PERFORMANCE OF PRILLED UREA AND UREA SUPER GRANULES IN CHICKPEA CULTIVATION

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CERTIFICATE

This is to certify that the thesis entitled '**Performance of Prilled Urea and Urea Super Granules in Chickpea Cultivation**' submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science (MS)** in **Agronomy**, embodies the result of a piece of bonafide research work carried out by **Rumana Aktar**, Registration number: **07-02417** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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The Author

PERFORMANCE OF PRILLED UREA AND UREA SUPER GRANULES IN CHICKPEA CULTIVATION

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ABSTRACT

The experiment was conducted during the period from November 2012 to March, 2013 to study the performance of prilled urea and urea super granules in chickpea cultivation. The variety BARI Chola 9 was used as test crop. The experiment consists of the following treatments: T_1= Prilled urea (PU) broadcasted; T_2 = PU given between two rows; T_3 = Urea Super Granules (USG) placed at 10 cm distance (avoid one row); T_4 = USG placed at 10 cm distance (avoid two rows); T_5 = USG placed at 10 cm distance (avoid three rows); T_6 = USG placed at 20 cm distance (avoid one row); T_7 = USG placed at 20 cm distance (avoid two rows); T_8 = USG placed at 20 cm distance (avoid three rows); T_9= USG placed at 30 cm distance (avoid one row); T_{10}= USG placed at 30 cm distance (avoid two rows); T_{11} = USG placed at 30 cm distance (avoid three rows); T_{12} = USG placed at 40 cm distance (avoid one row); T_{13} = USG placed at 40 cm distance (avoid two rows) and T_{14} = USG placed at 40 cm distance (avoid three rows). USG was placed at 10 cm depth at each case. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. At 20, 40, 60, 80 and 100 days after sowing (DAS) and harvest, the tallest plant (14.37 cm, 27.28 cm, 45.07 cm, 52.52 cm, 58.76 cm and 61.23 cm) was observed from T_7 [USG placed at 20 cm distance (avoid two rows)] and the shortest plant (10.35 cm, 23.26 cm, 35.32 cm, 41.52 cm, 47.40 cm and 49.27 cm) was recorded in T_{14} [USG placed at 40 cm distance (avoid three rows)]. The minimum days from sowing to harvest (122.33 days) was recorded from T_7 [USG placed at 20 cm distance (avoid two rows)], while the maximum days from sowing to harvest (135.33 days) was found from T_{14} [USG placed at 40 cm distance (avoid three rows)]. The highest pods plant^{-1} (68.60), seeds pod^{-1} (2.87), weight of 1000 seeds (221.81 g), seed yield (1.98 t ha^{-1}) and stover yield (2.87 t ha^{-1}) was recorded from T_7 [USG placed at 20 cm distance (avoid two rows)], while the lowest number of pods plant^{-1} (53.27), lowest number of seeds pod^{-1} (1.77), lowest weight of 1000 seeds (188.79 g), lowest seed yield (1.27 t ha^{-1}) and lowest stover yield (1.90 t ha^{-1}) was observed from T_{14} [USG placed at 40 cm distance (avoid three rows)]. This type of USG application showed better performance than prilled urea given in two rows but not with broadcasted prilled urea.

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CHAPTER I

INTRODUCTION

Chickpea (*Cicer arietinum* L.), is one of the leading pulse crops in Bangladesh belongs to the family Fabaceae. The crop is variously known as chola, boot or botjam in different parts of Bangladesh. Today, chickpea is the third most important pulse crop and about 15% percent of the total pulse productions belong to this crop (FAO, 2010). Due to the high population pressure the total cultivable lands have been decreasing day by day at a rate of one lac hectare per year for urbanization and other essentialities (BBS, 2010). The remaining land has been cultivating with rice, wheat, maize, oils, pulse and other crops. Pulse has been pushed down to marginal land to give space for the cereal crops. Moreover, pulses with poor yielding ability do not get farmers' choice in cultivating pulses on the main land.

Pulse crop is an important food crop because it provides a cheap source of easily digestible dietary protein which complements the staple rice food for better nourishment of human body. The average value of pulse production (736 kg ha^{-1}) is very low comparing the value of other countries of the world (FAO, 2002). Chickpea plays a vital role in human and animal nutrition having 20.8% protein (Gowda and Kaul, 1982). According to the FAO (2006) yield of chickpea in Bangladesh is miserably low (761 kg ha^{-1}) as compared to that of other countries like India (833 kg ha^{-1}), Myanmar (1,106 kg ha^{-1}), Mexico (1,600 kg ha^{-1}), Israel (1,813 kg ha^{-1}), Russian Federation (2,400 kg ha^{-1}), Kazakjhastan (3,000 kg ha^{-1}) and China (6,000 kg ha^{-1}). Such low yield in Bangladesh, however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons, viz. unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of aman rice, poor managements of pests etc. Among all application of nitrogen fertilizer may get important consideration.

Experimental findings revealed that pulse crop stop to nourish *Rhizobia* rather translocates energy towards development of flowers and pods. Thus bacteriological activities are closed down at flowering stage of crop. Being pulse crop, chickpea needs continuous uptake of nitrogen from vegetative stage to flowering. Otherwise available low nitrogen from basal application of nitrogen eventually hampers the development of reproductive traits. In this situation nitrogen given as basal to the crop is not sufficiently available to the plant for nourishing its flowers and pods thus seed yield value is lower (Patel *et al.,* 1984; BARC, 2005). Keeping this in mind attention is given on nitrogen placement or use of Urea Super Granule (USG) in pulse. Both these ways of nitrogen placement might have some influencing technique that would be better utilization of nitrogen by the crop for its maximum seed yield (Bhardwaj and Singh, 1993).

Nitrogen is very important growth nutrient which is given during final land preparation in a small amount for chickpea. The plant can fix nitrogen by symbiotic process with rhizobium bacteria. At the time of flowering, nodules generally lose their ability to fix nitrogen, because the plant feeds the developing seed rather than nodule. Legume nodules that are no longer fixing nitrogen usually turn green may actually be discarded by the plant. The basal application of Urea is not very much limited during reproductive stage thus abortion of flower to fruit is normal phenomenon. Application of USG may be an alternative approach to release nitrogen slowly from vegetative growth to reproductive stage. Thus plant can uptake nitrogen during its reproductive stage. Recovery of nitrogen from point placement of urea as super granule was 49% higher than prilled urea. The increase in plant nitrogen recovery consequently increases plant height, number of leaf, tillering and a yield or agronomic efficiency of plant (Humphreys *et al.*, 2006). Different worker reported that USG has many fold advantages to improve crop growth and yield (Alam, 2002). Triggering nitrogen at the plant demand would be attempt towards yield improvements of pulse (Deolankar, 2005; Mukesh, 2006). So, nitrogen management is required synchronizing this demand of plant growth stages.

Mansoor (2007) noted that lack of attention on fertilizer application in proper way with appropriate amount is identified for lowering chickpea yields. Deep point placement of USG (urea super granule) increases N use efficiency in wetland crop and the placement of USG at 8-10 cm depth of soil can save 30% nitrogen than prilled urea, increases nutrient absorption and ultimately increases yields (Singh *et al.*, 1993; Singh and Singh, 1986). Nitrogen available before flowering might have some influencing technique that would be better utilization of nitrogen for reducing flower and pod droppings. Applied basal nitrogen is lost due to leaching, surface run off, NH_3 volatilization, denitrification and other processes consequently decreases nitrogen use efficiency. The scientist all over the world is fighting to increase fertilizer use efficiency through the use of slow release fertilizers, timing and placement of fertilizers in splits. Among these deep placements of large granule instead of broadcasting prilled urea is most promising (Hossain, 2008).

Under the above considerations, the present study was undertaken to maximize the seed yield of chickpea answering the questions of application of prilled urea or urea super granules (USG) with the following objectives:

1. To investigate the effect of prilled and USGs on the plant characters, yield and yield attributes of Chickpea.
2. To find out the best methods of USGs application for maximum seed yield of Chickpea.

CHAPTER II

REVIEW OF LITERATURE

Chickpea is an important pulse crop in Bangladesh and in many other countries of the world. The crop has been given less attention by the researchers in respect of different agronomic practices especially response to nitrogen to the application of prilled urea and urea super granules (USG) and normally it grows without low management practices. Based on this a very few research work related to growth, yield and development of chickpea with different management practices have been carried out in our country. Research works related to the application of prilled urea and urea super granules are very limited in Bangladesh context. However, research findings related to the effect of prilled urea and USG on some crops so far have been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Effects of prilled urea on chickpea and other pulse crop

2.1.1 Plant height

An experiment was conducted by Abbasi *et al.* (2013) with nitrogen rates at four levels (0, 25, 50 and 75 kg urea ha^{-1}) the result reveal that plant height were significantly affected by urea nitrogen rates and seed inoculation.

Rhizobium and inorganic nitrogen fertilization on some physiological and agronomical traits of chickpea (*Cicer arietinum* L.) cv. ILC 482, investigated by Namvar *et al.* (2013) with mineral nitrogen fertilizer at four levels (0, 50, 75 and 100 kg urea ha^{-1}) in the main plots, and two levels of inoculation with Rhizobium bacteria as sub plots and found that plant height were obtained from the highest level of nitrogen fertilizer (100 kg urea ha^{-1}).

Aliloo *et al.* (2012) studied the effects of foliar spraying of aqueous solutions 2 and 4% urea at two stages (before and after flowering) and 20 kg ha^{-1} urea application in soil. Results showed that the effect of urea treatment on plant height was notable the highest plant height was obtained by application of 20 kg ha^{-1} urea in soil.

A field experiment was conducted by Raman and Venkataramana (2006) in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram (*V. radiata*). Crop nutrient uptake, yield and its attributes (number of pods per plant and number of seeds per pod) of greengram augmented significantly due to foliar nutrition. The foliar application of 2% diammonium phosphate + NAA + Penshibao was significantly superior to other treatments in increasing the values of plant height.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mungbean cv. AEM 96 in Tandojam, Pakistan. The different NPK levels significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.25.

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.

Dahiya *et al.* (1993) reported increased in plant height of chickpea using N and P at the rate of 18-27 and 46-69 kg ha^{-1}, respectively.

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

Patra and Padhi (1989) noticed increased plant height of chickpea over control with 20 kg N along with 40 kg P ha^{-1}. 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}.

Results of an experiment, conducted by Sardana and Verma (1987) in Delhi, India, revealed that application of nitrogen, phosphorus and potassium fertilizers in combination resulted in significant increase in plant height of mungbean.

2.1.2 Branches $plant^{-1}$

Namvar *et al.* (2013) conducted an experiment on rhizobium and inorganic nitrogen fertilization on some physiological and agronomical traits of chickpea (*Cicer arietinum* L.) cv. ILC 482, with mineral nitrogen fertilizer at four levels (0, 50, 75 and 100 kg urea ha^{-1}) in the main plots, and two levels of inoculation with Rhizobium bacteria as sub plots and found that number of primary and secondary branches were obtained from the highest level of nitrogen fertilizer (100 kg urea ha^{-1}).

Malik *et al.* (2003) conducted a study 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 mungbean cv. NM-98. They observed that number of branches per plant was found to be significantly higher by 25 kg N ha^{-1}.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mung bean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al.* (2002) in Hisar, Haryana, India during the summer. The number of branches increased with increasing N rates.

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

An experiment was conducted by Dahiya *et al.* (1993) and 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 doses of 18 kg N and 46 kg P ha^{-1} were most effective in increasing the number of branches $plant^{-1}$ of chickpea. Vadavia *et al.* (1991) reported that application of 20 kg N ha^{-1} and P ha^{-1} increased number of branches $plant^{-1}$ of chickpea.

2.1.3 Dry matter content

Mukesh (2006) conducted a field experiment to study the impact of starter doses of nitrogen (0, 15 and 30 kg ha^{-1}) on nodulation and yield of different cultivars (Radhey, Avarodhi and K-850) of chickpea under irrigated condition and reported that dry matter content $plant^{-1}$ were highest in the crop treated with 30 kg N ha^{-1}.

Yakadri *et al.* (2002) studied the effect of nitrogen (40 and 60 kg ha^{-1}) on crop growth and yield of green gram (cv. ML-267). Application of nitrogen at 20 kg ha^{-1} resulted in the significant increase in dry matter content in above ground part.

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

2.1.4 Pods $plant^{-1}$

An experiment was conducted by Abbasi *et al*. (2013) with nitrogen rates at four levels (0, 25, 50 and 75 kg urea ha^{-1}) the result reveal that number of pod $plant^{-1}$, were significantly affected by nitrogen rates and number of pod $plant^{-1}$ (32.48) was obtained in the higher nitrogen rates.

A research work was conducted by Namvar *et al*. (2013) with the application of rhizobium and inorganic nitrogen fertilization on some physiological and agronomical traits of chickpea (*Cicer arietinum* L.) cv. ILC 482, with mineral nitrogen fertilizer at four levels (0, 50, 75 and 100 kg urea ha^{-1}) in the main plots, and two levels of inoculation with Rhizobium bacteria as sub plots and found that number of pods $plant^{-1}$ were obtained from the highest level of nitrogen fertilizer (100 kg urea ha^{-1}).

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N:P:K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2% foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest values for number of pods/plant (38.3).

A field experiment to study the impact of starter doses of nitrogen (0, 15 and 30 kg ha^{-1}) on nodulation and yield of different cultivars (Radhey, Avarodhi and K-850) of chickpea under irrigated condition was conducted by Mukesh (2006) and reported that number of pods $plant^{-1}$ were highest in the crop treated with 30 kg N ha^{-1}.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mung bean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al.* (2002) in Hisar, Haryana, India during the summer and reported that the number of pods per plant increased with increasing N rates.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1}) and 0, 25, 50 and 60 kg P ha^{-1}) were tested. They observed that the number of pods per plant was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N.

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 $plant^{-1}$.

