TIME OF NITROGEN APPLICATION IN CHICKPEA CULTIVARS FOR MAXIMUM YIELD

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JUNE, 2013

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REGISTRATION NO. 06-01915

A Thesis

Submitted to the Department of Agronomy,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 2013

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CERTIFICATE

This is to certify that the thesis entitled **“TIME OF NITROGEN APPLICATION IN CHICKPEA CULTIVARS FOR MAXIMUM YIELD”** 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 bonafide research work carried out by ***A. K. M. LUTFAR QUADER,*** Registration. No. 06-01915, 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)
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ACKNOWLEDGEMENTS

*All praises are devoted to Almighty Allah, who the supreme authority of this universe, and who enable the author to complete the research work and submit the thesis for the degree of Master of Science (MS) in Agronomy***.**

The Author would like to express his heartiest gratitude, sincere appreciation and immense indebtedness to his supervisor ***Professor Dr. Md. Fazlul Karim****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for his scholastic guidance, planning, valuable suggestions, continuous encouragements and all kinds of support and help throughout the period of research work and preparation of this manuscript of thesis.*

The author deem it a proud privilege to acknowledge author's gratefulness, boundless gratitude and best regards to his respectable co-supervisor, ***Professor Md. Sadrul Anam Sardar****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice, constructive criticism and factual comments in upgrading the research work.*

It is a great pleasure and privilege to express his profound gratitude and sincere regards to ***Professor Dr. A.K.M. Ruhul Amin****, Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his help, valuable advice, constructive criticism and facilities and supports needed to undertake this research work.*

Special appreciation and warmest gratitude are extended to Author's esteemed teachers of his department of Agronomy, SAU, Dhaka for their sincere guidance to learn and practice himself in scientific knowledge towards development agriculture.

The author is honored to express his gratefulness to the Department of Agronomy for extending their cooperation by allowing me to use the laboratory for the different analysis. He also wishes to give thanks to the staff of the Agronomy Laboratory for their valuable cooperation during the experimentation.

The author wants to say thanks, to all of his classmates and friends, for their active encouragement and inspiration. He also cannot but thank and appreciate to Dipayan

Sarkar, Md. Nizam Atikulla and Md. Tanvir Ahamed (Apu) for supplying necessary support and sacrificing a lot of time during the research period.

The author is especially indebted to his wife Rifat Sultana who has been a constant source of inspiration and sacrificed a lot in the long process of making this paper which can never be repaid. The author is ever grateful to his beloved parents for their inspiration and blessings.

TIME OF NITROGEN APPLICATION IN CHICKPEA CULTIVARS FOR MAXIMUM YIELD

ABSTRACT

An experiment was conducted at the research field of Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2011 to March, 2012 to find out the effect of the time of application of nitrogen fertilizer to chickpea crops for increased seed yield. The treatment were designed with two factors i. Cultivars; V_1= BARI Chola-5, V_2= BARI Chola-6, V_3= BINA Chola-6 and ii. Nitrogen application; N_0= Control, N_1= Basal application of 20 kg N ha^{-1}, N_2= Basal application of 40 kg N ha^{-1}, N_3=Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage, N_4=Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage and N_5=Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage. The experiment was laid out in randomized complete block design with three replications. Results revealed that cultivars had significant effect on yield attributes and yield of chickpea. BARI Chola-6 gave maximum pods $plant^{-1}$ (28.63), 1000-seed weight (117.6 g), harvest index (43.97%) as well as seed yield (1.73 t ha^{-1}). BARI Chola-6 gave 29.11% higher seed yield than BINA Chola-6 which showed lowest grain yield (1.34 t ha^{-1}). In case of nitrogen application, significant variations were observed in yield attributes and yield of chickpea. N_3 gave higher pods $plant^{-1}$ (39.23), 1000-seed weight (123.1 g), harvest index (46.65%) as well as seed yield (2.08 t ha^{-1}). N_3 had 84.07% higher yield than N_0 (1.13 t ha^{-1}) which was minimum yield. Combination effect of cultivars and nitrogen management that yield attributes and yield of chickpea were significantly higher in V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage) where maximum pods $plant^{-1}$ (44.90), seeds pod^{-1} (2.68), 1000-seed weight (124.8 g), harvest index (50.08%) as well as seed yield (2.43 t ha^{-1}) were recorded. V_2N_3 had 358.4% increased seed yield over V_3N_0 which gave significantly minimum seed yield (0.53 t ha^{-1}).

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LIST OF ABBREVIATIONS

%	=	Percent
AEZ	=	Agro Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
cm	=	Centimetre
cv.	=	Cultivar (s)
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.	=	And Others
FAO	=	Food and Agriculture Organization
g	=	Gram
ha^{-1}	=	per Hectare
HYV	=	High Yielding Variety
$plant^{-1}$	=	per plant
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
t/ha	=	Tonne per Hectare

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Pulses occupy a unique position in the world agriculture by virtue of their high digestive protein content and capacity for fixing atmospheric nitrogen. Amongst seed legumes, chickpea is unique because of its nutritional quality, which depends on its protein content, amino acid makeup and protein digestibility. Chickpea (*Cicer arietinum* L.) as an intercrop play an important role in the cropping system in Bangladesh.

Chickpea is a temperate crop though it is well adapted in tropical and sub-tropical conditions (Kay, 1979). In the tropics and sub-tropics, chickpea 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 p^H ranging from 6.0 to 7.0. It cannot be cultivated successfully in poorly drained lowland.

Chickpea is one of the most important pulse crops in Bangladesh after grasspea and lentil occupying third position (BBS, 2008). The area coverage under pulses is about 233000 hectare while the contribution of chickpea is about 8233 hectare with seed production of 6605 metric ton (BBS, 2010). It contributes about 20% of the pulses. The average yield of chickpea is 0.76 mt ha^{-1} (BBS, 2008). Even though, the acreage of chickpea cultivation in Bangladesh is decreasing due to less return as compared to cereal crops and also due to increase in area under boro rice, maize and potato. The increasing gap between production and demand of pulses in Bangladesh has resulted in chronic problem of malnutrition mainly due to protein deficiency. The expansion in area under chickpea is not possible as it will have a direct impact on other major crops. So, proper management should be adopted to rise per hectare yield of chickpea. The yield of chickpea in Bangladesh is lower than the other chickpea growing countries in the world. This is mainly due to the use of traditional or low yielding varieties as well as adoption of poor management practices. A considerable variation of yield may be found with use of suitable varieties (Ullah *et al.*, 2002).

Chickpea meets 80% of its nitrogen for essential growth element requirement from symbiotic nitrogen fixation. N_2 fixation in chickpea range from 10 to 176 kg ha^{-1} $season^{-1}$, depending on method of cultivation, cultivar, presence of appropriate *rhizobia* and environment at variable

(Bcek *et al.,* 1991). There are evidents that nitrogen application becomes helpful to increase the seed yield (Chaudhari *et al.,* 1998; Khan *et al.,* 1992). Nitrogen is most useful element for pulse crops as a component of protein (BARC, 1997). Fertilizer management especially with nitrogen, phosphorus and sulpher produced seeds with high level of protein and amino acids in chickpea (Gupta and Singh, 1982).

One of the probable reasons for low yield of seed legumes in general is the high requirement of nitrogen for the formation and development of prominent grains stands (Alberda and Bower, 1983). To produce one unit of seeds, chickpea needs as much as three times more nitrogen than that needed by cereals like rice. Chickpea requires a large amount of nutrients in 2-3 phases (Trung and Yoshida, 1985). The former peak in the vegetative period is for the development of vegetative structures and the later peak in the reproductive phase is mainly for the production and development of seeds. Chickpea needs much more nitrogen at the reproductive stage than it does in the vegetative stage. In a study Mitra *et al.,* (1988) found that a moderate yielding chickpea crop requires 27.86 mg Ng^{-1} photosynthetic product during the first 20 days of the pod and seed development.

Pulses are mainly grown in cropping sequences with non pulse crops because of the assumption that they acquire all or at least part of their required nitrogen from biological nitrogen fixation (BNF) and any excess in their needs is assumed to accumulate in the soil and benefit non pulse crops. The amount of nitrogen fixed in some pulses is adequate to offset the amount of nitrogen used for growth while during reproductive stage is inadequate hence need for supplementing (People and Craswell, 1995).

Nodules formed on the roots of plants are short-lived and is replaced constantly during growing season. However, legume plants start to support their reproductive units with dry matter rather than the rhizobia. As a result nitrogen fixation at that time is ceased (Lindermann & Glover, 2003). But the flowering and pod filling are exhausted with limited nitrogen available to the plant. Plant grown with lower basal application of nitrogen to a certain stage when vegetative stage is supported by maximum use of fixed nitrogen present in the nodules. Thus nitrogen becomes very limiting during onset of pod filling which limits seed yield (Vikman & Vessey, 1992). At this stage the plants should be given additional nitrogen to remove plant stress for nitrogen (Lindermann & Glover, 2003).

The basal application of nitrogen could not be helpful in the plant when it requires during its life cycle though fixed is seemed to be utilized. It is believed that *rhizobium* bacteria are using plants dry matter for their energy requirement that may be a back drop of pulse production (Uddin, 2010). Considering the above facts the present work was conducted to evaluate the response of time of application of nitrogen on chickpea production with the following objectives.

- To compare the growth and yield parameters of chickpea cultivars in the field.
- To determine the optimum time of nitrogen application in chickpea cultivation for maximum yield of chickpea.
- To study the combined effect of variety and nitrogen management on the growth and yield of chickpea.

Chapter 2
Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

Chickpea is an important pulse crop in Bangladesh, which can contribute largely in the national economy. In Bangladesh, chickpea crop is generally grown without fertilizer. However, there are evidence that the yield of chickpea can be increased substantially by using fertilizers (Dahiya *et al.*, 1989 and Katare *et al.*, 1984). There are also controversies regarding the rates and time of application of N in chickpea. Information on fertilizer managements for chickpea related to the study are reviewed and presented in the following heads.

2.1. Effect of variety on growth and yield

2.1.1. Plant height

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its vicinity.

Das (2006) conducted an experiment in the field of Bangabandhu Sheikh Mujibur Rahaman Agricultural University, Salna, Gazipur during winter season of 2005-06 to study the effects of applied phosphorus on the growth, nutrient uptake and yield in chickpea (*Cicer arietinum* L.) and found plant height at the maturity across the varieties BU Chola-1, BARI Chola-6 and BARI Chola-7 varied from 32.14 cm to 35.16 cm. The BARI Chola-7 was the tallest and BU Chola-1 was the shortest.

Kabir *et al.* (2009) conducted a study to see the effect of sowing time and cultivars on the growth and yield performance of chickpea under rainfed condition. The varieties showed significant difference in case of plant height and insignificant in case of total dry matter production and crop growth rate. BARI Chola-4 produced the tallest plants (32.30 cm) being closely followed by BARI Chola-2 (30.9 cm). The shortest plants (29.26 cm) were found in BARI Chola-6.

Karasu *et al.* (2009) conducted an experiment to determine the effect of bacterial inoculation and different nitrogen doses on yield and yield components of some chickpea genotypes in Mustafakemalpa province. The research was conducted at

Uludag University, Mustafakemalpa Vocational School, Application and Training Field Bursa, Turkey in 1999 and 2000. Three genotypes; Local population, Canıtez 87 cultivar and ILC-114 Line were used as the crop material. The effects of cultivars were statistically significant at 1% probability level on the plant height. While maximum plant height was recorded on popular local genotype named Yerli (58.7 cm), Canıtez-87 cultivar and ILC-114 line had shorter plant height (54.7 and 53.7 cm, respectively).

A field experiment was conducted to study the effects of foliar spraying of aqueous solutions of 2% and 4% urea at two stages (before and after flowering) and 20 kg/ha urea application in soil (three-weed after sowing) on growth, yield and yield components of cultivars (Azad and ILC 482) under rain-fed conditions. Plant height of Azad cultivar was significantly higher than that of ILC 482 (Aliloo *et al.*, 2012).

2.1.2. Branches plant^{-1}

Nutrients help in initiation of buds in plant. These buds ultimately become active branches from where leaves as the photosynthetic organ and the flowering nodes are developed. Thus it plays a vital role in increasing the crop yield.

Das (2006) showed that the total number of branches across the varieties BU Chola-1, BARI Chola-6 and BARI Chola-7 averaged from 13.78 to 15.98. BARI Chola-6 produced the highest and BARI Chola-7 produced the lowest number of branches plant^{-1}.

2.1.3. Total dry weight plant^{-1}

Das (2006) showed total dry matter is the sum of the dry matter accumulated in the various components of the plant namely leaf, petiole, stem and the reproductive parts of the plant. The pattern of dry matter production in the varieties BU Chola-1, BARI Chola-6 and BARI Chola-7 is almost similar.

2.1.4. Nodules plant^{-1}

Das *et al.* (2009) the number of nodules plant^{-1} across the varieties ranged form 5.13 to 9.88 the highest number of nodules plant^{-1} was found in the variety BARI Chola-6 and the lowest number of nodules were observed in the variety BU Chola-1.

Bhuiyan *et al.* (2009) at a Regional Agricultural Research Station (RARS), Rahmatpur, Barisal, Bangladesh for two consecutive rabi seasons in 2002-03 and 2003-04 with a view to assessing the effect of *Rhizobium* inoculation on four cultivars of chickpea. Four chickpea cultivars, namely BARI Chola-3, BARI Chola-4, BARI Chola-5 and BARI Chola-6, were used in these trials. The variety BARI Chola-3 produced significantly higher nodule numbers (42.6). In another study, Eusuf Zai *et al.* (1999) found significantly more nodules in variety BARI Chola-6.

2.1.5. Nodule dry weight

Das *et al.* (2009) conducted an experiment to study the effects of applied phosphorus fertilizer doses on the nodulation and yield in chickpea (*Cicer arietinum* L.) and showed variation in nodule dry weight plant^{-1} in the different varieties was observed. The dry weight of nodule plant^{-1} was 8.49 mg and 6.63 mg in BARI Chola-7 and 4.17 mg in the BU Chola-1 respectively.

Solaiman *et al.* (2007) conducted an experiment at the research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh to study 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. Among the treatments, Barichola-5 performed best in recording number and dry weight of nodules.

2.1.6. Pods plant^{-1}

Hasanuzzaman *et al.* (2007) conducted an experiment at the experimental field of Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh, during the period from November, 2005 to March, 2006 and showed that BARI chola-4 produced maximum number of pods per plant (33.35) and BARI chola-1 produced lower pod. It reveals that all the varieties have similar capabilities of pod production. The maximum production of pod was 44% greater than the lower pod production.

Ali *et al.* (2010) performance of six brown chickpea (*Cicer arietinum* L.) genotypes viz. 90261, 93127, 97086, 98004, 98154 and Bittal-98 was tested under four NP levels (0-0, 12- 30, 24-60, 30-90 kg/ha) at Agronomic Research Institute, AARI, Faisalabad, Pakistan during 2006-07 and 2007-08. There was a linear increase in yield of all genotypes from 0-0 to 24-60 kg NP level. The differences among varietal means were non-significant during first year but significant during second year. However, on the basis of average of two years, genotype 98004 expressed comparatively more pods per plant (77.58).

2.1.7. Seeds pod^{-1}

Das (2006) showed the averaged number of seed pod^{-1} across the varieties ranged from 1.20 to 1.42 pod^{-1}. The BARI Chola-7 produced the highest and BU Chola-1 produced the lowest number of seed pod^{-1} respectively.

2.1.8. 1000-seed weight

Hasanuzzaman *et al.* (2007) said the maximum weight of 1000-seed (273.30 g) was found from the combination of BARI chola-5 and 1500 Knap application (V3G1) which was statistically similar with V2G1 (BARI chola-4 and 1500 ppm potassium napthelnte). The combination of BARI chola-1 and water spray (control) showed the lowest weight of 1000-seed (233.50 g).

BINA (2012) conducted an experiment to determine the optimum irrigation water requirement of chickpea developed at BINA. The experiment was conducted at BINA sub-stations, Magura and Ishurdi during the rabi season of 2010-2011. In Magura, highest 1000 seed weight produced form BINA Chola-6 (148.05 g).

Karasu *et al.* (2009) showed the effects of cultivars statistically significant at 1% probability level on the 1000-seed weight. While maximum 1000-seed weight was obtained from Canıtez- 87 cultivar (498.2 g) and popular local genotype Yerli (497.9 g), ILC-114 line had fewer 1000 seed weight (446.8 g).

2.1.9. Seed yield

Hasanuzzaman *et al.* (2007) showed among the varieties, BARI chola-5 gave the maximum seed yield (1.81 t ha), which was 36.09% more over BARI chola-1, which produced the lowest seed yield (1.33 t ha).

Bhuiyan *et al.* (2009) at a Regional Agricultural Research Station (RARS), Rahmatpur, Barisal, Bangladesh for two consecutive rabi seasons in 2002-03 and

2003-04 with a view to assessing the effect of *Rhizobium* inoculation on four cultivars of chickpea. Four chickpea cultivars, namely BARI Chola-3, BARI Chola-4, BARI Chola-5 and BARI Chola-6, were used in these trials. The seed yields of the BARI Chola-5 and BARI Chola-6 variety (1.80 t/ha and 1.85 t/ha) were increased by 20.0% and 19.4% over uninoculated treatments for two consecutive rabi seasons in 2002-03 and 2003-04.

Das (2006) found the averaged yield ha^{-1} among the varieties was 608.18 kg in BU Chola-1, 641.87 kg in BARI Chola-6 and 661.16 kg in BARI Chola-7.

Kabir *et al.* (2009) found that the heaviest seed weight was observed in BARI Chola-6 and lowest seed weight was observed in BARI Chola-4, which was statistically at par with BARI Chola-2, which might be due to genotypic variation. The highest seed yield per plant was found in BARI Chola-4, which was statistically similar with BARI Chola-2.

2.1.10. Stover yield

Ali *et al.* (2010) found in their study that chickpea genotype 97086 produced higher biological (7658 kg/ha).

2.1.11. % Harvest index (HI)

Das *et al.* (2009) reported that the highest harvest index (37.68 %) was found in the variety BARI Chola-7 and the lowest (36.28%) in the variety BARI Chola-6.

2.2. Effect of nitrogen on growth and yield

2.2.1. Plant height

Arvadia and Patel (1988) observed stimulatory effect of nitrogen or phosphorus alone at the rate of 25 kg ha^{-1} on the growth of chickpea plants. They also reported appreciable increase in the plant height than those in control plots. Application of phosphorus alone at the rate of 50 kg ha^{-1} did not show any significant effect on plant height over 25 kg P ha^{-1}.

Patra *et al.* (1998) noticed increased plant height of chickpea over control with 20 kg N along with 40 kg P ha^{-1}.

Rathore and Patel (1991) noticed that application of 18 kg N along with 46 kg P ha^{-1} increased plant height of chickpea over no N application.

Chaudhari *et al.* (1998) found a positive effect of nitrogen at the rate of 20 and 40 kg ha^{-1} on increase in chickpea plant height.

Vadavia *et al.* (1991) noticed that application of 20 kg N ha^{-1} and 40 kg P ha^{-1} increased plant height of chickpea significantly over no N and P application.

Dahiya *et al.* (1989) reported the increase in plant height of chickpea using N and P at the rate of 18-27 and 46-69 kg ha^{-1}, respectively.

Bahr (1997) conducted a field experiment on N in combination with phosphorus fertilizer to chickpea. They reported that application of 40 kg N ha^{-1} increased plant height.

Paikaray *et al.* (1996) in a study observed the application of 30 kg N ha^{-1} fertilizers significantly increased that plant height of chickpea.

Reddy and Ahlawat (1998) found that a starter dose of 30-35 kg N ha^{-1} applied at the time of sowing result in better initial growth & development of chickpea. A positive response to increasing level of N up to 40 kg ha^{-1} has been observed at Ropar and Patiala districts in Punjab, India.

Babar *et al.* (1991) suggested a starter dose of 20kg N ha^{-1} along with 50kg P_2O_5 ha^{-1} as basal for optimum plant height for chickpea.

Shri *et al.* (2004) reported that in Central Uttar Pradesh plant height, number of pods per plant, number of grains per pod, shelling percentage, pods yield was maximum with 25 kg N.

Nandan and Prasad (1998) also reported highest plant height at 40kg N ha^{-1}. Sardana and Varma (1987) carried out a study in New Delhi, India in 1983-84. They found that application of N. phosphorus and potassium fertilizers in combination resulted significant increase in plant height of chickpea.

2.2.2. Branches plant^{-1}

Dahiya *et al.* (1993) reported that application of 18-27 kg N and 46-69 kg P ha^{-1} increased number of branches plant^{-1} in chickpea.

Rathore and Patel (1991) found that the dosed of 18 kg N and 46 kg P ha^{-1} were most effective in increasing the number of branches palnt^{-1} of chickpea.

Chaudhari *et al.* (1998) found a positive effect of nitrogen at the rate of 20 and 40 kg ha^{-1} on increased in chickpea number of primary and secondary branches plant^{-1}.

Vadavia *et al.* (1991) reported that application of 20 kg N ha^{-1} and 40 kg P ha^{-1} increased number of branches plant^{-1} of chickpea.

Mishra (1995) reported that N deficient chickpea plants were shorter and got less branches plant^{-1} than the plants grown with applied N. The tallest plant and higher number of branches plant^{-1} was obtained by 30 kg N ha^{-1}.

Sabale (1995) found the number of branches per plant in pea significantly increased with increasing N levels from 0 to 36.8 kg ha^{-1}. The highest number of branches per plant was obtained at 36.8 kg N ha^{-1} and the lowest at 0 kg N ha^{-1}.

Dutt (1979) found that split application of 40 kg N ha^{-1} increased the number of leaves of lentil.

Srivastava and Varma (1982) showed that N application at the rate of 15 kg ha^{-1} increased the number of green leaves in pea plants.

2.2.3. Total dry weight $plant^{-1}$

Yadav *et al.* (1992) carried out an experiment under glass house condition in Mohendergrah district, India and found that nitrogen application significantly increased the dry matter yield of chickpea. In another study, Jain *et al.* (2003) using different levels of nitrogen found a significant increase in dry matter production of chickpea with 60 kg N ha^{-1}.

Kasole *et al.* (1995) carried out an experiment on chickpea cultivars, which was grown in pots in podzolic soil with 7 levels of N (0, 25, 50, 100, 200, 400 and 500 kg ha^{-1}). They noted that application of N up to 200 kg ha^{-1} increased the total dry matter and with use of higher rates decreased, the total dry matter decreased.

Sharma *et al.* (1989) carried out a field experiment on chickpea in Assam, India and reported that combined application of N and phosphorus significantly increased the dry weight of plants.

Kumar *et al.* (2005) reported that dry weight of chickpea plants responded favorably to nitrogen fertilizer application under normal and water stressed conditions. He also noted that in order to get the best out of the limited moisture, it is essential that nutrient requirements of dry land crops be adequately met.

