigation the soil surface became crusty and several mulching operation was needed to break down this hard soil crust. So after each irrigation mulching was done carefully to break the soil crust.

3.7.4 Plant protection

After pod development stage some plots were infested with Foot and root rot disease caused by *Sclerotium rolsii*, *Fusarium oxysporum.* To protect the crop plants Bavastin 250 WP @ 2 g liter^{-1} water was sprayed on 5 and 12 March, 2016. The insecticide Ripcord was sprayed at the rate of 1 litre ha^{-1} to protect the crop against pod borer (*Maruca testulalis*).

3.7.5. Harvesting and threshing

After 120 days of sowing about 80% of the pods attained maturity and the crops were harvested plot wise for data collection. The samples were collected from inner 2 m^2 areas of each plot. The harvested crops were then tied with rope and brought to the cleaned threshing floor. The pods were separated from plants by hand and dried well under bright sunlight. The seeds were separated from pods and the separated seed and stover were dried properly for 2-3 consecutive days.

3.8 Data collection

Experimental data on different parameters of chickpea were recorded from 20 DAS and continued until harvest at an interval of 20 days. The followings data were collected during the experiment.

Crop growth characters

- Plant height (cm)
- Leaflets plant^{-1} (no.)
- Above ground dry matter weight plant^{-1} (g)
- Nodules dry weight plant^{-1} (g)

Yield contributing characters

- Branches $plant^{-1}$ (no.)
- Pods $plant^{-1}$ (no.)
- Seeds pod^{-1} (no.)
- 1000 seeds weight (g)

Yields

- Seed yield (t ha^{-1})
- Stover yield (t ha^{-1})
- Biological yield (t ha^{-1})
- Harvest Index (%)

3.9 Detailed Procedures of Recording Data

3.9.1 Plant height (cm)

Five plants were selected randomly from the inner row of each plot .The height of the plants were measured from the ground level to the tip of the plant at 20, 40, 60, 80, 100 DAS and harvest (120 DAS). The mean value of plant height was recorded in cm.

3.9.2 Branches $plant^{-1}$ (no.)

The branches $plant^{-1}$ was counted done from five randomly selected plants at 20, 40, 60, 80, 100 DAS and harvest (120 DAS). Then the average data were recorded.

3.9.3 Leaflets $plant^{-1}$ (no.)

Number of leaflets was counted from randomly selected plant sample and then averaged at 20, 40, 60, 80, 100 DAS and harvest (120 DAS).

3.9.4. Above ground dry matter $plant^{-1}$ (g)

Five plants were collected randomly from each plot at 20, 40, 60, 80, 100 DAS and at harvest (120 DAS). Then the leaves were separated from each plant put into envelop and placed in oven maintaining 70^0 C for 72 hours for oven dry until attained a constant level and the mean of dry weight of leaves $plant^{-1}$ was determined.

Five plants were collected randomly from each plot at 20, 40, 60, 80, 100 DAS and at harvest (120 DAS). Then the stem of sample plants were put into envelop and placed in oven maintaining 70^0 C for 72 hours for oven dry until attained a constant level and after that the mean of dry weight of stem plant-1 was calculated. The calculated value of leaf dry weight and stem dry weight was added to determine the value of above ground dry matter weight and it was expressed in gram (g).

3.9.5 Nodule dry weight plant^{-1} (g)

Nodule of five randomly selected plants were collected at 60 DAS, 80 DAS and 100 DAS. Then the dry weight was averaged and was expressed in gram (g).

3.9.6 Pods plant^{-1} (no.)

Numbers of pods were counted from 10 selected plants and then the average pod number was determined.

3.9.7 Seeds pod^{-1} (no.)

The number of seeds pods^{-1} was recorded from randomly selected 20 pods at the time of harvest. Data were recorded as the average of 20 pods from each plot.

3.9.8 Weight of 1000 seeds (g)

1000 dried and cleaned seeds were counted from seed stock of each plot. The weight was then recorded in gram (g) using a digital electric balance.

3.9.9 Seed yield (t ha^{-1})

The seeds were collected from central 2 square meter of each plot and were sun dried properly. The weight of seeds per plot was taken carefully and the yield was converted in t ha^{-1}.

3.9.10 Stover yield (t ha^{-1})

After proper threshing, the straw and shell harvested was sun dried. The weight was recorded and finally it was converted into t ha^{-1}.

3.9.11 Biological yield (t ha^{-1})

Biological yield is the total yield including both the economic and stover yield. It was calculated with the following formula:

Biological yield = Seed yield + Stover yield.

3.9.12 Harvest index

Harvest index was calculated from the seed yield and stover yield of chickpea for each plot and expressed in percentage.

Harvest Index (%) = Economic yield (t ha^{-1}) /Biological yield (t ha^{-1}) × 100

3.10 Statistical analysis

The data collected on different parameters were statistically analyzed using MSTAT-C, a computer program Designed by (Fread, 1986). The mean separation was done by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

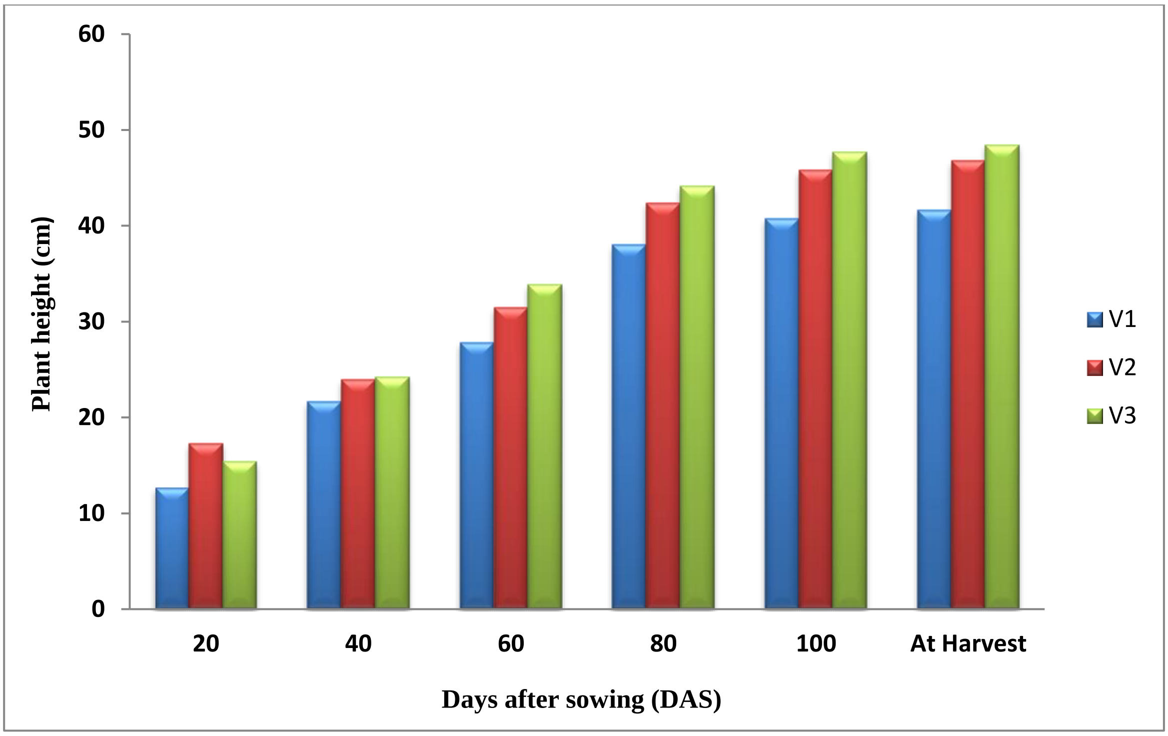
Data obtained from the study on "Growth and yield variations in chickpea as influenced by planting geometry" have been presented and discussed in this chapter. The analysis of variance (ANOVA) of the data on different parameters are presented in Appendix (IV-IX). Different graphs and tables have been used to present and discuss the results and possible interpretations given under the following headings:

4.1 Crop growth parameters

4.1.1 Plant height (cm)

4.1.1.1 Effect of Variety

Plant height of chickpea varied significantly due to use of different varieties at 20, 40, 60, 80, 100 DAS and harvest (Fig. 1). At 20 DAS, BARI Chola-6 (V_2) gave the tallest plant (17.30 cm) while the shortest plant (12.67 cm) was found from BARI Chola-5 (V_1). At 40 DAS the highest plant height (24.25 cm) was observed in BARI Chola-9 (V_3) which was statistically similar (23.93 cm) with BARI Chola-6 (V_2). The lowest plant height (21.67 cm) was recorded from BARI Chola-5 (V_1). At 60 DAS the tallest plant (33.88 cm) was found in BARI Chola-9 (V_3) while shortest plant (27.84 cm) was given by BARI Chola-5 (V_1). At 80 DAS, plant height of BARI Chola-9 (V_3) was the tallest (44.14 cm) and plants in BARI Chola-5 (V_1) were the shortest (38.03 cm). The tallest plants (47.71 cm) at 100 DAS were found from BARI Chola-9 (V_3) and the shortest one (40.75 cm) from BARI Chola-5 (V_1). At harvest BARI Chola-9 (V_3) had the tallest plants (48.42 cm) being closely followed (46.80) by BARI Chola-6 (V_2). Roy *et al*. (2016) observed tallest plant from BARI Chola-9.

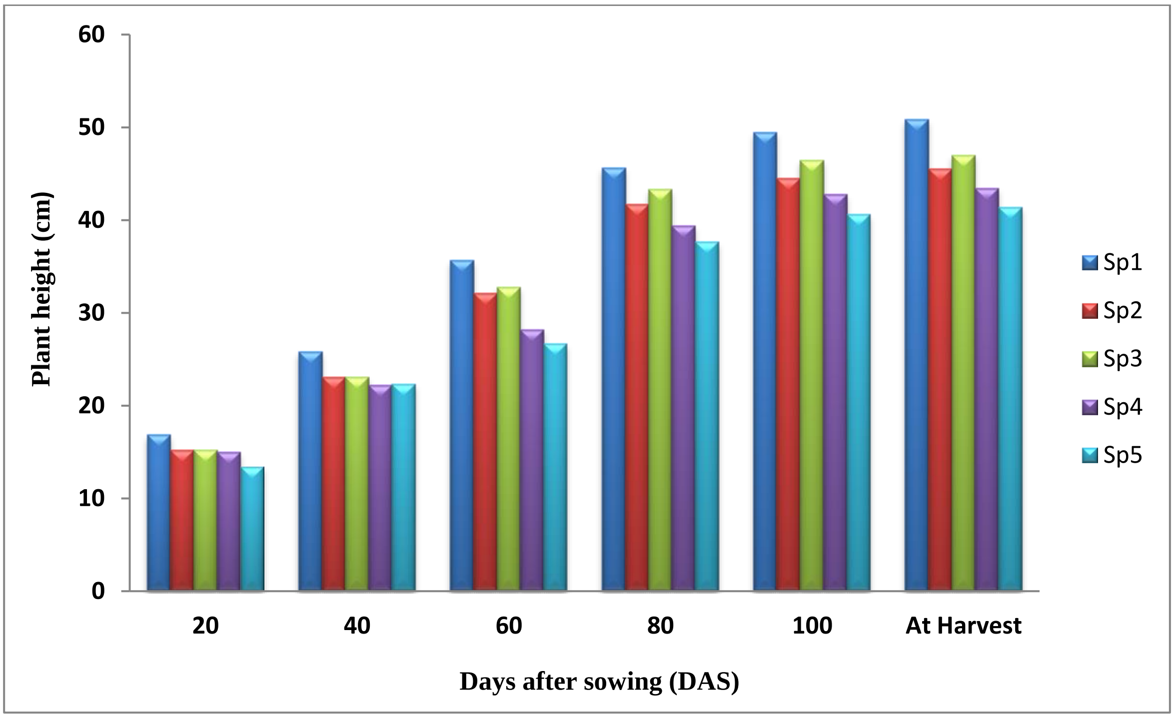


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 1. Effect of variety on plant height (cm) of chickpea at different days (LSD $_{(0.05)}$ = 1.41, 1.50, 2.68, 1.97, 5.04 and 3.71 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

4.1.1.2 Effect of Spacing

Statistically significant variation was observed in plant height of chickpea due to different spacing at 20, 40, 60, 80, 100 DAS and harvest (Fig. 2). At 20 DAS, treatment Sp_1 gave the tallest plant (16.83 cm) while the shortest plant (13.41 cm) was found from Sp_5. At 40 DAS the highest plant height (25.82 cm) was observed in Sp_1 and the shortest plant (22.20 cm) in Sp_4 which was statistically similar (23.04 cm, 23.06 cm, 22.31 cm) with Sp_2, Sp_3 and Sp_5, respectively. At 60 DAS Sp_1 gave the tallest plant of 35.66 cm. Treatment Sp_5 gave the shortest plant (26.66 cm) showing similarity (28.18 cm) with Sp_4. The tallest plant (45.64 cm) at 80 DAS was found from Sp_1 and the shortest one (37.63cm) in Sp_5. In case of 100 DAS, Sp_1 attained the longest plant (49.46 cm) and Sp_5 showed the shortest one (40.58 cm). At harvest, plant height in Sp_1 was the tallest (50.83 cm) and Sp_5 was the shortest (41.38 cm) which was statistically at par (43.43 cm) with Sp_4. Agajie (2013) and Singh and Singh (2002) obtained the tallest plants from a narrower spacing and the shortest plants from wider spacing. Several researchers (Felton *et al*., 1996; Parvez *et al.*, 1989 and Sharar *et al.*, 2001) reported a significant increase in plant height with increasing plant density. This may be due to plants tried to capture sunlight by changing their cell division and elongation under lower interception of light at densely populated plants.



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 2. Effect of spacing on plant height (cm) of chickpea at different stages (LSD $_{(0.05)}$ = 1.39, 1.45, 2.74, 1.88, 1.76 and 2.61 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

4.1.1.3 Combined effect of Variety and Spacing

Combined effect of variety and spacing showed significant differences for plant height throughout the whole growing season (Table 1). At 20 DAS, the highest plant height (19.51 cm) was obtained from treatment V_2Sp_1 which was statistically similar with V_2Sp_2 (17.75 cm) and the lowest height (11.45 cm) was recorded from V_1Sp_5 which was statistically identical with V_1Sp_2 (12.57 cm), V_1Sp_3 (12.85 cm), V_1Sp_4 (12.571cm) and V_3Sp_5 (13.60 cm). Treatment V_3Sp_1 produced the tallest plant (28.48 cm) at 40 DAS which was statistically at par with V_2Sp_1 (26.45 cm) whereas the shortest plant (20.85 cm) was found from V_1Sp_3 followed by V_1Sp_1 (22.53 cm), V_1Sp_2 (22.83 cm), V_1Sp_4 (21.19 cm), V_1Sp_5 (20.95 cm), V_2Sp_4 (22.77 cm), V_2Sp_5 (22.58 cm), V_3Sp_2 (22.61 cm), and V_3Sp_4 (22.64 cm). At 60 DAS, the highest plant height (39.98 cm) was recorded from V_3S_1 which was statistically similar with V_2Sp_1 (36.00 cm) and V_3Sp_3 (35.80 cm) while the lowest height (23.70 cm) from V_1Sp_5 which was statistically similar with V_1Sp_4 (25.77 cm) and V_2Sp_5 (26.63 cm). The tallest plants (49.63 cm) at 80 DAS were produced in V_3Sp_1 and the shortest one (33.48 cm) from V_1Spp_5 which was closely followed by V_1Sp_4 (35.39 cm). At 100 DAS V_3Sp_1 gave the tallest plant (53.34 cm) and the shortest height (36.87 cm) was obtained from V_1Sp_5 followed by V_1Sp_4 (38.27 cm). At harvest V_3Sp_1 produced the tallest plants (54.50 cm) being closely followed by V_2Sp_1 (51.93). The lowest plant height (37.58 cm) was from V_1S_5 which was statistically identical withV_1Sp_4 (39.29 cm), V_1Sp_2 (42.50 cm), V_1Sp_3 (42.90 cm), V_2Sp_5 (43.27 cm) and V_3Sp_5 (43.30 cm).