A field work was completed by Chaudhari *et al.* (1998) and from the observation they reported that 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.

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

Tank *et al.* (1992) observed when mungbean was fertilized with 20 kg N along with level of 40 kg P_2O_5 ha^{-1} increased seed yield significantly over the unfertilized control. They also reported that mungbean fertilized with 20 kg N ha^{-1} along with 75 kg P_2O_5 ha^{-1} significantly increased the number of pods per plant.

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} and K_2O at 30 kg ha^{-1}. They concluded that increasing N rates up to 40 kg ha^{-1} increased green pod yield. Further addition of nitrogen (60 kg ha^{-1}) tended to decrease the yield.

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}.

Vijai *et al.* (1990) carried out an experiment with gardenpea 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.

Patra *et al.* (1989) noticed that number of pods $plant^{-1}$ of chickpea increased over control with 20 kg N along with 40 kg P ha^{-1}.

Patel and Parmer (1986) conducted an experiment on the response of green gram to varying levels of nitrogen and phosphorus. They observed that increasing N application to rainfed mungbean (cv. Gujrat-1) from 0 to 50 kg N ha^{-1} increased the number of pods per plant.

In trials, on clay soils during the summer season Patel *et al.* (1984) observed the effect of N levels (0, 10, 20 and 30 kg N $ha^{-1)}$ and that of the P (0, 10, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) on the growth and seed yield of mungbean. In that experiment, it was found that application of 30 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} significantly increased the number of pods per plant.

2.1.5 Seeds pod^{-1}

A field experiment was successfully finished by Namvar *et al.* (2013) to find out the effect of rhizobium and inorganic nitrogen fertilization on some physiological and agronomical traits of chickpea (*Cicer arietinum* L.) cv. ILC 482, with mineral nitrogen fertilizer at four levels (0, 50, 75 and 100 kg urea ha^{-1}) in the main plots, and two levels of inoculation with Rhizobium bacteria as sub plots and found that number of grains plant^{-1} were obtained from the highest level of nitrogen fertilizer (100 kg urea ha^{-1}).

Nigamananda and Elamathi (2007) conducted an experiment in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N:P:K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2% foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest seeds/pod (7.67).

An experiment was carried out by Mukesh (2006) to study the impact of starter doses of nitrogen (0, 15 and 30 kg ha^{-1}) on nodulation and yield of different cultivars (Radhey, Avarodhi and K-850) of chickpea under irrigated condition and reported that number of seeds plant^{-1} were highest in the crop treated with 30 kg N ha^{-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.

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 ha^{-1} resulted with significant increase in the chickpea seeds pod^{-1}.

Patra and Padhi (1989) noticed in chickpea increased number of seeds pod^{-1} over control with 20 kg N along with 40 kg P ha^{-1}.

Patel and Parmer (1986) conducted an experiment on the response of green gram to varying levels of nitrogen and phosphorus. They observed that increasing N application to rainfed mungbean (cv. Gujrat-1) from 0 to 50 kg N ha^{-1} increased the number of seeds pod^{-1}.

2.1.6 Weight of 1000 seeds

An experiment was conducted by Abbasi *et al.* (2013) with nitrogen rates at four levels (0, 25, 50 and 75 kg urea ha^{-1}) the result reveal that 100 grains weight were significantly affected by nitrogen rates and seed inoculation.

Mukesh (2006) conducted a field experiment to study the impact of starter doses of nitrogen (0, 15 and 30 kg ha^{-1}) on nodulation and yield of different cultivars (Radhey, Avarodhi and K-850) of chickpea under irrigated condition and reported that 100 seeds weight were highest in the crop treated with 30 kg N ha^{-1}.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1}) and 0, 25, 50 and 60 kg P ha^{-1}) were tested. They observed 1000 seeds weight increased with increasing rates of N up to 40 kg ha^{-1}.

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

Bali *et al.* (1991) conducted a field trail one mungbean in kharif seasons on silty clay loam soil. They revealed that 1000 seeds weight increased with 40 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}.

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

Results of an experiment, conducted by Sardana and Verma (1987) in Delhi, India, revealed that application of nitrogen, phosphorus and potassium fertilizers in combination resulted in significant increases in 1000 seeds weight of mungbean.

In trials, on clay soils during the summer season Patel *et al.* (1984) observed the effect of N levels (0, 10, 20 and 30 kg N $ha^{-1)}$ and that of the P (0, 10, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) on the growth and seed yield of mungbean. They observed that application of 40 kg P_2O_5 ha^{-1} along with 20 kg N ha^{-1} significantly increased the 1000 seeds weight of mungbean.

2.1.7 Seed yield

An experiment was conducted by Abbasi *et al.* (2013) with nitrogen rates at four levels (0, 25, 50 and 75 kg urea ha^{-1}) and reported that grain yield were significantly affected by nitrogen rates and seed inoculation. Means comparison showed that maximum grain yield (1276.78 kg ha^{-1}) for 75 kg urea ha^{-1}.

Physiological and agronomical traits of chickpea (*Cicer arietinum* L.) cv. ILC 482, was affected by rhizobium and inorganic nitrogen fertilization reported by Namvar *et al.* (2013) when an investigation was conducted with mineral nitrogen fertilizer at four levels (0, 50, 75 and 100 kg urea ha^{-1}) in the main plots, and two levels of inoculation with Rhizobium bacteria as sub plots and found that grain were obtained from the highest level of nitrogen fertilizer (100 kg urea ha^{-1}).

To evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851 a study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India. The recommended rate of N:P:K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2% foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest grain yield (9.66 q ha^{-1}).

Tickoo *et al.* (2006) carried out an experiment on mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment conducted in Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher grain yield (1.63 t ha^{-1}) compared to cv. Pusa 105.

A field experiment was conducted by Raman and Venkataramana (2006) in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram (*V. radiata*). There were 10 foliar spray treatments, consisting of water spray, 2% diammonium phosphate at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA. Crop nutrient uptake, yield and its attributes (number of pods per plant and number of seeds per pod) of greengram augmented significantly due to foliar nutrition. The foliar application of urea + NAA + Penshibao was significantly superior to other treatments in increasing the values of yield. The highest grain yield of 1529 kg ha^{-1} was recorded with this treatment.

A field study conducted by Sharma and Sharma (2006) for two years at the Indian Agricultural Research Institute, New Delhi on a sandy clay loam soil showed that the application of NP increased the total grain production of a rice-wheat-mungbean cropping system by 0.5-0.6 t ha^{-1}, NK by 0.3-0.5 t ha^{-1} and NPK by

0.8-0.9 t ha^{-1} compared to N alone, indicating that the balanced use of primary nutrients was more advantageous than their imbalanced application.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mungbean in Tandojam, Pakistan. The different NPK levels significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording the highest seed yield of 1205.2 kg ha^{-1}.

Nadeem *et al.* (2004) studied the response of mungbean cv. NM-98 to seed inoculation and different levels of fertilizer (0-0, 15-30, 30-60 and 45-90 kg N-P_2O_5 ha^{-1}) under field conditions. Application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied.

Malik *et al.* (2003) 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 mungbean cv. NM-98. They observed that a fertilizer combination of 25 kg N + 75 P kg ha^{-1} resulted with maximum seed yield (1112.96 kg ha^{-1}).

Rajender *et al.* (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T_{44}. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mung bean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al.* (2002) in Hisar, Haryana, India during the summer and reported that grain yield increased with increasing rates of up to 40 kg N ha^{-1} only.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on mungbean at the agronomic research station, Farooqabad in Pakistan. They revealed that seed inoculation +50-50-0 NPK kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat, Assam, India. Mungbean was grown using farmers practices (no fertilizer) or using a combinations of fertilizer application (30 kg N + 35 kg P_2O_5 ha^{-1}). Seed yield was 0.40 ton ha^{-1} with farmer's practices, while the highest yield was obtained by the fertilizer application (0.77 ton ha^{-1}).

Karle and Pawar (1998) examined the effect of varying levels of N and P fertilizers on summer mungbean. They reported higher seed yield in mungbean with the application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

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 of chickpea.

Patel *et al.* (1992) conducted a field trial to evaluate the response of mungbean 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 ha^{-1}, 20kg N + 40 kg P ha^{1} and 0, 10, 20 or 30 kg S ha^{-1} as gypsum. Seed yield was 1.2 and 1.24 t ha^{-1} in Gujrarat 2 K 851 respectively 20 kg N + 40 kg P ha^{-1}.

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. 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.

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

A field experiments was conducted by Sarkar and Banik (1991) to study the effect of N and P on yield of mungbean. Results showed that application of N along with P significantly increased the seed yield of mungbean. The maximum seed yield was obtained with the combination of 20 kg N and 60 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).

Arya and Kalra (1988) reported that application of N at the rate of 50 kg ha^{-1} along with 50 kg P ha^{-1} increased mungbean yield. Another experimental result from field experiments conducted by Mahadkar and Saraf (1988) of mungbean revealed that the application of N with P and K at 20:25 kg ha^{-1} gave higher seed yield.

Arvadia and Patel (1988) observed stimulatory effect of nitrogen 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 nitrogen alone at the rate of 50 kg ha^{-1} showed no additional of that parameter over 25 kg N ha^{-1}.

Pongkao and Inthong (1988) applied N at the rate of 0-60 kg ha^{-1} on mungbean and reported that application of 15 kg N ha^{-1} was found to be superior giving 23%

higher seed yield over the control. However 60 kg N ha^{-1} tended to produced seed yield which was at par of 15 kg N ha^{1}.

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}.

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}. Application of 20 kg N ha^{-1} increased grain yield of chickpea reported by Subba Rao *et al.* (1986).

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. An experiment was conducted by Trung and Yoshida (1983) using 0-100 ppm N as treatment in the form of ammonium nitrate or 10 or 100 ppm N as urea, sodium nitrate, ammonium nitrate or ammonium sulphate. They found that seed yield of mungbean increased with the increase in N up to 50 ppm.

2.1.8 Stover yield

An experiment was conducted by Abbasi *et al.* (2013) with nitrogen rates at four levels (0, 25, 50 and 75 kg urea ha^{-1}) the result reveal that stover yield were significantly affected by nitrogen rates and seed inoculation.

Rajender *et al.* (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T_{44}. Stover yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mung bean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al.* (2002) in Hisar, Haryana, India during the summer and reported that straw yield increased with increasing N rates.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1}) and 0, 25, 50 and 60 kg P ha^{-1}) were tested and the experimented results they stated that the stover yield increased with increasing N up to 40 kg ha^{-1}.

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

2.1.9 Biological yield

Some physiological and agronomical traits of chickpea (*Cicer arietinum* L.) cv. ILC 482, investigated by Namvar *et al.* (2013) with mineral nitrogen fertilizer at four levels (0, 50, 75 and 100 kg urea ha^{-1}) in the main plots, and two levels of inoculation with Rhizobium bacteria as sub plots and found that biological yield were obtained from the highest level of nitrogen fertilizer (100 kg urea ha^{-1}).

Tickoo *et al.* (2006) carried out an experiment on mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment conducted in Delhi, India. Cultivar Pusa Vishal recorded higher biological (3.66 1.63 t ha^{-1}) compared to cv. Pusa 105.

Rajender *et al.* (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T_{44}. Biological yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect biological 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 significantly increased pods $plant^{-1}$.

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}.

Results of an experiment conducted by Sardana and Verma (1987) in Delhi, India and stated that the application of nitrogen, phosphorus and potassium fertilizers in combination resulted in the significant increase in biological yield of mungbean.

2.1.10 Harvest index

Rhizobium and inorganic nitrogen fertilization on some physiological and agronomical traits of chickpea (*Cicer arietinum* L.) cv. ILC 482, investigated by Namvar *et al.* (2013) with mineral nitrogen fertilizer at four levels (0, 50, 75 and 100 kg urea ha^{-1}) in the main plots, and two levels of inoculation with Rhizobium bacteria as sub plots and found that harvest index were obtained from the highest level of nitrogen fertilizer (100 kg urea ha^{-1}).

Mukesh (2006) conducted a field experiment to study the impact of starter doses of nitrogen (0, 15 and 30 kg ha^{-1}) on nodulation and yield of different cultivars (Radhey, Avarodhi and K-850) of chickpea under irrigated condition and reported that harvest index were highest in the crop treated with 30 kg N ha^{-1}.

From an earlier experiment Rajender *et al.* (2003) find out the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P fertilizer rates on mungbean genotypes MH 85-111 and T_{44}. Harvest index increased with increasing N rates up to 20 kg ha^{-1}.

Islam (2003) found a significant increase in harvest index in bush bean due to application of N. The lowest HI was in control and the maximum was at 36.8 was 36.8 kg N ha^{-1}.

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.

2.2 Effect of urea super granules on different crops

A field experiment was conducted by Akter (2010) at Sher-e-Bangla Agricultural University, Dhaka to assess the comparative advantages of using urea super granule (USG) over prilled urea and also the effect of different management of nitrogenous fertilizer on growth, yield and yield attributing characters of mustard and noted that USG reduces 40% use of urea which lowers 20% of total cost in mustard production. Experimental data also revealed that plant height, number of branches plant^{-1}, number of leaves plant^{-1}, total dry matter, number of siliqua plant^{-1}, siliqua length, number of seeds siliqua^{-1}, 1000-seed weight and seed yield (t ha^{-1}) was found highest when USG was applied as basal dose and all the characters showed lowest value when USG was applied at 25 DAS.

Ahmed *et al.* (2010) conducted a field experiment in farmers field at the MLT site at Madhupur and Ghatail upazila with four treatment on the production of hybrid maize and reported that the recommended dose of N as prilled urea gave yield of 9.2 t ha^{-1}. The highest grain yield (10.30 t ha^{-1}) was obtained from the plot treated with recommended dose of N as USG which was similar to that of plots treated with 10% less than recommended dose of N as USG (9.44 t ha^{-1}).