Maliwal *et al.* (1998) reported that N fertilizer influenced proportionally on the dry matter of chickpea. Irrespective of N levels DM increased progressively till 90 DAE. The rate of dry matter production of chickpea was higher during 50 to 70 DAE.

Kosgey *et al.* (1993) observed dry matter accumulation with increase in levels of N at all growth stages. The split application of N fertilizer increased the rate of photosynthetic accumulation, leaf dry weight; stem dry weight which finally resulted in increased DM production by plant at each stage of growth of chickpea.

Jain *et al.* (2003) found optimum accumulation of DM in leaf, stem and petiole of chickpea with 30 kg N ha^{-1}.

Maurya *et al.* (1987) studied the effect of N levels (0, 30, 60 or 90 kg ha^{-1}) on the rate of growth and yield performance of chickpea at Dilhi, India in 1988. They observed that N above the rate of 40 kg N ha^{-1} reduced the dry matter yield. They also noted that applied N at the levels above 40 kg ha^{-1} reduced the nodule dry weight and the seed yield consequently.

Katyal (1989) reported that application of 20 kg N, 40 kg P_2O_5 and 30 kg K_2O ha^{-1} resulted in 36.4 and 10.4 per cent more dry matter production in the first and second year over control, respectively.

2.2.4. Pods plant^{-1}

Patra *et al.* (1998) noticed that number of pods $plant^{-1}$ of chickpea increased over control with 20 kg N along with 40 kg P ha^{-1}.

Rathore and Patel (1991) observed that maximum number of pods $plant^{-1}$ when chickpea was provided with 18 kg N along with 46 kg P ha^{-1}.

Chaudhari *et al.* (1998) found a positive effect of nitrogen at the rate of 20 and 40 kg ha^{-1} on increased in chickpea pods per plant and protein content in seed over control.

Karadavut and Ozdemir (2001) conducted a field trial on *Rhozobium sp.* and nitrogen on chickpea cultivars. They found that *Rhizobium* inoculation and 30 kg N ha^{-1} significantly increased pods $plant^{-1}$.

Vadavia *et al.* (1991) found that number of pods $plant^{-1}$ of chickpea increased following application of 20 kg N ha^{-1} and 40 kg P ha^{-1}.

Bhopal and Singh (1990) conducted an experiment with the semi dwarf garden pea cv. Lincoln, which received N at the rate of 0, 20, 40 and 60 kg ha^{-1} , P_2O_5 at 0, 30, 60 and 90 kg ha^{-1} increased green pod yield. Further addition of nitrogen (60 kg ha^{-1}) tended to decrease the yield.

Khan *et al.* (1992) reported that the application of 20 kg N + 50 kg P_2O_5 ha^{-1} in chickpea produced significantly higher number of pods $plant^{-1}$.

Vijai *et al.* (1990) carried out an experiment with garden pea cv. Bonneville on N or P. They found that increasing rates of N or P up to 40 kg ha^{-1} significantly increased pod yield.

Negi (1992) carried out an experiment with 4 levels of N (10, 20, 40, 60 kg ha^{-1}) and 3 of P_2O_5 (0, 60, 120 kg ha^{-1}) on vegetable pea. He reported that the application of 20 kg ha^{-1} gave the highest green pod yield. A combination of 20 kg N and 60 kg P_2O_5 ha^{-1} also produced the higher yield (1.72 t ha^{-1}).

Kurhade *et al.* (1994) reported that application of 40 kg N ha^{-1} to chickpea resulted in appreciable improvement in the number of pods plants^{-1} while compared with no N.

Pawar *et al.* (1997) found a linear increase in seed yield and pods per plant due to increased in N level form 10 to 30 kg ha^{-1} in chickpea.

Jadhav *et al.* (1992) examined the effect of varying levels of N and P fertilizers on chickpea. He reported that chickpea seed production was higher with the application of 35 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}due to higher number of seeds per plant.

Singh *et al.* (1994a) reported that chickpea fertilized with 20 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} significantly increased the number of pods plant^{-1} and seed yield over the unfertilized control.

Vadavia *et al.* (1991) also reported that the number of pods plant^{-1} was highest with the application of 40 kg N at two spilt along with 75 kg P_2O_5 ha^{-1}and 60 kg K_2O ha^{-1} in summer chickpea.

2.2.5. Seeds pod^{-1}

Patra *et al.* (1998) noticed in chickpea increased number of seeds pod^{-1} over control with 20 kg N along with 40 kg P ha^{-1}.

Rathore and Patel (1991) performed an experiment on chickpea with different levels of nitrogen and phosphorus fertilizers. They reported that application of 18 kg N along with 46 kg P ha^{-1} resulted in significant increase in the chickpea seeds pod^{-1}.

Malik *et al.* (2003) investigated the effect of varying levels of nitrogen (0, 25 and 50 kg ha^{-1}) and P (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv.

NM-98. They found that number of seeds pod^{-1} was significantly affected by varying levels of nitrogen and phosphorus.

Ram *et al.* (1984) found that in chickpea application of N fertilizer significantly increased seeds per pod. The crop treated with 30 kg N per ha gave the highest seed yield (1.7t ha^{-1}) which was 150% higher than those in control plot.

2.2.6. 1000-seed weight

Patra *et al.* (1989) reported that when 20 kg N along with 40 kg P ha^{-1} were applied, it increased 1000-seed weight of chickpea over control.

Rathore and Patel (1991) reported that application of 18 kg N ha^{-1} along with 40 kg P ha^{-1} increased 1000-seed weight. Vadavia *et al.* (1991) found that seed weight increase following application of 20 kg N ha^{-1} and 40 kg P ha^{-1} of chickpea.

Javiya *et al.* (1989) found that plant height of chickpea was significantly increased by the application of N fertilizer at 50 kg ha^{-1}. They also noted that 100 seed weight of lentil increased significantly by the application of N at 40 kg ha^{-1}.

2.2.7. Seed yield

Kurhade and Nagre (1995) conducted an experiment to determine the effect of varying levels of nitrogen (0, 25 and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of chickpea cultivars. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg P_2O_5 ha^{-1} resulted in the maximum seed yield (1112.96 kg ha^{-1}) and harvest index (41.88%). They also observed that number of flowers plant^{-1} was found to be significantly higher by varying levels of nitrogen and phosphorus and pod length was significantly affected by both nitrogen and phosphorus application.

Khokar and Warsi (1987) reported maximum seed yield in chickpea with application of 18 kg N ha^{-1}. On the other hand, Patel *et al.* (1989) observed no significant yield variation in chickpea with the application of 15-30 kg N ha^{-1}.

Arvadia and Patel (1988) observed stimulatory effect of nitrogen or phosphorus alone at the rate of 25 kg ha^{-1} on chickpea plants and reported appreciable increased in seed yield than those in control plots. They also found application of phosphorus alone at the rate of 50 kg ha^{-1} showed no additional improvement of that parameter over 25 kg P ha^{-1}.

Takankhar *et al.* (1998) conducted a field trial to evaluate the response of chickepa to sulphur fertilization under different levels of nitrogen and phosphorus. Greengram cv. Gujrarat 2 and K 851 were given 10 kg N + 20 kg P_2O_5 ha^{-1} or triple these rates and 0, 10, 20 or 30 kg sulphurha^{-1}as gypsum. Seed yield was 1.20 and 1.24 t ha^{-1} in Gujrarat 2 and K 851, respectively and was increased with the increase in fertilizer rate up to 20 kg N + 40 kg P_2O_5 ha^{-1}.

Dahiya *et al.* (1989) noted an increase in seed yield in chickpea over control with the application of N, P and K at the rate of 20, 40 and 20 kg ha^{-1}, respectively.

Patra *et al.* (1989) conducted an experiment on chickpea with different N and P rates. They stated that application of 20 kg N and 40 kg P ha^{-1} increased grain yield of chickpea. Application of 25 kg N + 50 kg P ha^{-1} gave the highest yield in the experiment of Javiya *et al.* (1989).

Rathore and Patel (1991) noticed that application of 18 kg N along with 46 P ha^{-1} increased seed yield of chickpea by 28.7% over no N application.

Reddy and Ahlawat (1998) noticed that application 18 kg N, 46 kg P and 5.25 kg Zn ha^{-1} increased grain and straw yield of chickpea. They also found increase in nitrogen, phosphorus and zinc uptake by plants leading to increase in protein yield.

Chaudhari *et al.* (1998) conducted a field trial with chickpea grain with different rates of N and P fertilizer. They found a positive effect of nitrogen at the rate of 20 and 40 kg ha^{-1} on the growth and yield to chickpea.

Vadavia *et al.* (1991) found significant higher seed yield of chickpea following application of 20 kg ha^{-1} N and 40 kg P ha^{-1}. Application of 20 kg N ha^{-1} increased seed yield of chickpea reported by Subba-Rao *et al.* (1986).

Shamim and Naimat (1987) reported that application of 10 kg N + 75 kg P_2O_5 ha^{-1} to *Cicer arietinum* cv. C-727 increases seed yields cover uninoculated seed from 583 to 878 kg ha^{-1}.

Tomar and Sharma (1985) obtained highest seed yield in chickpea of two consecutive years with the application of N, P and K at the rate of 20, 40 and 20 kg ha^{-1} respectively over control. Similar result was obtained by Rawal and Yadava (1986) using those fertilizers at the same rate.

Dahiya *et al.* (1993) noticed higher seed yield in chickpea over control while using N and P at rate of 18-27 and 46-69 kg ha^{-1}, respectively. Khan *et al.* (1992) also reported that application of N and P increased grain yield of chickpea significantly over no N and P application. The application of 20 kg N + 50 kg P_2O_5 ha^{-1} resulted with significant increase in the chickpea yield.

Neeraj and Pandey (2008) showed that the application of 25 kg nitrogen with 30 cm row spacing was significantly better to harvest the maximum production from chickpea from per unit area, whereas, the minimum yield and net income was found with control and 50 cm row spacing.

Arvadia and Patel (1986) reported that chickpea production showed positive linear response to N level; the highest average yield (1890 kg ha^{-1}) was obtained from the plots receiving 40 kg N ha^{-1}.

Hernandez and Hill (1983) showed that *Rhizobium* inoclation along with the addition of 20 kg N ha^{-1} gave the maximum yield of chickpea under both loamy sand and sandy loam soil.

Jadhav *et al.* (1992) examined the effect of varying levels of N and P fertilizers on chickpea. He reported that chickpea seed production was higher with the application of 35 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}due to higher number of seeds per plant.

Sheoran *et al.* (1997) found that the application of 40 kg N/ha produced 96.7% of estimated maximum yield. They conducted field studies to determine the response of chickpea to N fertilized at different level (0, 20, 40, and 60 kg ha^{-1}) where N increased the seed yield.

Tellawi *et al.* (1986) conducted a field experiment on Vertisol soil in Gujarat, India with chickpea using 0 or 40 kg N ha^{-1}. They found that application of 40 kg N ha^{-1} significantly increased the seed yield (1.7 t ha^{-1}) when compared with that of control (1.08 t ha^{-1}).

Panda (1979) observed that the application of N and P fertilizer @ 0 to 90 kg P_2O_5 ha^{-1} increased seed yield.

Patel and Parmer (1986) conducted an experiment on the response of greengram to varying levels of nitrogen and phosphorus. They observed that increasing N application (30 to 45 kg ha^{-1}) with phosphorus (60 to 75 kg ha^{-1} to rainfed mungbean (cv. Gujrat-1) increased the seed yield.

Sing and Yadav (1971) conducted field trials in Assam, India, and applied N and P fertilizers to study their relative contributions towards increasing the seed yield of chickpea. Their studies showed that N along with P fertilizers increased the seed yield. They observed that 10 kg N in combination with 20 kg P_2O_5 ha^{-1} resulted in significant increases in the seed yield.

Rupela and Bcek (1990) reported that application of N at the rate of 50 kg ha^{-1} along with P_2O_5 (50 kg ha^{-1}) increased chickepa yield.

Muhammad *et al.* (2004) conducted a field experiment on clay soil during the rainy season of 1990 to study the response of chickpea cultivars to nitrogen, phosphorus and *Rhizobium* inoculation. They observed that seed yield increased with the application of nitrogen fertilizer up to 20 kg N ha^{-1} in combination with phosphorus fertilizer up to 40 kg P_2O_5 and inoculation with *Rhizobium.*

Krishna *et al.* (2004) conducted a field experiment on sandy loam soil during the kharif (monsoon) season of 1986 at Hisar, Hariana, India, with chickpea. Treatments 0, 50 or 100% of the recommended N and P fertilizers (20 kg N as Urea and 40 kg P_2O_5 ha^{-1} as single super phosphate) were tested. They found that chickpea receiving the recommended dose gave the highest seed yield.

Mudholker and Ahlawat (1979) reported that the use of recommended dose of NPK plus compost increased the seed yield of chickepa by 83 - 87%.

A field experiment was carried out by Panse and Khanna (1994) during summer seasons at Golaghat, Assam, India. Chickpea was grown using farmers' practices (no fertilizer) or using different combinations of fertilizer application (10 kg N + 35 kg P-$_2O_5$ ha^{-1}). Seed yield was 0.40 t ha^{-1} with farmers' practices, while the highest yield was obtained by the fertilizer application (0.77 t ha^{-1}).

Pulses have been found to fix varying amounts of nitrogen. Nitrogen balances have been determined for various pulses and examples of such balances range from as little as 42 to 34 Kg N/ha for chickpea (Doughton *et al*., 1993) and 32 to 96 Kg N/ha for field peas (Evans *et al*., 1989).

Chickpea, like other legumes, require only a starter dose of nitrogen ranging from 15 to 25kg/ha depending upon the soil (Mishra and Ram, 1971; Pasriche *et al.,* 1991).

Significantly high straw yield has been reported with the application of 22.5 to 30.0 kg N/ha (Sing and Yadav, 1971; Singh *et al*, 1972; Mudholker and Ahlawat, 1979; Panse and Khanna, 1994). The higher dose of N is likely to encourage vegetative growth (branches and leaves), thereby decreasing the grain to straw ratio- drastically.

Mahapatrre *et al.* (1973) reported that application of nitrogen alone give low response but when applied with adequate amounts of other nutrients such as phosphorous at 30 to 60 kg P2O5/ha, the response to 15 kg N/ha was significantly higher over control. On black cotton soils (clayey in texture), the response to N was not significant (Probhoojan *et al.,* 1973).

Subramanian and Pallaniappan (1979) observed no response even on application of 10 kg N/ha.

ICRISAT (1988) reported nitrogen response of chickpea genotype to nitrogen fertilizers with regard to studies with a non-nodulating mutant, ICC 435M. The response to 100 kg nitrogen/ha fertilizer gave grain yield of 1.2 tons/ha that were equal to its parent, ICC 435.

The importance of adequate supply of plant nutrients (NPK) to chickpea to ensure efficient crop production has been recognized for many years (Guto, 1997). Scientists and farmers are therefore continually striving to overcome nutrient deficiencies of chickpea in order to increase yields according to their genetic potentials (Tisdole *et al.*, 1990).

Fertilization does sometimes permit deeper penetration of the soil by roots and thus the amount of nutrient and water available for extraction is increased (Hedge, 1995). Under dry land condition, the deeper sub soil frequently contains little available plant nutrients and water for exploitation.

Srinivasarao *et al* (2004) investigated the available nutrient status in sub-soil layers (15-30 and 30-45 cm) in relation to that of surface soils of profiles collected from pulse growing regions of India. He reported higher nutrient contents (N, P, K) between top two layers and that many pulse crops like chickpea, pigeon pea and mung bean were deep rooted extending the root system beyond 15 cm hence substantially utilizing nutrients from deep layers to increase seed yield. A review of work done on fertilizer requirements under dry land conditions proves that the fertilizer application rates and planting population densities are tools to optimize the soil nutrients, moisture availability and seed yield (Kumar, 2005). In soils deficient in nitrogen, application of nitrogen fertilizer to crops will bring considerable increase in the productivity (Umrani, 1995). However, crops use nitrogen fertilizers inefficiently (Dobermann and Cassman, 2004).

Nitrogen (N) plays a big role in all metabolic processes. It forms an important constituent of cell structures and is indispensable for the transfer of genetic information. Akram *et al.* (2004) remarked that the addition of even small amounts of nitrogen (N) into agricultural lands can increase the growth and yield of crops effectively. Although N accounts for 78% of the air volume, its availability is relatively poor because only few plants (pulses) can utilize it directly from the atmosphere. Consequently the supply of available N often becomes inadequate especially during the critical growing periods of plants. Hence it has been a long time challenge for agriculturalists to maintain soil N at levels that are adequate for optimum crop production (Krishna *et al.*, 2004). Applications of nitrogen increase the source capacity, namely, leaf area, Leaf area index (LAI), early canopy closure and the rate of photosynthesis (Doughton *et al.*, 1993).

Chickpea responds favorably to low rates of 15 - 20 kg N/ha in nitrogen deficient soils (Sing and Khongaret, 1987; Thaku *et al*., 1989, and Ahlawat, 1990). Substantial increases in yield ranging from 0 to 40% have been obtained with application of 10-20 Kg N/ha (Ahlawat 1990). On calcareous soils, grain yield of chickpea significantly increased with application of 40 kg N/ha whereas there was no response to additional dose of nitrogen irrespective of the source (Kumar 1995). Shri *et al.,* (2004) conducted a field experiment in Kaptur, Uttar Pradesh, India, during the rabi seasons of 1996/97 and 1997/98 to study the interactive effects of nitrogen (0, 15, 30 and 45 kg/ha through urea) and sulphur (0,20,40 and 60 kg/ha) on the grain yield (kg/ha), harvest index (H1), total nitrogen (N) and Sulphur (S) uptake, and protein content of chickpea. He reported that application of 15 kg N/ha and 40 kg S/ha significantly increased grain, N and S uptake, and protein content over the control in both seasons under semi arid conditions.

Raut and Sabale (2003) used four different types of NPK fertilizer (25:50:0, 31.2:60.7:27, 47.45:80.33:33.45 and 126:138:52.8) and reported that number of branches/m2, dry matters/ha, harvest index (HI), stovers and grain yields increased with increasing fertilizer rates. Lopez *et al.* (2004) reported that chickpea crop seems incapable of meeting nitrogen demands by fixation and does not even supply an equivalent quantity of 50 kg/ha of nitrogen fertilizer. There is no work done for Naivasha area, therefore, there is need to determine the optimum fertilizer level for optimal growth of desi chickpea in the dry land of Naivasha- Kenya.

Akram *et al.* (2004) while working on sandy loam soil of Varanasi reported that application of nitrogen @ 20 kg ha^{-1} favorably influenced all the yield and quality traits of chickpea.

In a field trial in New Zealand, Mckenzie and Hill (1995) observed that there was significant increase in pea yield and was 6.5 t ha^{-1} with an application of 60 kg N compared with no N 2.36 t ha^{-1}.

In another experiment Raso (1996) revealed that pea yield significantly enhanced with increasing N levels upto 40 kg ha^{-1}. Maximum pea yield (150 q ha^{-1}) was also obtained with 40 kg N at two spilt.

Mishra and Ram (1971) conducted a field experiment on sandy loam soil at

Kukumseri and reported that application of 20 kg N, 69.9 kg P_2O_5 along with 66.4 kg K_2O ha^{-1} gave maximum pod yield, plant height, grains per pod, pod $plant^{-1}$ and pod weight $plant^{-1}$.

Patel (1998) conducted a green house experiment to study the effect of graded doses of NPK on yield and their uptake by pea and reported that application of 10 ppm N, 30 ppm P and 60 ppm K increased the grain and straw yield over control.

In a field experiment conducted by Vadavia *et al.* (1991) in the soil of Sangli, it was realized that application of 40 kg N, 46 kg P_2O_5 and 40 kg K_2O recorded maximum grain yield of pea as compared to other treatments.

Ayaz *et al.* (2004) while studying the effect of nitrogen and phosphorus on vegetable pea in cold desert area of Himachal Pradesh reported that application of 30 kg N, 39.6 kg P and 50.4 kg K ha^{-1} as an optimum dose for obtaining higher pea yield.

Doughton *et al.* (1993) reported that application of N, P and K in combination with or without inoculation significantly increased the yield over control. They further reported that the rate of 30 kg ha^{-1} each of N, P and K significantly improved the seed yield by 45.48 per cent over control.

In a sandy loam soils of New Delhi, Mahendran and Chandramani (1998) reported that application of 25 kg N, 26.2 kg P and 30 kg K ha^{-1} resulted in marked improvement in growth, yield attributes and yield of pea over alone application of N, P or K.

Guto (1997) studied the growth and yield of table pea as influenced by levels of NPK in an acid soil. They found that application of 30 kg N, 75 kg P and 40 kg K ha^{-1} gave the maximum values of growth parameters and pod yield.

Sharma and Maloo (1988) evaluated the effect of three fertilizer levels on yield and plant growth parameters of pea in an experiment at Solan. The result revealed that fertilizer treatments 25 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1} recorded maximum pea seed yield (11.5 q/ha), plant height, number of pods per plant, pod length and number of seeds per pod. Similar results were reported by Chaudhari *et al.* (1998), he also revealed that Integrated Nutrient Management practice is better over alone use of organics and in organics in pea.

In an experiment in India, Meena *et al.* (2003) evaluated the effect of N, P, K and S on yield of garden pea. The results revealed that application of these nutrients caused a significant increase in yield of the crop. The highest pod yield was achieved in treatment combination of 30 kg N + 50 kg P_2O_5 +40 kg K_2O +20 kg S ha^{-1}. Mans *et al.* (1997) reported that maximum green pod yield was obtained when 69 kg P_2O_5 ha^{-1} in combination with 40 kg N and 100 kg K_2O ha^{-1} were applied.

In a field experiment conducted by, Kumar *et al*. (2005) on the productivity of pea under Lahaul valley conditions of Himachal Pradesh reported that an application of 20 kg N, 60 kg P_2O_5 and 30 kg K_2O ha^{-1} resulted in a significantly higher seed yield, growth and yield contributing traits. The yield component values were higher with the application of 100% of the recommended rate of NPK + FYM as compared with NPK alone (Raut and Sabale, 2003).

El-Karamany and Bahar (1999) studied the effect of row spacing and nutrition on the quality and uptake of nutrients in pea in sandy loam soils of New Delhi. They reported that application of nitrogen and phosphorus @ 20 N and 78 kg P_2O_5 ha^{-1} resulted in higher N and Ca contents in pea seed yield.

In an experiment conducted by, Singh *et al*. (1972) reported that potassium addition to pea crop significantly increased its nitrogen content and uptake increasing seed yield. Similarly Dahiya *et al*. (1993) observed that nitrogen and phosphorus uptake increased with the advancement of crop stage, reaching maximum at seed yield.