Table 1. Combined effect of variety and spacing on plant height of chickpea at different days

Treatments	**Days after sowing (DAS)**					
	20	**40**	**60**	**80**	**100**	**At harvest**
V_1Sp_1	13.99 d-f	22.53 c-f	31.00 c-e	41.14 c-e	44.87 c-e	46.04 b-d
V_1Sp_2	12.57 fg	22.83 c-f	29.49 c-f	39.38 e	41.67 f	42.50 d-f
V_1Sp_3	12.85 e-g	20.85 f	29.24 d-f	40.75 de	42.09 ef	42.90 d-f
V_1Sp_4	12.51 fg	21.19 d-f	25.77 fg	35.39 f	38.27 g	39.29 ef
V_1Sp_5	11.45 g	20.95 ef	23.70 g	33.48 f	36.87 g	37.58 f
V_2Sp_1	19.51 a	26.45 ab	36.00 ab	46.15 b	50.17 b	51.93 ab
V_2Sp_2	17.75 ab	23.67 cd	32.72 b-d	41.50 c-e	44.13 d-f	46.06 b-d
V_2Sp_3	16.74 bc	24.18 bc	33.18 b-d	43.67 b-d	47.83 bc	48.09 a-d
V_2Sp_4	17.34 a-c	22.77 c-f	28.87 d-f	41.24 c-e	44.17 d-f	44.68 c-e
V_2Sp_5	15.18 c-e	22.58 c-f	26.63 e-g	39.50 e	42.73 ef	43.27 d-f
V_3Sp_1	16.99 bc	28.48 a	39.98 a	49.63 a	53.34 a	54.50 a
V_3Sp_2	15.20 c-e	22.61 c-f	34.05 bc	44.18 bc	47.70 bc	48.01 b-d
V_3Sp_3	15.99 b-d	24.15 bc	35.80 ab	45.43 b	49.50 b	49.94 a-c
V_3Sp_4	15.09 c-e	22.64 c-f	29.91 c-f	41.54 c-e	45.86 cd	46.33 b-d
V_3Sp_5	13.60 d-g	23.39 c-e	29.64 c-f	39.90 e	42.13 ef	43.30 d-f
$LSD_{(0.05)}$	2.41	2.51	4.74	3.25	3.04	6.43
CV (%)	9.47	6.41	9.06	8.01	8.28	8.36

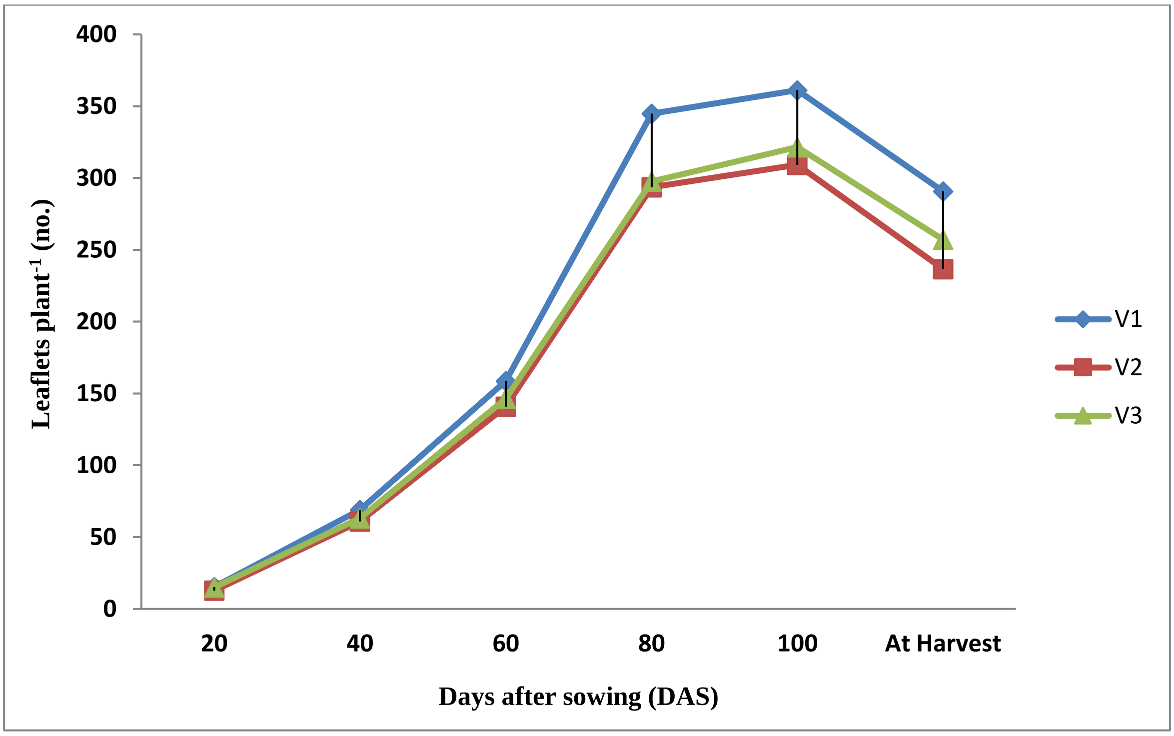
V_1 = BARI chola-5, V_2 = BARI chola-6, V_3 = BARI chola-9

Sp_1 = 40 cm x 10 cm. Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

4.1.2 Leaflets plant^{-1} (no.)

4.1.2.1 Effect of Variety

Number of leaflets plant^{-1} was found significant due to variation in different varieties at 20, 40, 60, 80, 100 DAS and harvest (Fig. 3). Total leaflets plant^{-1} increased up to 100 DAS and then decreased at harvest. Among different varieties BARI Chola-5 (V_1) performed well and gave maximum number of leaflets plant^{-1}. BARI Chola-5 (V_1) gave the highest number of leaflets plant^{-1} (15.33, 69.00, 158.7, 344.8, 361.1, and 290.60 at 20, 40, 60, 80, 100 DAS and harvest, respectively) which was statistically similar (15.03) with BARI Chola-9 (V_3) only at 20 DAS. On the other hand the lowest number of leaflets plant^{-1} (12.80, 60.93, 140.9, 293.6, 309.2 and 236.6) was found from BARI Chola-6 (V_2) at 20, 40, 60, 80, 100 DAS and harvest, respectively which was statistically similar (63.08, 146.5, 297.5 and 321.5) with BARI Chola-9 (V_3) at 40, 60, 80 and 100 DAS.

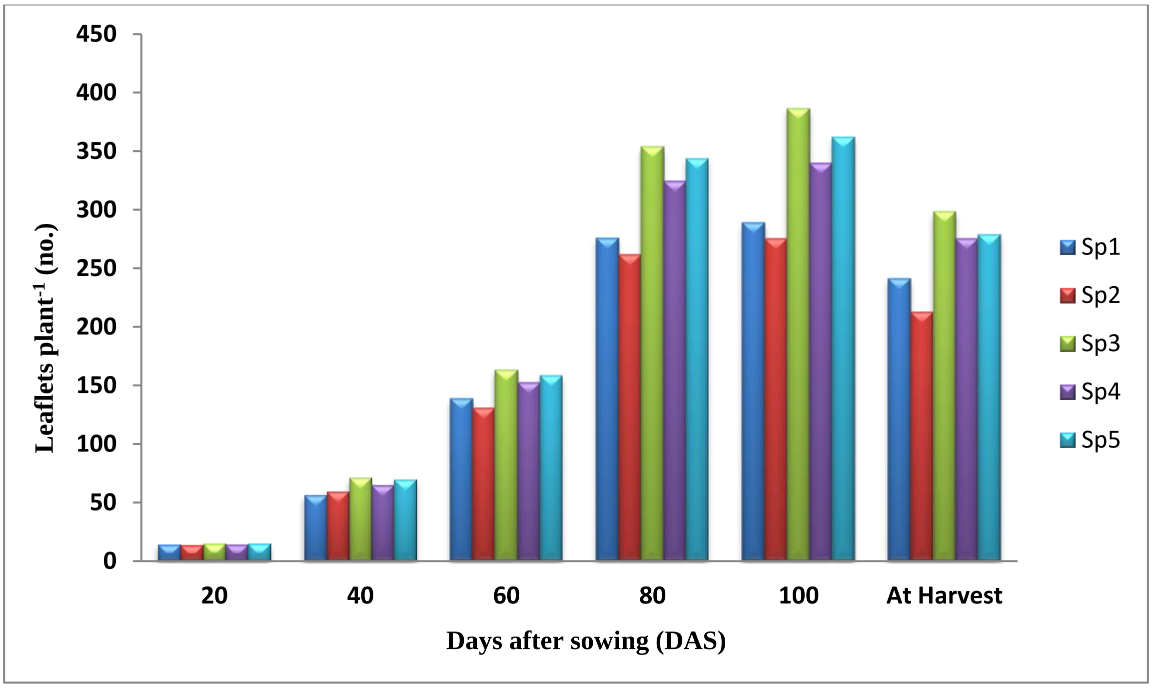


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 3: Effect of variety on number of leaflets plant^{-1} of chickpea at different days (LSD $_{(0.05)}$ = 0.68, 4.24, 8.81, 22.25, 20.43 and 7.79 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

4.1.2.2 Effect of Spacing

Spacing showed a significant variation on number of leaflets plant^{-1} throughout the growing season (Fig. 4). Maximum number of leaflets plant^{-1} (14.89) at 20 DAS were attained from treatment Sp_5 and the lowest number of leaflets plant^{-1} (13.60) were found from Sp_2 which was statistically similar with Sp_1 (14.21) and Sp_4 (14.43). At 40 DAS maximum number of leaflets plant^{-1} (71.13) was recorded from Sp_3 and it was statistically at par with Sp_5 (69.62). The minimum number of leaflets plant^{-1} (56.49) was obtained from Sp_1 which was closely followed by Sp_2 (59.54). At 60 DAS treatment Sp_3 gave higher number of leaflets plant^{-1} (163.0) which was statistically similar with Sp_4 (152.6) and Sp_5 (158.6) and treatment Sp_2 gave lower number of leaflets plant^{-1} (130.6) which was similar with Sp_1 (138.7). At 80 DAS maximum number of leaflets plant^{-1} (353.70) was recorded from Sp_3 which was statistically similar with Sp_5 (344.0) and the minimum number of leaflets plant^{-1} (261.8) was obtained from Sp_2 which was closely followed by Sp_1 (275.80). In case of 100 DAS, maximum number of leaflets plant^{-1} (386.50) were recorded from Sp_3 and it was statistically similar with Sp_5 (361.90). The minimum number of leaflets plant^{-1} (275.7) was obtained from Sp_2 which was closely followed by Sp_1 (289.0). At harvest, Sp_3 attained higher number of leaflets plant^{-1} (298.20) and Sp_2 gave the lower number of leaflets plant^{-1} (212.90).



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 4: Effect of spacing on number of leaflets plant^{-1} of chickpea at different days (LSD $_{(0.05)}$ = 1.06, 5.80, 11.60, 28.41, 25.52 and 14.75 at 20, 40, 60, 80, and 100 DAS and harvest, respectively).

4.1.2.3 Combined Effect of Variety and Spacing

Statistically significant variation was found in number of leaflets plant^{-1} of chickpea due to combined effect of variety and spacing at 20, 40, 60, 80, 100 DAS and harvest (Table 2). The result showed that, at 20 DAS the maximum number of leaflets plant^{-1} (16.00) was recorded from V_1Sp_5 which was closely followed by V_1Sp_1 (15.47), V_1Sp_2 (14.20), V_1Sp_3 (15.86), V_1Sp_4 (15.13), V_3Sp_1 (14.63), V_3Sp_2 (14.47), V_3Sp_3 (15.53), V_3Sp_4 (15.17) and V_3Sp_5 (15.33) while interaction of V_1Sp_3 produced significantly higher number of leaflets plant^{-1} (78.13, 180.4, 450.2, 473.8 and 359.0 at 40, 60, 80, 100 DAS and harvest, respectively) which was statistically similar with V_1Sp_4 (70.50), V_1Sp_5 (69.57), V_2Sp_3 (68.17) and V_3Sp_5 (72.33) at 40 DAS; V_1Sp_4 (163.1), V_1Sp_5 (165.7) and V_3Sp_5 (164.6) at 60 DAS. The lower number of leaflets plant^{-1} (48.50 at 40 DAS) was obtained from V_2Sp_1 which was similar with V_2Sp_2 (57.00), V_3Sp_1 (58.27) and V_3Sp_2 (57.53). But at 20, 60, 80, 100 DAS & harvest lower number of leaflets plant^{-1} (12.13, 124.9, 245.2, 253.7 and 206.1) was recorded from V_2Sp_2 which was statistically identical with V_2Sp_1 (12.53), V_2Sp_3 (13.00), V_2Sp_4 (13.00) and V_2Sp_5 (13.33) at 20 DAS; V_1Sp_2 (136.3), V_2Sp_1 (129.2), V_3Sp_1 (138.8) and V_3Sp_2 (130.6) at

60 DAS; V_1Sp_2 (277.8), V_2Sp_1 (252.9), V_3Sp_1 (272.6), V_3Sp_2 (262.2) and V_3Sp_3 (285.0) at 80 DAS; V_1Sp_2 (136.3), V_2Sp_1 (129.2), V_3Sp_1 (138.8) and V_3Sp_2 (130.6) at 60 DAS; V_1Sp_2 (222.4), V_2Sp_1 (213.3), and V_3Sp_2 (210.2) at harvest.

Table 2: Combined effect of variety & spacing on number of leaflets plant^{-1} of chickpea at different days

Treatments	Days after sowing (DAS)					
	20	40	60	80	100	At harvest
V_1Sp_1	15.47 a	62.70 b-f	148.0 b-e	301.8 c-h	315.5 cd	262.7 de
V_1Sp_2	14.20 a-d	64.10 b-f	136.3 d-f	277.8 e-i	283.3 de	222.4 fg
V_1Sp_3	15.86 a	78.13 a	180.4 a	450.2 a	473.8 a	359.0 a
V_1Sp_4	15.13 ab	70.50 ab	163.1 a-c	349.9 bc	364.5 b	298.3 bc
V_1Sp_5	16.00 a	69.57 a-c	165.7 ab	344.1 bc	368.6 b	310.6 b
V_2Sp_1	12.53 de	48.50 g	129.2 ef	252.9 hi	265.4 e	213.3 g
V_2Sp_2	12.13 e	57.00 fg	124.9 f	245.2 i	253.7 e	206.1 g
V_2Sp_3	13.00 c-e	68.17 a-d	156.1 b-d	325.8 b-e	350.3 bc	258.5 de
V_2Sp_4	13.00 c-e	64.03 b-f	148.6 b-e	316.6 b-f	335.9 bc	262.0 de
V_2Sp_5	13.33 b-e	66.97 b-f	145.6 c-e	327.7 b-d	340.8 bc	243.3 ef
V_3Sp_1	14.63 a-c	58.27 d-g	138.8 d-f	272.6 f-i	286.1 de	248.8 e
V_3Sp_2	14.47 a-c	57.53 e-g	130.6 ef	262.2 g-i	290.1 de	210.2 g
V_3Sp_3	15.53 a	67.10 b-e	152.5 b-d	285.0 d-i	335.3 bc	277.0 cd
V_3Sp_4	15.17 ab	60.18 c-f	146.1 b-e	307.6 c-g	319.6 cd	266.4 de
V_3Sp_5	15.33 a	72.33 ab	164.6 a-c	360.1 b	376.2 b	283.1 cd
LSD (0.05)	1.84	10.05	20.09	49.20	44.20	25.56
CV (%)	7.60	9.27	8.02	9.36	7.93	5.84