Hussain *et al.* (2010) conducted a number of experiments for three consecutive years at Farming System Research and development (FSRD) site at Tangail to evaluate the efficiency of USG application over prilled urea on the yield of cabbage and recorded the highest head yield (78.1 t ha^{-1}) was obtained with recommended dose of N as USG. The 10% and 20% reduction i. e. 175 kg USG ha^{-1} and 155 kg USG ha^{-1} also gave higher yield (77.1 t ha^{-1}, 72.0 t ha^{-1} respectively) than that of recommended dose of prilled urea application.

Singh and Singh (2006) conducted two field experiments for two crop cycles each for two years on an entities over *Citronella Java*. They found that the oil yields were 9% higher in USG than that of PU and N recovery of USG and PU were 31 and 21% respectively.

Khalil *et al.* (2006) conducted a field experiment to know the recovery of spring wheat with urea super granules. They observed that the translocation of N from vegetative part to grain portion during grain filling stage (67-116 DAA) was 34.9% with the USG and 28.7% with PU, resulting in (711 kg ha^{-1}) more grain yield with the former than the later.

Humphreys *et al.* (2006) reported that recovery of nitrogen from point placement of urea of super granule was 49% higher than prilled urea. The increase in plant nitrogen recovery consequently increases plant height, number of leaf, tillering and a yield or agronomic efficiency of rice plant.

Talukder *et al.* (2004) conducted an experiment at Syedpur and Tista meander flood plain to observe the efficiency of Urea super granule on tomato for two years. Two forms of urea i.e. prilled urea and USG were applied. Two years results revealed that USG had significant positive effect on the yield of tomato as compared to prilled urea. The recommended dose of N (150 kg/ha) from USG gave highest marketable fruit yield of 79.13 t/ha in the 1^{st} year and 73.60 t/ha in the 2^{nd} year. They also observed that when 150 kg and 135 kg/ha of N applied from USG gave 11% and 2% higher yield of tomato than that of using 150 kg/ha N from prilled urea, respectively.

Two field experiments were conducted by Rao *et al.* (2004) in Joypur to study the effect of prilled urea, neem coated urea and urea super granules on a perennial aromatic herb, geranium (*Pelargonium graveolens* L Her.) grown on a sandy loam soil. They reported that, application of nitrogen increased the biomass and essential oil yields. USG and neem coated urea significantly increased the yields over prilled urea. The concentration and quality of essential oil were not influenced either by levels or carrier of N.

Saikia *et al.* (2002) reported the response of Indian mustard cv. Pusa giant grown in New Delhi, India during rabi season. They found that those varieties response positively to the use of USG than prilled urea and neem coated urea.

Alam *et al.* (2000) carried out a socio economic study in two rice production environment (Gazipur and Tangail) to assess the comparative advantages of using urea super granule (USG) over prilled urea (PU) in modern rice production and to examine the differences in producers technical efficiency between USG urea and non user in crop management. Results revealed that comparatively low amount (36%) of urea was needed in modern boro rice production using USG instead of PU though 15% more labour was needed while weeding cost was a bit lower in USG using plots. Results also indicated additional yield of 0.87 t ha^{-1} by using USG and this yield gain additional benefit of TK. 11,506 ha^{-1}.

Department of Agricultural Extension (DAE) conducted 432 demonstrations of the effect of USG on boro rice in 72 thanas of 31 districts. It was reported that USG plots, on an average, produced higher yields than the PU plots while applying 30 to 40% less urea in the form of USG (Islam and Black, 1998).

Haque (1998) conducted a field experiment on potato at BAU farm and farmers field at Madhupur. Four treatment were used (1) Control (without any fertilizer), (2) 100 Kg N ha^{-1} from prilled urea, (3) USG, 2; 73 kg N ha^{-1} from USG (4) USG-3; 109 kg N ha^{-1} from USG point placement . USG greatly increased yield of potato tubers both at BAU farm and farmers field at Madhupur. Maximum potato tubers yield at BAU farm was from USG-3 treatment which was 24.16 t ha^{-1} compared to 17.52 t ha-01 from prilled urea application. Maximum yield of potato tubers at farmer's field was obtained from USG-3 treatment which was 26.50 t ha^{-1} compared to 20.78 t ha^{-1} from same dose of prilled urea application.

Vijaya and Subbaiah (1997) carried out an experiment with rice cv. IET 1444 treated with fertilizer @ 90 kg N ha^{-1} as prilled urea, large granular urea or urea super granules (USG) and 70 kg P_2O_5 ha^{-1} as single superphosphate or large diammonium phosphate, both applied by broadcasting or placement methods. They showed that plant height, number of tillers, root length, number and weight of panicles, dry matter and grain yield of rice increased with increasing urea super granule size and were greater with the deep placement of nitrogen.

Panday and Tiwari (1996) observed that grain yield was the highest with N applied as a basal dose of USG or mussoorie rock phosphate urea, (MRPU) applied in two split applications.

Subbaiah *et al.* (1994) reported that the highest grain yield (6.12 t ha^{-1}) was obtained with USG, 4.76 with PU + SSP and the lowest 2.89 t ha^{-1} with the control. Grain yield, N use efficiency and apparent N recovery are consistently higher particularly during the *boro* season when N as USG is deep placed. The efficiency is further improved if hole is properly closed immediately after deep point placement of USG.

Mishra *et al.* (1994) carried out a field experiment with rice cv. sita giving 0 or 80 kg N ha^{-1}as urea, USG and neem, lac, rock phosphate or karanj coated urea and showed that the highest grain yield was (3.39 t ha^{-1}) obtained by urea in three split applications. Das and Singh (1994) reported that grain yield and N use efficiency by rice were greater for deep placed USG than for USG broadcast and incorporated or three split applications of PU.

Patel and Mishra (1994) carried out an experiment on rice applied with 0, 30, 60 or 90 kg N ha^{-1} as Mussorie rock phosphate-coated urea, neem cake-coated urea, gypsum coated urea, USG or prilled urea. The coated materials were incorporated before transplanting, urea super granules were placed 5-10 cm deep a week after transplanting and urea was applied in 3 split doses. They showed that N rate had no significant effect on panicle length, percent sterility and harvest index.

Quayum and Prasad (1994) showed that application of N up to 112.5 kg ha^{-1} increased grain (4.37 t ha^{-1}) and straw (5.49 t ha^{-1}) yields with fertile grain $panicle^{-1}$ being the highest at this N rate. N applied as USG gave the best yield and yield attributes. It is reported that the slow release fertilizers were effective for rainfed lowland rice.

Bhale and Salunke (1993) conducted a field trial to study the response of upland irrigated rice to nitrogen applied through urea and USG. They found that grain yield increased with up to 120 kg urea and 100 kg USG. Singh *et al.* (1993) opined that grain yield and N uptakes increased with increased rate of N application and were the highest with deep placed USG. Bhardwaj and Singh (1993) observed that placement of 84 kg N as USG produced a grain yield of 6.8 t ha^{-1} which was similar to placing 112 kg USG and significantly greater than other nitrogen sources and rates.

Singh and Mishra (1993) conducted a field experiment on a calcareous alluvial sandy loam soil to see the comparative effect of prilled urea and urea super granules on yield and quality of Sugarcane. Use of USG up to 75% of the recommended dose of N increased sugar and sugarcane yields significantly as comparison with prilled urea. Cane juice quality was not affected significantly with these materials. USG was found stimulating ammonification significantly in the soil than priled urea and reduced nitrification significantly.

Reddy *et al.* (1991) carried out a field experiment in 1984 to study the effects of different N sources on rice cv. Jaya and Mangala. They found that the highest grain yield of 5863 kg $ha^{-1}$was gained from cv. Jaya treated with 112 kg ha^{-1} of urea super granules (USG) placed in the root zone.

Narayanan and Thangamuthu (1991) carried out field experiments on rice cv. TKM9 and IR 20 at combatore, Tamil Nadu in 1984-85, N was applied at 30, 60 or 90 kg ha^{-1} using USG placed at a depth of 10 cm in the main plot. They noted that maximum yields of grain and straw were obtained from 90 kg N ha^{-1}, while the lowest was under the control treatment.

Rama *et al.* (1989) mentioned that the number of panicles m^{-2} increased significantly when nitrogen level increased from 40 to 120 kg N ha^{-1} as different modified materials. Urea super granules (USG) produced significantly higher number of panicles m^{-2} and grains $panicle^{-1}$ than split application of prilled urea. Patra and Padhi (1989) stated that USG recorded the lowest number of tiller $hill^{-1}$, panicles $hill^{-1}$ and shortest panicle. Jee and Mahapatra (1989) also observed that number of panicles m^{-2} were significantly higher @ 90 kg N ha^{-1} as deep placed urea super granules (USG) than split application of urea.

Chauhan and Mishra (1989) conducted field experiments at pantnagar with rice applying 40, 80 or 120 kg N ha^{-1} as five different forms of urea. They reported that USG point placed one week after transplanting gave the highest mean DM yield and PU gave the lowest grain yield while deep placed USG.

Chakravorti *et al.* (1989) reported that applying 37.5 75.0 and 112.5 kg N ha^{-1} as USG to rice gave rice yield of 3.85, 5.22 & 5.48 t ha^{-1}, respectively compared with 3.10, 4.29 and 4.97 t respectively, with N as urea and 1.95 without N. Rao and Ghai (1989) reported that SCU did not influence grain yield, LCU decreased yields and USG increased yield significantly.

Lal *et al.* (1988) conducted a field experiment on a silty loam soil during the rainy season of 1981-83 to evaluate the performance of USG and SCU in transplanted rice. They reported that placement of N as USG and broadcast incorporation of SCU were superior to prilled urea (applied in three split surface dressings) at 29, 58 and 87 kg N ha^{-1} but not at 116 kg N ha^{-1}. SCU gave the highest response followed by USG and both maintained superiority over PU upto 87 kg N ha^{-1}.

Sarder *et al.* (1988) conducted a field experiment at Mymensingh on wetland rice applying urea, USG and sulphur coated urea (SCU) at 23.7, 47.4 and 94.8 kg N ha^{-1}. Urea was broadcast in three split applications, USG was point placed at transplanting and SCU was broadcast and incorporated at transplanting. SCU was more efficient than the conventional method of urea application and point placement of USG only at the highest N rate, giving higher grain yield and greater plant height, panicle length and total number of grains $panicle^{-1}$ than the other N sources. At lower N rate, the crop's response was similar. USG did not show any advantage over conventional urea application.

Raja *et al.* (1987) conducted an experiment with rice and six different forms of nitrogen and mentioned that nitrogen as USG gave the highest average yield of

5.44 t compared with 4.64-4.92 t for nitrogen in five other forms. The USG at 75 kg N ha^{-1} gave the highest yield of 7.2 t ha^{-1}. Juang and Wang (1987) stated that nitrogen rates were insignificant for both the broadcasting and deep placement.

Sudhakara and Prasad (1986) conducted a field experiment in rainy season in 1982-83 at the Indian agricultural Research Institute, New Delhi to study the relative efficiency of prilled urea, urea super granule and neem coated urea. They observed that performance of rice if more or less linear to USG and neem coated USG which were better than prilled urea.

Singh and Singh (1986) worked with different levels of nitrogen as urea, super granules (USG), sulphur coated urea and prilled urea @ 27, 54 and 87 kg ha^{-1}. They reported that number of tillers m^{-2} increased with increasing nitrogen fertilizer. The number of tillers m^{-2} was significantly greater in urea super granules than prilled urea in all levels of nitrogen.

Patel and Chandrawanshi (1986) conducted an experiment with rice cv. Sunuidhi (R-23.84) growing without N, or with 40 kg N ha^{-1} as urea broadcast and incorporated as a basal dose before sowing, USG applied in rows and seeds drilled in alternate rows, urea or USG and seed drilled in the same furrow. They reported that the treatments did not significantly affect the number of panicles m^{-2} but yield was highest (2.4 t ha^{-1}) in 40 kg N ha^{-1} treatments.

Rajagopalan and Palaniasamy (1985) carried out an experiment with rice cv. TK 43 giving 50 or 75 kg N ha^{-1} as neem-cake coated urea, coal coated urea and USG in the kharif season. They found that greatest plant height (83 cm), umber of panicles hill^{-1} (10.00), panicle length (21 cm) and number of filled grains panicle^{-1} (85) were obtained with 75 kg N as USG ha^{-1}.

Singh and Singh (1984) conducted a rainfed trial with rice on a calcareous silt-loam soil and reported that 29-87 kg N ha^{-1} as USG and SCU before transplanting gave rice yields of 3.7 and 3.69 t ha^{-1}, respectively compared with 3.56 t with urea in three split dressings, 3.45 t with urea at transplanting only.

Kumar and Singh (1983) carried out an experiment with rice cv. Hindham grown by applying 29-116 kg N ha^{-1} under flooded condition and stated that 87 kg N ha^{-1} in the form of USG gave the highest yield which was 14.4% more compared to split application of urea.

Rambabu *et al.* (1983) reported that of various forms and methods of application of N fertilizers to rice grown under flooded conditions, placement of N as USG (1 g sizes) in the root zone at transplanting was most effective in increasing DM production, rice yield, followed by SCU incorporated before transplanting. Yield and N recovery were lowest with urea applied as basal drilling.

In trails in several countries rice was given 0-176 to kg N ha^{-1} at each of three growth stages as urea or USG applied broadcast, incorporated or deep placed. Recovery of N was generally higher with USG than with urea and less than urea was needed to give the same grain yield (Yamada *et al.*, 1981). Umar *et al.* (1981) conducted field trials at Maros, Langrang and Sulawesc and found that grain yield of low land rice was not affected by N application date and did not differ when N was applied as mudballs, urea briquets or USG.

Yamda *et al.* (1981) stated that in trials in several countries rice was given 0176 kg ha^{-1} at each of three growth stages at urea or USG applied broadcast, incorporated or deep placed. Recovery of N was generally higher with USG than with urea and comparatively less amount USG was needed than urea to give the same grain yield. The superior performance of USG in increasing rice yield. The product is 40-50% more efficient than conventional urea.