Singh *et al.* (1994b) while studying the effect of N and P on grain and nutrient uptake by field pea observed that mean effect of all the P levels indicated an increase of 37.5 kg ha^{-1} of total N removed by pea grain and straw with the application of 30 kg P_2O_5 ha^{-1} and beyond this level the increase in uptake was non significant. Addition of N continued to increase total N uptake significantly upto 40 kg N ha^{-1} level.

Verma and Panday (1993) conducted an experiment in the soils of Solan in Himachal Pradesh with four levels of each N (0, 15, 30 45 kg/ha) and P_2O_5 (0, 30, 60, 90 kg/ha). They found that mineral concentration in seeds generally increased with the application of 15 kg N and 60 kg P_2O_5 ha^{-1}.

Yadav and Shrivastava (1997) in the soil of Morena (Madhya Pradesh) studied the effect of irrigation schedule and levels of phosphorus on nutrient uptake by pea. They found that uptake of nitrogen and phosphorus by seed yield was highest with the application of 75 kg P_2O_5 ha^{-1} and irrigation at flowering stage.

Verma (1994) reported that the N content in seeds and straw increased with increasing phosphorus levels upto 60 kg P_2O_5 ha^{-1} and the P content in seeds and straw increased with increasing levels of N upto 15 kg ha^{-1}. Combination of N and P increased the seed and straw yield in chickpea.

2.2.8. Stover yield

Vadavia *et al.* (1991) found that application of 20 kg ha^{-1} N and 40 kg P ha^{-1} increased significant straw yield of chickpea. Subba-Rao *et al.* (1986) also reported that the rate of 20 kg N ha^{-1} was most effective in increasing straw yield.

Karadavut and Ozdemir (2001) stated the application of *Rhizobium sp.* and 30 kg N ha^{-1} on 3 chickpea cultivars in the winter season of 1995-96 and 1996-97 significantly increased straw yield.

Khan *et al.* (1992) reported from his study that biological yield of chickpea increased significantly with 20 kg N + 50 kg P_2O_5 ha^{-1}.

2.2.9. % Harvest index (HI)

Harvest index may be influenced by N fertilization. Chaudhari *et al.* (1998) found that application of 20-40 kg N ha^{-1} significantly influenced harvest index of chickpea.

Islam (2002) found a significant increase in harvest index in bush bean due to application of N. Where the lowest HI was in control and the maximum was at 36.8 kg N ha^{-1}.

It may be concluded from the study of different scientists that nitrogen is essential element for chickpea production. 20-40 kg N ha^{-1} was found influential in most study to increase yield and yield components of chickpea and some other pulses.

Chapter 3

Methods and Materials

CHAPTER 3

MATERIALS AND METHODS

This chapter has been written on different resources, cultural managements, data collection and statistical analysis required in this experiment. The experiment was conducted during the period from November, 2011 to March, 2012 to study the response of chickpea varieties to different nitrogen managements. The details materials and methods of this experiment are presented below under the following headings:

3.1. Experimental site

The present research work conducted at the research field of Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka. The experimental area is located at 23.41˚ N and 90.22˚ E latitude and at an altitude of 8.6 m from the sea level.

3.2. Soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment to analyze soil according to Edris *et al.,* (1979) and the soil characterizes.

3.3. Climate

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

3.4. Planting materials

The crop used in this study was three cultivars of chickpea viz., BARI Chola-5 and BARI Chola-6 and BINA Chola-6. BARI Chola-5 and BARI Chola-6 varieties have been developed by the Bangladesh Agricultural Research Institute (BARI) and variety BINA Chola-6 has been developed by the Bangladesh Institute of Nuclear Agriculture (BINA) for cultivation in this country. The seeds were collected from BARI, Joydebpur, Gazipur and BINA, Mymensingh. The seeds were healthy, pulpy, well matured and free from mixture of other seeds, weed seeds and extraneous materials.

3.5. Land preparation

Power tiller was used for the preparation of the experimental field. Then it was exposed to the sunshine for 5/6 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed and deep ploughing was done to obtain good tilth, which was necessary to get better yield of this crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubble were removed from the experimental field. The plots were spaded one day before planting and the whole amount of fertilizers were incorporated thoroughly before planting according to fertilizers recommendation guide (BARC, 2005) except nitrogen. Nitrogen was used as per treatments.

3.6. Fertilizers

Phosphorus, potash and sulpher fertilizers were applied as basal during final land preparation. Nitrogenous fertilizer was applied as per treatment.

Manure and fertilizer	Dose (kg ha^{-1})
P_2O_5	40
K_2O	20
S	10

Source: *BARC, 2011.*

3.7. Treatments of the experiment

The experiment was consisted of two treatment factors as follows:

Factor A: Cultivar-3

V_1= BARI Chola-5

V_2= BARI Chola-6

V_3= BINA Chola-6

Factor B: N management-6

N_0= Control (No fertilizer)

N_1=Basal application of 20 kg N ha^{-1}

N_2=Basal application of 40 kg N ha^{-1}

N_3=Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4=Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5=Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

3.8. Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (Factorial) with three replications. Each block was divided into 18 plots where 18 treatment combinations were allotted at random. The unit plot size was 4 m × 2.5 m. The space between two blocks and two plots were 1.5 m and 0.50 m, respectively.

3.9. Sowing of seeds in the field

Seeds were sown on 17th November 2011. Row to row and plant to plant distances were 40 cm and 10 cm, respectively. Seeds were placed at about 2-3cm depth from the soil surface.

3.10. Intercultural operations

3.10.1. Thinning

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

3.10.2. Weeding

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

3.10.3. Irrigation

The irrigation was done as per requirement. Water application was continued till soil saturation.

3.10.4. Disease and pest management

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

3.11. Harvesting and threshing

Harvesting of the crop was done after 120 days of sowing for data collection when about 80% of the pods attained maturity. After germination, 2 m^2 areas from middle portion of each plot were marked for harvest at maturity. The harvested plants of 2 m^2 of each treatment were brought to the cleaned threshing floor and pods were separated from plants by hand and allowed them for drying well under bright sunlight.

3.12. Crop sampling and data collection

The data of the different parameters of chickpea were collected from randomly selected ten plant samples, which were collected from each plot excluding border lines. The sample plants were uprooted carefully from the soil. Plant height, branches plant^{-1}, above ground dry weight, nodules plant^{-1} and nodule dry weight plant^{-1} were recorded form selected plants at an interval of 20 days started from 20 DAS (for plant height) and 40 DAS (for others) up to harvest. Yield and yield contributing parameters were recorded from the remarked plants from the central part (2m^2) of the plots. A brief outline of the data recording on morpho-physiological and yield contributing characters are given below.

3.12.1. Plant height (cm)

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

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

Number of branches per plant was counted from selected plants. The average number of branches per plant was determined.

3.12.3. Total dry weight plant^{-1} (g)

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

3.12.4. Nodules plant^{-1} (no.)

Nodules were collected from ten randomly selected plants. The nodules per plant were calculated from their mean values.

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

Collected nodules from ten randomly selected plants were dried in an oven and the nodule dry weight plant^{-1} was calculated.

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

The pods from the branches of the selected ten plants were counted and the number of pods per plant was calculated from their mean values.

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

Number of seeds per pod was recorded from the selected 20 pods at the time of harvest. The seed per pod was calculated from their mean values.

3.12.8. 1000-seed weight (g)

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

3.12.9. Seed yield and Stover yield (t ha^{-1})

The seed weight was taken from the selected plants having threshed properly and then yield was expressed in kg per hectare. Stover weight was taken without seed and converted to kg per hectare.

3.12.10. Biological yield (t ha^{-1})

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

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

3.12.11. Harvest index (%)

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

$$\% \text{ Harvest index (HI)} = \frac{\text{Economic yield}}{\text{Biologicalyield}} \times 100$$

3.13. Statistical analysis

The data obtained from the experiment on various parameters were statistically analyzed in MSTAT-C computer program designed by (Fread, 1986). The mean values for all the parameters were analyzed by Duncan's Multiple Range Test (DMRT) at 5% levels of probability (Gomez and Gomez, 1984).

Chapter 4
Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to study the response of chickpea cultivars to different nitrogen applications. Data on different growth, yield contributing characters and yield was recorded. The data on different parameters was presented in Figure 1-22 and Table 1 to 6. The results have been presented and discussed with possible observations under the following headings:

4.1. Plant height

Effect of cultivars

Plant height varied significantly at 20, 40, 60, 80, 100 DAS and harvest for BARI Chola-5, BARI Chola-6 and BINA Chola-6 (Appendix I (a), I (b), I (c), I (d), I (e), I (f) and Figure 1).

At 20 DAS, the tallest plant (19.82 cm) was noted from V_3 (BINA Chola-6) and the shortest plant (13.01 cm) was noted form V_1 (BARI Chola-5). At 40 DAS, the tallest plant (23.64 cm) was noted from V_3 (BINA Chola-6) and the shortest plant (16.67 cm) was noted form V_1 (BARI Chola-5). At 60 DAS, the maximum plant height (29.32 cm) was observed form V_2 (BARI Chola-6) and the shortest plant (24.45 cm) was noted form V_1 (BARI Chola-5). At 80 DAS, the maximum plant height (42.03 cm) was observed form V_2 (BARI Chola-6) and the shortest plant (37.67 cm) was noted form V_1 (BARI Chola-5) which was statistically similar with V_3 (BINA Chola-6) (37.95). At 100 DAS, the maximum plant height (41.81 cm) was observed form V_2 (BARI Chola-6) and the shortest plant (37.94 cm) was noted form V_1 (BARI Chola-5) which was statistically similar with V_3 (BINA Chola-6) (38.83 cm).

At harvest the maximum plant height (41.59 cm) was observed form V_2 (BARI Chola-6) and the shortest plant (37.81 cm) was noted form V_1 (BARI Chola-5) which was statistically similar with V_3 (BINA Chola-6) (38.39 cm). The plant height depends on their varietal characters. This character is governed by genetic factors. Kabir *et al.* (2009) observed in plant height, BARI Chola-4 produced the tallest plants (32.30 cm) being closely followed by BARI Chola-2 (30.90 cm). The shortest plants (29.26 cm were found in BARI Chola-6. Das (2006) also found significant variation among chickpea varieties BU Chola-1, BARI Chola-6 and

BARI Chola-7 varied from 32.14 cm to 35.16 cm. the BARI Chola-7 was the tallest and BU Chola-1 was the shortest. Karasu *et al.* (2009) showed maximum plant height was recorded on popular local genotype of chickpea named Yerli (58.7 cm), Canıtez-87 cultivar and ILC-114 line had shorter plant height (54.7 and 53.7 cm, respectively).

Effect of nitrogen application

Different nitrogen application showed significant differences on plant height at 20, 40, 60, 80, 100 DAS and harvest (Appendix I (a), I (b), I (c), I (d), I (e), I (f) and Figure 2).

At 20 DAS, the tallest plant (16.51 cm) was found from N_2 (Basal application of 40 kg N ha^{-1}) it was as per with N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (16.32 cm). The shortest plant (14.97 cm) was observed from N_0 (No fertilizer). At 40 DAS, the maximum plant height (20.22 cm) was found from N_2 (Basal application of 40 kg N ha^{-1}) and the shortest plant (19.34 cm) was found from N_1 (Basal application of 20 kg N ha^{-1}). At 60 DAS, the maximum plant height (28.78 cm) was observed from N_2 (Basal application of 40 kg N ha^{-1}) which was statistically similar with N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) and the shortest plant was recorded from N_0 (No fertilizer) (25.06 cm). At 80 DAS, the tallest plant (40.34 cm) was observed from N_2 (Basal application of 40 kg N ha^{-1}) and the shortest plant (38.54 cm) was found from N_5 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation). At 100 DAS, the tallest plant (40.96 cm) was observed from N_2 (Basal application of 40 kg N ha^{-1}) and the shortest plant height (38.85 cm) was found from N_1 (Basal application of 20 kg N ha^{-1}). At harvest, the tallest plant (39.24 cm) was observed from N_2 (Basal application of 40 kg N ha^{-1}) and the shortest plant height (38.77 cm) was found from N_5 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation). Similarly Patra *et al.* (1998) noticed increased plant height of chickpea over control with 20 kg N along with 40 kg P ha^{-1}. Rathore and Patel (1991) noticed that application of 18 kg N along with 46 kg P ha^{-1} increased plant height of chickpea over no N application. Chaudhari *et al.* (1998) found a positive effect of nitrogen at the rate of 20 and 40 kg ha^{-1} on increased in chickpea plant height.

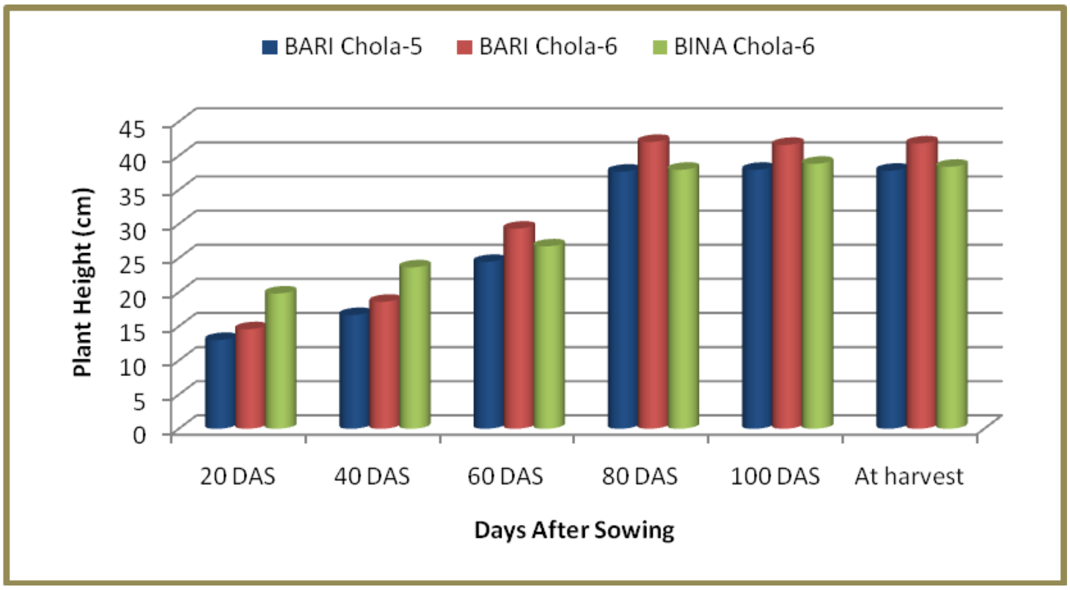
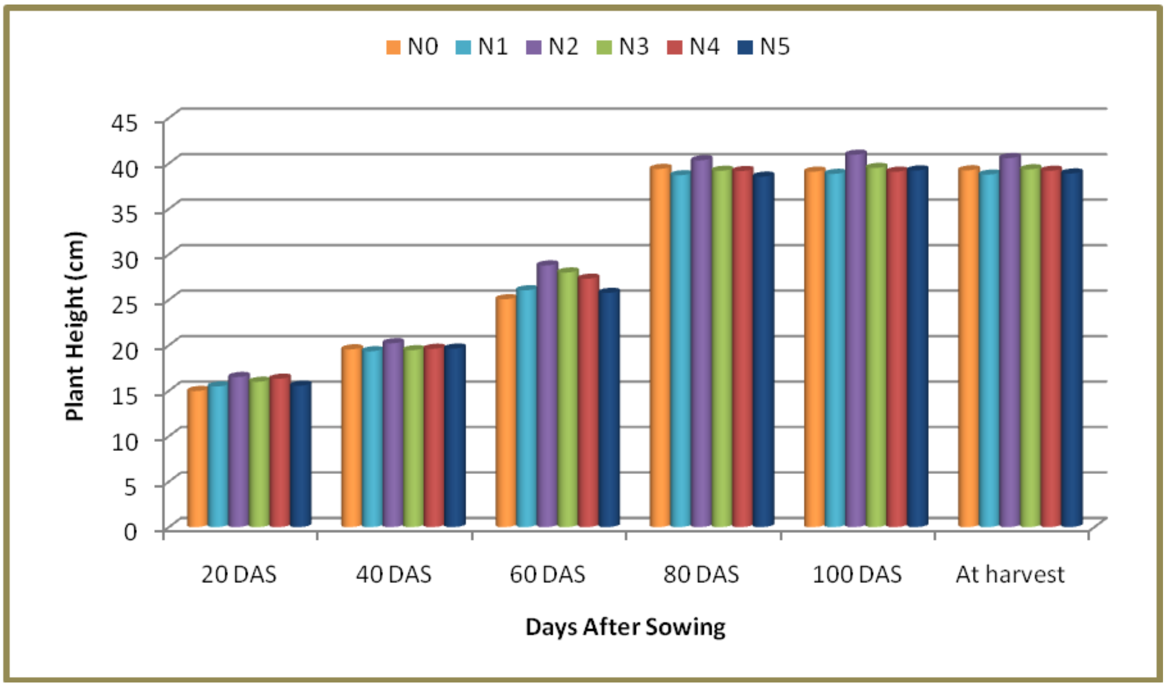


Figure 1: Effect of cultivar on plant height of chickpea at different days (S$\bar{x}$ = 0.0505, 0.1723, 0.1571, 0.2271, 0.1953 and 0.2091 at 20, 40, 60, 80, 100 DAS and harvest, respectively)



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 2: Effect of different nitrogen application on plant height of chickpea at different days (S$\bar{x}$ = 0.0851, 0.2898, 0.2643, 0.3819, 0.3284 and 0.3517 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

Combined effect of cultivar and nitrogen application

Combined effect of chickpea cultivar and nitrogen applications showed significant differences on plant height at 20, 40, 60, 80, 100 DAS and harvest (Table 1).

At 20 DAS, maximum plant height (21.53 cm) was noted from V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}). On the other hand, the shortest plant (12.02 cm) was recorded in V_1N_0 (BARI Chola-5 + No fertilizer) which was at par with V_1N_5 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (12.44 cm).

At 40 DAS, the highest plant (25.04 cm) was noted from V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) and it was followed by V_2N_2 (BARI Chalo-6 + Basal application of 40 kg N ha^{-1}) (24.84 cm), V_3N_3 (BINA Chola-6 + Application as basal with 50% (20 kg) N ha^{-1} and 50% (20 kg) N ha^{-1} at branch initiation stage) (24.06 cm) and V_1N_2 (BARI Chalo-5 + Basal application of 40 kg N ha^{-1}) (23.56 cm). On the other hand, the shortest plant (15.54 cm) was recorded in V_1N_0 (BARI Chola-5 + No fertilizer) and it was followed by V_3N_0 (BINA Chola-6 + No fertilizer) (16.44 cm), V_1N_1 (Basal application of 20 kg N ha^{-1}) (16.61 cm), V_1N_5 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (16.76 cm), V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (17.00 cm), V_1N_4 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (17.33 cm) and V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (17.33 cm) .

At 60 DAS, highest plan (32.17 cm) was noted from V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) which was followed by V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) (31.29 cm) and V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (30.63 cm). On the other hand, the shortest plant (21.03 cm) was recorded in V_1N_0 (BARI Chola-5 + No fertilizer).

At 80 DAS, highest plant (42.33 cm) was noted from V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) which was statistically similar to V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) (41.92 cm), V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (41.61 cm) and V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (41.58 cm). On the other hand, the shortest plant (32.36 cm) was recorded in V_1N_0 (BARI Chola-5 + No fertilizer).

At 100 DAS, the highest plant (43.22 cm) was noted from V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) which was statistically similar to V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) (42.36 cm), V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (41.93 cm), V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (41.81 cm) and V_2N_4 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (40.91 cm). On the other hand, the shortest plant (35.12 cm) was recorded in V_1N_0 (BARI Chola-5 + No fertilizer).

At harvest, the highest plant (43.28 cm) was noted from V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) which was statistically similar to V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) (42.64 cm), V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (42.26 cm) and V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (41.96 cm). On the other hand, the shortest plant (34.61 cm) was recorded in V_1N_0 (BARI Chola-5 + No fertilizer).

Table 1: Combined effect of cultivar and nitrogen application on plant height of chickpea at different days

Treatments	Plant Height (cm)					
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	Harvest
V_1N_0	12.02 h	15.54 i	21.03 i	32.36 e	34.12 h	34.61 f
V_1N_1	13.00 fg	16.61 g-i	25.36 f-h	36.96 cd	38.70 d-g	38.41 c-e
V_1N_2	14.04 e	23.56 a-c	30.63 ab	41.61 ab	41.81 a-c	42.26 ab
V_1N_3	13.38 f	17.33 f-i	23.70 h	35.95 d	37.36 g	37.29 e
V_1N_4	13.15 f	17.33 f-i	23.95 gh	36.35 d	37.58 g	37.94 c-e
V_1N_5	12.44 gh	16.76 g-i	26.46 d-f	36.69 cd	37.96 e-g	37.23 e
V_2N_0	13.30 f	18.33 e-h	28.34 cd	37.12 cd	38.74 d-g	38.36 c-e
V_2N_1	13.24 f	19.81 de	26.54 d-f	38.36 cd	40.22 b-f	40.30 c-d
V_2N_2	15.58 d	24.84 ab	31.29 a	41.92 ab	42.36 a-b	42.64 ab
V_2N_3	14.61 e	17.00 f-i	28.84 bc	41.58 ab	41.93 ab	41.96 ab
V_2N_4	16.18 c	18.76 e-g	26.20 ef	39.39 bc	40.91 a-d	40.14 b-d
V_2N_5	14.57 e	18.50 e-h	26.95 c-f	39.38 bc	40.47 b-e	40.42 bc
V_3N_0	19.58 b	16.44 hi	25.82 fg	36.86 cd	38.59 d-g	38.14 c-e
V_3N_1	19.13 b	21.61 cd	26.25 ef	36.30 d	37.62 g	37.60 de
V_3N_2	21.53 a	25.04 a	32.17 a	42.33 a	43.22 a	43.28 a
V_3N_3	19.37 b	24.06 ab	28.14 c-e	37.31 cd	38.85 c-g	38.10 c-e
V_3N_4	19.63 b	22.75 bc	27.39 c-f	36.58 cd	37.75 fg	37.35 e
V_3N_5	19.65 b	19.19 ef	23.87 h	37.74 cd	39.27 c-g	39.01 c-e
CV (%)	10.24	11.55	7.03	10.04	7.38	8.49
$S\bar{x}$	0.1939	0.6607	0.6024	0.8706	0.7486	0.8017

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

N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

4.2. Branches plant^{-1}

Effect of cultivar

Significant variation was recorded for number of branches plant^{-1} at 40, 60, 80, 100 DAS and harvest for BARI Chola-5, BARI Chola-6 and BINA Chola-6 under the present trial (Appendix II (a), II (b), II (c), II (d), II (e) & Figure 3). The maximum number of branches plant^{-1} (8.72, 13.11, 16.98, 21.08 and 24.69, respectively) was found from V_2 (BARI Chola-6) and it was followed by V_1 (BARI Chola-5) (12.02) at 60 DAS and V_3 (BINA Chola-6) (7.88, 14.65, 19.06 and 23.77 at 40, 80, 100 and harvest respectively). The minimum number of branches plant^{-1} (7.61, 13.01, 15.85, and 21.78 respectively) was recorded from V_1 (BARI Chola-5) at 40, 80, 100 and harvest respectively) and V_3 (BINA Chola-6) (10.39) at 60 DAS.