V_1 = BARI chola-5, V_2 = BARI chola-6, V_3 = BARI chola-9

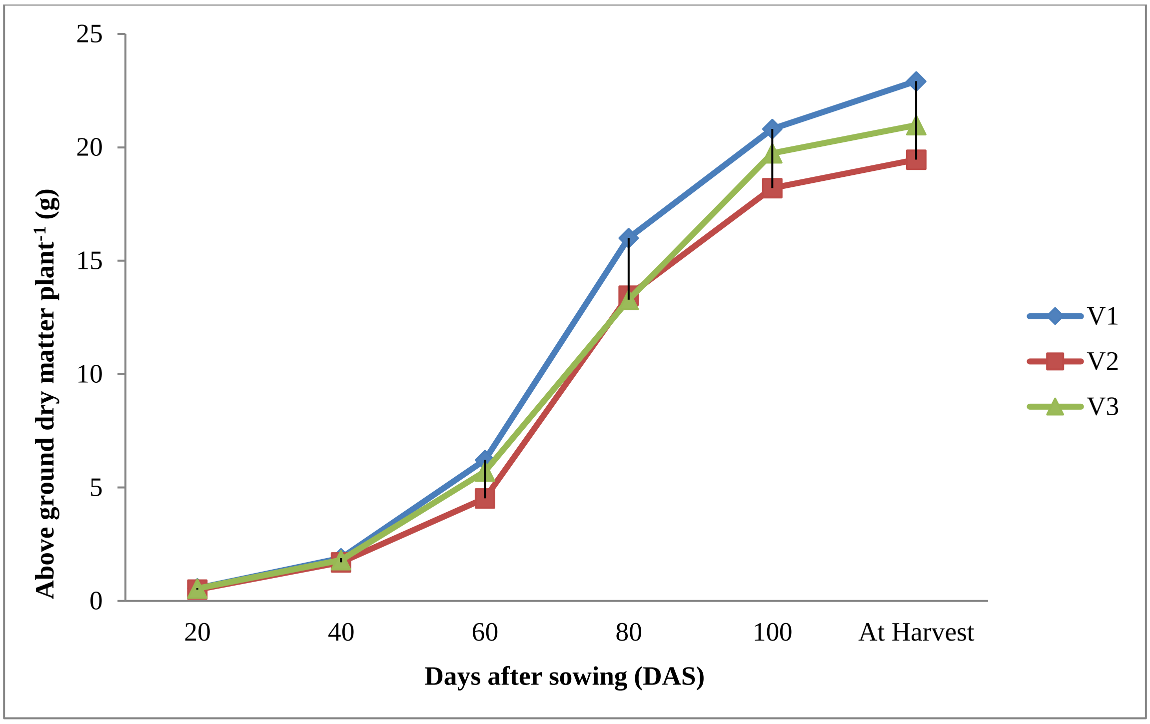
Sp_1 = 40 cm x 10 cm. Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

4.1.3 Above ground dry matter weight plant^{-1} (g)

Irrespective of treatment variables the trend of dry matter production in chickpea was very slow early in the growth stages then increased rapidly after flowering (60 DAS) and picked at harvest.

4.1.3.1 Effect of Variety

The effect of variety on above ground dry matter plant^{-1} showed significant variations at 40, 60, 100 DAS and harvest (Fig. 5). BARI Chola-5 (V_1) produced the highest above ground dry matter plant^{-1} (1.89 g, 6.22 g, 20.82 g and 22.92 g at 40, 60, 100 DAS and harvest, respectively). On the other hand, BARI Chola-6 (V_2) scored the lowest above ground dry matter plant^{-1} (1.71 g, 4.53 g, 13.47 g, 18.20 g and 19.46 g). Sandhya Rani and Giridhara Krishna (2016) noted that dry matter content of chickpea showed significant variation with different varieties.

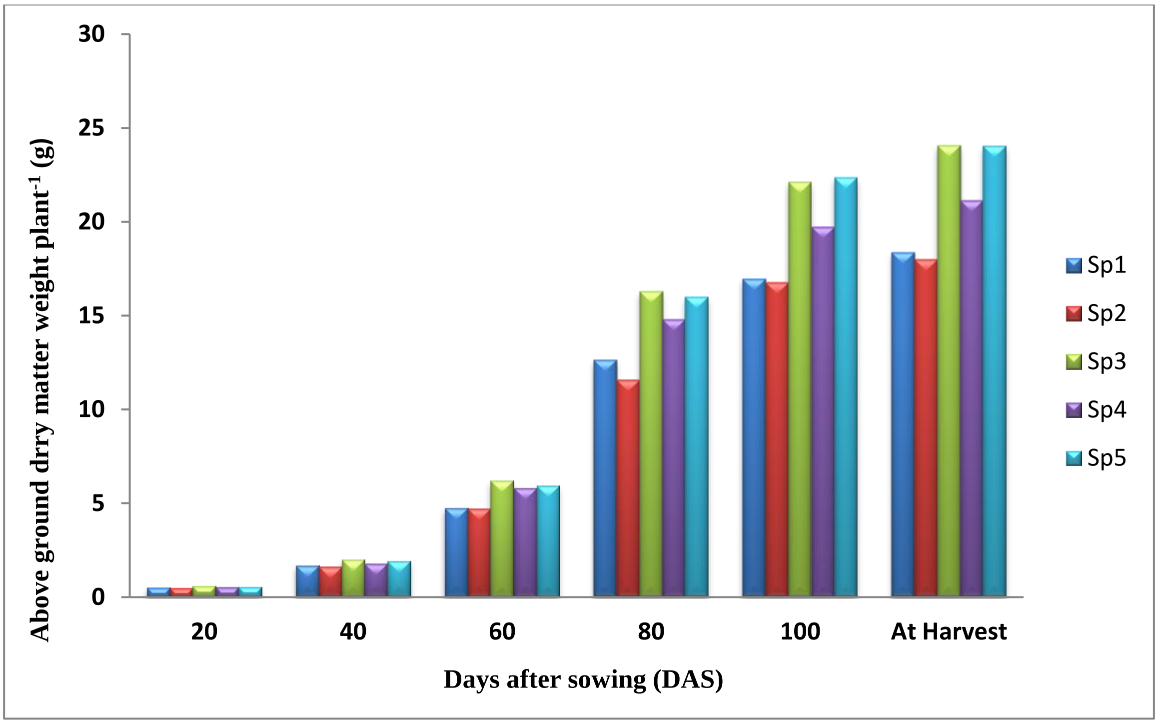


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 5. Effect of variety on above ground dry weight plant^{-1} (g) of chickpea at different days (LSD $_{(0.05)}$ = 0.08, 0.09, 0.92, 3.42, 1.54 and 2.32 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

4.1.3.2 Effect of Spacing

Above ground dry matter showed significant variations for different spacing at 20, 40, 60, 80, 100 DAS and harvest (Fig. 6). Among different treatments Sp_3 scored the highest value of dry matter plant^{-1} (0.58 g, 1.99 g, 6.21 g, 16.27 g, 22.12 g and 24.06 g at 20, 40, 60, 80, 100 DAS and harvest, respectively). On the other hand, the lowest value of above ground dry matter plant^{-1} (0.50, 1.62, 4.73, 11.57, 16.77 and 18.00 g at 20, 40, 60, 80, 100 DAS and harvest, respectively) was found from Sp_2 and it was statistically similar with Sp_1 at all sampling date. Beech and Leach (1989) found a little effect of spacing on above ground dry matter production of chickpea.



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 6. Effect of spacing on above ground dry weight plant^{-1} (g) of chickpea at different days (LSD $_{(0.05)}$ = 0.04, 0.12, 0.48, 1.43, 1.47 and 2.14 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

4.1.3.3 Combined effect of Variety and Spacing

Combined effect of variety and spacing produced significant differences in above ground dry matter plant^{-1} at 20, 40, 60, 80, 100 DAS and harvest (Table 3). Treatment combination V_3Sp_1 produced significantly higher amount of dry matter plant^{-1} (0.65 g, 2.24 g, 7.02 g, 18.80 g, 24.18 g and 26.89 g at 20, 40, 60, 80, 100 DAS and harvest, respectively which was statistically identical with V_3Sp_5 (0.60 g and 2.07 g) at 20 and 40 DAS; V_1Sp_4 (6.30 g), V_3Sp_4 (6.22 g) and V_1Sp_4 (6.74 g) at 60 DAS; V_1Sp_4 (16.74 g) and V_1Sp_5 (17.54 g) at 80 DAS; V_2Sp_3 (21.69 g), V_1Sp_5 (23.32 g) and V_3Sp_5 (22.60 g) at 100 DAS; V_1Sp_5 (25.44 g), V_2Sp_3 (23.75 g) and V_3Sp_5 (24.00 g) at harvest. The lowest amount of dry matter plant^{-1} (0.46 g, 1.54 g, 3.37 g, 10.13 g, 13.56 g and 14.22 g at 20, 40, 60, 80, 100 DAS and harvest, respectively was from V_2Sp_2 which was statistically identical with V_1Sp_2 (0.50 g), V_2Sp_1 (0.50 g), V_2Sp_3 (0.50 g), V_2Sp_4 (0.52 g), V_2Sp_5 (0.50 g), V_3Sp_1 (0.52 g), V_3Sp_2 (0.53 g) and V_3Sp_2 (0.51 g) at 20 DAS; V_1Sp_1 (1.75 g), V_1Sp_2 (1.65 g), V_2Sp_1 (1.60 g), V_2Sp_4 (1.71 g), V_3Sp_1 (1.70 g) and V_3Sp_2 (1.68 g) at 40 DAS; V_2Sp_1 (3.70 g) at 60 DAS; V_1Sp_2 (12.54 g), V_2Sp_1 (11.85 g), V_3Sp_1

(11.67 g) and V_3Sp_2 (12.03 g) at 80 DAS; V_2Sp_1 (15.33 g) at 100 DAS; V_2Sp_1 (16.60 g) at harvest.

Table 3. Combined effect of variety and spacing on dry matter weight plant^{-1} of chickpea at different days

Treatments	Days after sowing (DAS)					
	20	40	60	80	100	At harvest
V_1Sp_1	0.54 b-d	1.75 c-g	5.77 b-d	14.39 c-f	18.90 e-g	20.84 c-f
V_1Sp_2	0.50 de	1.65 e-g	5.90 b-d	12.54 e-h	17.64 f-h	19.45 e-g
V_1Sp_3	0.65 a	2.24 a	7.02 a	18.80 a	24.18 a	26.89 a
V_1Sp_4	0.56 b-d	1.89 b-d	6.30 ab	16.74 a-c	20.05 d-f	22.00 b-e
V_1Sp_5	0.55 b-d	1.92 bc	6.09 bc	17.54 ab	23.32 ab	25.44 ab
V_2Sp_1	0.50 de	1.60 fg	3.70 f	11.85 gh	15.33 hi	16.60 gh
V_2Sp_2	0.46 e	1.54 g	3.37 f	10.13 h	13.56 i	14.22 h
V_2Sp_3	0.50 de	1.92 bc	5.46 c-e	16.20 b-d	21.69 a-d	23.75 a-d
V_2Sp_4	0.52 c-e	1.71 c-g	4.89 e	14.67 c-e	19.26 d-f	20.06 d-g
V_2Sp_5	0.50 de	1.76 c-f	5.23 de	14.51 c-e	21.17 b-e	22.67 b-e
V_3Sp_1	0.52 b-e	1.70 d-g	4.79 e	11.67 gh	16.62 gh	17.67 f-h
V_3Sp_2	0.53 b-e	1.68 e-g	4.92 e	12.03 f-h	19.10 e-g	20.34 c-f
V_3Sp_3	0.59 a-c	1.83 c-e	6.17 bc	13.81 d-g	20.50 c-e	21.54 c-e
V_3Sp_4	0.51 de	1.77 c-f	6.22 a-c	12.96 e-g	19.87 d-f	21.33 c-f
V_3Sp_5	0.60 ab	2.07 ab	6.47 ab	15.92 b-d	22.60 a-c	24.00 a-c
$LSD_{(0.05)}$	0.075	0.213	0.832	2.47	2.54	3.71
CV (%)	9.22	6.99	9.00	10.30	7.70	10.42

V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

4.1.3.4 Dry matter partitioning (%)

Dry matter partitioning in different parts of chickpea (leaf, stem and reproductive unit) at different days had been shown in figure 7. Figure showed that the dry matter partitioning in leaves was maximum at initial stages (20 and 40 DAS) and declined there after. The partitioning of dry matter in leaves was 62.11, 51.74, 43.10, 36.54, 26.37 and 15.24% at 20, 40, 60, 80, 100 DAS and harvest, respectively. In stem it was 37.89, 48.25, 56.9, 54.94, 41.22 and 45.59% % at 20, 40, 60, 80, 100 DAS and harvest, respectively. In reproductive units, dry matter partitioning started at 80 DAS and continued till harvest. The amount partitioned in reproductive units was 8.52, 32.41, and 39.17% at 80, 100 DAS and harvest, respectively.

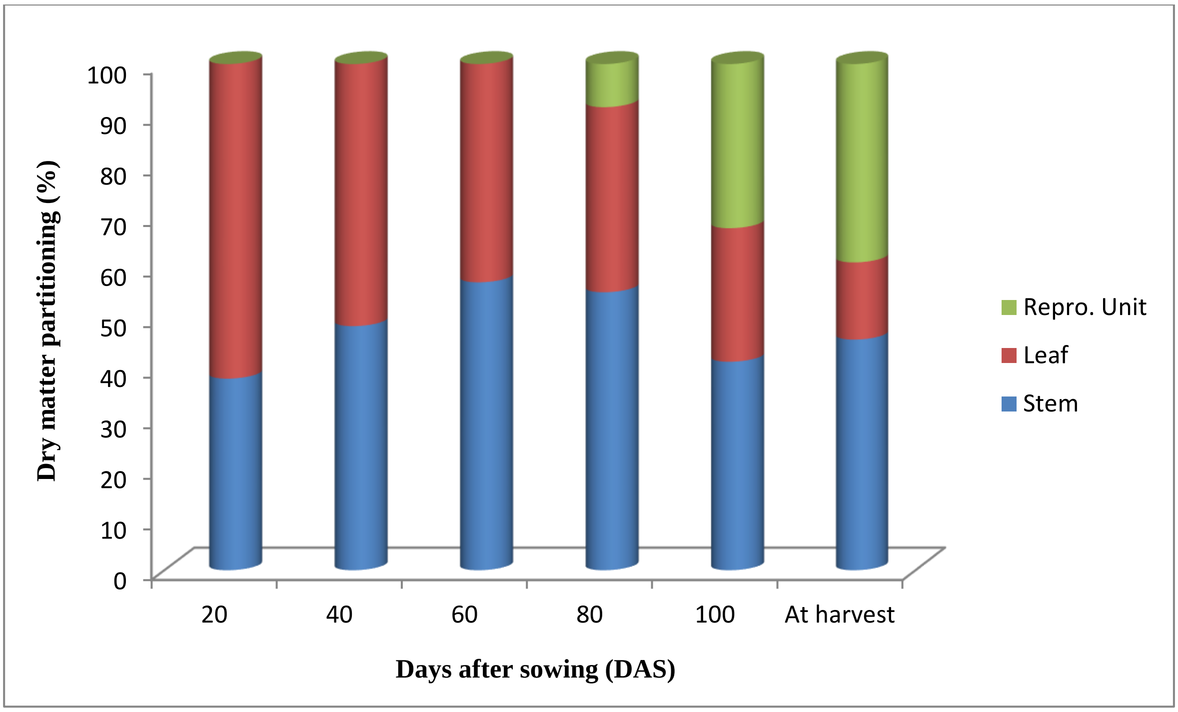
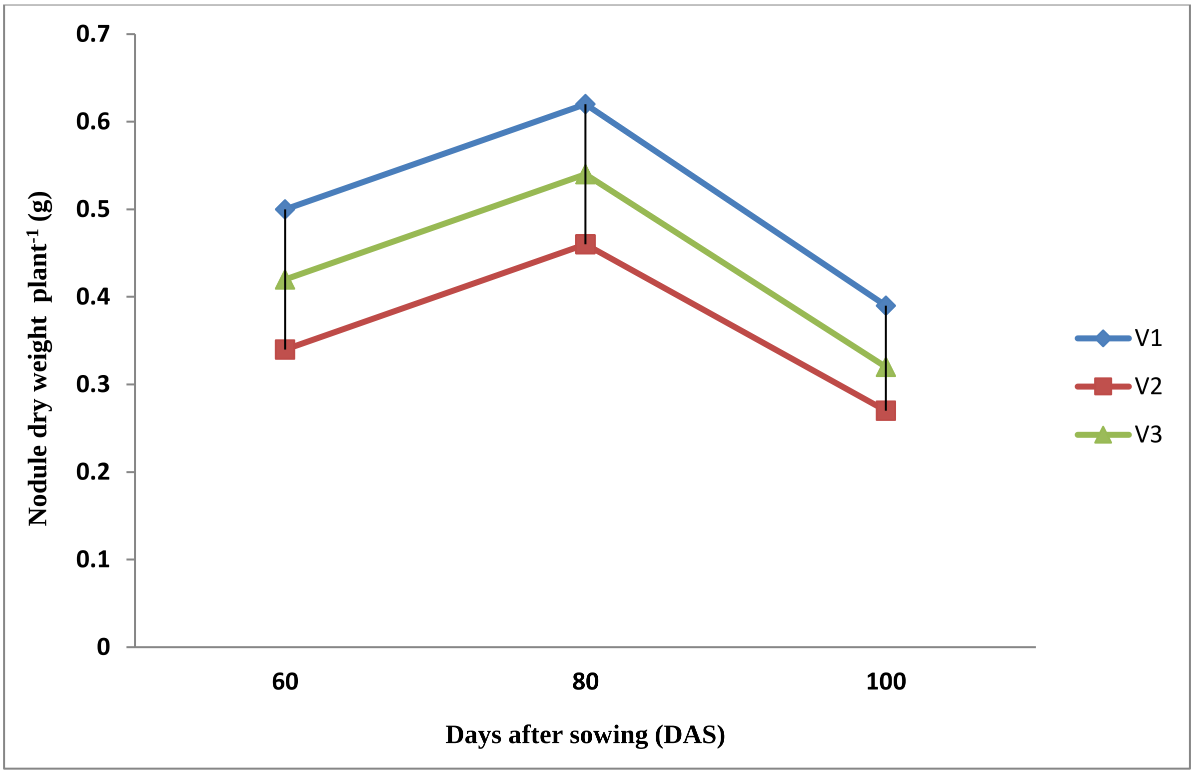