From the above reviews it is clear that nitrogen is an important nutrient for any crop which is given as basal or foliar spray. On the other hand, the use of USG is emerging as an important method of nitrogen application for better growth and development of different crops.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2012 to March, 2013 to study the indicative performance of prilled urea and urea super granules while used in chickpea cultivation. This chapter includes materials and methods i.e. location of experimental site, soil and climate condition of the experimental plot, materials used, design of the experiment, data collection procedure and procedure of data analysis that were used in conducting the experiment are presented below under the following headings:

3.1 Experimental site

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^{0}74^{\prime}$N latitude and $90^{0}35^{\prime}$E longitude (Anon., 1989).

3.2 Climatic condition

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. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I. During the experimental period the maximum temperature (31.7^{0}C) was recorded in the month of March 2013 while the minimum temperature (12.8^{0}C) in the month of January 2013. The highest humidity (78%) was recorded in the month of November, 2012, whereas the highest rainfall (39 mm) was recorded in the month of February 2013.

3.3 Characteristics of 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. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The results showed that the soil composed of 27% sand, 43% silt, 30% clay and organic matter 0.78%, which have been presented in Appendix II.

3.4 Planting material

The variety BARI Chola 9 was used as the test crop. The seeds were collected from the Agronomy Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. It was the released varieties of chickpea developed by Pulses Research Centre, which was recommended by the national seed board in the year of 2011. The variety can be grown in *Rabi* season. Life cycle of this variety ranges from 125-130 days. Maximum seed yield is 1.5-2.0 t ha^{-1}.

3.5 Land preparation

The land was irrigated before ploughing for land preparation. After having 'zoe' condition the land was first opened with the tractor drawn disc plough. Ploughed soil was brought into desirable tilth by 4 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 12 and 20 November 2012, respectively. Experimental land was divided into 42 unit plots following the design of experiment.

3.6 Fertilizer application

Urea, Triple super phosphate (TSP), Muriate of potash (MOP), gypsum, zinc sulphate and boric acid were used as a source of nitrogen, phosphorous, potassium, gypsum, sulphur and boron, respectively. The fertilizers were applied at the rate of 50, 90, 40, 110, 7 and 10 kg $hectare^{-1}$, respectively as N, P_2O_5, K_2O, S, Zn and Boron following the Fertilizer Recommendation Guide (FRG, 2005). All of the fertilizers except N were applied during final land preparation and urea and USG were applied as per treatment and methods.

3.7 Treatments of the experiment

The experiment consists of the following treatments:

T_1= Prilled urea (PU) broadcasted

T_2= PU given between two rows

T_3= USG placed at 10 cm distance (avoid one row)

T_4= USG placed at 10 cm distance (avoid two rows)

T_5= USG placed at 10 cm distance (avoid three rows)

T_6= USG placed at 20 cm distance (avoid one row)

T_7= USG placed at 20 cm distance (avoid two rows)

T_8= USG placed at 20 cm distance (avoid three rows)

T_9= USG placed at 30 cm distance (avoid one row)

T_{10}= USG placed at 30 cm distance (avoid two rows)

T_{11}= USG placed at 30 cm distance (avoid three rows)

T_{12}= USG placed at 40 cm distance (avoid one row)

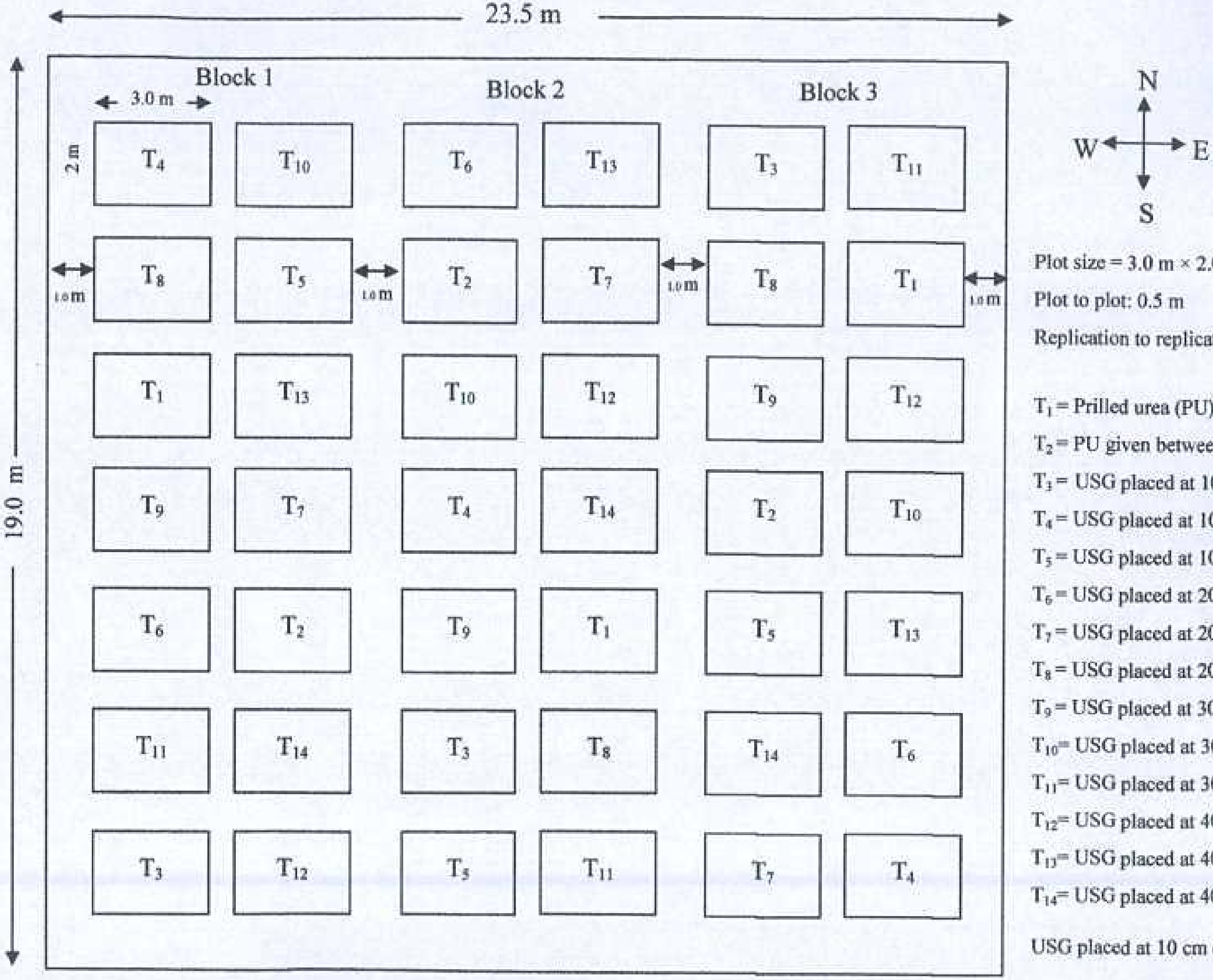
T_{13}= USG placed at 40 cm distance (avoid two rows)

T_{14}= USG placed at 40 cm distance (avoid three rows)

USG placed at 10 cm depth of each case.

3.8 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 23.5 m × 19.0 m was divided into three equal blocks. Each block was divided into 14 plots where 14 treatments were allotted at randomly. There were 42 unit plots altogether in the experiment. The size of the each unit plot was 3.0 m × 2.0 m. The space between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.



Plot size = 3.0 m × 2.0 m

Plot to plot: 0.5 m

Replication to replication: 1.0 m

T_1 = Prilled urea (PU) broadcasted

T_2 = PU given between two rows

T_3 = USG placed at 10 cm distance (avoid one row)

T_4 = USG placed at 10 cm distance (avoid two rows)

T_5 = USG placed at 10 cm distance (avoid three rows)

T_6 = USG placed at 20 cm distance (avoid one row)

T_7 = USG placed at 20 cm distance (avoid two rows)

T_8 = USG placed at 20 cm distance (avoid three rows)

T_9 = USG placed at 30 cm distance (avoid one row)

T_{10} = USG placed at 30 cm distance (avoid two rows)

T_{11} = USG placed at 30 cm distance (avoid three rows)

T_{12} = USG placed at 40 cm distance (avoid one row)

T_{13} = USG placed at 40 cm distance (avoid two rows)

T_{14} = USG placed at 40 cm distance (avoid three rows)

USG placed at 10 cm depth of each case

Figure 1. Field layout of the experimental plot

3.9 Sowing of seeds in the field

The seeds of chickpea were sown on 22 November, 2012. Before sowing seeds were treated with Bavistin to control the seed borne disease. The seeds were sown in solid rows in the furrows having a depth of 2-3 cm. Row to row distance was 30 cm.

3.10 Intercultural operations

3.10.1 Thinning

Seeds started germination of four DAS. Thinning was done two times; first thinning was done at 8 DAS and second was done at 15 DAS to maintain optimum plant population in each plot.

3.10.2 Irrigation and weeding

Irrigation was done as per requirements. The crop field was weeded as per treatment.

3.10.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) and virus vectors (jassid) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Dimacron 50EC was sprayed at the rate of 1 litre/ha to control the insects.

3.11 Crop sampling and data collection

Ten plants from each plot were randomly selected and marked with sample card for data recording. Plant height, number of leaves per plant, branches per plant were recorded from selected plants at an interval of 20 days started from 20 DAS and continued upto 100 DAS and to harvest.

3.12 Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown in color and it was done at 30 March, 2013. The matured pods were collected from a pre demarked area of three linear meter at the center of each plot.

3.13 Data collection

3.13.1 Crop growth characters

3.13.1.1 Plant height

The height of plant was recorded in centimeter (cm) at 20, 40, 60, 80, 100 DAS (Days after sowing) and at harvest. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot that were tagged earlier. The height was measured from the ground level to the tip of the plant with the help of a meter scale.

3.13.1.2 Branches plant^{-1}

Total number of branches plant^{-1} was recorded at 20, 40, 60, 80 and 100 DAS and at harvest. Data were recorded by counting branches from each plant and as the average of 10 plants selected at random from the inner rows of each plot.

3.13.1.3 Dry matter content plant^{-1}

Data from ten sample plants from each plot were collected and gently washed with tap water, thereafter soaked with paper towel. The sample was oven dried at 70^0C for a period of 72 hours. Then oven-dried samples were transferred into a desiccator and allowed to cool down to room temperature, thereafter dry weight of plant was taken and expressed in gram. Dry matter content plant^{-1} was recorded at 20, 40, 60, 80 and 100 DAS and at harvest.

3.13.1.4 Crop and relative growth rate

Using the data on total dry matter from each specific treatment, Crop Growth Rate (CGR) and Relative Growth Rate (RGR) growth parameters were determined with following formulae (Hunt, 1978):

Crop Growth Rate (CGR)

Crop growth rate was calculated using the following formula:

$$CGR = \frac{1}{GA} \times \frac{W_2-W_1}{T_2-T_1} \text{ g m}^{-2}\text{day}^{-1}$$

Where,

GA = Ground area (m^2)

W_1 = Total dry weight at previous sampling date (T_1)

W_2 = Total dry weight at current sampling date (T_2)

T_1 = Date of previous sampling

T_2 = Date of current sampling

Relative Growth Rate (RGR)

Relative growth rate was calculated using the following formula:

$$RGR = \frac{LnW_2 - LnW_1}{T_2 - T_1} \quad (g\ g^{-1} day^{-1})$$

Where,

W_1 = Total dry weight at previous sampling date (time T_1)

W_2 = Total dry weight at current sampling date (time T_2)

T_1 = Date of previous sampling

T_2 = Date of current sampling

Ln = Natural logarithm

3.13.2 Yield contributing characters and yield of chickpea

3.13.2.1 Days from sowing to harvest

Days to sowing to harvest were measured by counting the number of days required to attain harvest of pods at maturity stage. Maturity was measured on the basis of brown colour of leaves and stem and dark grey colour of pods.

3.13.2.2 Pods plant^{-1}

Number of total pods of selected plants from each plot was counted and the mean numbers were expressed as plant^{-1} basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.13.2.3 Seeds pod^{-1}

Seeds pod^{-1} was recorded randomly from selected plants at the time of harvest. Data were recorded as the average of 10 pods selected at random from the inner rows of each plot.

3.13.2.4 Weight of 1000 seeds

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

3.13.2.5 Seed yield hectare^{-1}

The seeds collected from 3 m^2 (3 m×1 m) square meter area of each plot were sun dried properly. The weight of seeds was taken and converted the yield in t ha^{-1}.

3.13.2.6 Stover yield hectare^{-1}

The stover collected from 3 m^2 (3 m×1 m) square meter area of each plot was sun dried properly. The weight of stover was taken and converted the yield in t ha^{-1}.

3.13.2.7 Biological yield hectare^{-1}

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Stover yield.