Das (2006) showed that the total number of branches across the varieties BU Chola-1, BARI Chola-6 and BARI Chola-7 averaged from 13.78 to 15.98. BARI Chola-6 produced the highest and BARI Chola-7 produced the lowest number of branches plant^{-1}. Similar results were noticed by Ferdous (2001) in pea.

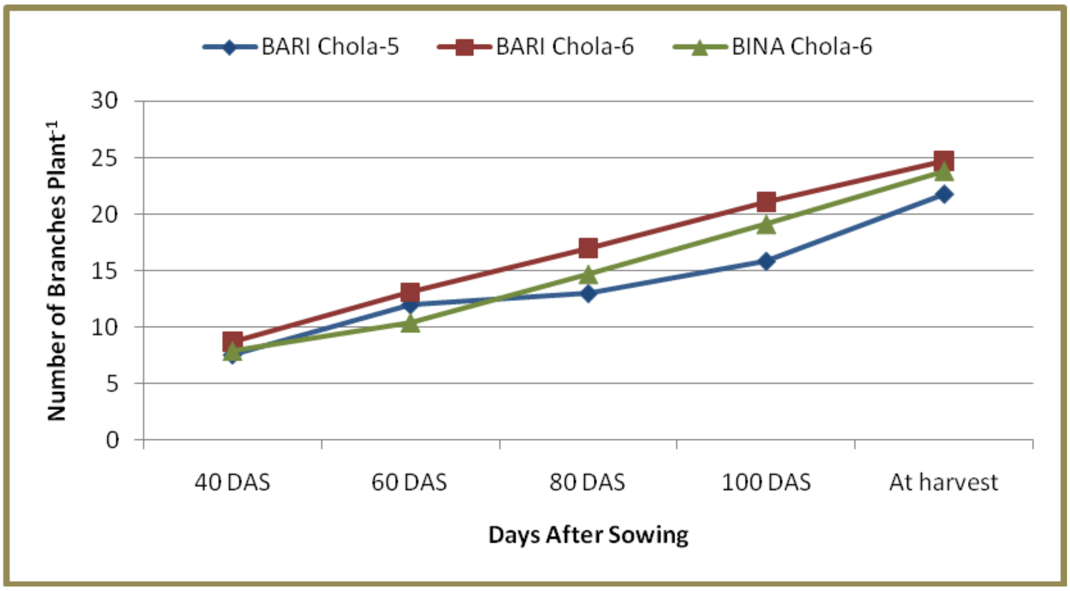
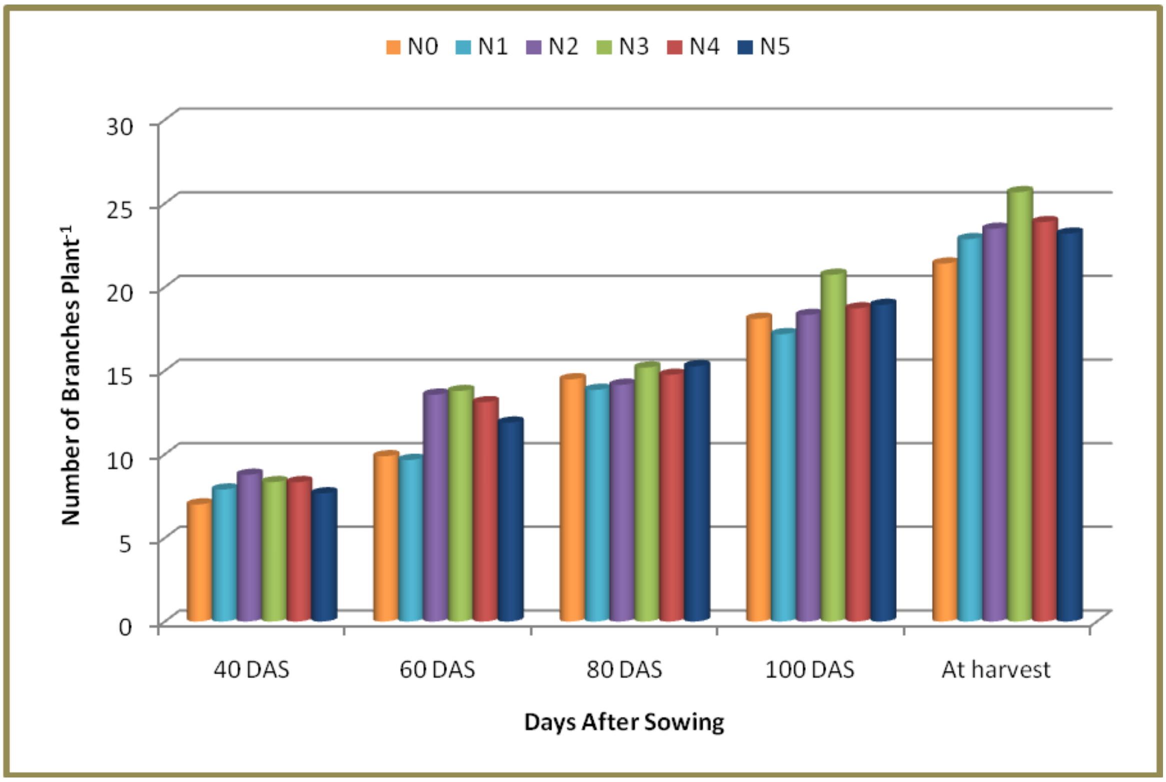


Figure 3: Effect of cultivar on number of branches plant^{-1} of chickpea at different days ($S\bar{x}$ = 0.1696, 0.2278, 0.2261, 0.2399 and 0.0611 at 40, 60, 80, 100 DAS and harvest, respectively)

Effect of nitrogen application

Number of branches plant^{-1} showed significant variation for different nitrogen application at 40, 60, 80, 100 DAS and harvest (Appendix II (a), II (b), II (c), II (d), II (e) and Figure 4). The maximum number of branches plant^{-1} at 40 DAS was recorded from N_2 (Basal application of 40 kg N ha^{-1}) (8.77) and it was followed by N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1}at branch initiation) (8.33) and N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1}at flower initiation) (8.33). At 60 DAS, the maximum number of branches plant^{-1} was recorded from N_3 (13.78) and it was followed by N_2 (13.56). At 80 DAS, the maximum number of branches plant^{-1} was recorded from N_3 (15.18) and it was closely followed by N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (14.75). At 100 DAS, the maximum number of branches plant^{-1} was recorded from N_3 (20.73) and it was closely followed by N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (18.72). At harvest, the maximum number of branches plant^{-1} was recorded from N_3 (25.67) and it was at par with N_4 (23.88) and N_2

(23.48). On the other hand, for different nitrogen application at 40, 60, 80, 100 DAS and harvest the minimum numbers of branches plant^{-1} were recorded from N_0 (No fertilizer) (7.00, 9.88, 14.48, 18.10 and 21.40). Chaudhari *et al.* (1998) found a positive effect of nitrogen at the rate of 20 and 40 kg ha^{-1} on increased in chickpea number of primary and secondary branches plant^{-1}. Vadavia *et al.* (1991) reported that application of 20 kg N ha^{-1} and 40 kg P ha^{-1} increased number of branches plant^{-1} of chickpea. Mishra (1995) reported that N deficient chickpea plants were shorter and got less branches plant^{-1} than the plants grown with applied N. The tallest plant and higher number of branches plant^{-1} was obtained by 30 kg N ha^{-1}.



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 4: Effect of different nitrogen application on number of branches plant^{-1} of chickpea at different days ($S\bar{x}$ = 0.2852, 0.3830, 0.3802, 0.4034 and 0.1027 at 40, 60, 80, 100 DAS and harvest, respectively)

Combined effect of cultivar and nitrogen application

Combined effect on number of branches plant^{-1} at 40, 60, 80, 100 DAS and harvest was found significant (Table 2).

At 40 DAS, the highest branches plant^{-1} (11.33) was noted from V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1}at branch initiation) and it was at par with V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1}at branch initiation) (10.00), V_3N_3 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1}at branch initiation) (9.66) and V_2N_4 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (9.33). On the other hand, the lowest branches plant^{-1} (4.33) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer).

At 60 DAS, the highest branches plant^{-1} (15.33) was noted from V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) and it was followed by V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (15.33) and V_2N_4 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (14.33), V_3N_3 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (14.33), V_1N_4 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (13.67), V_1N_5 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (13.33) and V_3N_5 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (12.67). On the other hand, the lowest number of branches plant^{-1} (5.69) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer).

At 80 DAS, the highest branches plant^{-1} (18.22) was noted from V_2N_3 which was statistically similar with V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (18.11), V_3N_3 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (17.44), V_3N_5 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (17.22), V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) (16.33), V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) (16.33) and V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (16.33). On the other hand, the lowest number of branches plant^{-1} (9.44) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer).

At 100 DAS, the highest branches plant^{-1} (23.44) was noted from V_2N_3 which was statistically similar with V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (22.74), V_2N_4 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (22.64), V_3N_3 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (21.81), V_3N_5 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (20.75), V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) (20.42), V_3N_4 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (20.41) and V_3N_1 (BINA Chola-6 + Basal application with 20 kg N ha^{-1}) (20.38). On the other hand, the lowest number of branches plant^{-1} (12.77) was recorded in V_3N_0 which was statistically similar with V_1N_0 (BARI Chola-5 + No fertilizer) (14.81), V_1N_1 (BARI Chola-5 + Basal application of 20 kg N ha^{-1}) (15.69) and V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (15.69).

At harvest, the highest branches plant^{-1} (27.00) was noted from V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation). On the other hand, the lowest branches plant^{-1} (19.33) was recorded in V_3N_0.

Table 2: Combined effect of cultivar and nitrogen application on number of branches plant^{-1} of chickpea at different days

Treatments	Number of Branches Plant^{-1}				
	40 DAS	60 DAS	80 DAS	100 DAS	Harvest
V_1N_0	7.66 c-e	10.67 d-g	12.55 d-g	14.81 fg	22.10 ij
V_1N_1	7.66 c-e	10.33 d-g	12.11 e-g	15.69 e-g	23.37 f-h
V_1N_2	7.00 e	12.33 b-e	16.33 a-c	15.69 e-g	23.50 f-h
V_1N_3	10.00 ab	15.33 a	18.11 a	22.74 a	26.30 ab
V_1N_4	7.66 c-e	13.67 a-c	11.00 fg	18.33 c-e	24.10 d-f
V_1N_5	7.66 c-e	13.33 a-d	14.55 b-e	17.77 c-f	23.23 gh
V_2N_0	8.00 b-e	11.00 c-f	13.45 c-f	16.80 d-f	22.77 hi
V_2N_1	8.66 b-e	10.33 e-g	13.11 d-g	16.34 d-f	23.97 d-g
V_2N_2	6.66 e	12.33 b-e	16.33 a-c	18.89 b-d	24.70 cd
V_2N_3	11.33 a	15.33 a	18.22 a	23.44 a	27.00 a
V_2N_4	9.33 a-d	14.33 ab	15.11 b-d	22.64 a	25.33 c
V_2N_5	8.33 b-e	10.67 d-g	13.00 d-g	16.28 d-f	24.37 de
V_3N_0	4.33 f	5.69 h	9.44 h	12.77 g	19.33 l
V_3N_1	7.00 e	8.33 fg	12.78 d-g	20.38 a-c	21.23 k
V_3N_2	7.33 de	11.00 c-f	16.33 a-c	20.42 a-c	22.23 ij
V_3N_3	9.66 a-c	14.33 ab	17.44 ab	21.81 ab	23.70 e-g
V_3N_4	8.00 b-e	11.67 b-e	15.1 b-d	20.41 a-c	22.20 ij
V_3N_5	7.00 e	12.67 a-e	17.22 ab	20.75 a-c	21.97 j
CV (%)	27.22	33.06	26.71	23.54	11.22
$S\bar{x}$	0.6503	0.8731	0.8666	0.9195	0.2342

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

N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

4.3. Total dry weight plant^{-1}

Effect of cultivar

Plant dry weight showed non-significant variation at 40 and 60 DAS for BARI Chola-5, BARI Chola-6 and BINA Chola-6 (Appendix III (a), III (b), III (c), III (d) and III (e) & Figure-5) though numerically higher values were shown by V_2 (BARI Chola-6) and V_3 (BINA Chola-6) on the other hand lower values were found from V_1 (BARI Chola-5). At 80, 100 DAS and harvest, BARI Chola-6 showed significantly the highest (4.35 g, 6.32 g and 6.95 g) plant dry weight, which was statistically similar with BINA Chola-6 (4.26 g, 6.25 g and 6.77 g). On the other hand BARI Chola-5 showed significantly the lowest (3.92 g, 5.47 g and 5.94 g) plant dry weight at 60, 80, 100 DAS and harvest. Plant dry weight of a cultivar depends on growing environment as well as on its genetic makeup. Das (2006) showed total dry matter is the sum of the dry matter accumulated in the various components of the plant namely leaf, petiole, stem and the reproductive parts of the plant. The pattern of dry matter production in the varieties BU Chola-1, BARI Chola-6 and BARI Chola-7 is almost similar. Jadhav *et al.* (1995) found that cowpea genotype V-240 was found to be superior in terms of plant dry weight over PS-16 cowpea genotype.

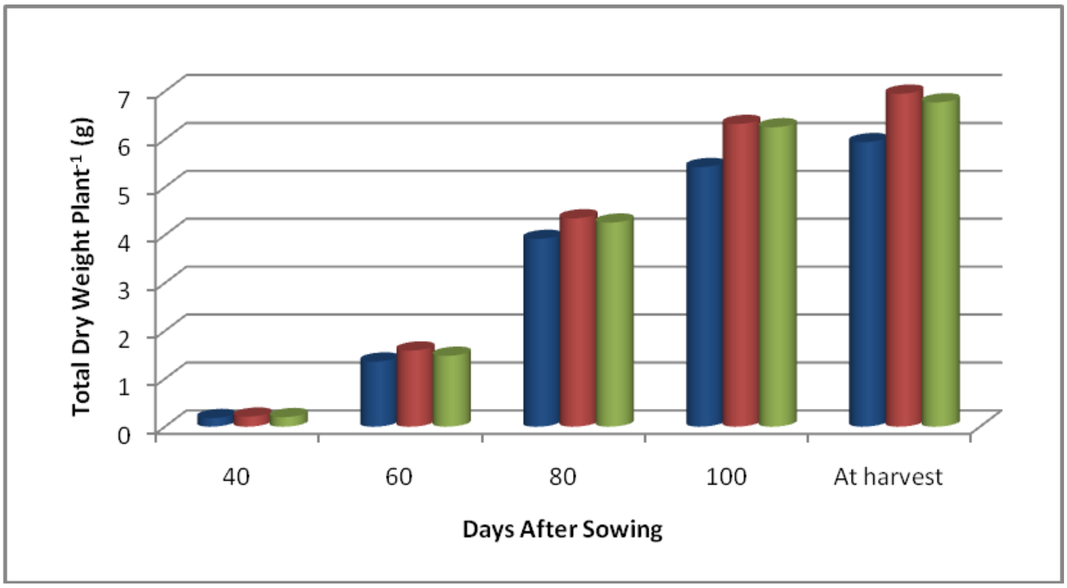
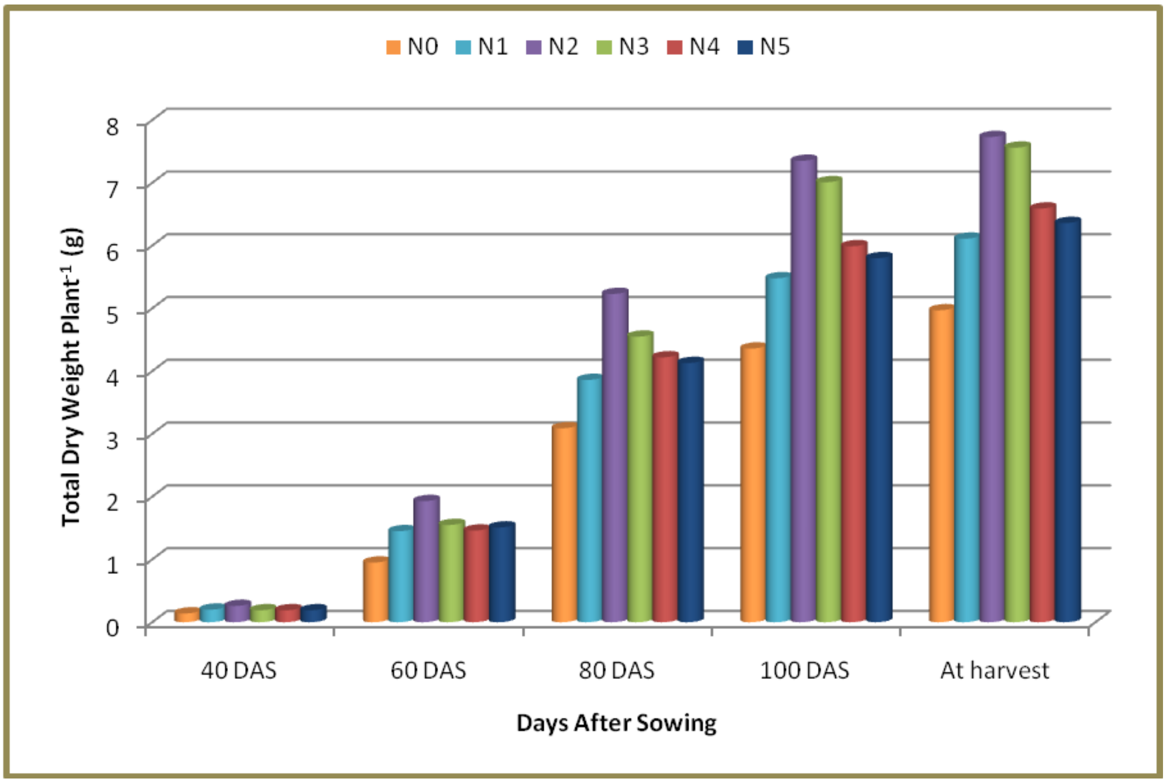


Figure 5: Effect of cultivar on total dry weight plant^{-1} of chickpea at different days ($S\bar{x}$ = 0.0135, 0.0402, 0.0492, 0.0461 and 0.0528 at 40, 60, 80, 100 DAS and harvest, respectively)

Effect of nitrogen application

Plant dry weight showed significant variation for different nitrogen application at 40, 60, 80, 100 DAS and harvest (Appendix III (a), III (b), III (c), III (d) and III (e) & Figure 6). The highest plant dry weight at 40, 60, 80 and 100 DAS was recorded from N_2 (Basal application of 40 kg N ha^{-1}) (0.26 g, 1.93 g, 5.23 g, and 7.35 g), where the lower plant dry weight at 40, 60, 80 and 100 DAS was recorded from N_0 (No fertilizer) (0.19 g, 1.51 g, 4.13 g and 5.8 g). At harvest, the maximum plant dry weight was recorded from N_2 (7.73 g) and it was statistically similar with N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (7.56 g). On the other hand, harvest the lowest plant dry weight was recorded from N_0 (No fertilizer) (4.97 g). Sharma *et al.* (1989) reported that combined application of N and phosphorus significantly increased the dry weight of plants. Kumar *et al.* (2005) reported that dry weight of chickpea plants responded favorably to nitrogen fertilizer application. Maliwal *et al.* (1998) reported that N fertilizer influenced proportionally on the dry matter of chickpea. Irrespective of N levels DM increased progressively till 90 DAE. The rate of dry matter production of chickpea was higher during 50 to 70 DAE.



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 6: Effect of different nitrogen application on total dry weight plant^{-1} of chickpea at different days ($S\bar{x}$ = 0.0228, 0.0677, 0.0829, 0.0776 and 0.0890 at 40, 60, 80, 100 DAS and harvest, respectively)

Combined effect of cultivar and nitrogen application

Except 40 DAS, combined effect on plant dry weight at different plant growth stages was not found significant (Table 3).

At 60 DAS, the highest plant dry weight (2.02 g) was noted from V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) and it was closely followed by V_1N_2 (BARI Chola-5 +

Basal application of 40 kg N ha^{-1}) (1.94 g), V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) (1.83 g), V_2N_1 (BARI Chola-6 + Basal application of 20 kg N ha^{-1}) (1.68 g), V_2N_5 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (1.68 g), V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (1.61 g), V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (1.57 g) and V_2N_4 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (1.52 g). On the other hand, the lowest plant dry weight (0.83 g) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer) which was as per with V_1N_0 (BARI Chola-5 + No fertilizer) (0.97 g), V_2N_0 (BARI Chola-6 + No fertilizer) (1.05 g) and V_3N_1 (BINA Chola-6 + Basal application of 20 kg N ha^{-1}) (1.22 g).

At 80 DAS, the highest plant dry weight (5.49 g) was noted from V_2N_2 and it was followed by V_1N_2 (5.37 g). On the other hand, the lowest plant dry weight (2.98 g) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer) at all five plant growth stages.

At 100 DAS, the highest plant dry weight (7.86 g) was noted from V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) which was followed by V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) (7.74 g), V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (7.50 g) and V_2N_3 (BARI Chola-6 + BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (7.42 g). On the other hand, the lowest plant dry weight (4.01 g) was recorded in V_2N_0 (BARI Chola-6 + No fertilizer) which was as per with V_1N_0 (BARI Chola-5 + No fertilizer) (4.52 g) and V_3N_0 (BINA Chola-6 + No fertilizer) (4.56 g).

At harvest, the highest plant dry weight (8.41 g) was noted from V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) and it was statistically similar with V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (8.17 g), V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) (7.93 g) and V_2N_3 (BARI Chola-6 + BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (7.87 g) . On the other hand, the lowest plant dry weight (4.48 g) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer).