Figure 7: Dry matter partitioning (%) of chickpea at different days

4.1.4. Nodule dry weight plant^{-1} (g)

4.1.4.1 Effect of Variety

The effect of variety on nodule dry weight plant^{-1} showed significant variations at 40, 80 and 100 DAS (Fig. 8). The highest value of nodule dry weights plant^{-1} (0.50 g, 0.62 g and 0.39 g at 60, 80 and 100 DAS, respectively) was obtained from V_1 while the lowest value of nodule dry weights plant^{-1} (0.34, 0.46 and 0.27 g at 60, 80 and 100 DAS, respectively) was found in V_2. Solaiman *et al.* (2007) found higher value of nodule dry weight from BARI Chola-5.

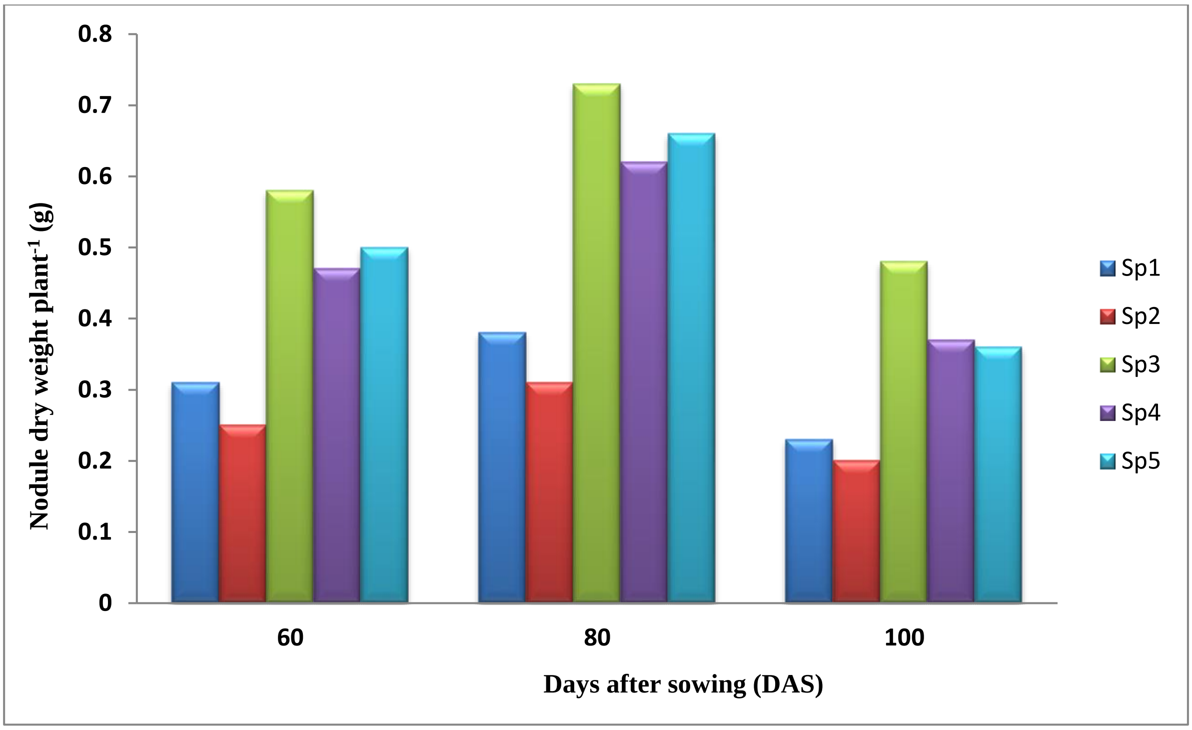


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 8. Effect of variety on nodule dry weight plant^{-1} (g) of chickpea at different days (LSD $_{(0.05)}$ = 0.05, 0.03 and 0.03 at 60, 80 and 100 DAS, respectively)

4.1.4.2 Effect of Spacing

Statistically significant variation was recorded for nodule dry weight plant^{-1} of chickpea at 60, 80 and 100 DAS due to different spacing (Fig. 9). At 60, 80 and 100 DAS the highest nodule dry weight plant^{-1} (0.58 g, 0.73 g and 0.48 g) was found in Sp_3 and the lowest nodule dry weight plant^{-1} (0.25 g, 0.31 g and 0.20 g) was obtained from Sp_2.



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 9. Effect of spacing on nodule dry weight plant^{-1} (g) of chickpea at different days (LSD $_{(0.05)}$ = 0.03, 0.53 and 0.04 at 60, 80 and 100 DAS, respectively)

4.1.4.3 Combined effect of Variety and Spacing

Statistically significant differences were detected for the combined effect of variety and spacing for nodule dry weight plant^{-1} of chickpea at 60, 80 and 100 DAS (Table 4). The highest value of nodule dry weight plant^{-1} (0.69 g, 0.85 g and 0.59 g at 60, 80 and 100 DAS, respectively) was observed in the treatment combination V_1Sp_3 which was statistically at par with V_1Sp_5 (0.79 g) at 80 DAS while the lowest value of nodule dry weights plant^{-1} (0.18 g, 0.24 g and 0.16 g at 60, 80 and 100 DAS, respectively) was observed in the combination of V_2Sp_2 which was similar with V_2Sp_1 (0.19 g) at 100 DAS.

Table 4. Combined effect of variety and spacing on nodule dry weight plant^{-1} of chickpea at different days

Treatments	Days after sowing (DAS)		
	60	80	100
V_1Sp_1	0.36 ef	0.41 fg	0.29 de
V_1Sp_2	0.30 gh	0.35 g	0.24 e-g
V_1Sp_3	0.69 a	0.85 a	0.59 a
V_1Sp_4	0.57 bc	0.70 bc	0.45 b
V_1Sp_5	0.60 b	0.79 ab	0.42 b
V_2Sp_1	0.26 h	0.36 g	0.19 gh
V_2Sp_2	0.18 i	0.24 h	0.16 h
V_2Sp_3	0.51 d	0.68 c	0.45 b
V_2Sp_4	0.35 fg	0.54 de	0.27 d-f
V_2Sp_5	0.41 e	0.50 ef	0.30 d
V_3Sp_1	0.30 gh	0.37 g	0.22 fg
V_3Sp_2	0.28 h	0.34 g	0.20 gh
V_3Sp_3	0.54 cd	0.67 c	0.41 bc
V_3Sp_4	0.49 d	0.62 cd	0.40 bc
V_3Sp_5	0.50 d	0.69 c	0.36 c
LSD $_{(0.05)}$	0.05	0.09	0.05
CV (%)	8.46	10.24	11.72

V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

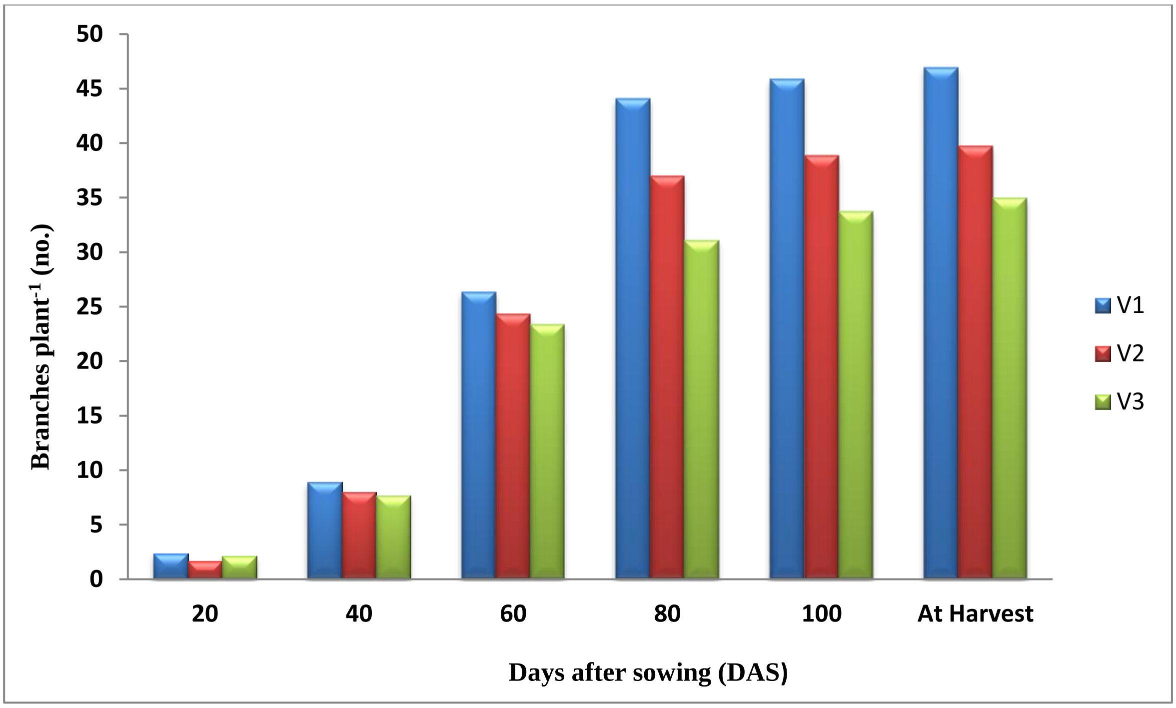
Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

4.2 Yield contributing characters

4.2.1 Branches plant^{-1} (no.)

4.2.1.1 Effect of Variety

Statistically significant variation was found in number of branches plant^{-1} of chickpea due to different varieties at 20, 40, 60, 80, 100 DAS and harvest (Fig. 10). BARI Chola-5 (V_1) scored higher number of branches plant^{-1} (2.36, 8.92, 26.35, 44.08, 45.90 and 46.93 at 20, 40, 60, 80, 100 DAS and at harvest, respectively). At 20 DAS, the lowest number of branch plant^{-1} (1.65) was noted in BARI Chola-6 (V_2). On the other hand, BARI Chola-9 (V_3) produced lowest number of branches (7.68, 23.36, 31.07, 33.71 and 34.97 at 40, 60, 80, 100 DAS and harvest, respectively) which statistically was similar with BARI Chola-6 (V_2) (8.02 and 24.32 at 40 and 60 DAS). Sharma *et al.* (1988) and Dixit *et al.* (1993) reported variation in number of branches plant^{-1} for different varieties.

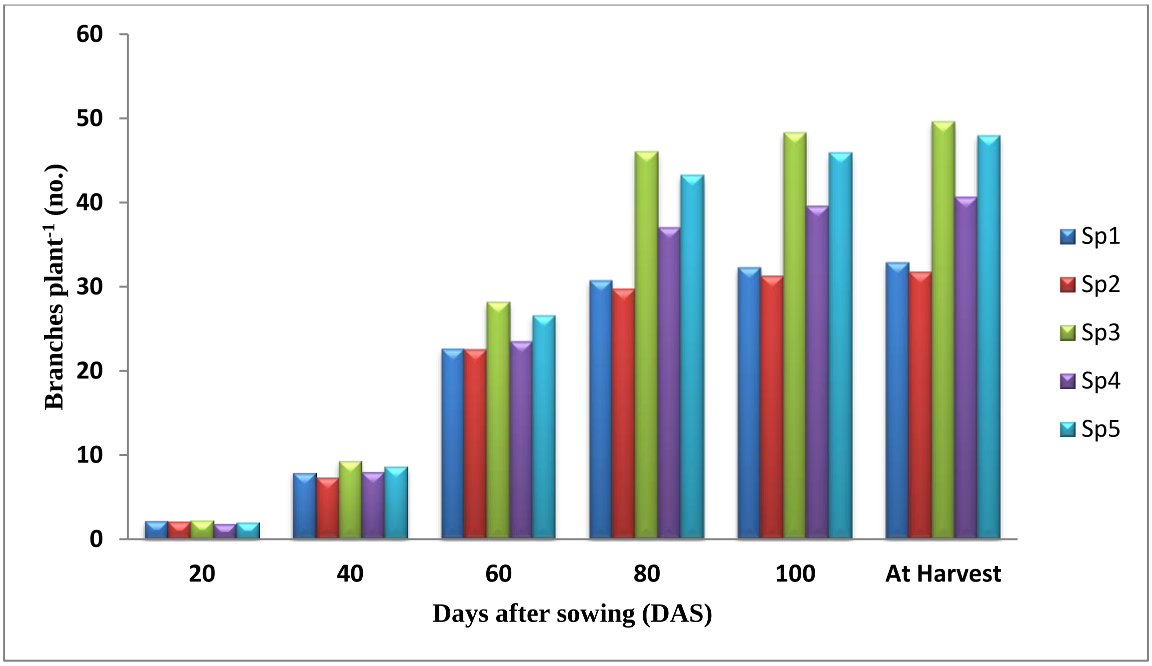


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 10. Effect of variety on number of branches plant^{-1}of chickpea at different stages (LSD $_{(0.05)}$ = 0.18, 0.43, 1.45, 2.88, 2.83 and 3.55 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

4.2.1.2 Effect of Spacing

Different spacing produced significant variations in number of branches plant^{-1} throughout the growing season (Fig. 11). At 20 DAS, treatment Sp_3 gave the highest number of branches plant^{-1} (2.22) which was statistically similar with Sp_1 (2.18) and S_2 (2.09) while the lowest number of branches plant^{-1} (1.82) was found from Sp_4. At 40 DAS, the highest number of branch plant^{-1} (9.29) was attained from Sp_3 while the lowest number of branches plant^{-1} (7.31) was found from $Sp_{2.}$ At 60 DAS, the highest number of branch plant^{-1} (28.21) was obtained from Sp_3 followed by Sp_5 (26.57) while the lowest number of branch plant^{-1} (21.68) was found from Sp_1 which was closely followed by Sp_2 (22.52). At 80 DAS, treatment Sp_3 gave the highest number of branch plant^{-1} (46.06) while the lowest number of branch (29.73) was found from Sp_2 which was statistically similar with Sp_1 (30.74). At 100 DAS, the highest number of branch plant^{-1} (48.32) was attained from Sp_3 which was statistically identical with Sp_5 (45.97) while the lowest number of branch plant^{-1} (31.27) was found from Sp_2 which was closely followed by Sp_1 (32.30). At harvest, treatment Sp_3 gave the highest number of branch plant^{-1} (49.62) while the lowest number of branches plant^{-1} (31.73) was found from Sp_2 which was statistically similar with Sp_1 (32.86). Minimum number of branches plant^{-1} at narrower spacing might be due to more competition for resources and production of lower assimilates among the plants. Togay *et al*. (2005) and Bakry *et al*. (2011) noticed decreased number of primary branches with the increase in density of chickpea. Mehmet (2008) found higher number of branches of Soybean at wider spacing.