3.13.2.8 Harvest index

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

$$HI (\%) = \frac{\text{Economic yield (seed weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.14 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference to the indicative performance of prilled urea and urea super granules while used in chickpea cultivation. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the indicative performance of prilled urea and urea super granules while used in chickpea cultivation. Data on different crop growth characters, yield contributing characters and yield of chickpea were recorded and found significant differences among the recorded characters. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix III-VII. The results have been discussed with the help of table and graphs and possible interpretations given under the following headings:

4.1 Crop growth characters of chickpea

4.1.1 Plant height

Plant height of chickpea showed statistically significant variation at 20, 40, 60, 80 and 100 DAS and at harvest due to the application of prilled urea and urea super granules (Appendix III). At 20 DAS, the tallest plant (14.37 cm) was observed from T_7 [USG placed at 20 cm distance (avoid two rows)] which was statistically similar (14.03 cm, 13.26 cm, 12.88 cm, 12.67 cm, 12.59 cm, 12.11 cm and 12.06 cm, respectively) with T_5 [USG placed at 10 cm distance (avoid three rows)], T_1 [Prilled urea (PU) broadcasted], T_6 [USG placed at 20 cm distance (avoid one row)], T_8 [USG placed at 20 cm distance (avoid three rows)], T_9 [USG placed at 30 cm distance (avoid one row)],T_{10} [USG placed at 30 cm distance (avoid two rows)], and T_2 [PU given between two rows], respectively. On the other hand, the shortest plant (10.35 cm) was recorded with T_{14} [USG placed at 40 cm distance (avoid three rows)] which was statistically similar (11.01 cm, 11.21 cm, 11.57 cm) with T_{12} [USG placed at 40 cm distance (avoid one row)], T_{11} [USG placed at 30 cm distance (avoid three rows)] and T_4 [USG placed at 10 cm distance (avoid two rows)], respectively (Table 1). At 40 DAS, T_7 (27.28 cm) gave the longest plant which was statistically similar with T_5 (26.76 cm), T_1 (26.35 cm), T_8 (25.58 cm), T_2 (25.56 cm), T_{10} (25.22 cm), T_9 (25.08 cm) and T_3 (24.85 cm), whereas the shortest plant was recorded from T_{14} (23.26 cm) which was similar with T_{11} (23.85 cm) and T_{12} (24.08 cm). At 60 DAS, the tallest plant was observed from T_7 (45.07 cm) which was statistically similar with T_5 (43.73 cm), T_1 (42.11 cm), T_2 (40.96 cm) and T_8 (40.02 cm), while the shortest plant was recorded from T_{14} (35.32 cm) which was similar with T_{12} (35.99 cm), T_{11} (36.25 cm) and T_4 (36.46 cm). At 80 DAS, the highest tallest plant was observed from T_7 (52.52 cm) which was statistically similar with T_5 (51.00 cm), T_1 (50.08 cm), T_2 (47.47 cm) and T_{10} (47.00 cm), whereas the shortest plant was recorded from T_{14} (41.52 cm) which was similar with T_{12} (42.59), T_{11} (42.85 cm), T_4 (43.29 cm) and T_3 (44.05 cm). At 100 DAS, T_7 (58.76 cm) gave the tallest plant which was statistically similar with T_5 (57.45 cm), T_1 (57.33 cm) and T_{10} (53.88 cm), while the shortest plant was found from T_{14} (47.40 cm) which was similar with T_4 (48.35 cm), T_{11} (48.47 cm), T_{12} (48.63 cm), T_3 (49.79 cm) and T_{13} (50.72 cm). At harvest, the highest longest plant was found from T_7 (61.23 cm) which was statistically similar with T_5 (59.87 cm), T_1 (59.74 cm), T_8 (55.87 cm), T_{10} (55.86 cm), T_2 (55.22 cm) and T_6 (55.10 cm), whereas the shortest plant was recorded from T_{14} (49.27 cm) which was similar with T_4 (50.37), T_{11} (50.49 cm), T_{12} (50.53 cm) and T_3 (51.91 cm). Among the different treatments T_7 was found very effective to had maximum taller plants as plants were able to uptake nitrogen efficiently from placed urea but not replacing prilled urea 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. Aliloo *et al*. (2012) reported that that the effect of urea treatment on plant height was notable the highest plant height was obtained by application of 20 kg ha^{-1} urea in soil. Humphreys *et al.* (2006) reported that recovery of nitrogen from point placement of urea of super granule was 49% higher than prilled urea. The increase in plant nitrogen recovery consequently increases plant height. Talukder *et al.* (2004), Rao *et al.* (2004), Saikia *et al.* (2002), Alam *et al.* (2000), Haque (1998) and many other researchers recorded similar results in different crops from their earlier experiment.

Table 1. Effect of application of prilled urea and urea super granules on plant height of chickpea

Treatment	Plant height (cm) at					
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	Harvest
T_1	13.26 a-c	26.35 a-c	42.11 a-c	50.08 a-c	57.33 ab	59.74 ab
T_2	12.06 a-d	25.56 a-d	40.96 a-d	47.47 a-d	52.96 b-d	55.22 a-c
T_3	11.83 b-d	24.85 a-d	37.73 c-e	44.05 de	49.79 cd	51.91 c
T_4	11.57 cd	24.26 b-d	36.46 de	43.29 de	48.35 cd	50.37 c
T_5	14.03 ab	26.76 ab	43.73 ab	51.00 ab	57.45 ab	59.87 ab
T_6	12.88 a-c	25.71 a-d	39.54 b-e	46.65 b-e	52.88 b-d	55.10 a-c
T_7	14.37 a	27.28 a	45.07 a	52.52 a	58.76 a	61.23 a
T_8	12.67 a-d	25.58 a-d	40.02 a-e	46.64 b-e	52.72 b-d	55.87 a-c
T_9	12.59 a-d	25.08 a-d	38.37 b-e	45.97 b-e	52.79 b-d	54.97 a-c
T_{10}	12.11 a-d	25.22 a-d	39.11 b-e	47.00 a-e	53.88 a-c	55.86 a-c
T_{11}	11.21 cd	23.85 cd	36.25 de	42.85 de	48.47 cd	50.49 c
T_{12}	11.01 cd	24.08 cd	35.99 de	42.59 de	48.63 cd	50.53 c
T_{13}	11.77 b-d	24.67 b-d	37.89 c-e	44.70 c-e	50.72 cd	53.47 bc
T_{14}	10.35 d	23.26 d	35.32 e	41.52 e	47.40 d	49.27 c
$S\bar{x}$	0.723	0.755	1.655	1.715	1.786	1.954
Significance level	0.05	0.05	0.01	0.01	0.01	0.01
CV(%)	10.21	5.19	7.32	6.44	5.92	6.20

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Prilled urea (PU) broadcasted
T_2 = PU given between two rows
T_3 = USG placed at 10 cm distance (avoid one row)
T_4 = USG placed at 10 cm distance (avoid two rows)
T_5 = USG placed at 10 cm distance (avoid three rows)
T_6 = USG placed at 20 cm distance (avoid one row)
T_7 = USG placed at 20 cm distance (avoid two rows)
T_8 = USG placed at 20 cm distance (avoid three rows)
T_9 = USG placed at 30 cm distance (avoid one row)
T_{10} = USG placed at 30 cm distance (avoid two rows)
T_{11} = USG placed at 30 cm distance (avoid three rows)
T_{12} = USG placed at 40 cm distance (avoid one row)
T_{13} = USG placed at 40 cm distance (avoid two rows)
T_{14} = USG placed at 40 cm distance (avoid three rows)

USG placed at 10 cm depth of each case

4.1.2 Branches plant^{-1}

Statistically significant variation was recorded for the application of prilled urea and urea super granules in terms of branches plant^{-1} of chickpea at 20, 40, 60, 80 and 100 DAS and at harvest (Appendix IV). Data from Table 2 revealed that at 20 DAS, the maximum number of branches plant^{-1} was recorded from T_7 (2.17) which was statistically similar with T_5 (2.07) and T_1 (2.03), while the minimum number from T_{14} (1.77) which was similar with T_{12} (1.80), T_3 (1.83), T_4 (1.83), T_{11} (1.83), T_9 (1.87), T_{13} (1.87), T_6 (1.90) and T_{10} (1.90). At 40 DAS, the maximum number branches plant^{-1} was found from T_7 (4.90), which was statistically similar with T_5 (4.53) and followed by T_1 (4.33), whereas the minimum number was recorded from T_{14} (3.83) which was similar with T_4 (3.90), T_{11} (3.90), T_{12} (3.90), T_3 (3.97), T_{13} (4.00), T_6 (4.07), T_9 (4.07) and T_{10} (4.07). At 60 DAS, the maximum number branches plant^{-1} was observed from T_7 (9.00) which was statistically similar with T_5 (8.83) and T_1 (8.63), while the minimum number from T_{14} (7.37) which was statistically similar with T_{12} (7.50), T_{11} (7.53), T_3 (7.60), T_4 (7.63), T_2 (7.73) and T_{13} (7.80). At 80 DAS, the maximum number branches plant^{-1} was observed from T_7 (14.23), which was similar with T_5 (14.03) and T_1 (13.97), while the minimum number of branches plant^{-1} was recorded from T_{14} (10.23) which was statistically similar with T_{12} (11.00), T_2 (11.47), T_{11} (11.53), T_3 (11.63) and T_{13} (11.73). At 100 DAS, the maximum number branches plant^{-1} was found from T_7 (17.67), which was similar with T_5 (17.33) and T_1 (16.63), whereas the minimum number from T_{14} (13.20), which was statistically similar with T_{12} (13.17), T_{13} (13.77), T_3 (14.27), T_4 (14.63) and T_{10} (14.97). At harvest, the maximum number branches plant^{-1} was found from T_7 (18.50) which was similar with T_5 (18.27), T_1 (17.93), T_{10} (17.93) and T_8 (17.43), again the minimum number from T_{14} (14.20) which was statistically similar with T_{12} (14.40), T_{13} (14.67), T_{11} (14.67), T_6 (15.17) and T_{10} (15.40). T_7 was found influential for higher numbers of branches plants^{-1} with uptake nitrogen efficiently from placed urea as prilled and urea super granules. Chaudhari *et al.* (1998) found a positive effect of nitrogen @ 20 and 40 kg ha^{-1} on increased number of primary and secondary branches plant^{-1}.

Table 2. Effect of application of prilled urea and urea super granules on branches plant^{-1} of chickpea

Treatment	Number of branches plant^{-1} at					
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	Harvest
T_1	2.03 a-c	4.33 bc	8.63 a-c	13.97 ab	16.63 a-c	17.93 ab
T_2	1.97 a-d	4.20 b-d	7.73 cd	11.47 c-e	13.83 de	16.00 a-d
T_3	1.83 b-d	3.97 cd	7.60 d	11.63 c-e	14.27 c-e	16.57 a-d
T_4	1.83 b-d	3.90 cd	7.63 d	12.43 a-e	14.63 c-e	15.97 a-d
T_5	2.07 ab	4.53 ab	8.83 ab	14.03 a	17.33 ab	18.27 a
T_6	1.90 b-d	4.07 cd	7.97 b-d	13.43 a-c	14.53 c-e	15.17 cd
T_7	2.17 a	4.90 a	9.00 a	14.23 a	17.67 a	18.50 a
T_8	1.93 a-d	4.10 b-d	8.03 b-d	13.07 a-d	15.90 a-d	17.43 a-c
T_9	1.87 b-d	4.07 cd	8.17 a-d	12.60 a-d	15.90 a-d	17.93 ab
T_{10}	1.90 b-d	4.07 cd	7.97 b-d	12.07 a-e	14.97 b-e	15.40 b-d
T_{11}	1.83 b-d	3.90 cd	7.53 d	11.53 c-e	14.07 de	14.67 d
T_{12}	1.80 d	3.90 cd	7.50 d	11.00 de	13.17 e	14.40 d
T_{13}	1.87 b-d	4.00 cd	7.80 cd	11.73 b-e	13.77 de	14.67 d
T_{14}	1.77 d	3.83 d	7.37 d	10.23 e	13.20 e	14.20 d
$S\bar{x}$	0.073	0.143	0.283	0.682	0.744	0.772
Significance level	0.05	0.01	0.01	0.01	0.01	0.01
CV(%)	6.66	5.98	6.15	9.53	8.59	8.24

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Prilled urea (PU) broadcasted
T_2 = PU given between two rows
T_3 = USG placed at 10 cm distance (avoid one row)
T_4 = USG placed at 10 cm distance (avoid two rows)
T_5 = USG placed at 10 cm distance (avoid three rows)
T_6 = USG placed at 20 cm distance (avoid one row)
T_7 = USG placed at 20 cm distance (avoid two rows)
T_8 = USG placed at 20 cm distance (avoid three rows)
T_9 = USG placed at 30 cm distance (avoid one row)
T_{10} = USG placed at 30 cm distance (avoid two rows)
T_{11} = USG placed at 30 cm distance (avoid three rows)
T_{12} = USG placed at 40 cm distance (avoid one row)
T_{13} = USG placed at 40 cm distance (avoid two rows)
T_{14} = USG placed at 40 cm distance (avoid three rows)

USG placed at 10 cm depth of each case

4.1.3 Dry matter content plant^{-1}

Application of prilled urea and urea super granules varied significantly at 20, 40, 60, 80 and 100 DAS and at harvest for dry matter content plant^{-1} of chickpea (Appendix V). At 20 DAS, the highest dry matter content plant^{-1} was recorded from T_7 (3.82 g), which was statistically similar to T_5 (3.72 g), T_1 (3.48 g), T_2 (3.25 g) and T_9 (3.22 g), whereas the lowest dry matter content plant^{-1} was observed from T_{14} (2.44 g), which was statistically similar to T_{12} (2.53 g), T_{11} (2.66 g), T_4 (2.71 g), T_3 (2.72 g), T_6 (2.83 g) and T_{13} (2.88 g) treatment (Table 3). At 40 DAS, the highest dry matter content plant^{-1} was recorded from T_7 (6.98 g), which was statistically similar to T_5 (6.73 g), T_1 (6.21 g) and T_6 (6.09 g), while the lowest dry matter content plant^{-1} was observed from T_{14} (4.27 g) which was statistically similar with T_{12} (4.82 g), T_{11} (4.85 g), T_3 (4.91 g), T_2 (5.15 g), T_{13} (5.21 g) and T_4 (5.23 g). At 60 DAS, the highest dry matter content plant^{-1} was recorded from T_7 (9.09 g) which was statistically similar with T_5 (8.69 g), T_1 (8.21 g), T_8 (7.84 g), T_3 (7.79 g) and T_2 (7.57 g), while the lowest dry matter content plant^{-1} was observed from T_{14} (5.72 g) which was statistically similar with T_{12} (6.44 g), T_{11} (6.69 g), T_{13} (6.95 g) and T_4 (7.21 g). At 80 DAS, the highest dry matter content plant^{-1} was recorded from T_7 (12.05 g) which was statistically similar with T_5 (11.67 g) and T_9 (11.30 g), while the lowest dry matter content plant^{-1} was observed from T_{14} (10.17 g) which was statistically similar with T_{11} (10.32 g), T_8 (10.33 g), T_{13} (10.34 g) and T_{12} (10.35 g). At 100 DAS, the highest dry matter content plant^{-1} was recorded from T_7 (14.62 g) which was statistically similar with T_5 (13.98 g), T_1 (13.65 g) and T_6 (13.46 g), while the lowest dry matter content plant^{-1} was observed from T_{14} (11.59 g) which was statistically similar with T_{12} (12.09 g), T_4 (12.31 g), T_{13} (12.46 g) and T_{11} (12.69 g). At harvest, the highest dry matter content plant^{-1} was recorded from T_7 (17.34 g) which was statistically similar with T_5 (16.81 g) and T_1 (15.55 g), while the lowest dry matter content plant^{-1} was observed from T_{14} (13.26 g) which was statistically similar with T_{12} (13.14 g). Chaudhari *et al.* (1998) found a positive effect of nitrogen at the rate of 20 and 40 kg ha^{-1} on increased in chickpea dry matter content plant^{-1}.