Table 3: Combined effect of cultivar and nitrogen application on total dry weight plant^{-1} of chickpea at different days

Treatments	Total Dry Weight Plant^{-1} (g)				
	40 DAS	60 DAS	80 DAS	100 DAS	Harvest
V_1N_0	0.16	0.97 fg	3.10 g	4.52 ef	5.26 c
V_1N_1	0.20	1.44 b-f	3.99 ef	5.60 d	6.47 b
V_1N_2	0.29	1.94 ab	5.38 ab	7.50 a	8.17 a
V_1N_3	0.19	1.57 a-e	4.84 bc	6.45 b	6.91 b
V_1N_4	0.19	1.46 b-f	4.19 c-e	6.06 b-d	6.69 b
V_1N_5	0.20	1.49 b-f	4.10 de	5.68 cd	6.36 b
V_2N_0	0.17	1.05 e-g	3.20 g	4.01 f	5.17 c
V_2N_1	0.21	1.68 a-d	4.20 c-e	5.84 cd	6.38 b
V_2N_2	0.28	2.03 a	5.49 a	7.74 a	7.93 a
V_2N_3	0.20	1.61 a-d	4.67 cd	7.42 a	7.87 a
V_2N_4	0.21	1.52 a-e	4.41 c-e	5.96 b-d	6.80 b
V_2N_5	0.20	1.65 a-d	4.17 de	5.93 b-d	6.59 b
V_3N_0	0.12	0.83 g	2.98 g	4.56 ef	4.48 d
V_3N_1	0.19	1.22 b-g	3.41 fg	4.68 e	5.19 c
V_3N_2	0.22	1.83 a-c	4.83 bc	7.86 a	8.41 a
V_3N_3	0.18	1.47 b-f	4.15 de	6.22 b-d	6.85 b
V_3N_4	0.19	1.41 c-f	4.08 de	6.12 b-d	6.23 b
V_3N_5	0.20	1.41 c-f	4.12 de	5.85 cd	6.22 b
CV (%)	7.10	8.37	4.43	12.71	13.26
$S\bar{x}$	NS	0.1544	0.1889	0.1770	0.2029

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

N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

4.4. Nodules plant^{-1}

Effect of cultivar

Irrespective of treatment difference, nodules were initiated at 40 DAS, than maximum at 60 DAS and gradually reduced with time. Nodules plant^{-1} at 40, 60, 80 and 100 DAS varied significantly due to varietal difference (Appendix IV (a), IV (b), IV (c), IV (d) & Figure 7). At 40 and 60 DAS, BARI Chola-6 showed maximum (17.61 and 20.78, respectively) nodules plant^{-1}, which was statistically similar with BARI Chola-5 (17.39 and 20.56, respectively). At 80 and 100 DAS, BARI Chola-5 had highest (17.58 and 13.61) nodules plant^{-1} and was at par with BARI Chola-6 (15.94 and 13.47), respectively. BINA Chola-6 showed lowest (12.17, 15.72, 13.19and 10.81, respectively) nodules plant^{-1} at different stages. It is genetical performance of varieties that makes the difference. Das *et al.* (2009) observed nodules plant^{-1} across the varieties ranged form 5.13 to 9.88 where maximum with BARI Chola-6. Bhuiyan *et al.* (2009) reported BARI Chola-3 as higher producer of nodules (42.6). Eusuf Zai *et al.* (1999) counted significantly more nodules in variety BARI Chola-6.

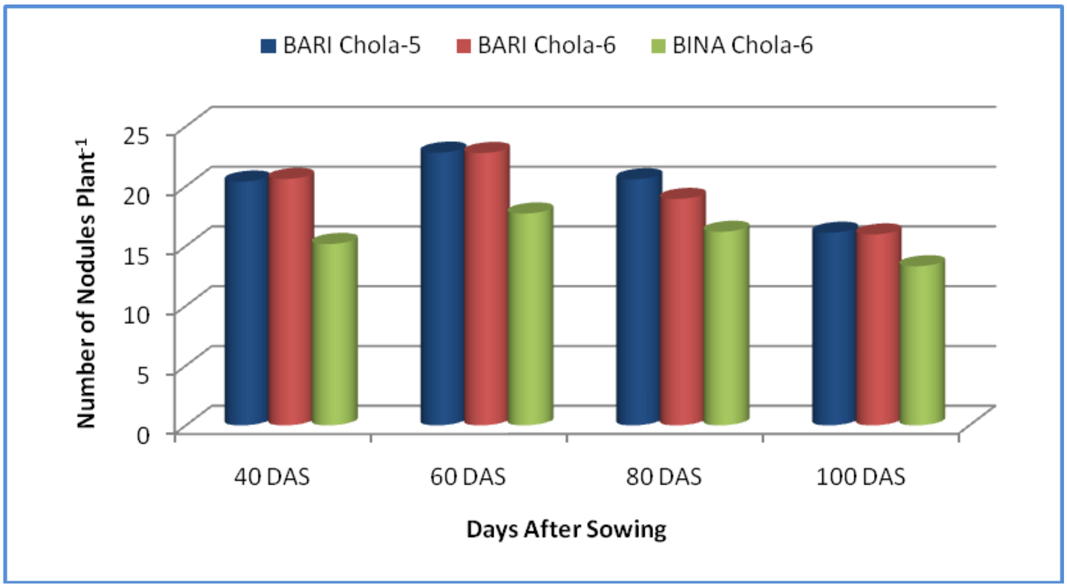
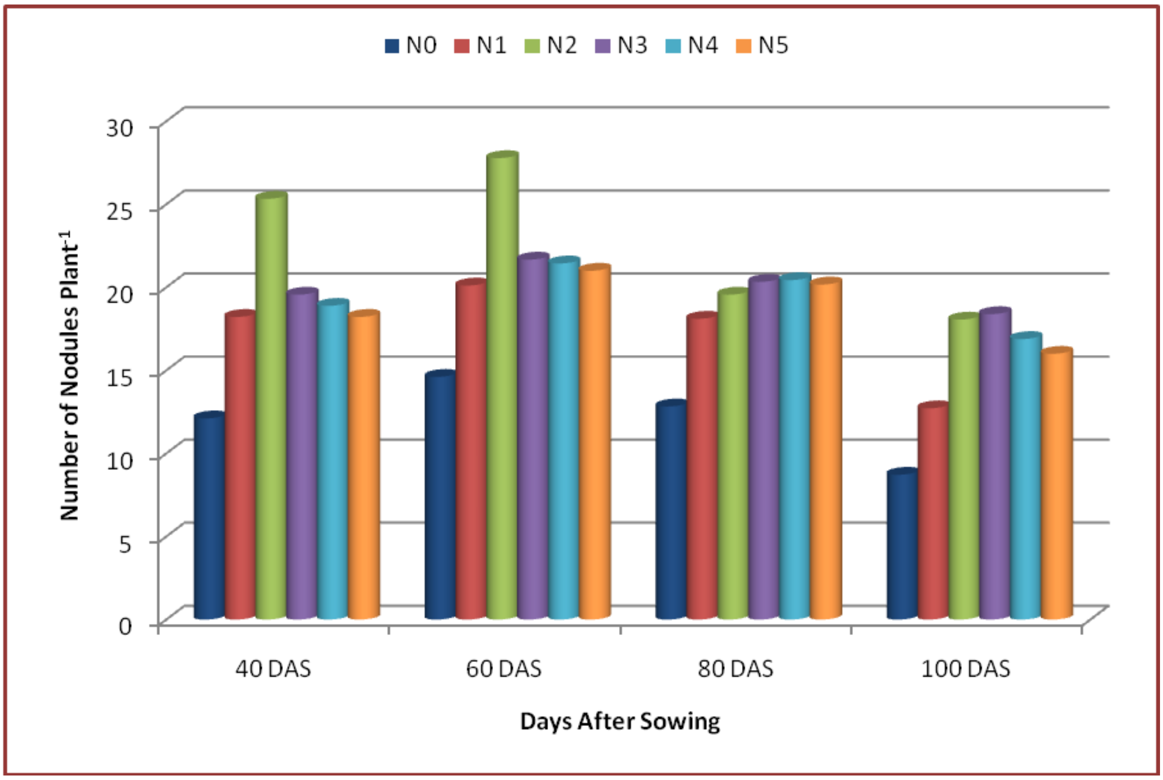


Figure 7: Effect of cultivar on number of nodules plant^{-1} of chickpea at different days ($S\bar{x}$ = 0.1799, 0.1859, 0.1089 and 0.1074 at 40, 60, 80 and 100 DAS, respectively)

Effect of nitrogen application

Number of nodule plant^{-1} showed significant variation for different nitrogen application at 40, 60, 80 and 100 DAS (Appendix IV (a), IV (b), IV (c), IV (d) & Figure 8). The highest nodules plant^{-1} at 40 and 60 DAS were recorded from N_2 (Basal application of 40 kg N ha^{-1}) (25.33 and 27.78) respectively. At 80 DAS, the maximum nodules plant^{-1} was recorded from N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (20.44) and was statistically similar with N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (20.33) and N_5 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (20.17). At 100 DAS, the maximum nodules plant^{-1} was recorded from N_3 (18.39) and followed by N_2 (18.06). Treatments N_0 (No fertilizer) had plants with lower number of nodules plant^{-1} at different days of study (12.11, 14.61, 12.83 and 8.72). Inthong (1987) observed that the application of 15 kg N ha^{-1} to mungbean increased nodule production and enhanced nitrogen fixation while further higher rates (30, 60 and 90 kg N ha^{-1}) suppressed it.



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 8: Effect of different nitrogen application on number of nodules plant^{-1} of chickpea at different days ($S\bar{x}$ = 0.3026, 0.3122, 0.1832 and 0.1807 at 40, 60, 80 and 100 DAS, respectively)

Combined effect of cultivar and nitrogen application

Combined effect of cultivar and nitrogen application on nodules plant^{-1} at different growth stages was found significant (Table 4).

At 40 DAS, the highest nodules plant^{-1} (25.03) was noted from V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) and it was statistically similar with V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (24.67). The lowest nodules plant^{-1} (6.67) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer).

At 60 DAS, the highest nodules plant^{-1} (27.67) was noted from V_1N_2. The lowest nodules plant^{-1} (9.667) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer).

At 80 DAS, the highest nodules plant^{-1} (20.83) was noted from V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) which was statistically similar with V_1N_4 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional of 20 kg N ha^{-1} at flower initiation) (20.17), V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional of 20 kg N ha^{-1} at branch initiation) (20.00) and V_2N_5 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional of 20 kg N ha^{-1} at pod initiation) (19.83). Nodules plant^{-1} (7.83) was recorded minimum in V_3N_0 (BINA Chola-6 + No fertilizer).

At 100 DAS, the identical highest nodules plant^{-1} (16.50) was noted from V_1N_4 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) and V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) and they were statistically similar with V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (16.17), V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (16.17), V_1N_2 (BARI Chola-5 + Basal application of 40 kg N ha^{-1}) (16.00), V_1N_5 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (15.67), V_2N_4 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional of 20 kg N ha^{-1} at flower initiation) (15.17) and V_2N_5 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional of 20 kg N ha^{-1} at pod initiation) (15.17). The lowest nodules plant^{-1} (5.167) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer).

Table 4: Combined effect of cultivar and nitrogen application on number of nodules plant^{-1} of chickpea at different days

Treatments	Number of Nodules Plant^{-1} (no.)			
	40 DAS	60 DAS	80 DAS	100 DAS
V_1N_0	10.33 d	13.33 ef	10.33 h	6.67 f
V_1N_1	16.00 c	19.00 c	16.33 e	10.67 cd
V_1N_2	24.67 a	27.67 a	20.83 a	16.00a
V_1N_3	18.67 b	21.33 bc	20.00 ab	16.17 a
V_1N_4	18.33 bc	21.67 b	20.17 a	16.50 a
V_1N_5	16.33 bc	20.33 bc	17.83 cd	15.67 a
V_2N_0	10.33 d	13.33 f	11.33 gh	6.83 f
V_2N_1	17.00 bc	20.00 bc	16.83 de	11.00 cd
V_2N_2	25.03 a	16.00 d	11.83 g	16.50 a
V_2N_3	18.67 b	21.33bc	17.17 de	16.17 a
V_2N_4	17.67 bc	21.00 bc	13.83 f	15.17 ab
V_2N_5	17.00 bc	20.67 bc	19.83 ab	15.17 ab
V_3N_0	6.67 e	9.67 g	7.83 i	5.17 g
V_3N_1	12.33 d	15.33 d-f	12.17 g	9.00 e
V_3N_2	17.33 bc	21.33 b	17.00 de	14.17 b
V_3N_3	12.33 d	16.33 d	14.83 f	9.67 de
V_3N_4	11.67 d	15.67 de	13.50 f	11.50c
V_3N_5	12.67 d	16.00 d	13.83 f	9.67 de
CV (%)	15.73	13.17	5.82	6.98
$S\bar{x}$	0.6898	0.7126	0.4177	0.4118

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

N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

4.5. Nodule dry weight plant^{-1}

Effect of cultivar

Nodule dry weights showed significant variation at 40, 60, 80 and 100 DAS for the three varieties (Appendix V (a), V (b), V (c), V (d) & Figure 9). At 40 DAS, BARI Chola-5 showed significantly highest (0.915 g) nodule dry weight, which was statistically similar with BINA Chola-6 (0.875 g) and BARI Chola-6 (0.849 g). At 60, 80 and 100 DAS V_1 (BARI Chola-5) showed significantly highest (0.653 g, 0.575 g and 0.298 g respectively) nodule dry weight followed by V_2 (BARI Chola-6) (0.598 g, 0.547 g and 0.294 g, respectively) and V_3 (BINA Chola-6) (0.501 g, 0.431 g and 0.211 g respectively). Similar results were observed by many other scientists while experimenting with various legumes. Das *et al.* (2009) showed variation in nodule dry weight plant^{-1} with different varieties. The dry weight of nodule plant^{-1} was 8.49 mg and 6.63 mg in BARI Chola-7 and 4.17 mg in the BU Chola-1 respectively. Solaiman *et al.* (2007) opinioned that BARI Chola-5 performed best in recording number and dry weight of nodules.

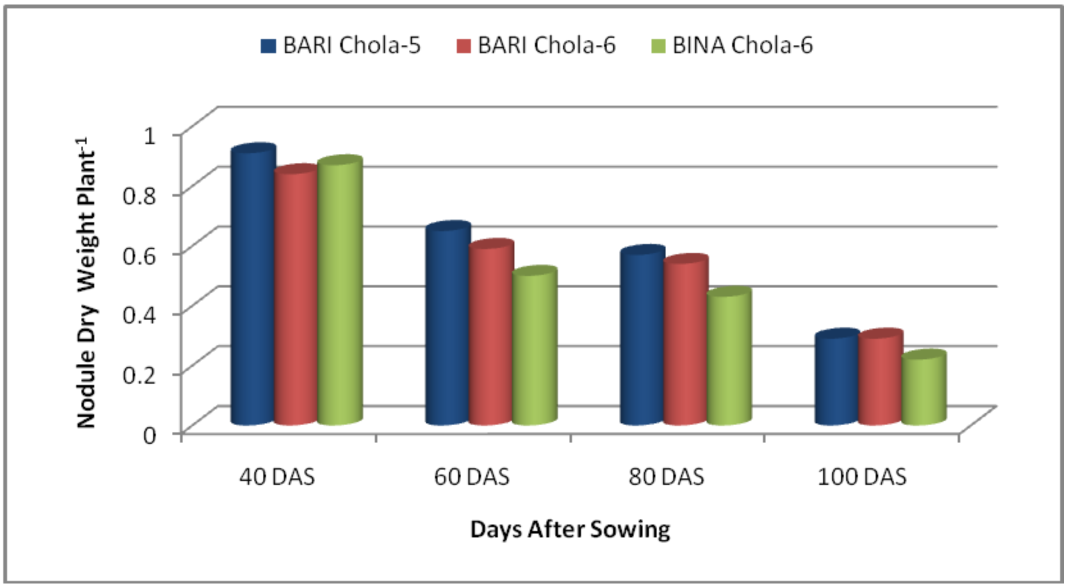
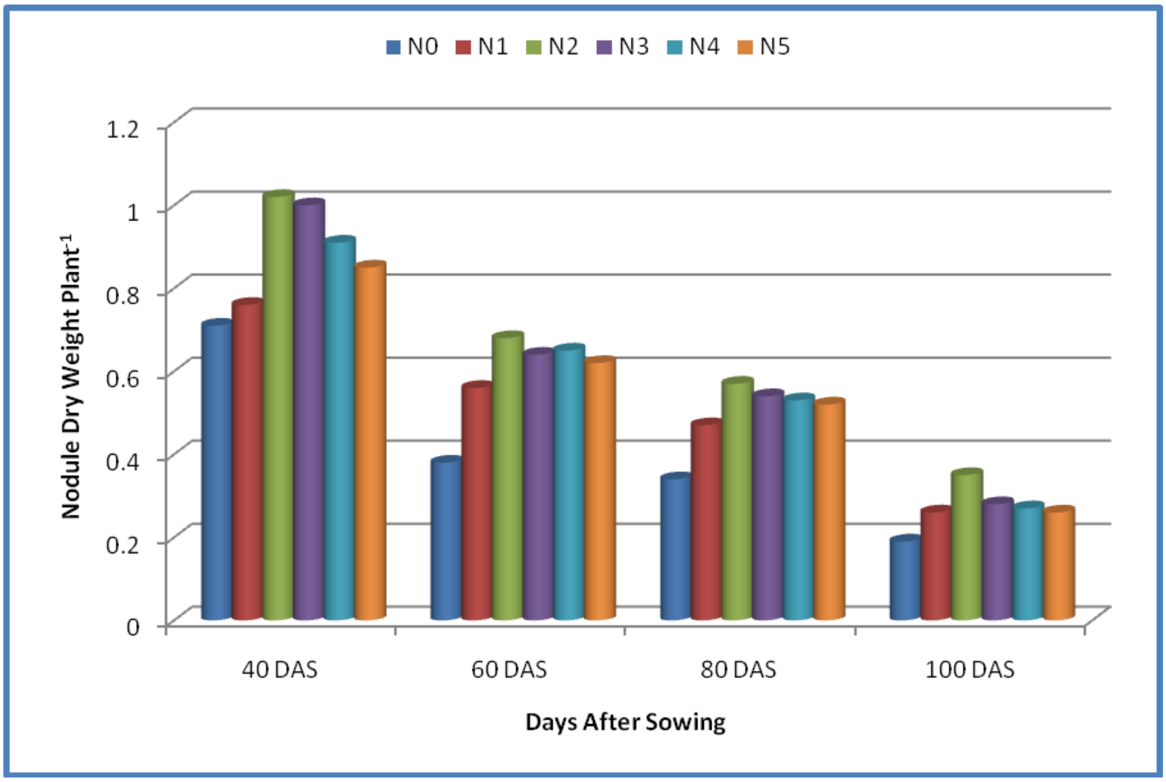


Figure 9: Effect of cultivar on nodule dry weight plant^{-1} of chickpea at different days ($S\bar{x}$ = 0.0548, 0.0214, 0.0330 and 0.0221 at 40, 60, 80 and 100 DAS, respectively)

Effect of nitrogen application

Nodule dry weight showed significant variation for different nitrogen application at 40, 60, 80 and 100 DAS (Appendix V (a), V (b), V (c), V (d) & Figure 10). At 40 DAS, the maximum nodule dry weight was recorded from N_2 (Basal application of 40 kg N ha^{-1}) (1.02 g) and it was statistically similar with N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (1.00 g), N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (0.91 g) and N_5 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (0.85 g) and the lowest nodule dry weight were recorded from N_0 (No fertilizer) (0.71 g). At 60 DAS, the maximum nodule dry weight was recorded from N_2 (Basal application of 40 kg N ha^{-1}) (0.68 g) and it was similar with N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (0.65 g), N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (0.64 g) and N_5 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (0.62 g) and the lowest nodule dry weight were recorded from N_0 (No fertilizer) (0.38 g). The highest nodule dry weight at 80 and 100 DAS was recorded from N_2 (Basal application of 40 kg N ha^{-1}) (0.65 g and 0.35 g, respectively). The lowest nodule dry weight were recorded from N_0 (No fertilizer) (0.33 g and 0.14 g) respectively at those days of study. Islam (2002) reported that N fertilizer positively influenced on the nodule weight of lentil. Chowdhury and Rosario (1992) noted that applied N at the levels above 40 kg ha^{-1} reduced the nodule dry weight. Bachchhav *et al.* (1994) observed that root nodule weight per plant was highest with 30 kg N $ha^{-1}$for mungbean (*Vigna radiata*) cv. Phule-M.



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 10: Effect of different nitrogen application on nodule dry weight plant^{-1} of chickpea at different days ($S\bar{x}$ = 0.0922, 0.0360, 0.0556 and 0.0372 at 40, 60, 80 and 100 DAS, respectively)

Combined effect of cultivar and nitrogen application

Combined effect on nodule dry weights at 40, 60 and 80 DAS was found significant except 100 DAS (Table 5). At 40 DAS, the highest nodule dry weight (1.04 g) was noted from V_1N_4 and it was statistically similar with V_2N_2 (1.04), V_1N_3 (1.02), V_2N_3 (1.02), V_1N_2 (1.01), V_1N_5 (0.99), V_3N_3 (0.97), V_2N_4 (0.96), V_2N_5 (0.96), V_3N_2 (0.89), V_3N_4 (0.77) and V_2N_1 (0.69). On the other hand, the lowest nodule dry weight (0.33 g) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer) and was followed by V_1N_0 (0.40), V_2N_0 (0.43), V_3N_1 (0.57), V_3N_5 (0.60) and V_1N_1 (0.67).

At 60 DAS, the highest nodule dry weight (0.77 g) was noted from V_1N_2 and it was statistically similar with V_1N_4 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (0.74 g), V_2N_5 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (0.74 g), V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (0.73 g), V_2N_4 (0.69 g), V_1N_5 (0.66 g), V_2N_3 (0.64 g), V_3N_2 (0.63 g), V_2N_1 (0.63 g), V_1N_1 (0.60 g), V_3N_3 (0.55 g), V_3N_4 (0.51 g) and V_3N_5 (0.50 g). On the other hand, the lowest nodule dry weight (0.30 g) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer) and it was statistically similar with V_1N_0 (0.38 g), V_2N_0 (0.42 g), V_2N_2 (0.44 g), V_3N_1 (0.45 g), V_3N_5 (0.50 g), V_3N_4 (0.51 g) and V_3N_3 (0.55 g).

At 80 DAS, higher nodule dry weight (0.76 g) was recorded in V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) and it was followed by other treatments except V_3N_0 (BINA Chola-6 + No fertilizer) which was significantly lower (0.26 g) and followed by other treatments except V_2N_2.