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 11. Effect of spacing on number of branches plant^{-1}of chickpea at different days (LSD $_{(0.05)}$ = 0.14, 0.52, 1.94, 2.66, 2.65 and 3.20 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

4.2.1.3 Combined effect of Variety and Spacing

Number of branches plant^{-1} showed significant differences at 20, 40, 60, 80, 100 DAS and harvest due to combined effect of variety and spacing (Table 5). At 20 DAS, highest number of branches plant^{-1} (2.67) was found from V_1Sp_3 which was statistically similar with V_1Sp_2 (2.47) and V_3Sp_1 (2.53). On the contrary, the lowest number of branch plant^{-1} (1.60) was obtained from V_2Sp_5 which was statistically similar withV_2Sp_2 (1.67) and V_2Sp_1 (1.73). At 40 DAS, the highest number of branch plant^{-1} (11.38) was recorded from V_1Sp_3 and the lowest number of branch plant^{-1} (6.90) was recorded from V_3Sp_2 which was statistically similar with V_2Sp_1 (7.30), V_2Sp_2 (7.20), V_3Sp_1 (7.60) and V_3Sp_3 (7.53). At 60 DAS, the highest number of branch plant^{-1} (31.33) was noted from V_1Sp_3

and the lowest number of branch plant^{-1} (18.75) was recorded from V_3Sp_1 which was statistically similar with V_2Sp_2 (21.64) and V_3Sp_4 (21.50). At 80 DAS, the highest number of branch plant^{-1} (56.43) was noted from V_1Sp_3 and the lowest number of branch plant^{-1} (25.67) was recorded from V_3Sp_1 which was statistically similar with V_2Sp_2 (28.44), V_3Sp_2 (30.07) and V_3Sp_4 (27.10). At 100 DAS, the highest number of branch plant^{-1} (59.10) was noted from V_1Sp_3 and the lowest number of branch plant^{-1} (27.35) was recorded from V_3Sp_1 followed by V_1Sp_2 (31.72), V_2S_2 (30.07) and V_3Sp_4 (30.67). At harvest, the highest number of branch plant^{-1} (60.22) was recorded from V_1Sp_3 and the lowest number of branch plant^{-1} (28.20) was observed from V_3Sp_1 which was at par withV_1Sp_2 (32.20), V_2Sp_1 (33.28), V_2Sp_2 (30.49), V_3Sp_2 (32.50) and V_3Sp_4 (32.50).

Table 5. Combined effect of variety and spacing on branches plant^{-1} of chickpea at different days

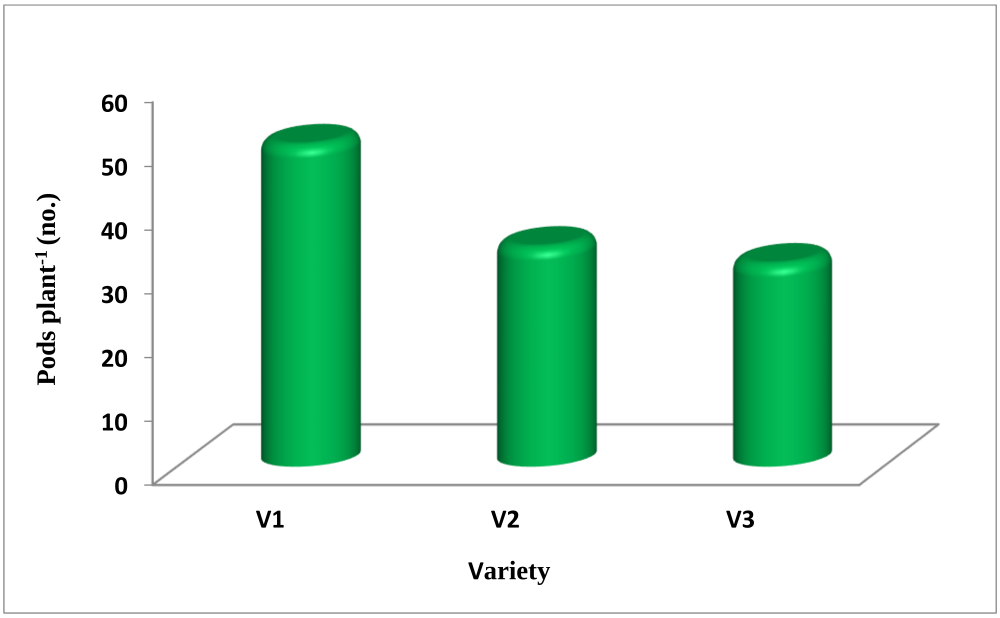
Treatments	**Days after sowing**					
	20 DAS	**40 DAS**	**60 DAS**	**80 DAS**	**100 DAS**	**At harvest**
V_1Sp_1	2.27 bc	8.70 b-d	23.98 cd	35.72 de	36.67 ef	37.10 f-h
V_1Sp_2	2.47 ab	7.83 d-g	22.67 cd	30.67 fg	31.72 g-i	32.20 h-j
V_1Sp_3	2.67 a	11.38 a	31.33 a	56.43 a	59.10 a	60.22 a
V_1Sp_4	2.20 c	8.33 c-e	26.00 bc	47.60 b	48.70 c	49.28 cd
V_1Sp_5	2.20 c	8.37 b-e	27.78 b	50.00 b	53.30 b	55.83 ab
V_2Sp_1	1.73 ef	7.30 f-h	22.31 d	30.82 fg	32.87 f-h	33.28 h-j
V_2Sp_2	1.67 f	7.20 gh	21.64 de	28.44 gh	30.07 hi	30.49 ij
V_2Sp_3	1.93 de	8.98 bc	27.47 b	48.50 b	50.67 bc	52.67 bc
V_2Sp_4	1.33 g	8.40 b-e	25.67 bc	36.46 c-e	39.50 de	40.07 fg
V_2Sp_5	1.60 f	8.20 c-f	24.50 b-d	40.67 c	41.30 d	42.33 ef
V_3Sp_1	2.53 a	7.60 e-h	18.75 e	25.67 h	27.35 i	28.20 j
V_3Sp_2	2.13 cd	6.90 h	23.27 cd	30.07 f-h	32.01 gh	32.50 h-j
V_3Sp_3	2.07 cd	7.53 e-h	25.84 bc	33.25 ef	35.20 e-g	35.97 g-i
V_3Sp_4	1.93 de	7.11 gh	21.50 de	27.10 gh	30.67 g-i	32.50 h-j
V_3Sp_5	2.13 cd	9.27 b	27.44 b	39.25 cd	43.30 d	45.67 de
LSD (0.05)	0.25	0.90	3.36	4.61	4.59	5.54
CV (%)	7.22	6.53	8.07	7.31	6.91	8.11

V_1 = BARI chola 5, V_2 = BARI chola 6, V_3 = BARI chola 9, Sp_1 = 40 cm x 10 cm
Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

4.2.2 Pods plant^{-1} (no.)

4.2.2.1 Effect of Variety

Pods plant^{-1} of chickpea varied significantly due to different varieties (Fig. 12). The highest number of pods plant^{-1} was found in V_1 (50.43) which was 50.43% and 46.39% more than V_2 and V_3 and the lowest number of pods plant^{-1} was found in V_3 (31.81). Sikdar *et al*. (2015) reported BARI chola 4 as maximum pod bearing variety.

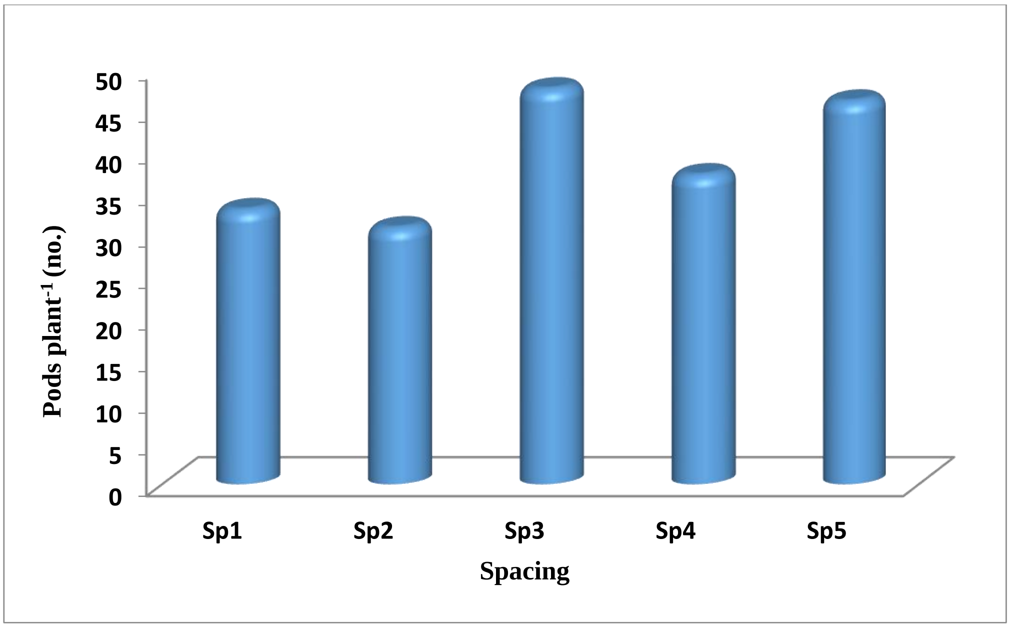


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 12. Effect of variety on pods plant^{-1} (no.) of chickpea (LSD $_{(0.05)}$ = 2.23)

4.2.2.2 Effect of Spacing

Pods plant^{-1} of chickpea showed significant variation for spacing (Fig. 13). The highest number of pods per plant was found in Sp_3 (47.49) which was statistically similar with Sp_5 (46.03). Sp_3 produced 54.14% more pods plant^{-1} than Sp_2 which produced the lowest number of plant^{-1} (30.81). The difference among spacing on number of pods might be due to the fact that, in narrow spacing there was more competition for the growth factors due to increased number of plant population as compared to wider spacing. In wider spacing the reduced competition for light and reduced overlapping from adjacent chickpea plants could have enabled the plants to utilize its energy for more branching and subsequently, the greater number of pods plant^{-1}. In agreement to the present result, Khan *et al*. (2010) also reported higher number of pods plant^{-1} in the wider inter row spacing of chickpea.



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 13. Effect of spacing on pods plant^{-1} (no.) of chickpea (LSD (0.05) = 2.08)

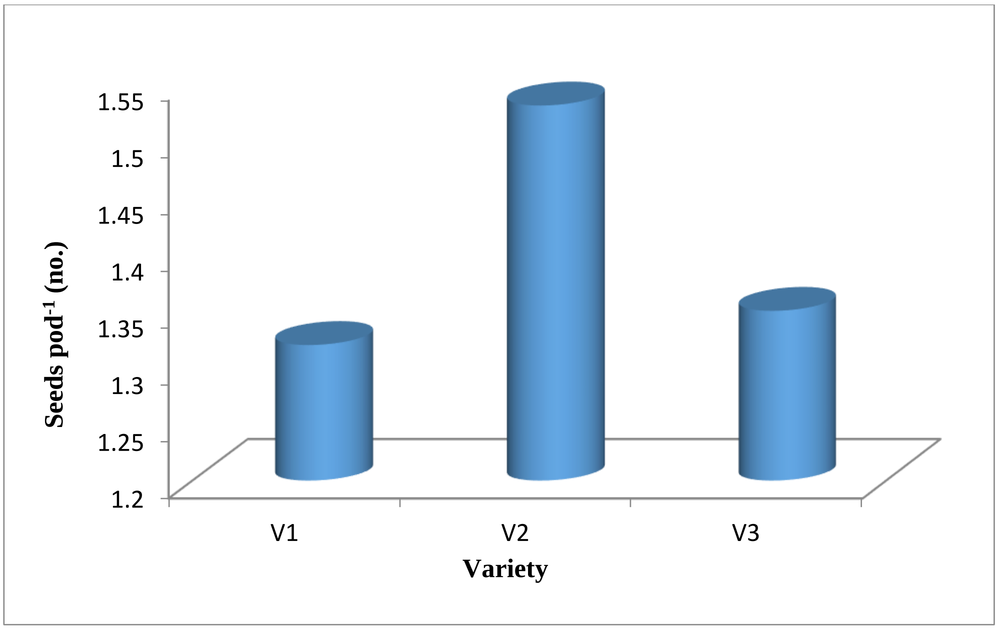
4.2.2.3 Combined effect of Variety and Spacing

Significant variation on number of pods plant^{-1} was observed due to the combined effect of chickpea varieties and different spacing (Table 6). The maximum number of pods plant^{-1} (66.00) was found from treatment V_1Sp_3 and the minimum pods plant^{-1} (23.07) from V_2Sp_2 which was statistically at par with V_3Sp_1 (26.40).

4.2.3 Seeds pod^{-1} (no.)

4.2.3.1 Effect of Variety

Statistically significant variation was recorded for number of seeds pod^{-1}of chickpea due to different varieties (Fig.14). The highest number of seeds pod^{-1} was found in V_2 (1.53) while the lowest number of seeds pod^{-1} was found in V_1 (1.33), which was statistically similar to V_3 (1.35). The result was in agreement with Bhuiyan *et al.* (2008).

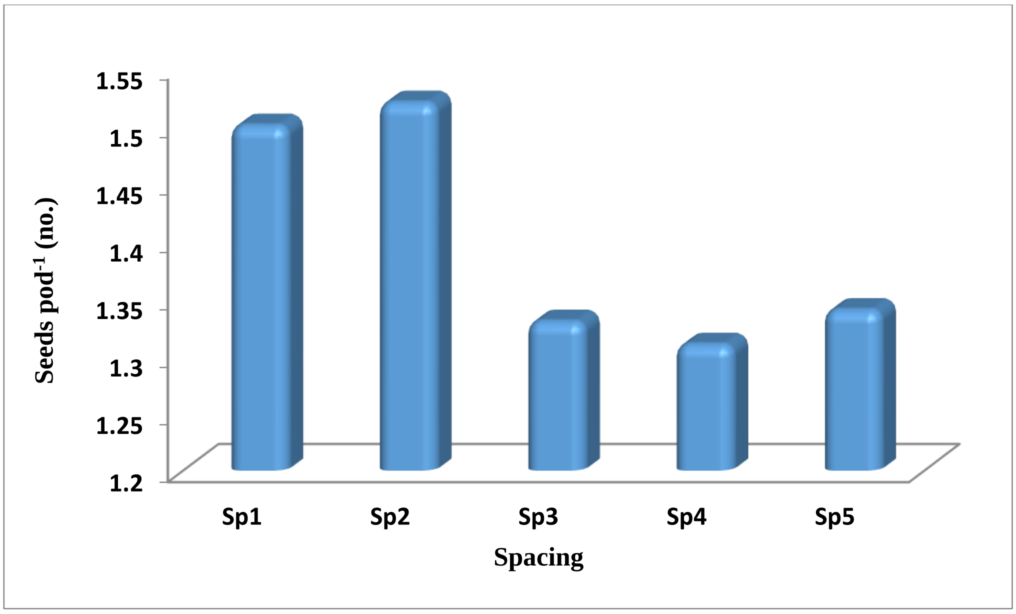


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 14. Effect of variety on seeds pod^{-1} (no.) of chickpea (LSD (0.05) = 0.17)

4.2.3.2 Effect of Spacing

Seeds pod^{-1} of chickpea showed significant variation against spacing (Fig. 15). The highest number of seeds pod^{-1} was found in Sp_2 (1.52) and the lowest number of seeds pod^{-1} was found in Sp_4 (1.31) which was statistically similar with Sp_5 (1.34). The result of a study conducted by Sharar *et al*. (2001) showed that with an increase in seeding density the number of seeds pod^{-1} decreased in chickpea. On contrary Sarwar (1998) noted non influence of different spacing on number of seeds pod^{-1}.