Table 3. Effect of application of prilled urea and urea super granules on dry matter content plant^{-1} of chickpea

Treatment	Dry matter content plant^{-1} (g)					
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	Harvest
T_1	3.48 ab	6.21 ab	8.12 a-c	11.00 b-d	13.65 a-c	15.55 ab
T_2	3.25 a-c	5.15 b-d	7.57 a-d	10.50 cd	12.93 a-d	13.93 bc
T_3	2.72 cd	4.91 cd	7.79 a-d	10.54 cd	12.90 a-d	14.47 bc
T_4	2.71 cd	5.23 b-d	7.21 b-e	10.49 cd	12.31 b-d	14.22 bc
T_5	3.72 a	6.73 a	8.69 ab	11.67 ab	13.98 ab	16.81 a
T_6	2.83 b-d	6.09 ab	7.94 a-d	10.53 cd	13.46 a-c	14.69 bc
T_7	3.82 a	6.98 a	9.09 a	12.05 a	14.62 a	17.34 a
T_8	3.17 a-d	5.66 bc	7.84 a-d	10.33 d	13.10 a-d	14.47 bc
T_9	3.22 a-c	5.58 bc	7.31 b-d	11.30 a-c	13.31 a-d	14.28 bc
T_{10}	3.13 a-d	5.55 bc	7.15 b-e	10.50 cd	13.08 a-d	14.63 bc
T_{11}	2.66 cd	4.85 cd	6.69 c-e	10.32 d	12.69 b-d	14.02 bc
T_{12}	2.53 cd	4.82 cd	6.44 de	10.35 d	12.09 cd	13.14 c
T_{13}	2.88 b-d	5.21 b-d	6.95 c-e	10.34 d	12.46 b-d	13.69 bc
T_{14}	2.44 d	4.27 d	5.72 e	10.17 d	11.59 d	13.26 c
$S\bar{x}$	0.218	0.324	0.478	0.263	0.524	0.667
Significance level	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	12.40	10.17	11.07	4.25	6.97	7.91

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Prilled urea (PU) broadcasted
T_2 = PU given between two rows
T_3 = USG placed at 10 cm distance (avoid one row)
T_4 = USG placed at 10 cm distance (avoid two rows)
T_5 = USG placed at 10 cm distance (avoid three rows)
T_6 = USG placed at 20 cm distance (avoid one row)
T_7 = USG placed at 20 cm distance (avoid two rows)
T_8 = USG placed at 20 cm distance (avoid three rows)
T_9 = USG placed at 30 cm distance (avoid one row)
T_{10} = USG placed at 30 cm distance (avoid two rows)
T_{11} = USG placed at 30 cm distance (avoid three rows)
T_{12} = USG placed at 40 cm distance (avoid one row)
T_{13} = USG placed at 40 cm distance (avoid two rows)
T_{14} = USG placed at 40 cm distance (avoid three rows)

USG placed at 10 cm depth of each case

4.1.4 Crop growth rate

Crop growth rate (CGR) of chickpea showed significant variation at 20-40 DAS, 40-60 DAS, 60-80 DAS and 80-100 DAS for the application of prilled urea and urea super granules (Appendix VI). At 20-40 DAS, the highest CGR was attained from T_6 (20.41 g $m^{-2}day^{-1}$), which was similar with T_7 (19.74 g $m^{-2}day^{-1}$), T_5 (18.77 g $m^{-2}day^{-1}$) and T_1 (17.06 g $m^{-2}day^{-1}$), while the lowest CGR was found from T_5 (11.43 g $m^{-2}day^{-1}$) which was similar to T_2 (11.87 g $m^{-2}day^{-1}$), T_3 (13.65 g $m^{-2}day^{-1}$), T_{11} (13.67 g $m^{-2}day^{-1}$), T_{12} (14.35 g $m^{-2}day^{-1}$) and T_{13} (14.58 g $m^{-2}day^{-1}$) (Table 4). At 40-60 DAS, the highest CGR was attained from T_3 (17.99 g m^{-2} day^{-1}) which was similar with T_2 (15.16 g $m^{-2}day^{-1}$), whereas the lowest CGR was found from T_5 (9.06 g $m^{-2}day^{-1}$), which was similar with T_{10} (10.02 g $m^{-2}day^{-1}$) and T_{12} (10.10 g $m^{-2}day^{-1}$). At 60-80 DAS, the highest CGR was attained from T_{14} (28.75 g $m^{-2}day^{-1}$), which was similar with T_9 (24.91 g $m^{-2}day^{-1}$) and T_{12} (24.46 g $m^{-2}day^{-1}$), while the lowest from T_8 (15.54 g $m^{-2}day^{-1}$), which was similar with T_6 (16.14 g $m^{-2}day^{-1}$) and T_3 (17.24 g $m^{-2}day^{-1}$). At 80-100 DAS, the highest CGR was attained from T_6 (18.33 g $m^{-2}day^{-1}$), which was similar with T_8 (17.38 g $m^{-2}day^{-1}$), while the lowest CGR was observed from T_{14} (7.94 g $m^{-2}day^{-1}$), which was similar to T_{12} (10.85 g $m^{-2}day^{-1}$) and T_4 (11.38 g $m^{-2}day^{-1}$).

4.1.5 Relative growth rate

Statistically significant variation was recorded for relative growth rate (RGR) of chickpea at 20-40 DAS, 40-60 DAS, 60-80 DAS and 80-100 DAS for the application of prilled urea and urea super granules (Appendix VI). At 20-40 DAS, the highest RGR was found from T_6 (0.078 g g^{-1} day^{-1}), which was statistically similar with T_4 (0.067 g g^{-1} day^{-1}), whereas the lowest RGR was found from T_2 (0.045 g g^{-1} day^{-1}) (Table 5). At 40-60 DAS, the highest RGR was found from T_3 (0.047 g g^{-1} day^{-1}), whereas the lowest RGR was recorded from T_{10} (0.025 g g^{-1} day^{-1}). At 60-80 DAS, the highest RGR was found from T_{14} (0.060 g g^{-1} day^{-1}), whereas the lowest RGR was found from T_8 (0.027 g g^{-1} day^{-1}). At 80-100 DAS, the highest RGR was found from T_6 (0.025 g g^{-1} day^{-1}), while the lowest RGR was found from T_{14} (0.012 g g^{-1} day^{-1}).

Table 4. Effect of application of prilled urea and urea super granules on crop growth rate of chickpea

Treatment	Crop Growth Rate (g $m^{-2} day^{-1}$)			
	20-40 DAS	40-60 DAS	60-80 DAS	80-100 DAS
T_1	17.06 a-c	11.91 bc	18.00 bc	16.55 ab
T_2	11.87 d	15.16 ab	18.31 bc	15.18 ab
T_3	13.65 cd	17.99 a	17.24 c	14.74 ab
T_4	15.74 a-d	12.37 bc	20.48 bc	11.38 bc
T_5	18.77 a-c	12.29 bc	18.58 bc	14.44 ab
T_6	20.41 a	11.58 bc	16.14 c	18.33 a
T_7	19.74 ab	13.21 bc	18.53 bc	16.03 ab
T_8	15.62 a-d	13.58 bc	15.54 c	17.38 a
T_9	14.73 b-d	10.84 bc	24.91 ab	12.56 a-c
T_{10}	15.13 b-d	10.02 c	20.90 bc	16.14 ab
T_{11}	13.67 cd	11.51 bc	21.73 bc	15.76 ab
T_{12}	14.35 cd	10.10 c	24.46 ab	10.85 bc
T_{13}	14.58 cd	10.91 bc	21.15 bc	13.27 a-c
T_{14}	11.43 d	9.06 c	28.75 a	7.94 c
$S\bar{x}$	1.529	1.388	2.118	1.728
Significance level	0.01	0.01	0.01	0.05
CV(%)	17.10	19.73	18.04	20.89

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Prilled urea (PU) broadcasted
T_2 = PU given between two rows
T_3 = USG placed at 10 cm distance (avoid one row)
T_4 = USG placed at 10 cm distance (avoid two rows)
T_5 = USG placed at 10 cm distance (avoid three rows)
T_6 = USG placed at 20 cm distance (avoid one row)
T_7 = USG placed at 20 cm distance (avoid two rows)
T_8 = USG placed at 20 cm distance (avoid three rows)
T_9 = USG placed at 30 cm distance (avoid one row)
T_{10} = USG placed at 30 cm distance (avoid two rows)
T_{11} = USG placed at 30 cm distance (avoid three rows)
T_{12} = USG placed at 40 cm distance (avoid one row)
T_{13} = USG placed at 40 cm distance (avoid two rows)
T_{14} = USG placed at 40 cm distance (avoid three rows)

USG placed at 10 cm depth of each case

Table 5. Effect of application of prilled urea and urea super granules on relative growth rate of chickpea

Treatment	Relative growth rate (g g^{-1} day^{-1})			
	20-40 DAS	40-60 DAS	60-80 DAS	80-100 DAS
T_1	0.058 bc	0.027 b	0.030 bc	0.022 a-c
T_2	0.045 c	0.039 ab	0.033 bc	0.021 a-d
T_3	0.058 bc	0.047 a	0.030 bc	0.020 a-d
T_4	0.067 ab	0.032 ab	0.038 bc	0.016 c-e
T_5	0.059 bc	0.026 b	0.029 bc	0.018 b-d
T_6	0.078 a	0.026 b	0.028 c	0.025 a
T_7	0.060 a-c	0.027 b	0.028 c	0.019 a-d
T_8	0.058 bc	0.033 ab	0.027 c	0.024 ab
T_9	0.054 bc	0.026 b	0.046 a-c	0.016 c-e
T_{10}	0.057 bc	0.025 b	0.038 bc	0.022 a-c
T_{11}	0.061 a-c	0.032 ab	0.042 a-c	0.022 a-c
T_{12}	0.065 a-c	0.029 ab	0.048 ab	0.015 de
T_{13}	0.060 a-c	0.029 ab	0.040 bc	0.019 a-d
T_{14}	0.057 bc	0.029 ab	0.060 a	0.012 e
$S\bar{x}$	0.006	0.006	0.006	0.002
Significance level	0.01	0.01	0.05	0.01
CV(%)	12.68	18.43	19.39	17.76

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Prilled urea (PU) broadcasted
T_2 = PU given between two rows
T_3 = USG placed at 10 cm distance (avoid one row)
T_4 = USG placed at 10 cm distance (avoid two rows)
T_5 = USG placed at 10 cm distance (avoid three rows)
T_6 = USG placed at 20 cm distance (avoid one row)
T_7 = USG placed at 20 cm distance (avoid two rows)
T_8 = USG placed at 20 cm distance (avoid three rows)
T_9 = USG placed at 30 cm distance (avoid one row)
T_{10} = USG placed at 30 cm distance (avoid two rows)
T_{11} = USG placed at 30 cm distance (avoid three rows)
T_{12} = USG placed at 40 cm distance (avoid one row)
T_{13} = USG placed at 40 cm distance (avoid two rows)
T_{14} = USG placed at 40 cm distance (avoid three rows)

USG placed at 10 cm depth of each case

4.2 Yield contributing characters and yield of chickpea

4.2.1 Days from sowing to harvest

Days from sowing to harvest of chickpea showed statistically significant variation for the application of prilled urea and urea super granules (Appendix VII). The minimum days from sowing to harvest was recorded from T_7 (122.33 days) which was statistically similar with T_5 (123.67 days), T_1 (125.67 days) and T_6 (126.33 days), while the maximum days from sowing to harvest was found from T_{14} (135.33 days) which was similar with T_{13} (134.67 days), T_8 (134.00 days), T_9 (132.67 days), T_{11} (132.00 days) and T_2 (131.67 days) (Figure 2). Data revealed that T_7 matured by 13.00% days earlier than T_{14}.

4.2.2 Pods plant^{-1}

Statistically significant variation was recorded in terms of number of pods plant^{-1} of chickpea due to the application of prilled urea and urea super granules (Appendix VII). The highest number of pods plant^{-1} was recorded from T_7 (68.60) which was similar with T_5 (67.40), T_1 (66.20) and T_3 (62.80), while the lowest number was observed from T_{14} (53.27) which was similar with T_{12} (54.10), T_8 (55.33), T_{11} (55.47), T_{13} (56.50), T_4 (57.47) and T_6 (57.97) (Table 6). Data revealed that T_7 produced 28.78% more pods over T_{14}. Application of prilled urea and urea super granules supported plant with maximum dry matter which eventually produced maximum number of pods plant^{-1}. Abbasi *et al.* (2013) reported that number of pod plant^{-1} were significantly affected by nitrogen rates number of pod plant^{-1} (32.48) was obtained in the higher nitrogen rates.