Table 5: Combined effect of cultivar and nitrogen application on nodule dry weight plant^{-1} of chickpea at different days

Treatments	Nodule Dry Weight Plant^{-1} (g)			
	40 DAS	60 DAS	80 DAS	100 DAS
V_1N_0	0.40 ef	0.38 cd	0.36 ab	0.17
V_1N_1	0.67 b-f	0.60 a-c	0.51 ab	0.24
V_1N_2	1.01 ab	0.77 a	0.65 ab	0.37
V_1N_3	1.02 ab	0.73 a	0.58 ab	0.28
V_1N_4	1.04 a	0.74 a	0.59 ab	0.28
V_1N_5	0.99 ab	0.66 ab	0.55 ab	0.25
V_2N_0	0.43 ef	0.42 b-d	0.36 ab	0.16
V_2N_1	0.69 a-e	0.63 a-c	0.46 ab	0.26
V_2N_2	1.04 a	0.44 b-d	0.76 a	0.38
V_2N_3	1.02 ab	0.64 a-c	0.58 ab	0.28
V_2N_4	0.96 a-c	0.69 ab	0.57 ab	0.27
V_2N_5	0.96 a-c	0.74 a	0.56 ab	0.26
V_3N_0	0.33 f	0.30 d	0.26 b	0.10
V_3N_1	0.57 d-f	0.45 b-d	0.42 ab	0.19
V_3N_2	0.89 a-d	0.63 a-c	0.58 ab	0.26
V_3N_3	0.97 ab	0.55 a-d	0.43 ab	0.19
V_3N_4	0.77 a-d	0.51 a-d	0.42 ab	0.18
V_3N_5	0.60 c-f	0.50 a-d	0.44 ab	0.19
CV (%)	6.77	5.42	14.55	15.50
$S\bar{x}$	0.2102	0.0820	0.01270	NS

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

N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

4.6. Pods plant^{-1}

Effect of cultivar

BARI Chola-5, BARI Chola-6 and BINA Chola-6 showed significant variation among them for pods plant^{-1} (Appendix VI & Figure 11). The significant highest (28.63) pods plant^{-1} was found in BARI Chola-6 and it was followed by BARI Chola-5 (26.44). On the other hand BINA Chola-6 showed significantly the lowest (24.79) pod number plant^{-1} among the three varieties. Pod number plant^{-1} of a cultivar depends on nutrient availability during reproductive stage as well as on genetical factor. Kabir *et al.* (2009) observed the highest number of (26.37) pods plant^{-1} in BARI Chola-4 followed by BARI Chola-2. The lowest number of (21.27) pods were found in BARI Chola-6. Hasanuzzaman *et al.* (2007) showed that BARI chola-4 produced maximum number of pods per plant (33.35) and BARI chola-1 produced lower pod. It reveals that all the varieties have similar capabilities of pod production. The maximum production of pod was 44% greater than the lower pod production. Ali *et al.* (2010) showed that among the performance of six brown chickpea (*Cicer arietinum* L.) genotypes viz. 90261, 93127, 97086, 98004, 98154, genotype 98004 expressed comparatively more pods per plant (77.58).

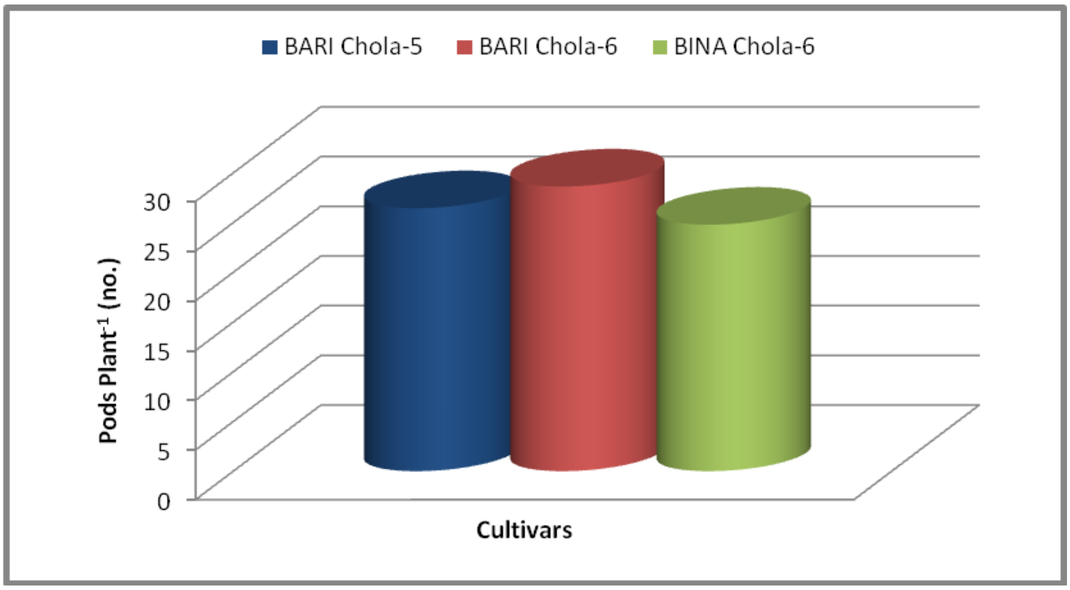
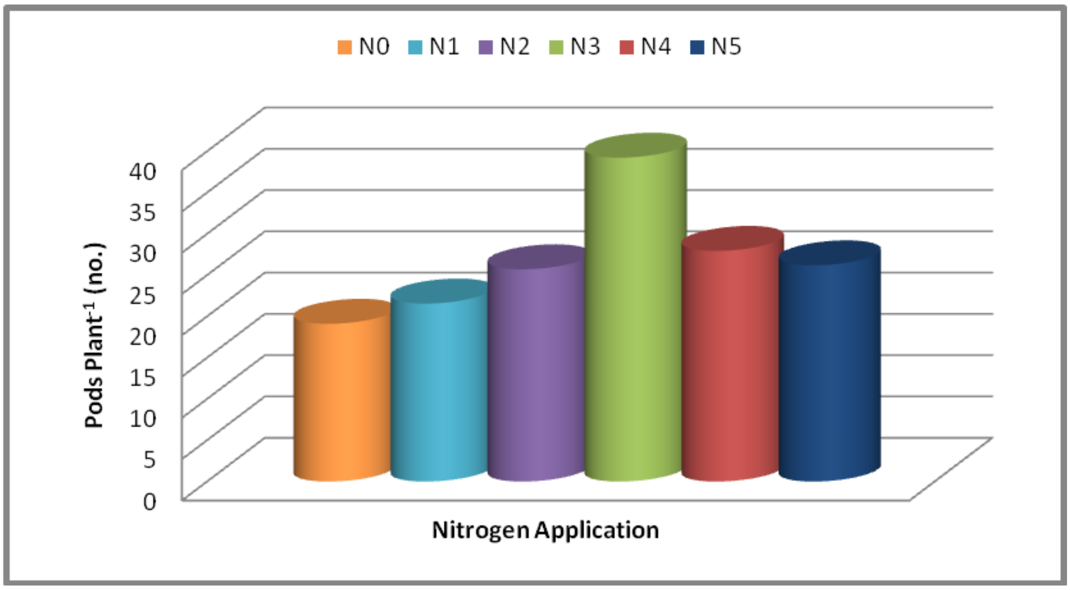


Figure 11: Effect of cultivar on number of pods plant^{-1}of chickpea (S$\bar{x}$ = 0.2330)

Effect of nitrogen application

Number of pods plant^{-1} showed significant variation for different nitrogen application (Appendix VI & Figure 12). The highest pods plant^{-1} was recorded from N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (39.23). On the other hand, for different nitrogen application techniques, the lowest pods plant^{-1} was recorded from N_0 (No fertilizer) (19.11). Patra *et al.* (1998) noticed that number of pods plant^{-1} of chickpea increased over control with 20 kg N along with 40 kg P ha^{-1}. Rathore and Patel (1991) observed that maximum number of pods plant^{-1} when chickpea was provided with 18 kg N along with 46 kg P ha^{-1}. Chaudhari *et al.* (1998) found a positive effect of nitrogen at the rate of 20 and 40 kg ha^{-1} on increase in chickpea pods per plant and protein content in seed over control. Karadavut and Ozdemir (2001) found that *Rhizobium* inoculation and 30 kg N ha^{-1} significantly increased pods plant^{-1}. Vadavia *et al.* (1991) found that number of pods plant^{-1} of chickpea increased following application of 20 kg N ha^{-1} and 40 kg P ha^{-1}.



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 12: Effect of different nitrogen application on number of pods plant^{-1}of chickpea ($S\bar{x}$ = 0.3918)

Combined effect of cultivar and nitrogen application

Combined effect of cultivar and nitrogen application on pods plant^{-1} was found significant (Table 6). The highest pods plant^{-1} (44.90) was noted from V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) which was followed by V_1N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (41.40) . On the other hand, the lowest pods plant^{-1}(14.80) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer) which was statistically similar with V_3N_1 (BINA Chola-6 + Basal application of 20 kg N ha^{-1}) (16.00).

4.7. Seeds pod^{-1}

Effect of cultivar

BARI Chola-5, BARI Chola-6 and BINA Chola-6 showed significant variation for seeds pod^{-1}(Appendix VII & Figure 13). Significantly the highest (2.04) seeds pod^{-1} was found in BARI Chola-6, which was statistically similar with BARI Chola-5 (2.02). On the other hand BINA Chola-6 showed significantly the lowest (1.89) seeds pod^{-1} among the three varieties. Number of seeds pod^{-1} is also a character which largely depends on varietal properties. Kabir *et al.* (2009) said the highest number (1.37) of seeds within individual pod was found in BARI Chola-4 and it was closely followed by BARI Chola-2 (1.32). The lowest number (1.26) of seeds per pod was found in BARI Chola-6. Das (2006) showed the averaged number of seed pod^{-1} across the varieties ranged from 1.20-1.42 pod^{-1}. The BARI Chola-7 produced the highest and BU Chola-1 produced the lowest number of seed pod^{-1} respectively. The study indicated that genotypes with more pod development period having higher seed growth would be desirable character for maintaining higher yield.

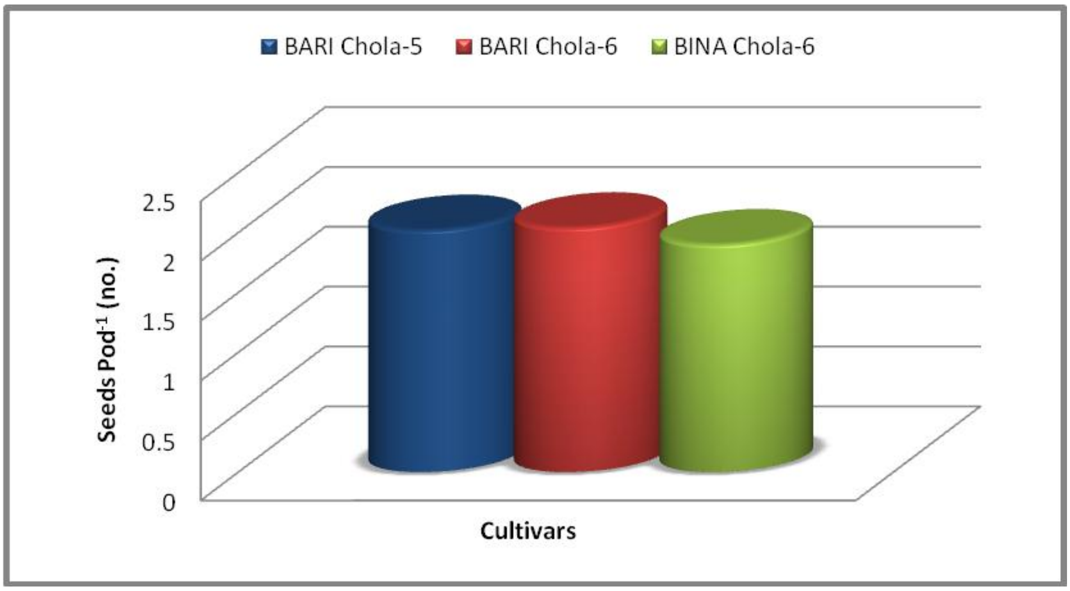
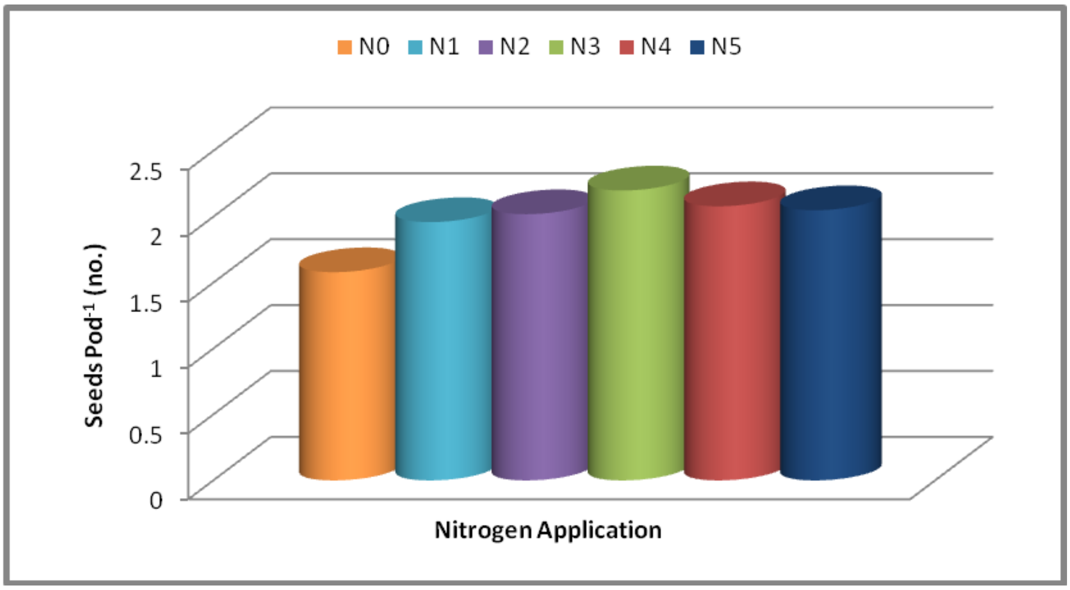


Figure 13: Effect of cultivar on number of seeds pod^{-1} of chickpea ($S\bar{x}$ = 0.0579)

Effect of nitrogen application

Number of seed pod^{-1} showed significant variation for different nitrogen application (Appendix VII & Figure 14). The highest seeds pod^{-1} was recorded from N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (2.20) and it was statistically similar with N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (2.08), N_5 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (2.05), N_2 (Basal application of 40 kg N ha^{-1}) (2.02) and N_1 (Basal application of 20 kg N ha^{-1}) (1.96). On the other hand, for different nitrogen application techniques, the lowest seed number pod^{-1} was recorded from N_0 (No fertilizer) (1.58). Patra *et al.* (1998) noticed in chickpea increased number of seeds pod^{-1} over control with 20 kg N along with 40 kg P ha^{-1}. Rathore and Patel (1991) reported that application of 18 kg N along with 46 kg P ha^{-1} resulted in significant increase in the chickpea seeds pod^{-1}. Malik *et al.* (2003) investigated the effect of varying levels of nitrogen (0, 25 and 50 kg ha^{-1}) and P (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98 and found that number of seeds pod^{-1} was significantly affected by varying levels of nitrogen and phosphorus.



N_0= Control (No fertilizer)	N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage
N_1= Basal application of 20 kg N ha^{-1}	N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage
N_2= Basal application of 40 kg N ha^{-1}	N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 14: Effect of different nitrogen application on number of seeds pod^{-1} of chickpea ($S\bar{x}$ = 0.0974)

Combined effect of cultivar and nitrogen application

Combined effect of cultivar and nitrogen application on seeds pod^{-1} was found significant (Table 6). The highest seeds pod^{-1} (2.68) was noted from V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) and it was followed by V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (2.21), V_2N_4 (2.18), V_1N_4 (2.16), V_2N_5 (2.10), V_1N_5 (2.09), V_3N_3 (2.08), V_2N_2 (2.08), V_3N_2 (2.02). On the other hand, the lowest seed number pod^{-1} (1.13) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer) which was statically similar with V_2N_0 (BARI Chola-6 + No fertilizer) (1.56) and V_1N_0 (BARI Chola-5 + No fertilizer) (1.69). Hamid and Sarwar (1976) found that nitrogen applied in two splits was more effective for seed yield of chickpea. Bhalerao and Sahasrabuddhe, (1977) observed that application of 15 kg N ha^{-1} through soil and remaining 15 kg ha^{-1} N through two foliar sprays given at maximum tillering and flag leaf stages and further to be more economical than applying all the nitrogen through soil at seeding time.

4.8. 1000-seed weight

Effect of cultivar

1000-seed weight varied significantly among the three varieties (Appendix VIII & Figure 15). Significantly the highest (117.6 g) 1000-seed weight was found in BARI Chola-6, which was statistically similar with BARI Chola-5 (117.2 g). On the other hand BINA Chola-6 showed significantly the lowest (115.9 g) 1000-seed weight among the three varieties. BINA (2012) showed in Magura, highest 1000 seed weight produced form BINA Chola-6 (148.05 g). Karasu *et al.* (2009) showed that the effects of cultivars were statistically significant at 1% probability level on the 1000 seed weight. While maximum 1000 seed weight was obtained from Canıtez- 87 cultivar (498.2 g) and popular local genotype Yerli (497.9 g), ILC-114 line had fewer 1000 seed weight (446.8 g). Kabir *et al.* (2009) observed BARI Chola-6 produced that the heaviest seeds (20.87 g/100 seed), which was significantly different over those in BARI Chola-2 and BARI Chola-4.

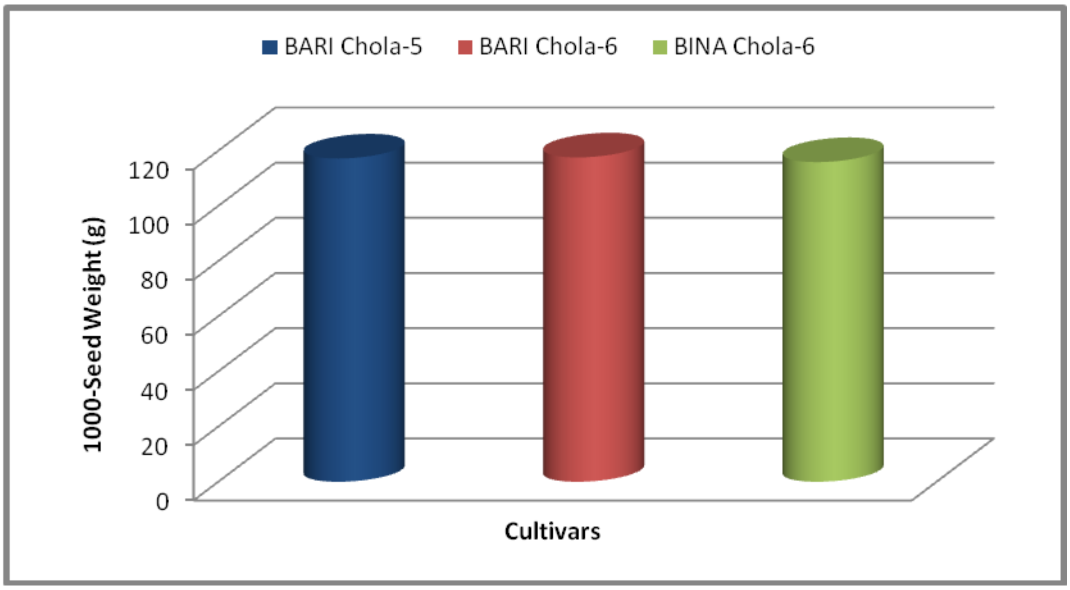
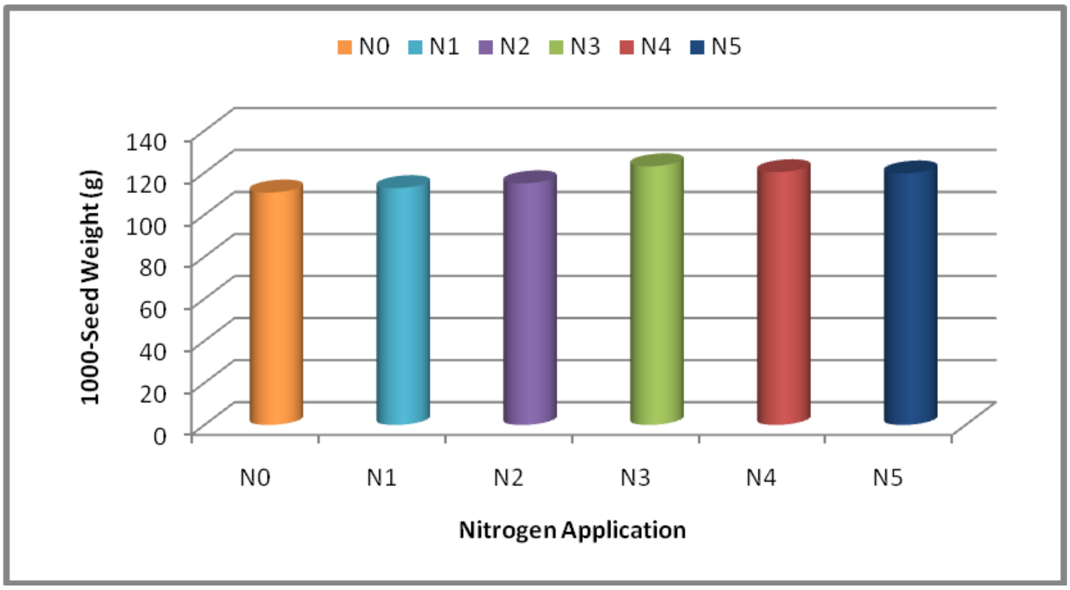


Figure 15: Effect of cultivar on 1000-seed weight of chickpea ($S\bar{x}$ = 0.0.1345)

Effect of nitrogen application

1000-seed weight showed significant variation for different nitrogen application (Appendix VIII & Figure 16). The highest 1000-seed weight was recorded from N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (123.1 g) and it was statistically similar with N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (120.3). On the other hand, for different nitrogen application techniques, the lowest 1000-seed weight was recorded from N_0 (No fertilizer) (110.6 g). Patra *et al.* (1998) reported that when 20 kg N along with 40 kg P ha^{-1} were applied, it increased 1000-seed weight of chickpea over control. Rathore and Patel (1991) reported that application of 18 kg N ha^{-1} along with 40 kg P ha^{-1} increased 1000-seed weight. Vadavia *et al.* (1991) found that seed weight increase following application of 20 kg N ha^{-1} and 40 kg P ha^{-1} of chickpea. Javiya *et al.* (1989) found that plant height of chickpea was significantly increased by the application of N fertilizer at 50 kg ha^{-1}. They also noted that 100 seed weight of lentil increased significantly by the application of N at 40 kg ha^{-1}.



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 16: Effect of different nitrogen application on1000-seed weight of chickpea ($S\bar{x}$ = 0.2262)

Combined effect of cultivar and nitrogen application

Combined effect of cultivar and nitrogen application on 1000-seed weight at different plant growth stages was found significant (Table 6). The highest 1000-seed weight (124.8 g) was noted from V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) and it was followed by V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (124.3 g). On the other hand, the lowest 1000-seed weight (110.2 g) was recorded in V_2N_0 (BARI Chola-6 + No fertilizer) followed by V_3N_0 (BINA Chola-6 + No fertilizer) (110.4 g), V_1N_0 (BARI Chola-5 + No fertilizer) (111.2 g) and V_3N_1 (BINA Chola-6 + Basal application of 20 kg N ha^{-1}) (111.7 g).

4.9. Seed yield

Effect of cultivar

Seed yield varied significantly among the three varieties (Appendix IX & Figure 17). The highest (1.73 ton ha^{-1}) seed yield was found in BARI Chola-6, which was statistically similar with BARI Chola-5 (1.54 ton ha^{-1}). On the other hand BINA Chola-6 showed significantly the lowest (1.34 ton ha^{-1}) seed yield among the three varieties. Kabir *et al.* (2009) observed seed yield per hectare BARI Chola-4 produced the highest seed yield (855.50 kg/ha). The second highest yield (764.5 kg/ha) was recorded in BARI Chola-6. Rashid *et al.* (1999) reported seed yield of chickpea as 1300-1600 kg/ha, 1900-2000 kg/ha and 1800-2000 kg/ha form BARI Chola-2, BARI Chola-4 and BARI Chola-6, respectively. Hasanuzzaman *et al.* (2007) showed among the varieties, BARI chola-5 gave the maximum seed yield (1.81 t ha) which was 36.09% more over BARI chola-1 which produced the lowest seed yield (1.33 t ha). Das (2006) showed the averaged yield ha^{-1} among the varieties was 608.18 kg in BU Chola-1, 641.87 kg in BARI Chola-6 and 661.16 kg in BARI Chola-7 respectively.

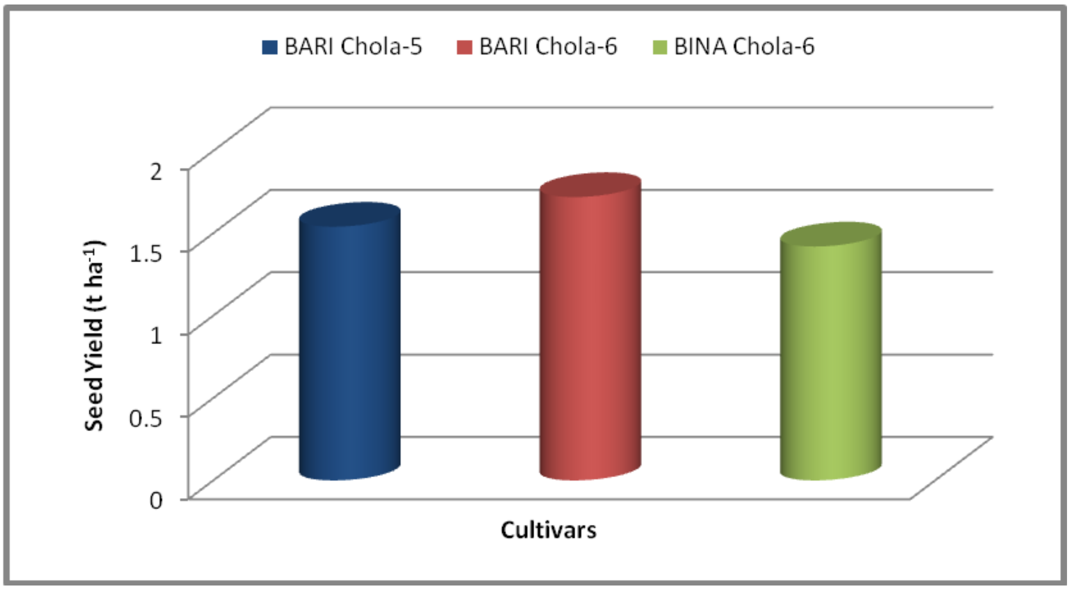
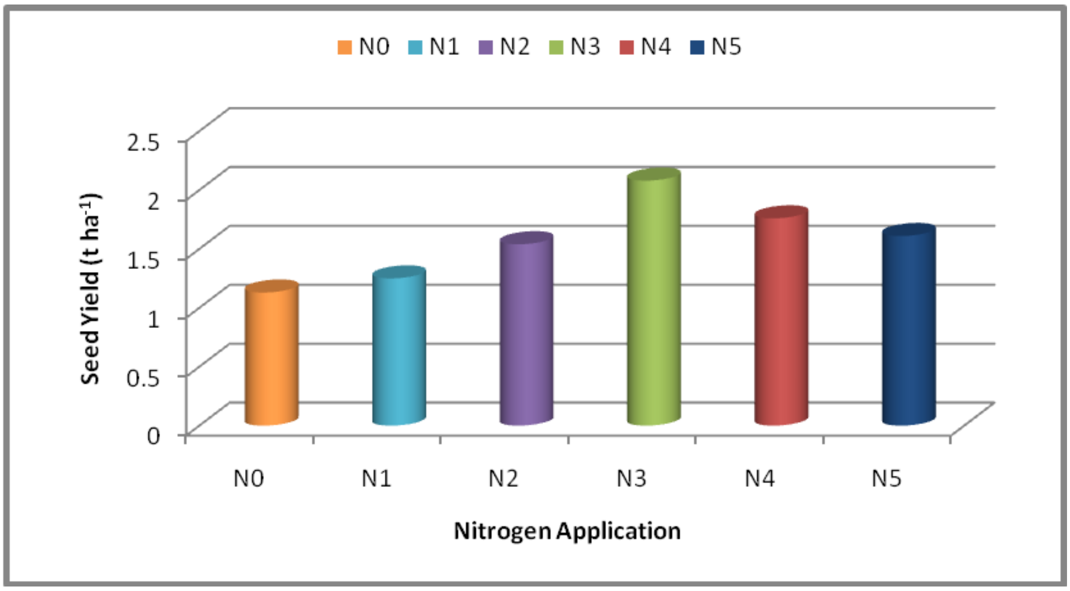


Figure 17: Effect of cultivar on seed yield of chickpea ($S\bar{x}$ = 0.06687)

Effect of nitrogen application

Seed yield showed significant variation for different nitrogen application (Appendix IX & Figure 18). The highest seed yield was recorded from N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (2.08 ton ha^{-1}) and it was followed by N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (1.76 ton ha^{-1}). On the other hand, for different nitrogen application techniques, the lowest seed yield was recorded from N_0 (No fertilizer) (1.13 ton ha^{-1}) which statistically similar with N_1 (Basal application of 20 kg N ha^{-1}) (1.25 ton ha^{-1}) and N_2 (Basal application of 40 kg N ha^{-1}) (1.54 ton ha^{-1}). Vadavia *et al.* (1991) found significant higher seed yield of chickpea following application of 20 kg ha^{-1} N and 40 kg P ha^{-1}. Application of 20 kg N ha^{-1} increased seed yield of chickpea reported by Subba Rao *et al.* (1986). Shamim and Naimat (1987) reported that application of 10 kg N + 75 kg P_2O_5 ha^{-1} to *Cicer arietinum* cv. C-727 increases seed yields cover uninoculated seed from 583 to 878 kg ha^{-1}. Tomar and Sharma (1985) obtained highest seed yield in chickpea of two consecutive years with the application of N, P and K at the rate of 20, 40 and 20 kg ha^{-1} respectively over control. Similar result was obtained by Rawal and Yadava (1986) using those fertilizers at the same rate.



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 18: Effect of different nitrogen application on seed yield of chickpea ($S\bar{x}$ = 0.1125)

Combined effect of cultivar and nitrogen application

Combined effect of cultivar and nitrogen application on seed yield at different plant growth stages was found significant (Table6). The highest seed yield (2.43 ton ha^{-1}) was noted from V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) and it was followed by V_1N_3 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (2.09 ton ha^{-1}), V_2N_4 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (2.01 ton ha^{-1}), V_2N_5 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (1.85 ton ha^{-1}), V_2N_2 (BARI Chola-6 + Basal application of 40 kg N ha^{-1}) (1.78 ton ha^{-1}), V_3N_3 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (1.66 ton ha^{-1}), V_3N_4 (BINA Chola-6 + Basal application of 20 kg

N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (1.64 ton ha^{-1}) and V_1N_4 (BARI Chola-5 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (1.62 ton ha^{-1}). On the other hand, the lowest seed yield (0.53) was recorded in V_3N_0 (BINA Chola-6 + No fertilizer) it was as per with V_1N_0 (BARI Chola-5 + No fertilizer) (1.04 t ha^{-1}), V_2N_0 (BARI Chola-6 + No fertilizer) (1.09 t ha^{-1}), V_3N_1 (BINA Chola-6 + Basal application of 20 kg N ha^{-1}) (1.15 ton ha^{-1}) and V_1N_1 (BARI Chola-5 + Basal application of 20 kg N ha^{-1}) (1.15 ton ha^{-1}). Singh (1987), reported that because the response of *cicer* to fertilizer was less, producing the cultivar which had positive response to fertilizer will be useful, in order to increase yield.

4.10. Stover yield

Effect of cultivar

Stover yield varied significantly among the three varieties (Appendix X & Figure 19). Significantly the highest (2.16 ton ha^{-1}) stover yield was found in BARI Chola-6. On the other hand BARI Chola-5 showed significantly the lowest (1.96 ton ha^{-1}) followed by BINA Chola-6 (1.98 ton ha^{-1}). Ali *et al.* (2010) showed in their study chickpea genotype 97086 produced higher biological (7658 kg/ha). Purushotham *et al.* (2001) reported that among different cultivars UPC-921, UPC-952, UPC-953, IFC-9502, IFC-9503, UPC-5286 and Bund lobia (control), the highest mean dry matter was registered by IFC-9503 (18.1 q/ha).

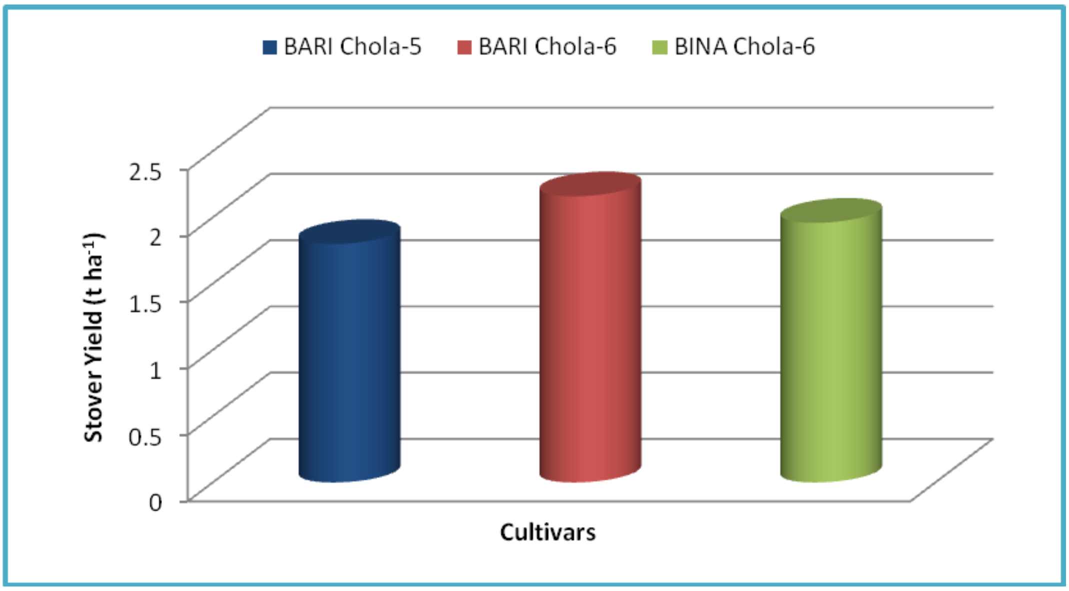
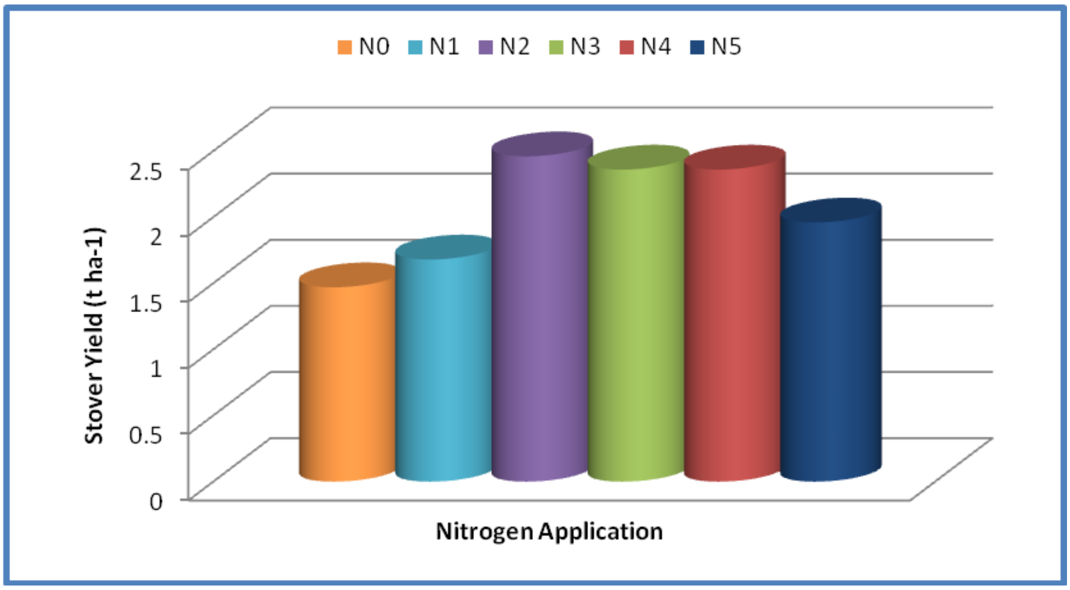


Figure 19: Effect of cultivar on stover yield of chickpea ($S\bar{x} = 0.0712$)

Effect of nitrogen application

Stover yield showed significant variation for different nitrogen application (Appendix X & Figure 20). The highest stover yield was recorded from N_2 (Basal application of 40 kg N ha^{-1}) (2.46 ton ha^{-1}) and it was followed by N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1}at branch initiation) (2.36 ton ha^{-1}) which was statistically similar with N_4 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation) (2.27 ton ha^{-1}). On the other hand, for different nitrogen application techniques, the lowest stover yield was recorded from N_0 (No fertilizer) (1.47 ton ha^{-1}). Subba-Rao *et al.* (1986) also reported that the rate of 20 kg N ha^{-1} was most effective in increasing straw yield of chickpea. Karadavut and Ozdemir (2001) stated the application of *Rhizobium sp.* and 30 kg N ha^{-1} on 3 chickpea cultivars in the winter season of 1995-96 and 1996-97 significantly increased straw yield.



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 20: Effect of different nitrogen application on stover yield of chickpea ($S\bar{x}$ = 0.1199)

Combined effect of cultivar and nitrogen application

Combined effect of cultivar and nitrogen application on stover yield at different plant growth stages was found significant (Table6). The highest stover yield (2.54 ton ha^{-1}) was noted from V_3N_2 (BINA Chola-6 + Basal application of 40 kg N ha^{-1}) and it was statistically similar with V_3N_3 (BINA Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (2.53 ton ha^{-1}), V_2N_3 (2.50 t ha^{-1}), V_1N_2 (2.46 t ha^{-1}), V_2N_2 (2.39 t ha^{-1}), V_2N_4 (2.35 t ha^{-1}), V_1N_4 (2.25 t ha^{-1}), V_1N_3 (2.23 t ha^{-1}), V_2N_5 (2.21 t ha^{-1}), V_3N_4 (2.02 t ha^{-1}), V_1N_5 (1.89 t ha^{-1}) and V_3N_5 (1.79 t ha^{-1}). On the other hand, the lowest stover yield (1.29 ton ha^{-1}) was recorded in V_1N_0 (BARI Chola-5 + No fertilizer) which was statistically similar with V_2N_0 (BARI Chola-6 + No fertilizer) (1.54 t ha^{-1}), V_3N_0 (BINA Chola-6 + No fertilizer) (1.58 t ha^{-1}), V_3N_5 (1.79 t ha^{-1}), V_1N_5 (1.89 t ha^{-1}), V_3N_4 (2.02 t ha^{-1}), V_2N_5 (2.21 t ha^{-1}) and V_1N_3 (2.23 t ha^{-1}). Halikatti (1980) reported that application of nitrogen levels (80 and 120 kg ha^{-1}) in two splits, half at planting and remaining half at 25 days after sowing recorded higher leaf area index, plant height, dry matter production per metre row length and higher seed yield, than application of nitrogen all at planting or in three (one-third each at planting, 25 and 55 days after sowing) or in four (one fourth each at planting, 25, 55 and 70 days after sowing) splits.

4.11. Harvest index

Effect of cultivar

Harvest index varied significantly among the three varieties (Appendix XI & Figure 21). Significantly the highest (43.97%) harvest index was found in BARI Chola-6, which was followed by BINA Chola-6 (43.80%). On the other hand BARI Chola-5 showed significantly the lowest (42.29%) harvest index among the three varieties. Das *et al.* (2009) showed the highest harvest index (37.68 %) was found in the variety BARI Chola-7 and the lowest (36.28%) in the variety BARI Chola-6.

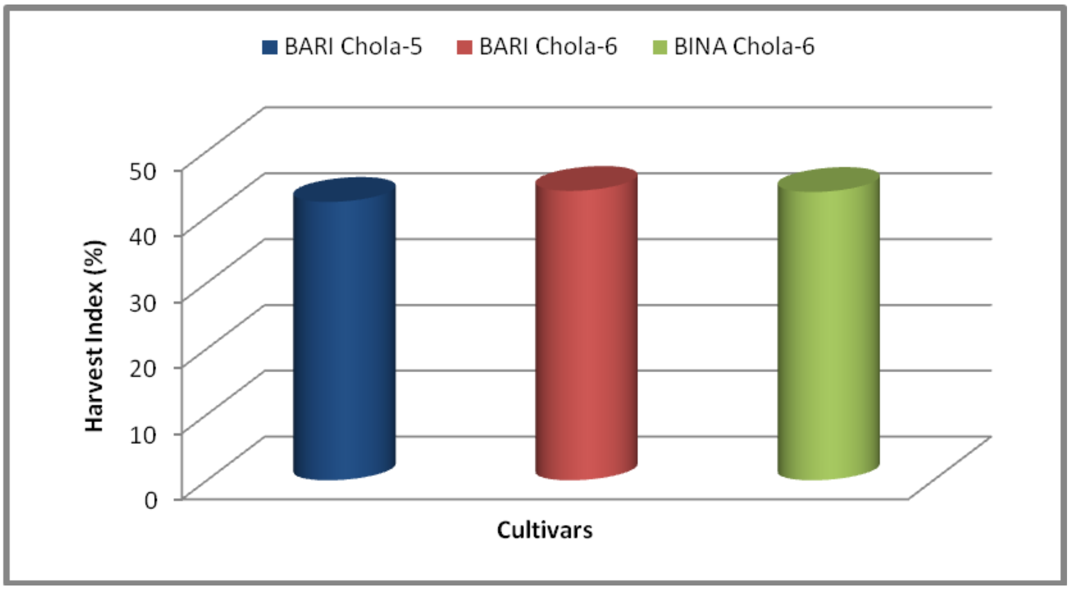
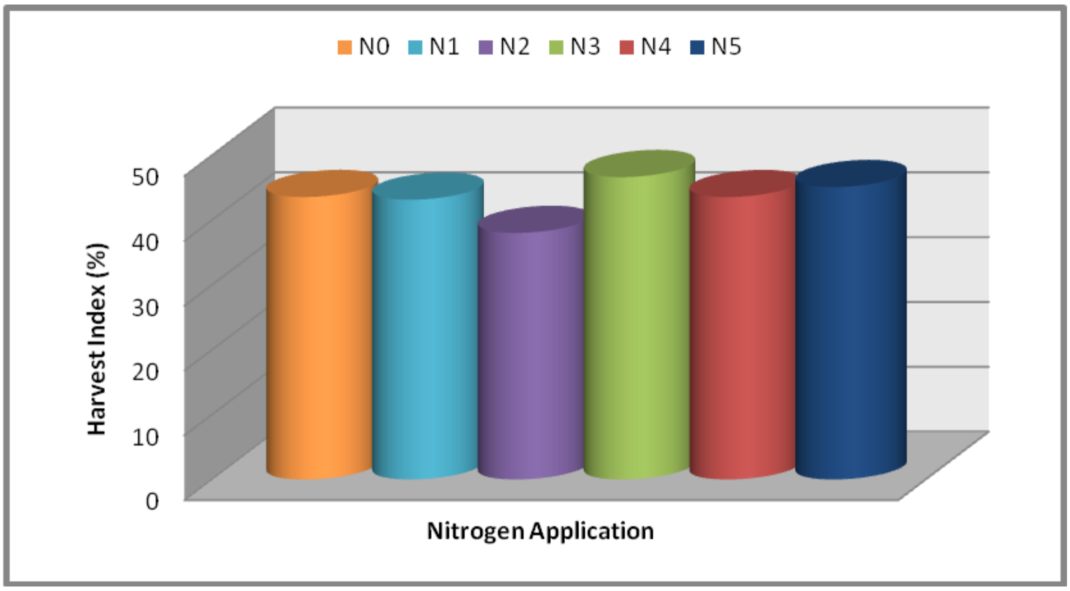


Figure 21: Effect of cultivar on harvest index of chickpea ($S\bar{x}$ = 0.0272)

Effect of nitrogen application

Harvest index showed significant variation for different nitrogen application (Appendix XI & Figure 22). The highest harvest index was recorded from N_3 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation) (46.65%) and it was followed by N_6 (Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation) (45.11%). On the other hand, the lowest harvest index was recorded from N_0 (No fertilizer) (38.04%). It seems from the results that initial higher dose of nitrogen (N_2: Basal application of 40 kg N ha^{-1}) helped in initial growth of the plants but basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation (N_3) ensured more nitrogen availability during reproductive stage and thus provided higher on pods plant^{-1}, seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and harvest index of chickpea than any other treatments. So, split application can surely benefit the farmers to get more yield and economic return. Chaudhari *et al.* (1998) found that application of 20-40 kg N ha^{-1} significantly influenced harvest index of chickpea. Islam (2002) found a significant increase in harvest index in bush bean due to application of N. Where the lowest HI was in control and the maximum was at 36.8 kg N ha^{-1}.



N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Figure 22: Effect of different nitrogen application on harvest index of chickpea ($S\bar{x}$ = 0.4577)

Combined effect of cultivar and nitrogen application

Combined effect of cultivar and nitrogen application on harvest index at different plant growth stages was found significant (Table 6). The highest harvest index (48.21%) was noted from V_2N_3 (BARI Chola-6 + Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation). On the other hand, the lowest harvest index (36.76%) was recorded in V_1N_2 (BARI Chola-5 + Basal application of 20 kg N ha^{-1}) which was followed by V_3N_2 (BINA Chola-6 + Basal application of 20 kg N ha^{-1}) (36.36 %).

Table 6: Combined effect of cultivar and nitrogen application on pods plant^{-1}, seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and harvest index of chickpea

Treatments	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
V_1N_0	22.47 gh	1.69 bc	111.2 h	1.04 de	1.29 d	45.72 bc
V_1N_1	23.53 fg	1.98 b	113.4 ef	1.28 b-e	1.78 a-d	42.39 c-f
V_1N_2	25.67 ef	1.97 b	114.5 d-f	1.42 b-d	2.46 a-e	36.76 g
V_1N_3	38.95 b	2.21 ab	124.3 a	2.09 ab	2.23 a-d	43.42 b-f
V_1N_4	25.47 ef	2.10 ab	121.5 b	1.62 b-d	2.25 a-e	41.58 d-f
V_1N_5	25.13 e-g	2.09 ab	120.5 bc	1.47 b-d	1.89 a-d	43.88 b-e
V_2N_0	20.07 h	1.56 c	110.2 h	1.09 de	1.54 cd	40.31 f
V_2N_1	25.13 e-g	1.98 b	113.0 fg	1.32 b-d	1.62 a-d	42.44 c-f
V_2N_2	25.70 ef	2.08 ab	115.7 d	1.78 a-d	2.39 a-c	41.01 ef
V_2N_3	44.90 a	2.68 a	124.8 a	2.43 a	2.50 ab	50.08 a
V_2N_4	28.90 cd	2.18 ab	120.6 bc	2.01 a-c	2.35 a-c	44.23 b-e
V_2N_5	27.10 c-e	2.10 ab	119.2 c	1.85 a-d	2.21 a-d	45.75 bc
V_3N_0	14.80 i	1.13 c	110.4 h	0.53 e	1.58 b-d	44.72 b-d
V_3N_1	16.00 i	1.90 b	111.7 gh	1.15 c-e	1.64 a-d	44.65 b-d
V_3N_2	25.77 ef	2.02 ab	114.7 de	1.42 b-d	2.54 a	36.36 g
V_3N_3	36.40 b	2.08 ab	120.2 bc	1.66 a-d	2.53 a	46.47 b
V_3N_4	29.47 c	1.92 b	118.9 c	1.64 a-d	2.02 a-d	44.91 b-d
V_3N_5	26.33 d-f	1.96 b	119.4 c	1.51 b-d	1.79 a-d	45.71 bc
CV (%)	15.57	12.90	7.18	21.79	19.04	13.05
$S\bar{x}$	2.665	0.6629	1.539	0.7652	0.8151	3.113

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

N_0= Control (No fertilizer)

N_1= Basal application of 20 kg N ha^{-1}

N_2= Basal application of 40 kg N ha^{-1}

N_3= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at branch initiation stage

N_4= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at flower initiation stage

N_5= Basal application of 20 kg N ha^{-1} and additional 20 kg N ha^{-1} at pod initiation stage

Chapter 5

Summary and Conclusions

CHAPTER 5

SUMMARY AND CONCLUSION

A field experiment was carried out at the research field of Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka from November, 2011 to March 2012 to study the response of chickpea varieties to different nitrogen managements. Three varieties of chickpea (V_1: BARI Chola-5, V_2: BARI Chola-6 and V_3: BINA Chola-6) and six nitrogen management treatments (N_0: Control, N_1: Basal application with 20 kg N ha^{-1}, N_2: Basal application with 40 kg N ha^{-1}, N_3: Basal application with 20 kg N ha^{-1} and 20 kg N ha^{-1} at branch initiation, N_4: Basal application with 20 kg N ha^{-1} and 20 kg N ha^{-1} at flower initiation and N_5: Basal application with 20 kg N ha^{-1} and 20 kg N ha^{-1} at pod initiation) were used in this experiment.

At 20 DAS, the tallest plant was noted from V_3 and the shortest plant was noted form V_1. At 40 DAS, the tallest plant was noted from V_3 and the shortest plant was noted form V_1. At 60 DAS, the maximum plant height was observed form V_2 and the minimum plant height was noted form V_1. At 80 DAS, the maximum plant height was observed form V_2 and the minimum plant height was noted form V_1. At 100 DAS, the maximum plant height was observed form V_2 and the minimum plant height was noted form V_1. At harvest the maximum plant height was observed form V_2 and the shortest plant was noted form V_1. The maximum numbers of branches plant^{-1} were found from V_2, while the minimum numbers were recorded from V_3 at 60 DAS and V_1 at 40, 80, 100 and harvest respectively. Plant dry weight showed non-significant variation at 40, 60 DAS for varietal effect. Numerically higher values were shown by V_2 and lower values were found from V_1. At 80, 100 DAS and harvest, V_2 showed significantly the highest plant dry weight and V_1 showed significantly the shortest plant dry weight. Significantly highest pods plant^{-1} was found in V_2. On the other hand V_3 showed significantly the lowest pods plant^{-1} among the three varieties. Significantly the highest seeds pod^{-1} was found in V_2. On the other hand, V_3 showed significantly the lowest seeds pod^{-1} among the three varieties. Highest 1000-seed weight was found in V_2, while V_3 showed significantly the lowest 1000-seed weight among the three varieties. Highest seed yield was found in V_2. V_3 showed significantly the lowest seed yield. Significantly the highest stover yield was found in V_2. On the other hand, V_1 showed significantly the lowest stover yield among the three varieties. Significantly the highest harvest index was found in V_2. On the other hand V_3 showed significantly the lowest harvest index among the three varieties.

Different nitrogen management showed significant differences on plant at 20, 40, 60, 80, 100 DAS and harvest. At 20 DAS, the tallest plant was found from N_2 it was as per with N_4. The shortest plant was observed from N_0. At 40 DAS, the maximum plant height was found from N_2 and the shortest plant was found from N_1. At 60 DAS, the maximum plant height was observed from N_2 and the shortest plant was recorded from N_0. At 80 DAS, the tallest plant was observed from N_2 and the shortest plant was found from N_5. At 100 DAS, the tallest plant was observed from N_2 and the shortest plant height was found from N_1. At harvest, the tallest plant was observed from N_2 and the shortest plant height was found from N_5. At 60 and 80 DAS and harvest, the maximum branches plant^{-1} was recorded from N_3. On the other hand, for different nitrogen management at 40, 60, 80, 100 DAS and harvest the minimum branches plant^{-1} were recorded from N_0. The highest plant dry weights at all stages were recorded from N_2 while at 80 DAS and harvest. On the other hand, for different nitrogen management at 40, 60, 80, 100 DAS and harvest the lowest plant dry weight were recorded from N_0. On the other hand, for different nitrogen management techniques, the lowest pods plant^{-1} was recorded from N_0. The highest seeds pod^{-1} was recorded from N_3. On the other hand, for different nitrogen management techniques, the lowest seeds pod^{-1} was recorded from N_0. The highest 1000-seed weight was recorded from N_3. On the other hand, for different nitrogen management techniques, the lowest 1000-seed weight was recorded from N_0. The highest seed yield was recorded from N_3. On the other hand, for different nitrogen management techniques, the lowest seed yield was recorded from $N_{0,}$ N_1 and N_2. The highest stover yield was recorded from N_2. On the other hand, for different nitrogen management techniques, the lowest stover yield was recorded from N_0. The highest harvest index was recorded from N_3. On the other hand, for different nitrogen management techniques, the lowest harvest index was recorded from N_0.

Combined effect of chickpea variety and nitrogen managements showed significant differences on plant at 20, 40, 60, 80, 100 DAS and harvest. At 20 DAS, maximum plant height was noted from V_3N_2. On the other hand, the lowest plant was recorded in V_1N_0. At 40 DAS, the highest plant was noted from V_3N_2 and the lowest plant was recorded in V_1N_0. At 60 DAS, highest plant was noted from V_3N_2 and the lowest plant was recorded in V_1N_0. At 80 DAS, highest plant was noted from V_3N_2 and the lowest plant was recorded in V_1N_0. At 100 DAS, the highest plant was noted from V_3N_2 and the lowest plant was recorded in V_1N_0. At harvest, the highest plant was noted from V_3N_2 and the lowest plant was recorded in V_1N_0. At 40 DAS, the highest branches plant^{-1} was noted from V_2N_3. On the other hand, the lowest branches plant^{-1} was recorded in V_3N_0. At 60 DAS, the highest branches plant^{-1} was noted from V_2N_3 and the lowest number of branches plant^{-1} was recorded in V_3N_0. At 80 DAS, the highest branches plant^{-1} was noted from V_2N_3 and the lowest number of branches plant^{-1} was recorded in V_3N_0. At 100 DAS, the highest branches plant^{-1} was noted from V_2N_3 and the lowest number of branches plant^{-1} was recorded in V_3N_0. At harvest, the highest branches plant^{-1} was noted from V_2N_3 and the lowest branches plant^{-1} was recorded in V_3N_0. At 60 DAS, the highest plant dry weight was noted from V_2N_2. On the other hand, the lowest plant dry weight was recorded in V_3N_0. At 80 DAS, the highest plant dry weight was noted from V_2N_2 and the lowest plant dry weight was recorded in V_3N_0. At 100 DAS, the highest plant dry weight was noted from V_3N_2 and the lowest plant dry weight was recorded in V_2N_0. At harvest, the highest plant dry weight was noted from V_3N_2 and the lowest plant dry weight was recorded in V_3N_0. Combined effect of cultivar and nitrogen application on pod number plant^{-1} was found significant. The highest pod number plant^{-1} was noted from V_2N_3. On the other hand, the lowest pod number plant^{-1} was recorded in V_3N_0. The highest seeds pod^{-1} was noted from V_2N_3. On the other hand, the lowest seed number pod^{-1} was recorded in V_3N_0. The highest 1000-seed weight was noted from V_2N_3. On the other hand, the lowest 1000-seed weight was recorded in V_2N_0. The highest seed yield was noted from V_2N_3. On the other hand, the lowest seed yield was recorded in V_3N_0. The highest stover yield was noted from V_3N_2. On the other hand, the lowest stover yield was recorded in V_1N_0. The highest harvest index was noted from V_2N_3. On the other hand, the lowest harvest index was recorded in V_3N_2.

From the above results it can be concluded that BARI Chola-6 is more productive compare to BARI Chola-5 and BINA Chola-6. Application of 20 kg N ha^{-1} as basal and additional 20 kg N ha^{-1} at branch initiation influenced plant with higher growth of chickpea thus gave better yield in comparison to others. So BARI Chola-6 cultivated with basal 20 kg N ha^{-1} with additional 20 kg N ha^{-1} of branch initiation stage could be a better management for their yield of chickpea.

Recommendation: This trait could be replicated at different agro ecological zones of Bangladesh for validating the present results.

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Appendices

APPENDICES

Appendix I (a): ANOVA table of plant height of Chickpea at different growth stages (at 20 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.062	0.031	0.8121	
2	Factor A	2	457.380	228.690	5994.7698	0.0000
4	Factor B	5	14.954	2.991	78.3974	0.0000
6	AB	10	24.630	2.463	64.5627	0.0000
-7	Error	34	1.297	0.038		
	Total	53	498.322			

Appendix I (b): ANOVA table of plant height of Chickpea at different growth stages (at 40 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	118.532	59.266	11.5219	0.0002
2	Factor A	2	466.746	233.373	45.3698	0.0000
4	Factor B	5	4.197	0.839	0.1632	
6	AB	10	41.354	4.135	0.8039	
-7	Error	34	174.889	5.144		
	Total	53	805.718			

Appendix I (c): ANOVA table of plant height of Chickpea at different growth stages (at 60 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	22.372	11.186	3.1452	0.0558
2	Factor A	2	213.794	106.897	30.0567	0.0000
4	Factor B	5	92.580	18.516	5.2062	0.0012
6	AB	10	101.060	10.106	2.8416	0.0111
-7	Error	34	120.921	3.557		
	Total	53	550.727			

Appendix I (d): ANOVA table of plant height of Chickpea at different growth stages (at 80 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	79.485	39.742	2.5623	0.0919
2	Factor A	2	214.855	107.427	6.9262	0.0030
4	Factor B	5	18.137	3.627	0.2339	
6	AB	10	26.846	2.685	0.1731	
-7	Error	34	527.348	15.510		
	Total	53	866.670			

Appendix I (e): ANOVA table of plant height of Chickpea at different growth stages (at 100 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	66.515	33.258	3.9214	0.0293
2	Factor A	2	130.336	65.168	7.6840	0.0018
4	Factor B	5	26.530	5.306	0.6256	
6	AB	10	21.158	2.116	0.2495	
-7	Error	34	288.354	8.481		
	Total	53	532.895			

Appendix I (f): ANOVA table of plant height of Chickpea at different growth stages (at harvest).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	72.475	36.237	3.2486	0.0512
2	Factor A	2	168.540	84.270	7.5546	0.0019
4	Factor B	5	19.215	3.843	0.3445	
6	AB	10	22.456	2.246	0.2013	
-7	Error	34	379.264	11.155		
	Total	53	661.950			

Appendix II (a): ANOVA table of branches plant^{-1} of Chickpea at different growth stages (at 40 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	15.815	7.907	1.6375	0.2094
2	Factor A	2	12.037	6.019	1.2463	0.3004
4	Factor B	5	18.148	3.630	0.7516	
6	AB	10	53.519	5.352	1.1083	0.3842
-7	Error	34	164.185	4.829		
	Total	53	263.704			

Appendix II (b): ANOVA table of branches plant^{-1} of Chickpea at different growth stages (at 60 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	42.481	21.241	1.3536	0.2719
2	Factor A	2	72.481	36.241	2.3095	0.1147
4	Factor B	5	150.537	30.107	1.9187	0.1169
6	AB	10	13.963	1.396	0.0890	
-7	Error	34	533.519	15.692		
	Total	53	812.981			

Appendix II (c): ANOVA table of branches plant^{-1} of Chickpea at different growth stages (at 80 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	52.089	26.044	1.7103	0.1960
2	Factor A	2	205.435	102.717	6.7455	0.0034
4	Factor B	5	14.143	2.829	0.1858	
6	AB	10	85.965	8.596	0.5645	
-7	Error	34	517.737	15.228		
	Total	53	875.368			

Appendix II (d): ANOVA table of branches plant^{-1} of Chickpea at different growth stages (at 100 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	35.241	17.620	0.9128	
2	Factor A	2	251.253	125.627	6.5081	0.0040
4	Factor B	5	62.766	12.553	0.6503	
6	AB	10	169.559	16.956	0.8784	
-7	Error	34	656.308	19.303		
	Total	53	1175.127			

Appendix II (e): ANOVA table of branches plant^{-1} of Chickpea at different growth stages (at harvest).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.243	0.122	1.4970	0.2382
2	Factor A	2	79.684	39.842	490.2176	0.0000
4	Factor B	5	87.411	17.482	215.1008	0.0000
6	AB	10	3.451	0.345	4.2462	0.0007
-7	Error	34	2.763	0.081		
	Total	53	173.553			

Appendix III (a): ANOVA table of total plant dry weight (g) of Chickpea at different growth stages (at 20 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.002	0.001	4.7033	0.0157
2	Factor A	2	0.007	0.004	17.7087	0.0000
4	Factor B	5	0.060	0.012	59.9390	0.0000
6	AB	10	0.006	0.001	3.1515	0.0059
-7	Error	34	0.007	0.000		
	Total	53	0.082			

Appendix III (b): ANOVA table of total plant dry weight (g) of Chickpea at different growth stages (at 40 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.002	0.001	4.7033	0.0157
2	Factor A	2	0.007	0.004	17.7087	0.0000
4	Factor B	5	0.060	0.012	59.9390	0.0000
6	AB	10	0.006	0.001	3.1515	0.0059
-7	Error	34	0.007	0.000		
	Total	53	0.082			

Appendix III (c): ANOVA table of total plant dry weight (g) of Chickpea at different growth stages (at 60 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.047	0.024	1.5456	0.2278
2	Factor A	2	0.481	0.240	15.6545	0.0000
4	Factor B	5	4.437	0.887	57.7863	0.0000
6	AB	10	0.124	0.012	0.8051	
-7	Error	34	0.522	0.015		
	Total	53	5.611			

Appendix III (d): ANOVA table of total plant dry weight (g) of Chickpea at different growth stages (at 80 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.104	0.052	1.5082	0.2357
2	Factor A	2	1.833	0.916	26.6115	0.0000
4	Factor B	5	22.713	4.543	131.9033	0.0000
6	AB	10	0.933	0.093	2.7093	0.0146
-7	Error	34	1.171	0.034		
	Total	53	26.754			

Appendix III (e): ANOVA table of total plant dry weight (g) of Chickpea at different growth stages (at 100 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.057	0.028	1.0734	0.3532
2	Factor A	2	8.985	4.493	169.3269	0.0000
4	Factor B	5	52.540	10.508	396.0448	0.0000
6	AB	10	2.444	0.244	9.2131	0.0000
-7	Error	34	0.902	0.027		
	Total	53	64.929			

Appendix III (f): ANOVA table of total plant dry weight (g) of Chickpea at different growth stages (at harvest).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.419	0.209	4.5752	0.0174
2	Factor A	2	10.553	5.276	115.3389	0.0000
4	Factor B	5	46.271	9.254	202.2900	0.0000
6	AB	10	3.226	0.323	7.0519	0.0000
-7	Error	34	1.555	0.046		
	Total	53	62.024			

Appendix IV (a): ANOVA table of nodules plant^{-1}of Chickpea at different growth stages (at 40 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	5.444	2.722	0.4452	
2	Factor A	2	341.778	170.889	27.9487	0.0000
4	Factor B	5	797.722	159.544	26.0933	0.0000
6	AB	10	28.000	2.800	0.4579	
-7	Error	34	207.889	6.114		
	Total	53	1380.833			

Appendix IV (b): ANOVA table of nodules plant^{-1} of Chickpea at different growth stages (at 60 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	5.444	2.722	0.4452	
2	Factor A	2	341.778	170.889	27.9487	0.0000
4	Factor B	5	797.722	159.544	26.0933	0.0000
6	AB	10	28.000	2.800	0.4579	
-7	Error	34	207.889	6.114		
	Total	53	1380.833			

Appendix IV (c): ANOVA table of nodules plant^{-1} of Chickpea at different growth stages (at 80 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	13.120	6.560	0.9423	
2	Factor A	2	308.398	154.199	22.1482	0.0000
4	Factor B	5	793.134	158.627	22.7842	0.0000
6	AB	10	15.324	1.532	0.2201	
-7	Error	34	236.713	6.962		
	Total	53	1366.690			

Appendix IV (d): ANOVA table of nodules plant^{-1} of Chickpea at different growth stages (at 100 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	24.565	12.282	14.9490	0.0000
2	Factor A	2	177.065	88.532	107.7531	0.0000
4	Factor B	5	389.370	77.874	94.7808	0.0000
6	AB	10	173.769	17.377	21.1494	0.0000
-7	Error	34	27.935	0.822		
	Total	53	792.704			

Appendix V (a): ANOVA table of nodule dry weight (g) of Chickpea at different growth stages (at 40 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.007	0.003	2.3578	0.1099
2	Factor A	2	0.070	0.035	24.7995	0.0000
4	Factor B	5	0.116	0.023	16.5060	0.0000
6	AB	10	0.008	0.001	0.5944	
-7	Error	34	0.048	0.001		
	Total	53	0.248			

Appendix V (b): ANOVA table of nodule dry weight (g) of Chickpea at different growth stages (at 60 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.011	0.006	1.0593	0.3578
2	Factor A	2	0.169	0.084	15.6498	0.0000
4	Factor B	5	0.532	0.106	19.7733	0.0000
6	AB	10	0.033	0.003	0.6115	
-7	Error	34	0.183	0.005		
	Total	53	0.929			

Appendix V (c): ANOVA table of nodule dry weight (g) of Chickpea at different growth stages (at 80 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.043	0.022	3.0927	0.0583
2	Factor A	2	0.211	0.106	15.0611	0.0000
4	Factor B	5	0.547	0.109	15.5877	0.0000
6	AB	10	0.034	0.003	0.4787	
-7	Error	34	0.239	0.007		
	Total	53	1.074			

Appendix V (d): ANOVA table of nodule dry weight (g) of Chickpea at different growth stages (at 100 DAS).

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.040	0.020	16.4590	0.0000
2	Factor A	2	0.199	0.100	81.2914	0.0000
4	Factor B	5	0.496	0.099	80.8988	0.0000
6	AB	10	0.273	0.027	22.2476	0.0000
-7	Error	34	0.042	0.001		
	Total	53	1.050			

Appendix VI: ANOVA table of number of pods plant^{-1} of Chickpea.

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	27.394	13.697	0.7972	
2	Factor A	2	133.505	66.752	3.8851	0.0302
4	Factor B	5	2195.048	439.010	25.5512	0.0000
6	AB	10	280.020	28.002	1.6298	0.1400
-7	Error	34	584.173	17.182		
	Total	53	3220.139			

Appendix VII: ANOVA table of number of seeds pod^{-1} weight of chickpea.

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.052	0.026	0.3924	
2	Factor A	2	0.209	0.105	1.5897	0.2188
4	Factor B	5	2.039	0.408	6.2006	0.0003
6	AB	10	0.141	0.014	0.2151	
-7	Error	34	2.236	0.066		
	Total	53	4.678			

Appendix VIII: ANOVA table of 1000-seed weight of Chickpea.

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	2.868	1.434	0.7510	
2	Factor A	2	29.825	14.913	7.8110	0.0016
4	Factor B	5	1077.096	215.419	112.8341	0.0000
6	AB	10	31.244	3.124	1.6365	0.1380
-7	Error	34	64.912	1.909		
	Total	53	1205.945			

Appendix IX: ANOVA table of seed yield of Chickpea.

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.067	0.033	0.2863	
2	Factor A	2	0.809	0.405	3.4664	0.0426
4	Factor B	5	5.352	1.070	9.1697	0.0000
6	AB	10	1.224	0.122	1.0490	0.4260
-7	Error	34	3.969	0.117		
	Total	53	11.421			

Appendix X: ANOVA table of stover yield of Chickpea.

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.298	0.149	0.9894	
2	Factor A	2	0.418	0.209	1.3884	0.2633
4	Factor B	5	7.102	1.420	9.4443	0.0000
6	AB	10	0.625	0.063	0.4156	
-7	Error	34	5.113	0.150		
	Total	53	13.555			

Appendix XI: ANOVA table of harvest index (%) of Chickpea.

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	46.467	23.233	0.7259	
2	Factor A	2	30.851	15.426	0.4820	
4	Factor B	5	381.228	76.246	2.3824	0.0589
6	AB	10	160.838	16.084	0.5026	
-7	Error	34	1088.142	32.004		
	Total	53	1707.525			