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 15. Effect of spacing on seeds pod^{-1} (no.) of chickpea (LSD (0.05) = 0.38)

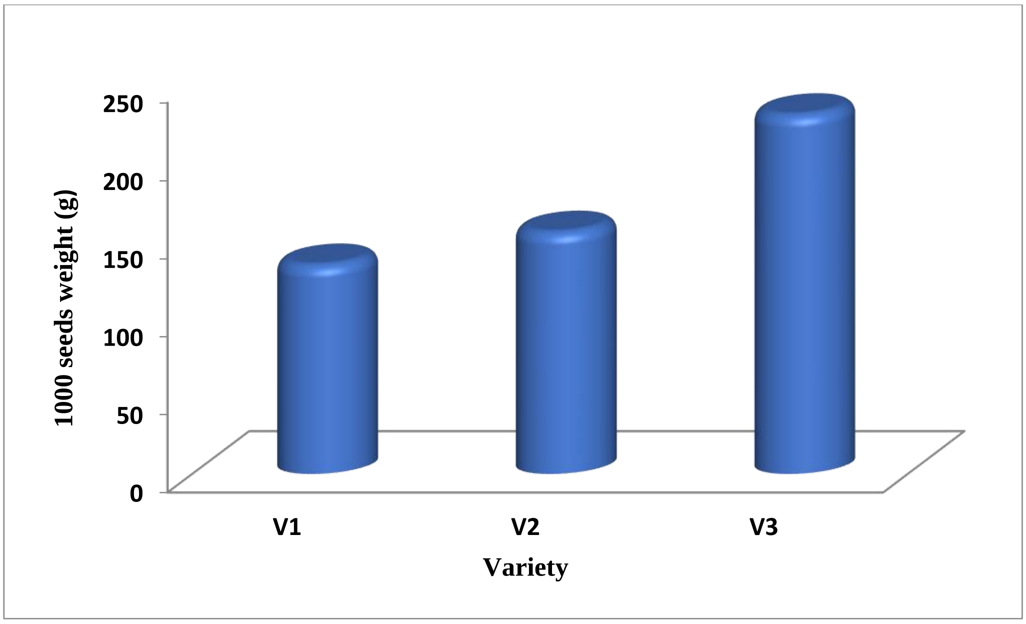
4.2.3.3 Combined effect of Variety and Spacing

Combined effect of variety and spacing showed statistically significant differences for number of seeds pod^{-1} (Table 6). The highest number of seeds pod^{-1} was recorded from V_2Sp_2 (1.75) which was statistically similar with V_1Sp_2 (1.52), V_1Sp_3 (1.38), V_2Sp_1 (1.55), V_2Sp_3 (1.37), V_2Sp_4 (1.45), V_2Sp_5 (1.53) and V_3Sp_1 (1.65). The lowest number of seeds pod^{-1} was found in V_1Sp_4 (1.20) which was closely followed by V_1Sp_1 (1.30), V_1Sp_2 (1.52), V_1Sp_3 (1.38), V_1Sp_5 (1.25), V_2Sp_1 (1.55), V_2Sp_3 (1.37), V_2Sp_4 (1.45), V_2Sp_5 (1.53), V_3Sp_2 (1.30), V_3Sp_3 (1.28), V_3Sp_4 (1.28) and V_3Sp_5 (1.25).

4.2.4 1000 seeds weight (g)

4.2.4.1 Effect of Variety

Statistically significant variation was recorded for 1000 seeds weight of chickpea due to different variety (Fig. 16). The highest 1000 seeds weight was found in V_3 (230.33 g) and the lowest 1000 seeds weight was found in V_1 (134.33 g).

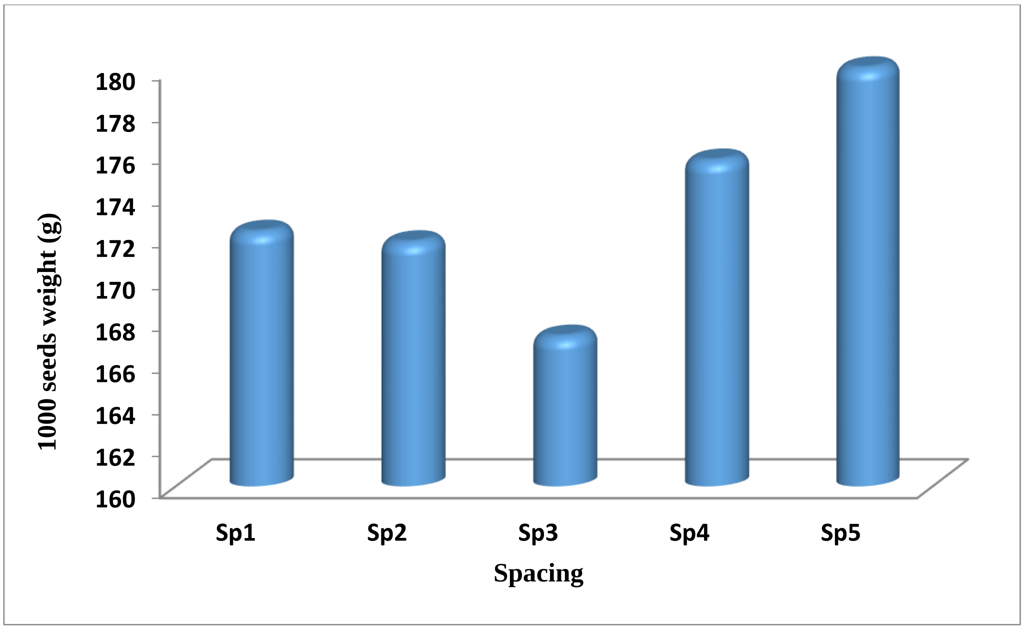


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 16. Effect of variety on 1000 seeds weight (g) of chickpea (LSD $_{(0.05)}$ = 3.27)

4.2.4.2 Effect of Spacing

1000 seeds weight of chickpea varied significantly due to different spacing (Fig. 17). The highest 1000 seeds weight was found in Sp_5 (180.0 g) which was closely followed by Sp_1 (172.2 g), Sp_2 (171.7 g) and Sp_4 (175.6). The lowest 1000 seeds weight was found in Sp_3 (167.2 g) which was followed by Sp_1 (172.2 g), Sp_2 (171.7 g) and Sp_4 (175.6 g). Sarwar (1998) found 1000 seeds weight non-significant due to different spacing.



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 17. Effect of spacing on 1000 seeds weight (g) of chickpea (LSD $_{(0.05)}$ = 9.71)

4.2.4.3 Combined effect of Variety and Spacing

Combined effect of variety and spacing showed statistically significant differences for 1000 seeds weight of chickpea (Table 6). The highest 1000 seeds weight was recorded from V_3Sp_5 (250 g) which was statistically similar with V_3Sp_4 (240 g) and the lowest was found in V_1Sp_2 (128.3 g) which was statistically similar with V_1Sp_1 (140.0 g), V_1Sp_3 (130.0 g), V_1Sp_4 (130.0 g) and V_1Sp_5 (143.3 g).

Table 6. Combined effect of variety and spacing on pods plant^{-1}, seeds pod^{-1} and 1000 seeds weight of chickpea

Treatment	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000-seeds weight (g)
V_1Sp_1	43.53 cd	1.30 bc	140.0 e-g
V_1Sp_2	39.50 ef	1.52 a-c	128.3 g
V_1Sp_3	66.00 a	1.38 a-c	130.0 fg
V_1Sp_4	46.53 c	1.20 c	130.0 fg
V_1Sp_5	56.60 b	1.25 c	143.3 e-g
V_2Sp_1	29.07 h	1.55 a-c	153.3 de
V_2Sp_2	23.07 i	1.75 a	163.3 d
V_2Sp_3	43.53 cd	1.37 a-c	156.7 de
V_2Sp_4	37.20 f	1.45 a-c	156.7 de
V_2Sp_5	39.40 ef	1.53 a-c	146.7 d-f
V_3Sp_1	26.40 hi	1.65 ab	223.3 bc
V_3Sp_2	29.87 gh	1.30 bc	223.3 bc
V_3Sp_3	32.93 g	1.25 c	215.0 c
V_3Sp_4	27.77 h	1.28 bc	240.0 ab
V_3Sp_5	42.10 de	1.25 c	250.0 a
$LSD_{(0.05)}$	3.61	0.38	16.87
CV (%)	5.51	12.39	5.78

V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

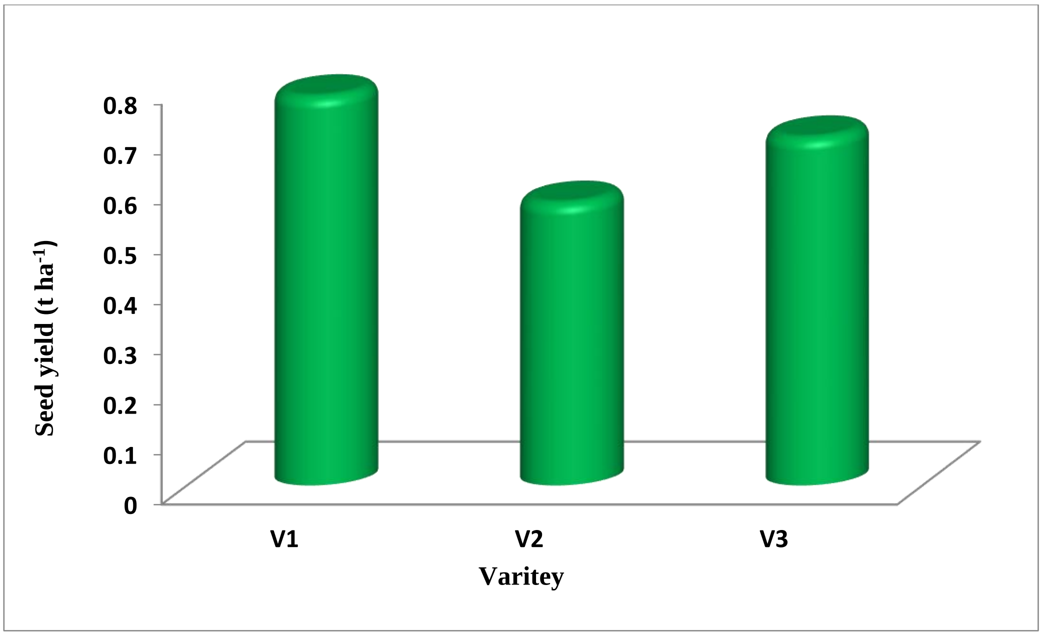
Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

4.3 Yield

4.3.1 Seed yield (t ha^{-1})

4.3.1.1 Effect of Variety

Seed yield of chickpea varied significantly due to different varieties (Fig. 18). The highest seed yield was found in V_1 (0.78 t ha^{-1}) which was 37.41% more than V_2 (0.57 t ha^{-1}).

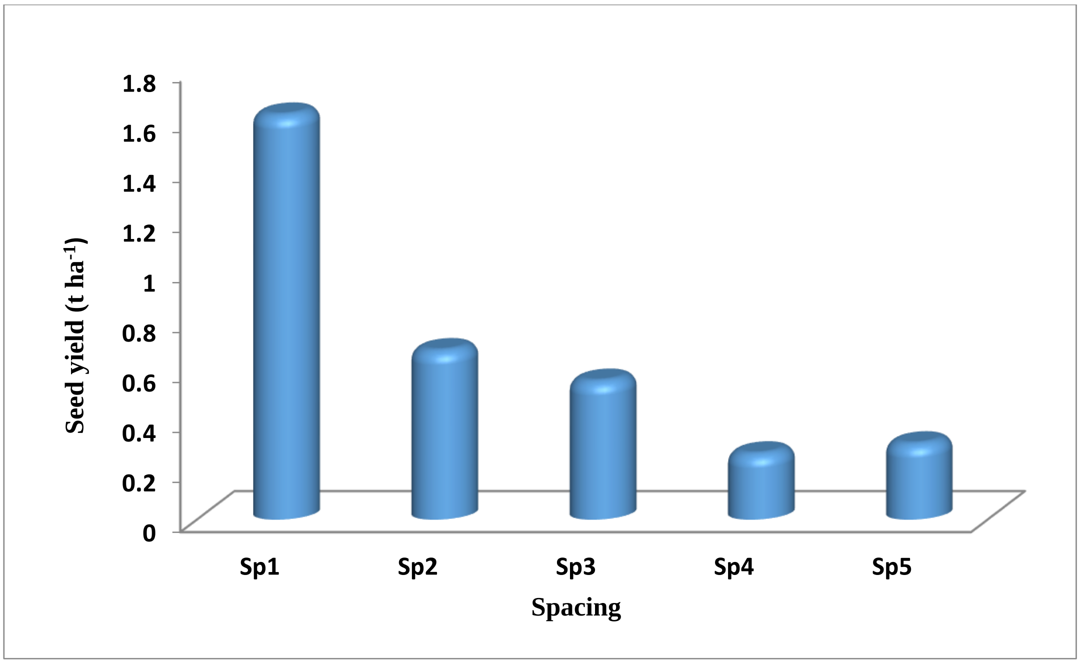


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 18. Effect of variety on seed yield (t ha^{-1}) of chickpea (LSD $_{(0.05)}$ = 0.07)

4.3.1.2 Effect of Spacing

Seed yield of chickpea showed significant variation for different spacing (Fig. 19). The highest seed yield was found in Sp_1 (1.62 t ha^{-1}), while the lowest seed yield was found in Sp_5 (0.30 t ha^{-1}) which was statistically similar with Sp_4 (0.26 t ha^{-1}). The reason of lower yield at wider spacing as lower number of plant per unit area which could not compensate yield while producing higher yield contributing parameters. The similar result was also observed by Agajie (2013). On the contrary Jettner *et al.* (1999) and Singh and Singh (2002) found higher seed yield with increasing plant density.



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 19. Effect of spacing on seed yield (t ha^{-1}) of chickpea (LSD $_{(0.05)}$ = 0.05)

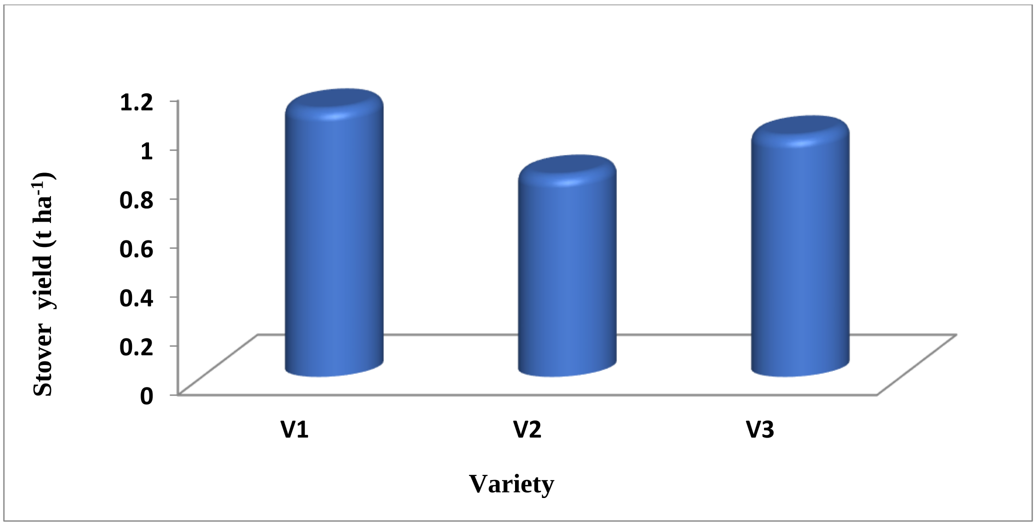
4.3.1.3 Combined effect of Variety and Spacing

Significant variation was observed due to combined effect of chickpea variety and spacing on seed yield (Table 7). The maximum seed yield (1.82 t ha^{-1}) was found from treatment V_1Sp_1 and the minimum seed yield (0.23 t ha^{-1}) from V_2Sp_5 which was statistically at par with V_2Sp_4 (0.27 t ha^{-1}), V_1Sp_4 (0.29 t ha^{-1}) and V_1Sp_5 (0.31 t ha^{-1}). Wider spacing produced minimum seed yield due to lower number of plants per unit area which did not improve due to combined effect of variety and spacing.

4.3.2 Stover yield (t ha^{-1})

4.3.2.1 Effect of Variety

Stover yield of chickpea varied significantly due to different varieties (Fig. 20). The highest stover yield was found in V_1 (1.09 t ha^{-1}) and the lowest stover yield was found in V_2 (0.82 t ha^{-1}).

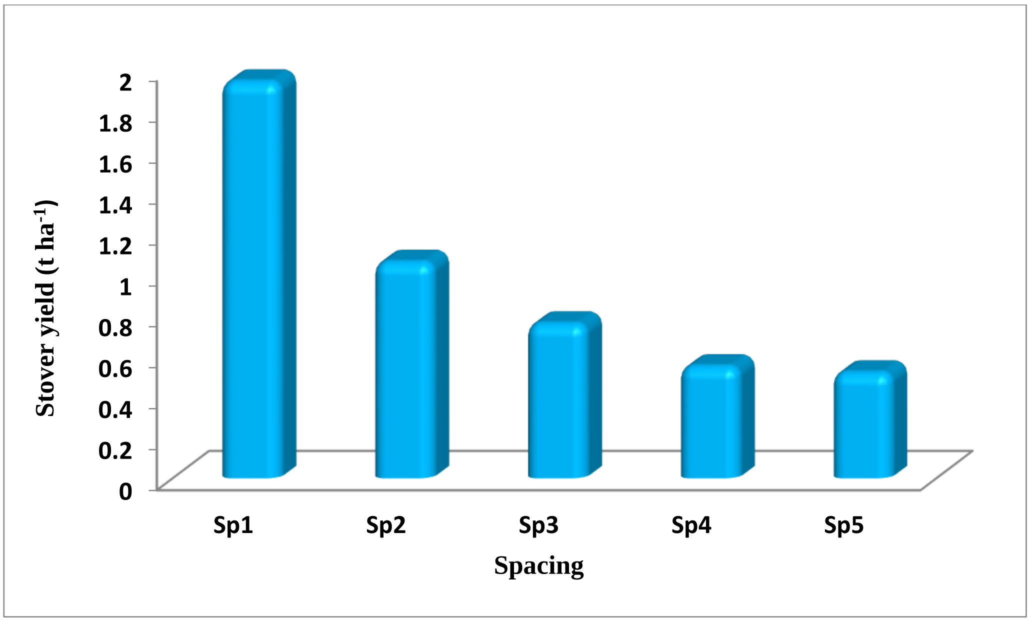


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 20. Effect of variety on stover yield (t ha^{-1}) of chickpea (LSD $_{(0.05)}$ = 0.08)

4.3.2.2 Effect of spacing

Stover yield of chickpea showed significant variation for different spacing (Fig. 21). The highest stover yield was found in Sp_1 (1.94 t ha^{-1}) and the lowest stover yield was found in Sp_5 (0.52 t ha^{-1}) which was statistically similar with Sp_4 (0.55 t ha^{-1}).



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 21. Effect of spacing on stover yield (t ha^{-1}) of chickpea (LSD $_{(0.05)}$ = 0.11)

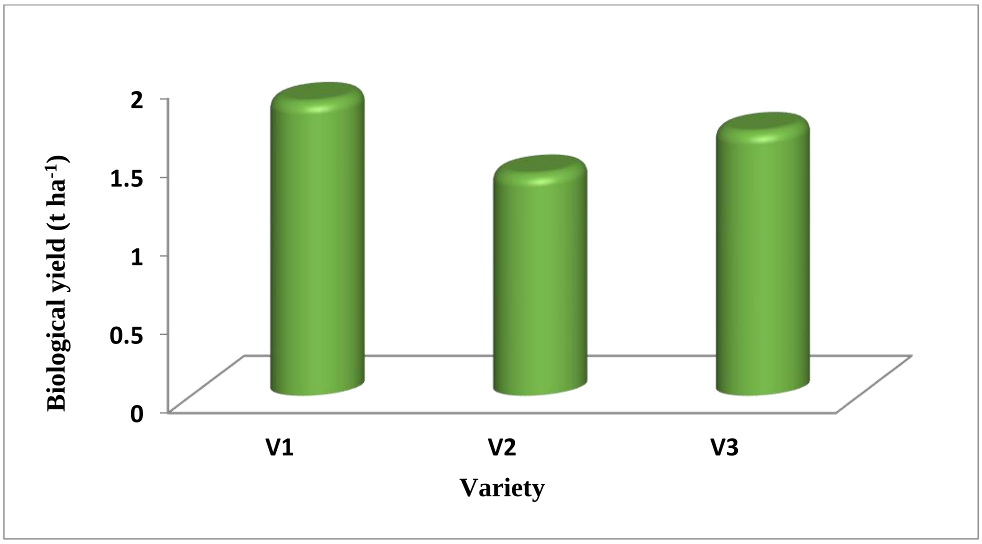
4.3.2.3 Combined effect of Variety and Spacing

Significant variation was observed due to the combined effect of chickpea variety and different spacing on stover yield (Table 7). The maximum stover yield (2.12 t ha^{-1}) was found from treatment V_1Sp_1 which was statistically similar V_3Sp_1 (1.94 t ha^{-1}) and the minimum stover yield (0.44 t ha^{-1}) from V_2Sp_5 which was statistically at par with V_3Sp_5 (0.45 t ha^{-1}).

4.3.3 Biological yield (t ha^{-1})

4.3.3.1 Effect of Variety

Biological yield of chickpea varied significantly due to different varieties (Fig. 22). The highest biological yield was found in V_1 (1.87 t ha^{-1}) and the lowest biological yield was found in V_2 (1.68 t ha^{-1}).

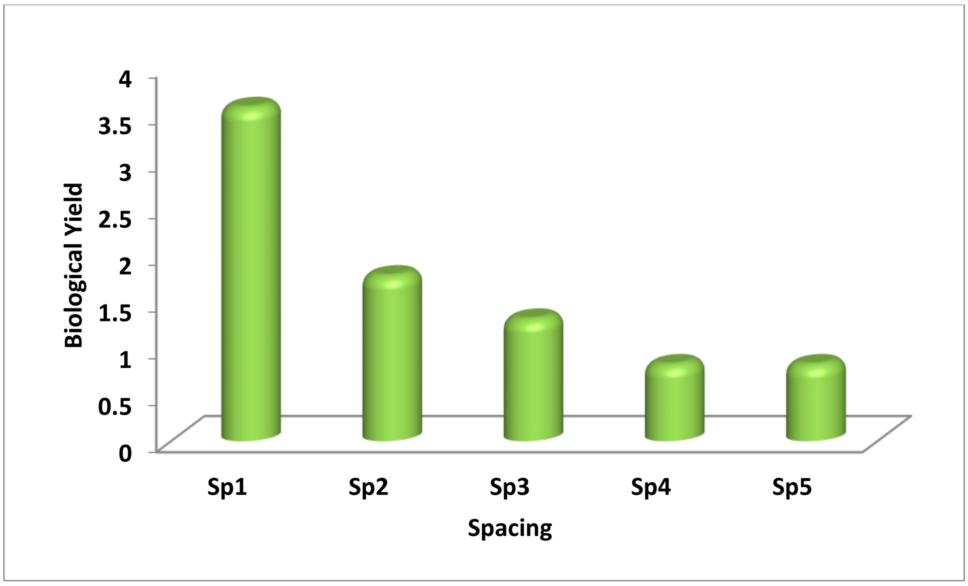


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 22. Effect of variety on biological yield (t ha^{-1}) of chickpea (LSD $_{(0.05)}$ = 0.16)

4.3.3.2 Effect of Spacing

Biological yield of chickpea showed significant variation for different spacing (Fig. 23). The highest biological yield was found in Sp_1 (1.94 t ha^{-1}), while the lowest biological yield was found in Sp_4 (0.82 t ha^{-1}) and Sp_5 (0.82 t ha^{-1}).



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 23. Effect of spacing on biological yield (t ha^{-1}) of chickpea (LSD $_{(0.05)}$ =0.16)

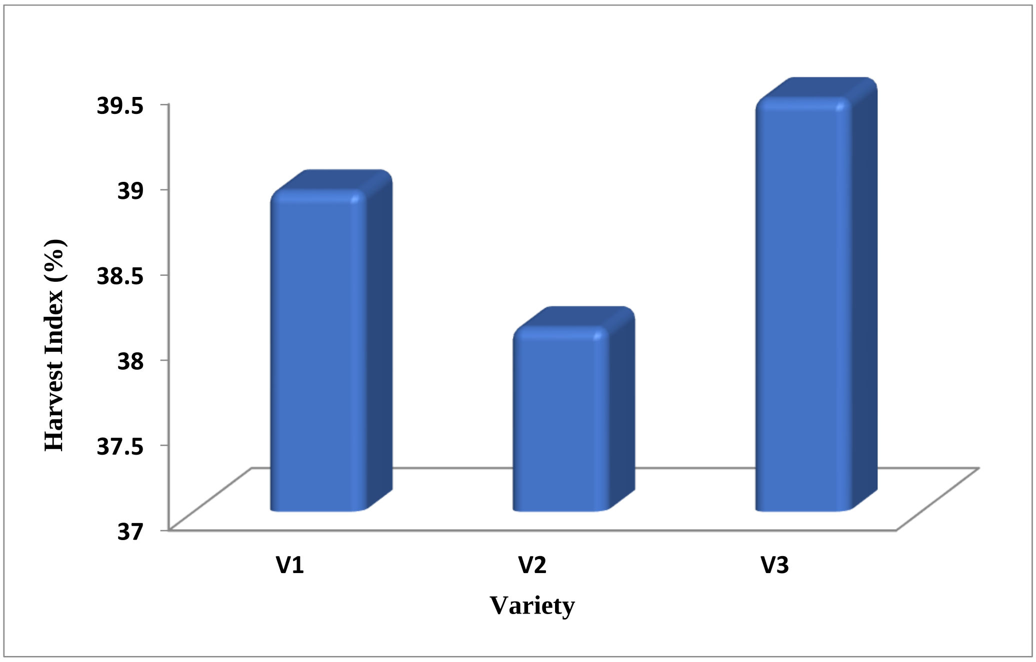
4.3.3.3 Combined effect of Variety and Spacing

Significant variation was observed due to the combined effect of chickpea varieties and different spacing on biological yield (Table 7). The maximum biological yield (3.94 t ha^{-1}) was found from treatment V_1Sp_1 and the minimum biological yield (0.67 t ha^{-1}) was found from V_2Sp_5.

4.3.4 Harvest index (%)

4.3.4.1 Effect of Variety

Harvest index of chickpea showed non-significant differences due to different variety (Fig. 24). Numerically the highest harvest index was attained from V_3 (39.42%) and lowest from V_2 (38.08%).

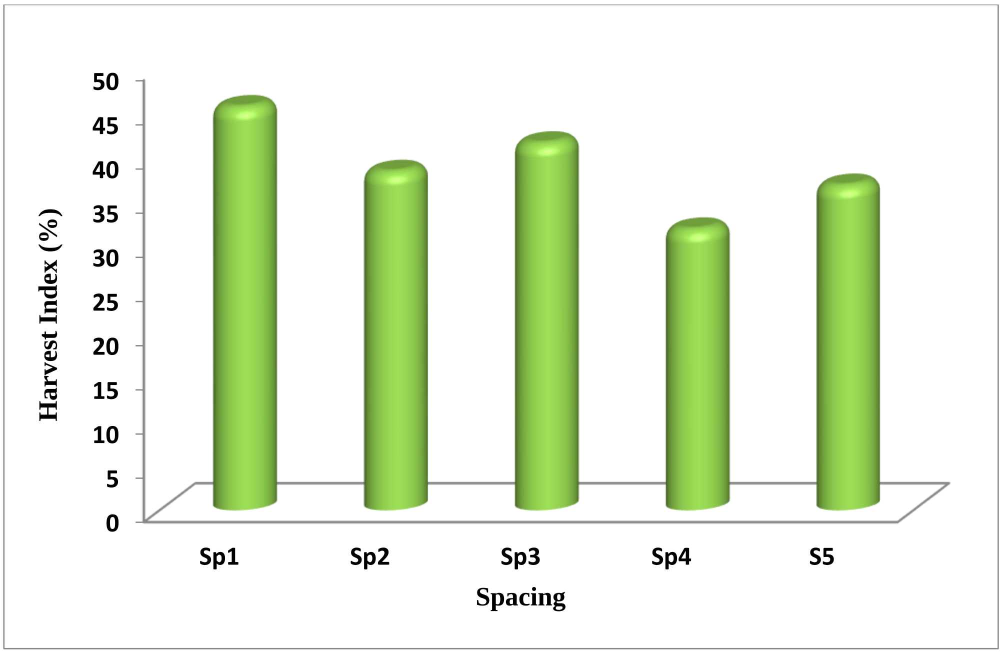


V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Figure 24. Effect of variety on harvest index (%) of chickpea (LSD $_{(0.05)}$ = 1.26)

4.3.4.2 Effect of Spacing

Differences in spacing showed significant variations in terms of harvest index of chickpea (Fig. 25). The highest harvest index was found from Sp_1 (45.61%) whereas the lowest value was recorded from Sp_5 (36.74%), which was similar to Sp_2 (38.30%). Khan *et al*. (2010) reported maximum harvest index at 45 cm row spacing.



Sp_1 = 40 cm x 10 cm, Sp_2 = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

Figure 25. Effect of spacing on harvest index (%) of chickpea (LSD $_{(0.05)}$ = 1.26)

4.3.4.3 Combined effect of variety and Spacing

Combined effect of different varieties and spacing showed significant variation in terms of harvest index (Table 7). The highest havest index was found from V_3Sp_1 (47.15%) being followed by V_1Sp_1 (46.44%), V_1Sp_3 (43.76%), V_2Sp_1 (43.25%), V_2Sp_1 (44.03%), and the lowest was observed from V_3Sp_4 (30.50%) which was followed by V_1Sp_4 (32.74%), V_1Sp_5 (31.87 %), V_2Sp_4 (32.13%) and V_2Sp_5 (34.34 %).

Table 7. Combined effect of variety and spacing on seed yield, stover yield, biological yield and harvest index of chickpea

Treatments	**Seed yield ($t\ ha^{-1}$)**	**Stover yield ($t\ ha^{-1}$)**	**Biological yield ($t\ ha^{-1}$)**	**Harvest Index (%)**
V_1Sp_1	1.82 a	2.12 a	3.94 a	46.44 a
V_1Sp_2	0.81 d	1.23 c	2.04 d	39.64 c-e
V_1Sp_3	0.66 e	0.85 d	1.51 e	43.76 a-c
V_1Sp_4	0.29 gh	0.60 e-g	0.89 g-i	32.74 fg
V_1Sp_5	0.31 gh	0.67 d-f	0.98 gh	31.87 fg
V_2Sp_1	1.343 c	1.76 b	3.12 c	43.25 a-d
V_2Sp_2	0.5033 f	0.69 d-f	1.29 ef	39.41 de
V_2Sp_3	0.4900 f	0.67 d-f	1.16 fg	41.26 b-d
V_2Sp_4	0.2667 h	0.56 fg	0.83 hi	32.13 fg
V_2Sp_5	0.2300 h	0.44 g	0.67 i	34.34 fg
V_3Sp_1	1.687 b	1.94 ab	3.63 b	47.15 a
V_3Sp_2	0.7100 e	1.26 c	1.97 d	35.86 ef
V_3Sp_3	0.5033 f	0.77 de	1.27 ef	39.54 c-e
V_3Sp_4	0.2233 h	0.51 fg	0.73 hi	30.50 g
V_3Sp_5	0.3600 g	0.45 g	0.82 hi	44.03 ab
LSD $_{(0.05)}$	0.09	0.19	0.27	4.32
CV (%)	8.25	11.81	9.66	6.61

V_1 = BARI Chola-5, V_2 = BARI Chola-6, V_3 = BARI Chola-9

Sp_1 = 40 cm x 10, cm $_2$ = 30 cm x 30 cm, Sp_3 = 40 cm x 40 cm, Sp_4 = 50 cm x 50 cm, Sp_5 = 60 cm x 60 cm

CHAPTER V

SUMMARY AND CONCLUSION

A study on "Growth and yield variations in chickpea as influenced by planting geometry" was conducted at the Agronomy field of Sher-e-Bangla agricultural University, Dhaka-1207 during November, 2015 to April, 2016.

The experiment was laid out in split plot design with three replications having chickpea varieties in the main plot and five spacing in the sub plot. The individual plot size was 2.5 m x 2.0 m. There were 15 treatment combinations and the total number of plots were 45. The experiment consisted of three varieties *i.e*. BARI Chola-5, BARI Chola-6 and BARI Chola-9 and five spacing viz. Sp_1 = 40 cm × 10 cm, Sp_2 = 30 cm × 30 cm, Sp_3 = 40 cm × 40 cm, Sp_4 = 50cm × 50 cm and Sp_5 = 60 cm × 60 cm. Seeds of 3 varieties of chickpea were sown 30 November, 2015 maintaining row to row and plant to plant distances as per treatments of the experiment. Experimental data were recorded from 20 DAS and continued until harvest at an interval of 20 days.

The tallest plants (48.42 cm) at harvest was attained from V_3 and the shortest one (41.66 cm) was from V_1. At harvest, Sp_1 produced the tallest (50.83 cm) plant and Sp_5 produced the shortest (41.38 cm) plant. Treatment combination of V_3Sp_1 scored tallest plants (54.50 cm) and the lowest plant height (37.58 cm) was from V_1Sp_5.

The higher number of leaflets plant^{-1} at harvest (290.6) was found from V_1 and lower number (236.6) was recorded from V_2. At harvest, treatment Sp_3 attained higher number of leaflets plant^{-1} (298.20) and Sp_2 gave the lower number of leaflets plant^{-1} (212.90). The maximum number of leaflets plant^{-1} (359.0) was recorded from treatment combination of V_1Sp_3 and the minimum number (206.1) from V_2Sp_2.

V_1 gave the highest above ground dry matter (AGDM) plant^{-1} (20.92 g) at harvest and V_2 gave the lower value of AGDM plant^{-1} (19.46 g). Among different spacings Sp_3 scored the maximum value (24.06 g) of AGDM plant^{-1} and the minimum value (18.00 g) was from Sp_2. Treatment combination of V_3Sp_1 produced significantly higher amount of AGDM plant^{-1} (26.89 g) while treatment combination V_2Sp_2 gave lower value of AGDM plant^{-1} (14.22 g).

The highest value of nodule dry weight plant^{-1} (0.62) was obtained from V_1 while the lowest value of nodule dry weight plant^{-1} (0.46) at 80 DAS was found in V_2. At 80 DAS nodule dry weight plant^{-1} in Sp_3 was higher (0.73 g) and the lowest nodule dry weight plant^{-1} (0.31 g) was obtained from Sp_2. The highest value of nodule dry weight plant^{-1} (0.85 g) was observed in the treatment combination of V_1Sp_3 and the lowest amount (0.24 g) was from V_2Sp_2.

The maximum number of branches plant^{-1} at harvest (46.93) was found from V_1 and lower number (34.97) was recorded from V_3. During harvest, treatment Sp_3 gave the highest number of branches plant^{-1} (49.62) while the lowest number of branches plant^{-1} (31.73) was found from Sp_2. At harvest, the highest number of branches plant^{-1} (60.22) was noted from treatment combination of V_1Sp_3 and the lowest number of branches plant^{-1} (28.20) was recorded from V_3Sp_1.

The number of pods plant^{-1} was higher in V_1 (50.43) and the lower in V_3 (31.81). The highest number of pods plant^{-1} was found in treatment Sp_3 (47.49) whereas the lowest number of pods plant^{-1} was found in Sp_4 (30.81). The maximum number of pods plant^{-1} (66.00) was found from treatment V_1Sp_3 and the minimum pods plant^{-1} (23.07) from V_2Sp_2.

At harvest the highest number of seeds pod^{-1} was found in V_2 (1.53) and the lowest number of seeds pod^{-1} was found in V_1 (1.33), which was statistically similar to V_3 (1.35). Treatment Sp_2 gave maximum number of seeds pod^{-1} (1.52) and Sp_4 gave the minimum number of seeds pod^{-1} (1.31). The highest number of seeds pod^{-1} was recorded from V_2Sp_2 (1.75) and the lowest number of seeds pod^{-1} was found in V_1Sp_4 (1.20).

V_3 gave the highest 1000 seed weight (230.33g) and the lowest 1000 seed weight was found in V_1 (134.33g) at harvest. Maximum 1000 seed weight was found in Sp_5 (180 g) and the minimum was from Sp_3 (167.2 g).The highest 1000 seed weight was recorded from treatment combination V_3Sp_5 (250 g) and the lowest was found in V_1Sp_2 (128.3 g).

The highest seed yield was found in V_1 (0.78 t ha^{-1}) and the lowest seed yield was found in V_2 (0.57 t ha^{-1}). The highest seed yield was obtained from Sp_1 (1.62 t ha^{-1}) while the lowest seed yield was recorded in Sp_5 (0.30 t ha^{-1}). The highest seed yield (1.82 t ha^{-1})

was recorded from treatment V_1Sp_1 and the minimum seed yield (0.23 t ha^{-1}) from V_2Sp_5.

The maximum stover yield was found in V_1 (1.09 t ha^{-1}) and the minimum stover yield was found in V_2 (0.82 t ha^{-1}). S_1 attained the highest stover yield (1.94 t ha^{-1}) while Sp_5 scored the lowest stover yield (0.52 t ha^{-1}). Treatment combination V_1Sp_1 gave maximum stover yield (2.12 t ha^{-1}) and treatment combination V_2Sp_5 gave the minimum stover yield (0.44 t ha^{-1}).

The highest biological yield was attained in V_1 (1.87 t ha^{-1}) and the lowest biological yield was observed from V_2 (1.68 t ha^{-1}).Treatment Sp_1 gave the maximum biological yield (1.94 t ha^{-1}) and treatment Sp_5 attained minimum biological yield (0.82 t ha^{-1}). Treatment combination V_1Sp_1 scored the maximum biological yield (3.94 t ha^{-1}) and treatment combination V_2Sp_5 gave minimum biological yield (0.67 t ha^{-1}).

Among the variety V_3 gave the highest harvest index (39.42%) and V_2 scored the lowest harvest index (38.08%). In case of spacing the higest harvest index was found from Sp_1 (45.61%) whereas the lowest value was recorded from Sp_5 (36.74%) treatment. The maximum havest index was found from treatment combination V_3Sp_1 (47.15%) and the minimum (30.50%) was from V_3Sp_4.

From the results of present study it can be concluded that wider spacing (40 cm x 40 cm) influenced individual plant with vigorous growth consequently produced maximum yield contributing characters but failed to show optimum seed yield due to lower number of plant per unit area where recommended spacing (40 cm x 10 cm) did better with optimum plant stand.

Recommendation

This study could be done for further result verification within other growing areas around the country may interact with this technique.

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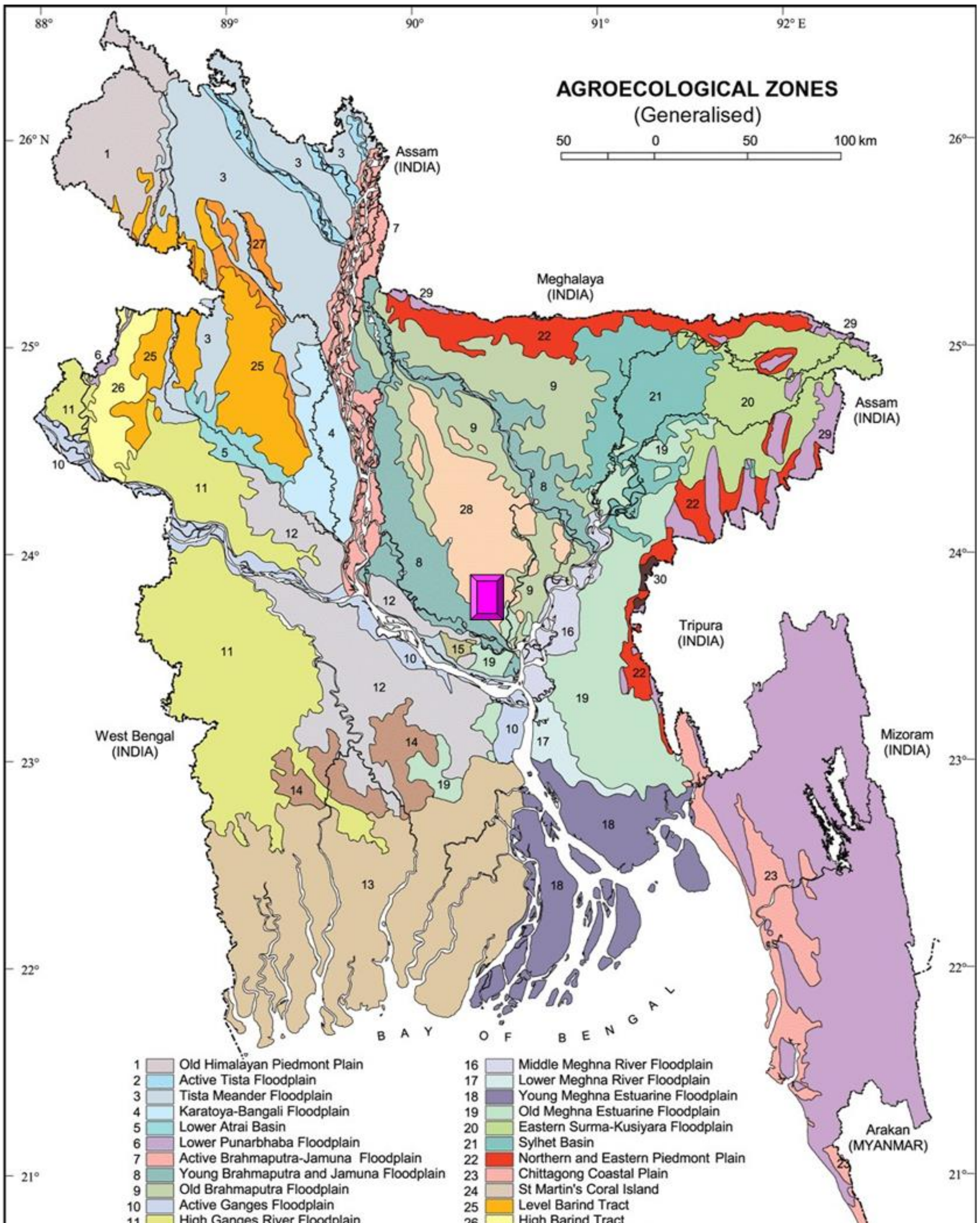
APPENDICES

Appendix I. Photograph showing location of experimental site.



Appendix II. Characteristics of the soil of experimental field

Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
%Silt	43
%Clay	30
Textural class	Silty-clay
pH	6.1
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100g soil)	0.10
Available S (ppm)	23

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly average Temperature, Relative Humidity and Total Rainfall and Sunshine of the experimental site during the period from November, 2015 to March, 2016

Month	Air temperature(^{0}c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
November, 2015	34.8	18	77	00	5.8
December, 2015	32.3	16.3	69	00	7.9
January, 2016	29	13	79	00	3.9
February, 2016	28	11	72	27	5.1
March, 2016	33	12.2	60	41	8.7

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka– 1207

Appendix IV. Analysis of variance of the data on plant height of chickpea as influenced by different varieties, spacing and their combination effect

Source of variation	Degrees of freedom	Mean square					
		Number of leaflets plant^{-1} (No.) at					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	2.07	45.50	27.21	38.45	14.27	17.95
Variety (A)	2	81.09*	29.71*	138.58*	148.73*	193.74*	186.71*
Error	4	1.94	2.40	6.96	3.76	24.66	6.61
Spacing (B)	4	13.24*	19.49*	118.56*	89.59*	104.71*	116.29*
Interaction (A x B)	8	0.68*	4.16*	2.95*	3.73*	3.25*	1.59*
Error	24	2.05	2.21	7.92	11.06	13.74	14.56

* Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on leaflets plant^{-1} of chickpea as influenced by different varieties, spacing and their combination effect

Source of variation	Degrees of freedom	Mean square					
		Number of leaflets plant^{-1} (No.) at					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	8.54	199.57	184.89	3243.01	288.00	677.09
Variety (A)	2	28.67*	261.78*	1248.36*	12169.36*	11044.28*	1137.69 *
Error	4	0.44	17.47	75.53	481.62	406.18	59.11
Spacing (B)	4	2.42*	357.76*	1678.39*	15201.67*	20087.34*	10362.5 3*
Interaction (A x B)	8	0.21*	39.45*	111.12*	3737.38*	2972.92*	1055.56 *
Error	24	1.19	35.55	142.11	852.39	687.84	229.98

* Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on above ground dry matter weight plant^{-1} of chickpea as influenced by different varieties, spacing and their combination effect

Source of variation	Degrees of freedom	Mean square					
		Dry matter content plant^{-1} (g) at					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.001	0.046	0.13	0.84	3.12	0.03
Variety (A)	2	0.018 NS	0.127*	11.25*	34.68 NS	25.91*	45.18*
Error	4	0.007	0.007	0.82	11.44	2.31	5.23
Spacing (B)	4	0.009*	0.217*	4.36*	38.69*	65.40*	77.48*
Interaction (A x B)	8	0.003*	0.037*	0.45*	3.37*	5.82*	8.12*
Error	24	0.002	0.016	0.24	2.16	2.28	4.84

* Significant at 0.05 level of probability

NS= Non-significant

Appendix VII. Analysis of variance of the data on nodule dry weight plant^{-1} of chickpea as influenced by different varieties, spacing and their combination effect

Source of variation	Degrees of freedom	Mean square		
		Nodule dry weight plant^{-1} (g) at		
		60 DAS	80 DAS	100 DAS
Replication	2	0.001	0.002	0.005
Variety (A)	2	0.098*	0.091*	0.059*
Error	4	0.002	0.001	0.001
Spacing (B)	4	0.170*	0.308*	0.118*
Interaction (A x B)	8	0.004*	0.009*	0.004*
Error	24	0.001	0.003	0.001

* Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on branches plant^{-1} of chickpea as influenced by different varieties, spacing and their combined effect

Source of variation	Degrees of freedom	Mean square					
		Number of branches plant^{-1} (No.) at					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.001	1.95	3.31	7.06	7.81	4.261
Variety (A)	2	1.990*	6.17*	35.06*	637.29*	561.72*	543.42*
Error	4	0.033	0.18	2.05	8.06	17.05	12.25
Spacing (B)	4	0.235*	5.26*	67.05*	479.89*	538.47*	616.14*
Interaction (A x B)	8	0.091*	2.50	10.24*	69.33*	79.02*	85.59*
Error	24	0.023	0.29	3.97	7.47	7.44	10.83

* Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data on yield and yield attributes of chickpea as influenced by different varieties, spacing and their combination effect

Source of variation	Degrees of freedom	Mean square						
		Pods per plant	Seed per pod	Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Replication	2	8.74	0.007	677.4	0.004	0.001	0.008	11.239
Variety (A)	2	1522.59*	0.186*	38205.0*	0.171*	0.276*	0.807*	6.792*
Error	4	4.826	0.027	10.40	0.005	0.006	0.025	1.544
Spacing (B)	4	512.77*	0.091*	204.17*	2.729*	3.064*	11.552*	241.71*
Interaction (A x B)	8	78.25*	0.052*	327.92*	0.031*	0.052*	0.105*	40.288*
Error	24	4.59	0.030	100.23	0.003	0.013	0.026	6.572

* Significant at 0.05 level of probability