4.2.3 Seeds pod^{-1}

Application of prilled urea and urea super granules showed statistically significant variation for number of seeds pods^{-1} of chickpea (Appendix VII). The highest number of seeds pods^{-1} was recorded from T_7 (2.87) which was statistically similar with T_5 (2.73), T_1 (2.53) and T_9 (2.40), while the lowest number from T_{14} (1.77) which was similar with T_4 (1.80) (Table 6). Patra and Padhi (1989) noticed in chickpea increased number of seeds pod^{-1} over control with 20 kg N ha^{-1}.

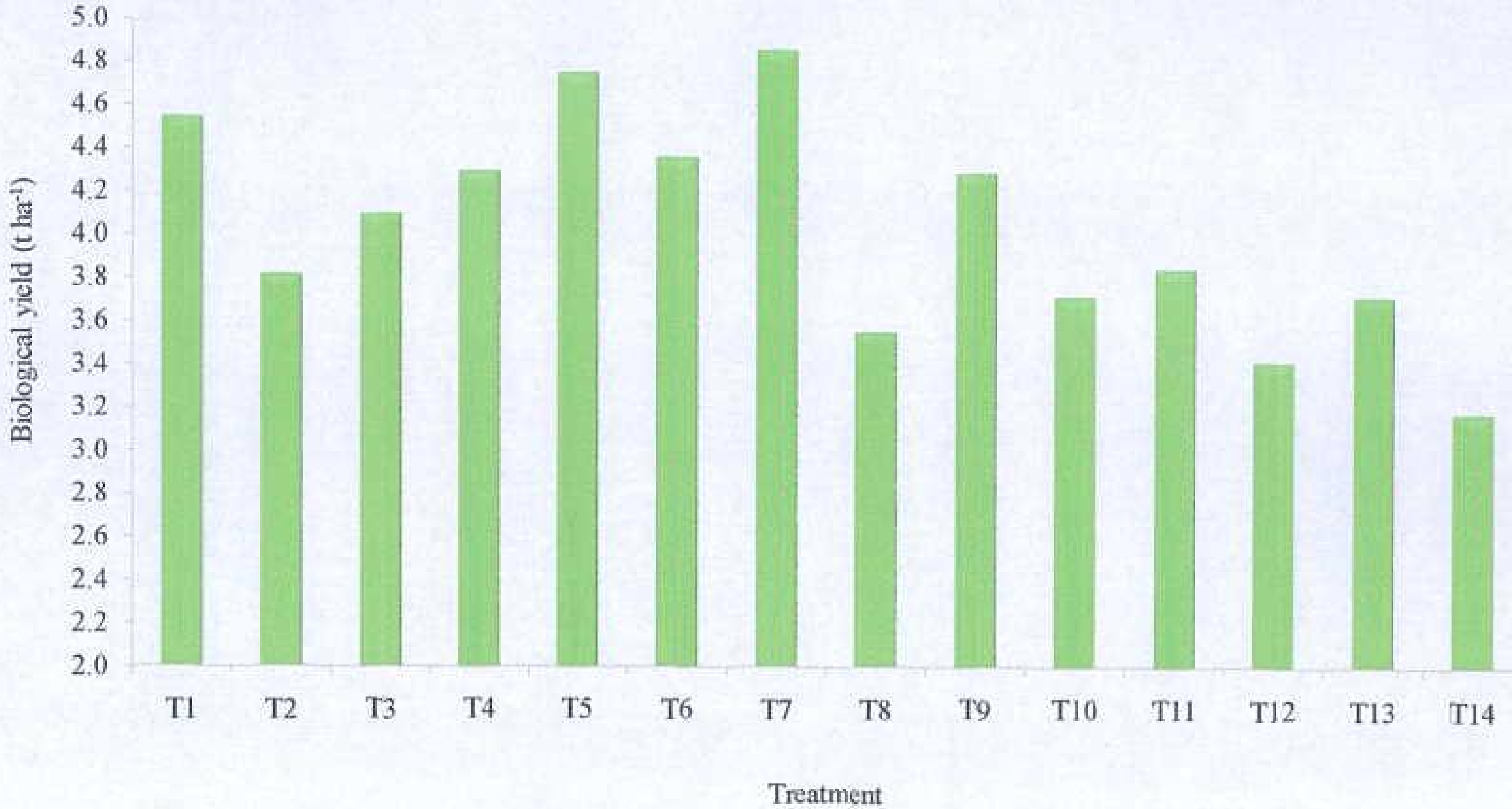


Figure 4. Effect of application of prilled urea and urea super granules on biological yield of chickpea (Sx = 0.268)

Table 6. Effect of application of prilled urea and urea super granules on yield contributing characters and yield of chickpea

Treatment	Pods $plant^{-1}$	Seeds pod^{-1}	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Harvest index (%)
T_1	66.20 ab	2.53 ab	1.78 ab	2.76 a-c	39.15
T_2	59.00 b-d	2.07 bc	1.50 b-d	2.31 b-f	39.41
T_3	62.80 a-c	2.13 bc	1.62 a-d	2.47 a-e	39.40
T_4	57.47 cd	1.80 c	1.62 a-d	2.67 a-d	37.68
T_5	67.40 a	2.73 a	1.92 a	2.82 ab	40.43
T_6	57.97 cd	1.97 bc	1.75 ab	2.60 a-e	40.22
T_7	68.60 a	2.87 a	1.98 a	2.87 a	40.71
T_8	55.33 cd	2.10 bc	1.42 b-d	2.11 d-f	40.22
T_9	59.20 b-d	2.40 ab	1.68 a-c	2.60 a-e	39.49
T_{10}	60.17 b-d	2.17 bc	1.47 b-d	2.24 c-f	39.72
T_{11}	55.47 cd	1.97 bc	1.52 b-d	2.32 b-f	39.63
T_{12}	54.10 d	2.03 bc	1.35 cd	2.05 ef	39.78
T_{13}	56.50 cd	2.03 bc	1.44 b-d	2.27 b-f	38.80
T_{14}	53.27 d	1.77 c	1.27 d	1.90 f	40.13
$S\bar{x}$	2.272	0.175	0.113	0.165	0.925
Significance level	0.01	0.01	0.01	0.01	NS
CV(%)	6.61	13.87	12.24	11.79	4.04

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Prilled urea (PU) broadcasted
T_2 = PU given between two rows
T_3 = USG placed at 10 cm distance (avoid one row)
T_4 = USG placed at 10 cm distance (avoid two rows)
T_5 = USG placed at 10 cm distance (avoid three rows)
T_6 = USG placed at 20 cm distance (avoid one row)
T_7 = USG placed at 20 cm distance (avoid two rows)
T_8 = USG placed at 20 cm distance (avoid three rows)
T_9 = USG placed at 30 cm distance (avoid one row)
T_{10} = USG placed at 30 cm distance (avoid two rows)
T_{11} = USG placed at 30 cm distance (avoid three rows)
T_{12} = USG placed at 40 cm distance (avoid one row)
T_{13} = USG placed at 40 cm distance (avoid two rows)
T_{14} = USG placed at 40 cm distance (avoid three rows)

USG placed at 10 cm depth of each case

4.2.4 Weight of 1000 seeds

Weight of 1000 seeds showed statistically significant variation due to the application of prilled urea and urea super granules (Appendix VII). The maximum weight of 1000 seeds was found from T_7 (221.81 g) which was statistically similar with T_5 (217.22 g), T_1 (215.22 g), T_{13} (212.34 g) and T_8 (211.58 g), while the lowest weight of 1000 seeds was recorded from T_{14} (188.79 g) which was similar with T_4 (190.70 g), T_{11} (193.36 g) and T_{12} (194.10 g) (Figure 3). Data revealed that T_7 produced 17.5% more weight of 1000 seeds over T_{14}. Akter (2010) reported that 1000 seeds weight was highest when USG was applied as basal dose and lowest when USG was applied at 25 DAS in mustard. Vadavia *et al.* (1991) found that seed weight increased following application of 20 kg N ha^{-1} and 40 kg P ha^{-1} of chickpea.

4.2.5 Seed yield hectare^{-1}

Statistically significant variation was recorded for seed yield hectare^{-1} of chickpea due to the application of prilled urea and urea super granules (Appendix VII). The highest seed yield was recorded from T_7 (1.98 t ha^{-1}) which was statistically similar with T_5 (1.92 t ha^{-1}), T_1 (1.78 t ha^{-1}), T_6 (1.75 t ha^{-1}) and T_9 (1.68 t ha^{-1}), while the lowest seed yield was observed from T_{14} (1.27 t ha^{-1}), which was similar with T_{12} (1.35 t ha^{-1}) (Table 6). Data revealed that T_7 produced 55.90% more stover yield over T_{14}. The maximum yield was harvested due to maximum pods plant^{-1}, seed pods^{-1}, which had greater number of seeds and highest 1000 grains weight. Nadeem *et al.* (2004) reported that the application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied. Patel *et al.* (1984) reported that application of nitrogenous fertilizers becomes helpful in increasing the yield. Bali *et al.* (1991) reported that an adequate supply of nitrogen is essential for vegetative growth and desirable yield of pulse crop. The placement of USG at 8-10 cm depth of soil can save 30% nitrogen than prilled urea, increases nutrient absorption, improves soil health and ultimately increases the crop yields (Singh *et al.*, 1993; Singh and Singh, 1986).

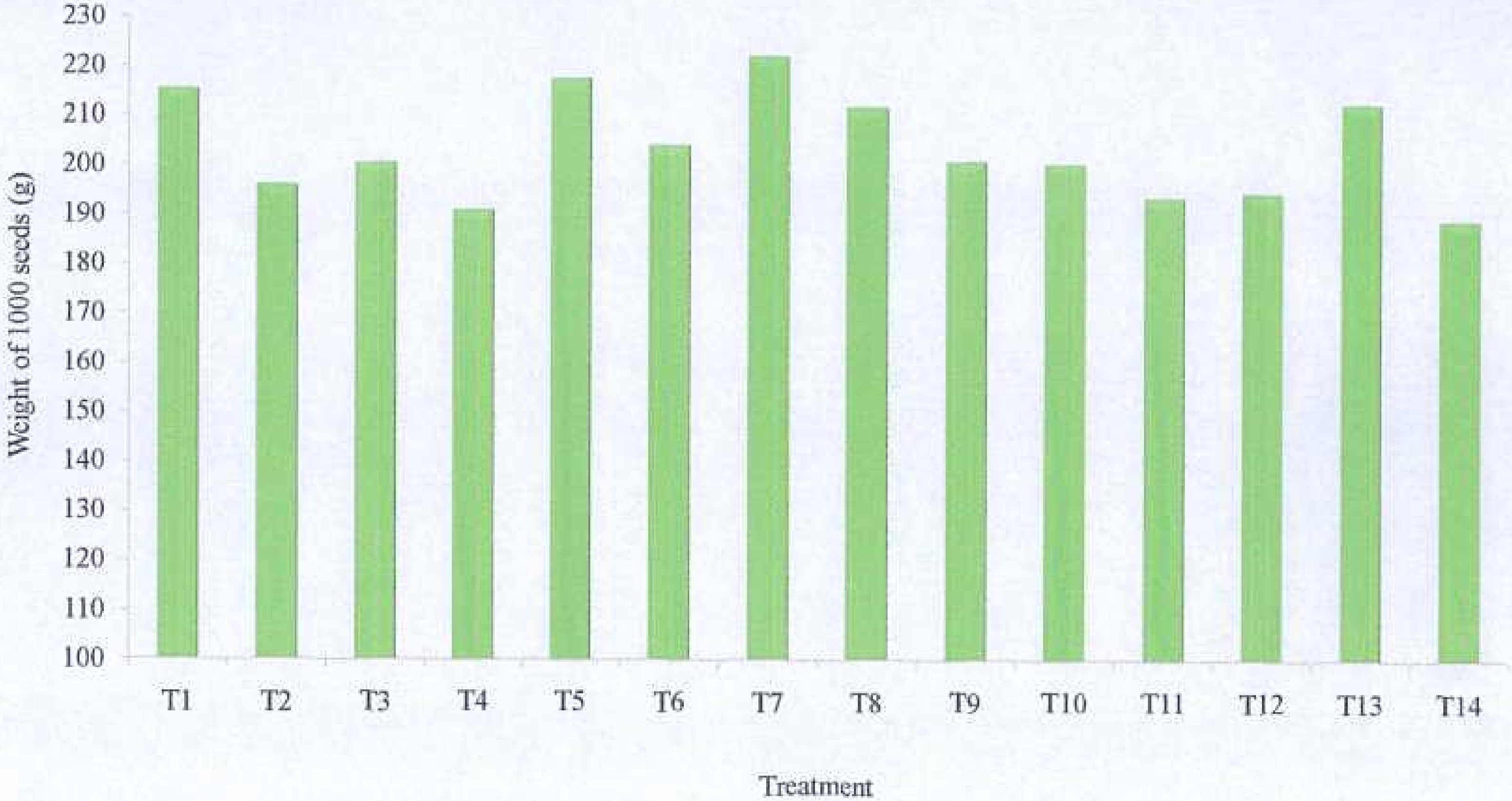


Figure 3. Effect of application of prilled urea and urea super granules on weight of 1000 seeds of chickpea (Sx = 2.625)

4.2.6 Stover yield hectare^{-1}

Stover yield hectare^{-1} of chickpea varied significantly due to the application of prilled urea and urea super granules (Appendix VII). The highest stover yield was recorded from T_7 (2.87 t ha^{-1}), which was statistically similar with T_5 (2.82 t ha^{-1}), T_1 (2.76 t ha^{-1}), T_6 (2.60 t ha^{-1}), T_9 (2.60 t ha^{-1}) and T_3 (2.47 t ha^{-1}). On the other hand, the lowest stover yield was observed from T_{14} (1.90 t ha^{-1}), which was similar with T_{12} (2.05 t ha^{-1}) (Table 6). Data revealed that T_7 produced 51.05% more seed yield over T_{14}. Srinivas *et al.* (2002) observed that stover yield increased with increasing rates of N up to 40 kg ha^{-1}.

4.2.7 Biological yield hectare^{-1}

Application of prilled urea and urea super granules showed statistically significant variation for biological yield hectare^{-1} of chickpea (Appendix VII). The highest biological yield was found from T_7 (4.85 t ha^{-1}), which was statistically similar with T_5 (4.74 t ha^{-1}), T_1 (4.54 t ha^{-1}), T_6 (4.35 t ha^{-1}), T_4 (4.29 t ha^{-1}), T_9 (4.28 t ha^{-1}) and T_3 (4.09 t ha^{-1}), whereas the lowest biological yield was observed from T_{14} (3.17 t ha^{-1}) which was similar with T_{12} (3.41 t ha^{-1}) (Figure 4). Data revealed that T_7 produced 53.0% more biological yield over T_{14}. Srinivas *et al.* (2002) observed that stover yield increased with increasing rates of N up to 40 kg ha^{-1}. Vadavia *et al.* (1991) found that application of 20 kg ha^{-1} N and 40 P ha^{-1} increased significant straw yield of chickpea.

4.2.8 Harvest index

Statistically non-significant variation was recorded for harvest index due to the application of prilled urea and urea super granules (Appendix VII). Table 6 revealed that the highest harvest index was recorded from T_7 (40.71%), while the lowest harvest index was attained from T_4 (37.68%). Chaudhari *et al.* (1998) found that application of 20-40 kg N ha^{-1} significantly influenced harvest index of chickpea.

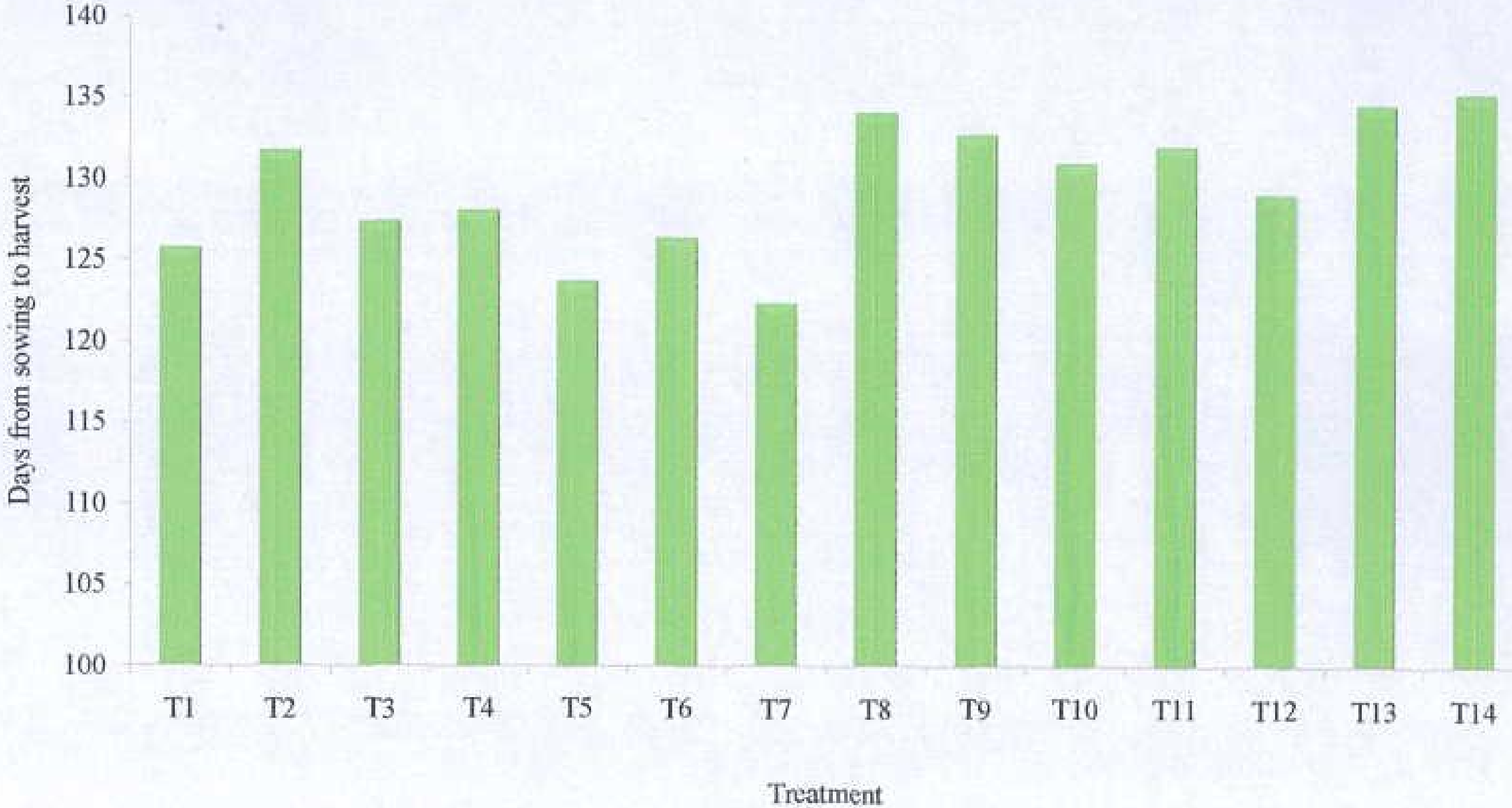


Figure 2. Effect of application of prilled urea and urea super granules on days from sowing to harvest of chickpea (Sx = 2.272)

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from November, 2012 to March, 2013 to study the performance of prilled urea and urea super granules in chickpea cultivation. The variety BARI Chola 9 was used as test crop. The experiment consists of the following treatments: T_1= Prilled urea (PU) broadcasted; T_2 = PU given between two rows; T_3 = USG placed at 10 cm distance (avoid one row); T_4 = USG placed at 10 cm distance (avoid two rows); T_5 = USG placed at 10 cm distance (avoid three rows); T_6 = USG placed at 20 cm distance (avoid one row); T_7 = USG placed at 20 cm distance (avoid two rows); T_8 = USG placed at 20 cm distance (avoid three rows); T_9= USG placed at 30 cm distance (avoid one row); T_{10} = USG placed at 30 cm distance (avoid two rows); T_{11} = USG placed at 30 cm distance (avoid three rows); T_{12} = USG placed at 40 cm distance (avoid one row); T_{13} = USG placed at 40 cm distance (avoid two rows) and T_{14} = USG placed at 40 cm distance (avoid three rows). USG placed at 10 cm depth of each case. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different crop growth characters, yield contributing characters and yield of chickpea were recorded and found significant differences for treatment variables.

At 20, 40, 60, 80 and 100 DAS and at harvest, the tallest plant (14.37 cm, 27.28 cm, 45.07 cm, 52.52 cm, 58.76 cm and 61.23 cm) was observed from T_7 [USG placed at 20 cm distance (avoid two rows)] and the shortest plant (10.35 cm, 23.26 cm, 35.32 cm, 41.52 cm, 47.40 cm and 49.27 cm) was recorded T_{14} [USG placed at 40 cm distance (avoid three rows)]. At 20, 40, 60, 80 and 100 DAS and at harvest, the maximum branches plant^{-1} (2.17, 4.90, 9.00, 14.23, 17.67 and 18.50) was recorded from T_7, while the minimum number (1.77, 3.83, 7.37, 10.23, 13.20 and 14.20) was recorded from T_{14}. At 20, 40, 60, 80 and 100 DAS and at harvest the highest dry matter content plant^{-1} (3.82 g, 6.98 g, 9.09 g, 12.05 g, 14.62 g and 17.34 g) was recorded from T_7, whereas the lowest dry matter content plant^{-1} (2.44 g, 4.27 g, 5.72 g, 10.17 g, 11.59 g and 12.26 g) from T_{14}.

In crop growth rate (CGR) of chickpea at 20-40 DAS, the highest CGR (20.41 g $m^{-2}day^{-1}$) was attained from T_6, while the lowest CGR (11.43 g $m^{-2}day^{-1}$) was found from T_5. At 40-60 DAS, the highest CGR (17.99 g $m^{-2}day^{-1}$) was attained from T_3, whereas the lowest CGR (9.06 g $m^{-2}day^{-1}$) was found from T_5. At 60-80 DAS, the highest CGR (28.75 g $m^{-2}day^{-1}$) was recorded from T_{14}, while the lowest (15.54 g $m^{-2}day^{-1}$) from T_8. At 80-100 DAS, the highest CGR (18.33 g $m^{-2}day^{-1}$) was attained from T_6, while the lowest CGR (7.94 g $m^{-2}day^{-1}$) was observed from T_{14}. For relative growth rate (RGR) of chickpea at 20-40 DAS, the highest RGR (0.078 g g^{-1} day^{-1}) was found from T_6, whereas the lowest RGR (0.045 g g^{-1} day^{-1}) was found from T_2. At 40-60 DAS, the highest RGR (0.047 g g^{-1} day^{-1}) was found from T_3, whereas the lowest RGR (0.025 g g^{-1} day^{-1}) was recorded from T_{10}. At 60-80 DAS, the highest RGR (0.060 g g^{-1} day^{-1}) was found from T_{14}, whereas the lowest RGR (0.027 g g^{-1} day^{-1}) was recorded from T_8. At 80-100 DAS, the highest RGR (0.025 g g^{-1} day^{-1}) was recorded from T_6, while the lowest RGR (0.012 g g^{-1} day^{-1}) was recorded from T_{14}.

The minimum days from sowing to harvest (122.33 days) was recorded from T_7, while the maximum days from sowing to harvest (135.33 days) was found from T_{14}. The highest pods plant^{-1} (68.60) was recorded from T_7, while the lowest pods plant^{-1} (53.27) was observed from T_{14}. The highest seeds pods^{-1} (2.87) was counted from T_7, while the lowest number (1.77) from T_{14}. The maximum weight of 1000-seeds (221.81 g) was found from T_7, while the lowest weight of 1000-seeds (188.79 g) from T_{14}. The greater seed yield (1.98 t ha^{-1}) was recorded from T_7, while the lowest seed yield (1.27 t ha^{-1}) was observed from T_{14}. The highest stover yield (2.87 t ha^{-1}) was measured from T_7 and the lowest stover yield (1.90 t ha^{-1}) was observed from T_{14}. The highest biological yield (4.85 t ha^{-1}) was found from T_7, whereas the lowest biological yield (3.17 t ha^{-1}) was observed from T_{14}. The highest harvest index (40.71%) was recorded from T_7, while the lowest harvest index (37.68%) was attained from T_4.

From the observed data of present experiment it may be concluded that chickpea plant gave maximum seed yield with USG placed at 10 cm depth at 20 cm distance (avoid two rows) which was similar to that of broadcasted prilled urea. This USG treatment facilitated plant to uptake maximum nitrogen for better growth, development and yield of chickpea.

Such experiment could be tested further in different chickpea cultivated areas of Bangladesh to justify the present findings.

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APPENDICES

Appendix I. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from November, 2012 to March, 2013

Month	*Air temperature (°C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November, 2012	25.8	16.0	78	00
December, 2012	22.4	13.5	74	00
January, 2013	25.2	12.8	69	00
February, 2013	27.3	16.9	66	39
March, 2013	31.7	19.2	57	23

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1212

Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

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

Appendix III. Analysis of variance of the data on plant height of chickpea as influenced by application of prilled urea and urea super granules

Source of variation	Degrees of freedom	Mean square					
		Plant height (cm)					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	Harvest
Replication	2	0.126	0.335	0.467	1.312	2.812	4.707
Treatment	13	3.814*	3.870*	26.208**	32.831**	40.113**	43.937**
Error	26	1.569	1.709	8.218	8.828	9.568	11.454

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on number of branches plant^{-1} of chickpea as influenced by application of prilled urea and urea super granules

Source of variation	Degrees of freedom	Mean square					
		Number of branches plant^{-1}					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	Harvest
Replication	2	0.006	0.012	0.032	0.447	1.246	1.597
Treatment	13	0.038*	0.255**	0.784**	4.490**	6.482**	7.145**
Error	26	0.016	0.061	0.241	1.395	1.659	1.786

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on dry matter content plant^{-1} of chickpea as influenced by application of prilled urea and urea super granules

Source of variation	Degrees of freedom	Mean square					
		Dry matter content plant^{-1}					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	Harvest
Replication	2	0.038	0.271	0.058	0.136	1.255	0.279
Treatment	13	0.556**	1.754**	2.355**	0.973**	1.850**	4.406**
Error	26	0.142	0.315	0.684	0.207	0.823	1.335

**: Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on crop growth rate and relative growth rate of chickpea as influenced by application of prilled urea and urea super granules

Source of variation	Degrees of freedom	Mean square							
		Crop Growth Rate (g m^{-2}day^{-1})				Relative growth rate (g g^{-1} day^{-1})			
		20-40 DAS	40-60 DAS	60-80 DAS	80-100DAS	20-40DAS	40-60 DAS	60-80 DAS	80-100DAS
Replication	2	4.021	1.148	5.313	3.245	0.0001	0.0001	0.0001	0.0001
Treatment	13	21.847**	15.859**	41.030**	24.290**	0.0001**	0.0001**	0.0001*	0.0001**
Error	26	7.009	5.777	13.458	8.955	0.00001	0.00001	0.00001	0.00001

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on yield contributing characters, yields and harvest index of chickpea as influenced by application of prilled urea and urea super granules

Source of variation	Degrees of freedom	Mean square							
		Days from sowing to harvest	Pods plant^{-1}	Seeds pod^{-1}	Weight of 1000 seeds (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.167	6.403	0.015	24.070	0.010	0.016	0.037	1.613
Treatment	13	51.108*	73.592**	0.328**	337.79**	0.129**	0.274**	0.766**	1.765
Error	26	20.679	15.481	0.092	108.384	0.038	0.082	0.216	2.568

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability