EFFECT OF ZINC AND BORON ON YIELD AND YIELD CONTRIBUTING CHARACTERS OF GREEN GRAM (*Vigna radiata* L. Wilczek) IN CENTRAL DRY ZONE

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A thesis submitted to the post-graduate committee of the Yezin Agricultural University as a partial fulfillment of the requirements for the degree of Master of Agricultural Science (Soil and Water Science)

Department of Soil and Water Science
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The thesis attached here to, entitled "**Effect of Zinc and Boron on Yield and Yield Contributing Characters of Green Gram (*Vigna radiata* L. Wilczek) in Central Dry Zone**" was prepared under the direction of the chairman of the candidate supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Soil and Water Science).**

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DECLARATION OF ORIGINALITY

This thesis represents the original works of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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DEDICATED TO MY BELOVED PARENTS

U BO TAR AND DAW HLA SHWE

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ABSTRACT

The field experiments were conducted in Kyunpyar Village, Minbu Township, Magway Region, in Central Dry Zone during monsoon and post-monsoon seasons, 2017 and to evaluate the effect of zinc (Zn) and boron (B) on yield and yield contributing characters of green gram, to investigate the combined effect of Zn and B on yield and yield components of green gram, and to find out the optimum dose of Zn and B for increased yield of green gram in the experimental area. The experimental design was 4 x 3 factorial arrangements in randomized completed block design (RCBD) with three replications. There were 12 treatment combinations comprising four levels of each of zinc (0.0, 1.0, 2.0 and 3.0 kg ha^{-1}) and three levels of boron (0.0, 0.5 and 1.0 kg ha^{-1}) along with a recommended dose of N_{20} P_{40} K_{40} kg ha^{-1}. Results indicated that the soil application of Zn level (3.0kg Zn ha^{-1}) and boron level (1.0kg B ha^{-1}) produced the greatest yield in both seasons. The combined application of zinc and boron treatment T_{12} (3.0kg Zn ha^{-1} + l.0kg B ha^{-1}) gave the maximum yield (1690 kg ha^{-1}) in monsoon season, which was statistically similar to that of T_6 (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1}) treatment. The tallest plant height (40.73cm), the greatest number of seeds per pod (12.80) and maximum harvest index (0.46) were obtained from the treatment T_6 in monsoon season. In post-monsoon season, T_{12} showed the greatest number of seeds per pod (11.46), greatest 100 seed weight, highest number of pods per plant, greatest total dry matter and highest yield (557kg ha^{-1}). The treatment T_6 was the optimum dose for monsoon season and the treatment T_{12} was the suitable dose for post-monsoon season to get the maximum yield of green gram cultivation in the experimental area.

Key words: Zinc, Boron, Green gram, Yield and yield contributing characters

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CHAPTER I
INTRODUCTION

Pulses are the important group of crops belonging to the family Fabaceae. For both large and small farmers, which represent important economic opportunities to increase income and reduce risk by diversifying their crop and income stream portfolio. Pulses could help at future needs for protein, help minimize soil degradation, and support diversification in food production and consumption. Pulses are an important component in diversifying diets and in replenishing soil nutrients (Kissinger & lexeme, 2016). It is an important source of protein and several essential micronutrients. It synthesizes nitrogen (N) in symbiosis with Rhizobia and enriches the soil. It ameliorates the fertility status of soil through atmospheric N fixation (Quddus, Naser, Hossain & Abul Hossain, 2014).

Pulses are the major source of dietary protein in vegetarian diets in most countries. Myanmar is the second largest global producer of pulses and the world's second largest exporter of peas and beans after Canada and the largest exporter in the ASEAN region. Pulses are mostly produced in the Dry Zone, Bago and Sagaing and Ayeyarwaddy. Over twenty kinds of pulses are being grown in Myanmar. Production of Pulses in Myanmar during the year (2017-2018), the annual sown area is 4.4 million hectares and yield production is 5.64 million metric tons (Ministry of Agriculture, Livestock and Irrigation [MOALI], 2018).

Among the pulse crops, green gram (*Vigna radiata* L. Wilczek) is an important annual legume (Kaur, Jain, Joshi, Choudhary & Vyas, 2016). It cultivated in tropical, subtropical, and temperate zones of Asia including Bangladesh, India, Pakistan, Myanmar, Indonesia, Philippines, Sri Lanka, Nepal, China, Korea, and Japan (Shanmugasundaram, 2001). Green gram is native to the northeastern India-Myanmar region of Asia (Li, Gao & Ward, 2011). Green gram has the potential to establish symbiosis with rhizobia, and symbiotic association of soil micro-flora. It is an important conventional pulse crop and is growing in worldwide not only due to its high nutritional value but also its important role in soil nitrogen enrichment via symbiotic fixation of atmospheric nitrogen. It is commercially produced in China, Myanmar, India, Korea, Pakistan, Japan, Thailand, and other parts of Southeast Asia (Gao et al., 2015).

In Myanmar, Sagaing, Mandalay and Magway becoming to account for a large acreage of green gram cultivation than lower Myanmar (Fujita & Okamoto, 2006). Among the pulses crops in Myanmar during the year (2017-2018), the sown area of green gram is 1.24 million hectares and the yield is 1.27 metric tons per hectare and the production is 1.57 million metric tons (MOALI, 2018).

Legume production have been limited by the nutrient deficiencies of not only major nutrients but also micronutrients such as molybdenum (Mo), zinc (Zn) boron (B), and iron (Fe) (Bhuiyan, Khanam & Ali, 1999). Micronutrient deficiency is a limiting factor for crop productivity in many parts of the world.

Green gram is a food source of vitamins, minerals, and essential amino acids and is rich in lysine and has a high nutrient value comparable to that of soybean (*Glycine max* L. Merr.) and kidney bean (*Phaseolus vulgaris* L.) (Mubarak, 2005). Amino acids are important for the biological activity in human body owning to their biological activities (Shi, Yao, Zhu & Ren, 2016).

Micronutrients constitute an important role in increasing yield of pulses and oilseed legumes through their effects on the plant itself and on nitrogen fixing symbiotic process. Their deficiencies have been occurred due to multiple cropping systems with high yield variety (HYV) crops and hence their exogenous supplies are urgently required (Quddus et al., 2011). Mineral nutrient deficiencies limit nitrogen fixation by the legume rhizobium symbiosis, resulting in low yield (Malla Reddy, Padmaja, Malathi & Jalapathi Rao, 2007).

Since Zinc (Zn) is not mobile in the plants, thus zinc-deficiency symptoms occur mainly in terminal growth. Due to poor mobility in plants, constant supply of zinc is essential for optimum growth. Besides its major role in formation of chlorophyll, it is involved in several enzyme systems, growth hormone (auxins) and the synthesis of nucleic acids and plays an important role in the intake and use of water by plants (Singh, Praharaj, Choudhary, Narendra Jumar & Venkatesh, 2011). Plants emerged from seeds with low concentrations of zinc could be highly sensitive to biotic and abiotic stresses (Obata, Kawamura, Senoo & Tanaka, 1999). Zinc enriched seeds can perform better with respect to seed germination, seedling health, crop growth and finally yield advantage (Cakmak et al., 1996).

Boron (B) is very important in cell division and in pod and seed formation (Vitosh, Wameke & Lucas, 1997). Reproductive growth, especially flowering, fruit and seed set is more sensitive to B deficiency than vegetative growth (Noppakoonwong, Rerkasem, Bell, Dell & Loneragan, 1997). Boron influence the absorption of nutrigen (N), phosphorus (P), potassium (K) and its deficiency changed the equilibrium of optimum of those three macronutrients. An adequate supply of available boron is required especially during flowering and seed development.

Green gram when sown under Zn deficient soils undergoes yield loss. Soil application of Zn is efficient in combating their deficiencies but may be less efficient to increase its concentration in edible parts (Cakmak, 2008). Soil application of Zinc was considered to be the most yield-limiting micronutrients (Fagreia & Baligar, 2005). The zinc essentially is being employed in functional and structural component of several enzymes (Vallee & Auld, 1990). Boron is another essential element for all vascular plants, whose deficiency or excess causes impairments in several metabolic physiological processes (Reid, 2007) including cell wall structure and function (O'Neill, Ishii, Albershim & Darvill, 2004). Boron has a critical role in growing tissues and imbalance may inhibit the vegetative and reproductive stages in plants (Dell & Haung, 1997).

Application of fertilizers in balanced amount was the first and foremost requirement for better crop production. Sometimes there is no deficiency of nutrient in soil actually, but presence of other nutrient in excess creates deficiency of a particular nutrient. In some cases some nutrients also behaves synergistically and increase the availability of other nutrients. In addition to that continuous application of one nutrient source may interact with other nutrient elements and alter their availability and uptake leads to their accumulation in soil. Nutrient interaction occur when the level of one production factor influence the response of other factor (Kamboj, 2014). By utilizing micronutrients, either through soil application, foliar spray, or seed treatment, increased yield and quality grain, as well as macronutrient use efficiency, could be achieved (Saviour & Stalin, 2013).

The micronutrients including Zn and B are the most important nutrients to maintain proper and optimal plant growth. The presence of Zn and B in the soil helps plant to uptake adequate amount of NPK properly to maintain crop plant growth and production (Shojaei & Makariian, 2015). The combined application of zinc and boron must increase yield and yield contributing characteristics of green gram. Therefore, the present study was undertaken with the following objectives:

(1) To evaluate the effect of zinc and boron on yield and yield contributing characters of green gram

(2) To investigate the combined effect of Zn and B on yield and yield components of green gram and

(3) To find out the optimum dose of Zn and B for increased yield of green gram in the experimental area

CHAPTER II
LITERATURE REVIEW

2.1 Green Gram

Among pulses, mung bean (*Vigna radiate* L. Wilczek) is an important grain legume in Asia and an important source of protein and several essential micronutrients. It contains 24.5 % protein and 59.9 % carbohydrates. It contains 75 mg calcium, 8.5 mg iron and 49 mg β-carotene per 1 00g of split dal (Afzal, Bakr, Hamid, Haque & Aktar, 2004). The foliage and stem are a good source of fodder for livestock. It synthesizes N in symbiosis with rhizobia and enriches the soil. Total biomass of the soil through atmospheric N fixation and can fix N in soil (Kaisher, Rahman, Amin, Amanullah & Ahsanullah, 2010). It fixes atmospheric nitrogen symbiotically with Rhizobia and enriches soil through fixing nitrogen (Ram & Katiyar, 2013).

2.2 Problems of Deficiency

Soil fertility status has declined due to intensive cropping with improper replenishment of nutrients (Sakal & Singh, 1995; Singh, 2008). Their deficiencies have been occurred under multiple cropping systems with growing high yield variety (HYV) of crops (Jahiruddin, Haque, Haque & Ray, 1992; Rabman, Jahiruddin & Mian, 1993; Islam, Riasat & Jahiruddin, 1997). On the other hand, due to intensive cropping and use of (HYV) has caused depletion of soil fertility especially of micronutrients (Mondal, Pal, Mandal, & Mandal, 1991; Sakal, Singh, Sinha & Bhogal, 1996). Chemicals are continuously used in agriculture seriously destroyed the soil health and environment. In severe deficiencies of micronutrients, the food grain production may be reduced to meet the target (Sharma, 2014).

Multi cropping systems are heavy feeders of plant nutrients and mining the nutrients from the soil. Nutrient use efficiency of micronutrients is extremely low. Very less part of these nutrients is taken up by the crops and the rest are lost (Sharma, 2014). Productivity of pulses is low because of growing on marginal and sub-marginal soils with little or no application of fertilizers. Deficiency of a micronutrient can be corrected through addition of chemical fertilizers (off-farm inputs), organic manures/residues (on-farm inputs) and by cultivation of tolerant plants (Singh et al., 2011).

2.3 Zinc Deficient Soils

Zinc deficient soils include vertisol and alfisols, vast areas of entisols and inceptisols. Zn deficiency progressively increases with increase in pH and $CaCO_3$ and decreases with increase in soil organic matter (SOM). Light textured alluvial soils are also deficient in available Zn.

Typical Zn deficiencies mainly occur in sandy soils, which are low in SOM, and on organic soils. Zinc uptake by plants decreases with increase in the soil pH. High pH and low SOM reduce root absorption and cause Zn deficiency in all dry regions of the world (Singh et al., 2011).

2.4 Zinc Deficiency Symptoms

Zn deficiency appears generally 10-15 day after sowing (DAS) of the crop. The tips (cotyledon) of the plants change to dead brown color, while the older leaves turn into chocolate brown. At later stages, these leaves drop down. The newly emerging leaves are smaller in size. Plants suffering with zinc deficiency exhibit delayed maturity, short internodes and a decrease in leaf size. Zinc deficiencies reduce root growth and activity (Singh et al., 2011).

2.5 Functional Role of Zinc

Green grams are very responsive to zinc (Gentry, 2010). Zinc is included in auxin formation, activation of dehydrogenase enzymes, stabilization of ribosomal fractions (Obata et al., 1999). Uptake of zinc is also adversely affected with high levels of available P, K and Fe in soils. Its major role in formation of chlorophyll, it is involved in several enzyme systems, growth hormone (auxins) and the synthesis of nucleic acids and plays an important role in the intake and use of water by plants. Zn application enhanced the grain yield and quality. The crops require low amount of Zinc (Singh et al., 2011). Zinc enriched seeds performs better with respect to seed germination and seedling growth (Cakmak et al., 1996).

2.6 Amelioration of Zinc Deficiency

Inorganic salts, synthetic chelates, natural organic complexes and mixtures do contain Zn in large quantities. Other inorganic sources of Zn include its chelates and mixtures. Zinc sulphate mono-hydrated (33%) and hepta hydrated zinc sulphate containing (21% Zn) have been found equally efficient for correcting zinc deficiency either through soil and foliar application. Zinc first release slowly in the soil. Some of the fertilizers containing Zn are Zinc sulphate (21% Zn), Zinc Sulphate mono-hydrate

(33% Zn), Zinc Phosphate $Zn_3 (PO_4)_2.4H_2O$ (19.5% Zn), Chelated Zn (EDTA form, 12% Zn), Zincated urea (2% Zn $^{+}$ 43% N) (Singh et al., 2011).

2.7 Effect of Zinc Sulphate Application

Zinc sulphate is one of the major sources of Zn and sulfur and is being used worldwide (Aye, 2011). For green gram, zinc application of 1.5 kg ha^{-1} was found optimum of micro nutrients (Quddus et al., 2011) which are soil application, seed treatment and foliar application and this dose can increase plant height, primary branches, functional leaves, dry matter, nodule number, nodule weight per plant and seed yield (Thalooth, Tawfik & Mohamed, 2006). The seed priming improve the seed germination and seedling growth (Hameed, Sheikh, Jamil & Basra, 2013).

Application of zinc sulphate 25 kg ha^{-1} to one crop on zinc deficient soils is helpful to both the crops of a pulse based cropping system. The application of zinc sulphate helps in more pod bearing branches as it contributes to the formation of stamens as well as pollens. Zinc sulphate application increased the number of seeds per pod in green gram. This increase might be due to the formation of stamens in as well as pollens (Awlad, Chowdhury &Tahukde, 2003; Teixeira, Boren, & Araujo, 2004).

2.8 Boron Deficiency Symptoms

Boron deficiency may cause grain sterility in crops. Usually dicots have more boron requirement than monocots (Prashantha et al., 2019). Visible symptoms of B deficiency (0.3 μm) initiated on young leaves as internal chlorosis later leading to necrosis (Sinha, Mandah & Jana, 2002). If the deficiency of boron was observed, the symptoms first appeared in the tip of the crop. Total seed weight is highly correlated with leaf boron content (Kumar & Padbhushan, 2014).

2.9 Boron Deficient Soils

Boron (B) deficiency mainly occurs in soils during periods of drought. The reduced level of water in the soil also causes a proportionate decrease in rate of boron diffusion to root (Barber, 1995). Boron is one of the most common deficiencies in soils. Its deficiency is found in the soils which are highly calcareous, leached or sandy (Mondal et al., 1991; Sakal et al., 1996). Imbalance NPK fertilization also results in deficiency of boron in soils (Maji, Sahu, Das, Saha, Sarkar & Saha, 2013).

Boron is mostly deficient in calcareous soils. Calcareous soils contain sufficient amount of calcium carbonate. Calcium carbonate is likely to decrease B-availability (Shaaban, Abdalla, Abou El-Nour & El-Saady, 2006). Besides, calcium carbonate acts as a sink for boron in the soil, where it adsorbs a great portion of the soluble boron on the surface of their particles (Goldberg & Forster, 1991). Boron deficiency occurred in crop plants grown on light textured sandy, calcareous and soils with relatively low amount of organic matter (Singh & Nayyar, 1999).

Goldberg and Forster (1991) investigated the boron sorption on two calcareous soils, one non-calcareous soil and two references calcites in batch systems both as a function of solution pH (5.5-12.0) and initial boron concentration (1- 250 g B m^{-3}) and observed that calcite acts as an important sink for boron in calcareous soils. Calcium carbonate acts as an important B adsorbing surface in calcareous soils (Elseewi, 1974; Elseewi & Elmalky, 1979; Goldberg & Forster, 1991).

2.10 Functional Role of Boron

Boron is very important in cell division and in pod and seed formation (Vitosh et al., 1997). Rate of water adsorption and carbohydrate translocation restricted due to boron deficiency. Boron ranks third place among micronutrients, its concentration in seed and stem as well as its total amount after zinc (Robinson, 1973). Uptakes of B, P, and K increased with increasing B levels whereas uptake of N decreased with B applications.

This improvement in seed weight can be ascribed to B as it is directly linked with process of fertilization, pollen-producing capacity of anther, viability of pollen grains, pollen germination, and pollen tube growth (Agarwal, Sharma, Chatterjee & Sharma, 1981; Dickinson, 1978; Vaughan, 1997). This increase may be due to B, which makes the stigma receptive and sticky, makes pollen grain fertile, and enhances the pollination. This also increases fruit setting, which reduces the sterility of flower and therefore increases seed weight.

Boron influences the absorption of NPK. Inadequate supply of B decreased the economic yield of legume (Raj, 1985). Boron had a positive role on protein synthesis (Quddus et al., 2011). Essential amino acid increased with increasing B supply (lqtidar & Rahman, 1984). The critical level of boron was a range from 0.3 to 0.8 ppm depending on soil types (Shorrocks, 1984).

Boron, which affects cell division, carbohydrate metabolism, sugar and starch formation, which increased the size and weight of grain. Boron is an essential nutrient, which is needed for efficient conversion of sunlight, water, and air into high yields and quality food and fiber. The actual B availability, therefore, can be assessed to a greater degree by the B concentration of the soil solution which can be maintained well over the whole crop growth period (Goldberg, 1993).

Boron helps in the formation of flower and pollen grain. Mean leaf B content increased with soil applied B. There was a marked increase in total seed weight with increase in B content in the leaf. The leaf boron content of the leaf increased with increase in available boron content in the soil. Leaf boron content directly influenced the flower development, pollen tube growth, pollen viability, cell division and differentiation. Leaf boron concentration had played a major role in the croup. Boron plays an important role in influencing nutrient uptake from soil to plant system (Padbhushan & Kumar, 2015). Boron application has positive effect on mung bean yield (Quddus et al., 2011).

2.11 Methods of Application

Zinc may be applied once in a year, alternate years or after 3-5 years depending on Zn status of the soil. The application quantity is mostly determined by the severity of deficiency, soil types, nature of crops and cultivars, cropping systems etc. Generally the cereal crop requires more Zn containing fertilizers than oilseeds and pulses crops (Singh et al., 2011).

Boron is a trace element that can be applied in soil as well as foliar (Kumar & Padbhushan, 2014).

2.11.1 Foliar Application

Foliar application is usually considered as costly because it needs high cost equipment’s (Quddus et al., 2011).

2.11.2 Soil or Basal Application

Soil application of Zn depends on nutrient status in soil, soil types, rainfall, organic matter addition and cropping systems. The Zn applied in one crop of the system generally takes care of the Zn requirements of the succeeding crop too (Singh et al., 2011). Soil application of zinc improved the seeding growth, morphological and yield parameters, grain yield and grain Zn concentration of mumgbean (Haider, Hassain, Farooq & Nawaz, 2018).

There are many methods of Zn application viz., soil, seed coating, spraying, etc. Among which, soil application of $ZnSO_4$ is most common and sometimes, it provides more beneficial results than other sources of Zn application. Zn not only increases the yield, but also improves the quality of the produce.

Although Zn is applied as basal application through broadcast and mixed, its band placement below the seed proved superior to top dressing. But in pulses, it is generally applied in form of basal dressing, seed coating and foliar spray (Singh et al., 2011).

Soil applied boron has more influence on mean dry matter yield while foliar applied boron has on mean grain yield. Soil with lower calcium carbonate was best soil in respect of mean yield and yield components in calcareous soil (Kumar & Padbhushan, 2014).

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site and Growing Season

3.1.1 Lcoation

The field experiments were conducted at Kyunpyar Village, Minbu Township, Magway Region in Central Dry Zone, during monsoon (from Jun to August) and post-monsoon (from September to December), 2017. The experimental site is situated at 19˚56´ 13.0" N latitude and 94˚45´ 57.3" E longitude and at the altitude of 525 feet above the sea level. Many pulses especially green gram are growing in this area.

3.1.2 Climate

Geographical location of the experimental site was under the tropical climate. Details in the meteorological data of minimum and maximum temperatures, rainfall condition during the period of experiment obtained from the Department of Agriculture (DOA), Minbu Township, was presented in Appendix I.

3.2 Collection of Soil Sample

The surface soil of 0-15 cm depth was collected from the experimental field before conducting the experiment. The land was fallow when the soil sample was collected. Soil sample was collected by using auger in zig-zag pattern. The soil sample was put into the bag and sent to Department of Soil and Water Science, Yezin Agricultural University. The plant residues and other extraneous materials were removed and the soil samples were air-dried. Then, the soil was sieved through 2.0mm sieve and mixed thoroughly to get composite sample. Significant amount of sieved soil was kept in a polyethylene bag for physical and chemical analysis.

Physicochemical properties of the initial soils before experiment was shown in Table 3.1.

3.3 Land Preparation

For experiment I, land preparation was started by harrowing in the fourth week of April. Harrowing was done by bullock in five times. For experiment II, land preparation was started by tractor twice in the first week of September. Final land preparation was done by harrowing twice for each experiment. Stubbles of previous crop and weeds were collected and removed from the field. After the final land preparation, the experimental plots were laid out as the design.

Table 3.1 Physicochemical properties of the initial soils before experiment

Parameters	Values	Range
1. Soil texture	-	Loamy sand
2. Soil pH	6.9	Neutral
3. Cation exchange capacity (CEC)	16.0	Medium
4. Organic matter (%)	1.4	Low
5. Available nitrogen (ppm)	88	Medium
6. Available phosphorus (ppm)	13.4	Medium
7. Exchangeable potassium (ppm)	232	Medium
8. Exchangeable calcium ($cmol_c$/kg)	4.9	Low
9. Available zinc (ppm)	0.7	Low
10. Available boron (ppm)	0.4	Low

3.4 Experimental Design and Treatments

The experimental design was 4 x 3 factorial arrangements in randomized complete block design with 3 replications. The unit plot size was 5 m x 3 m with spacing (45 cm x 15 cm). The total experimental area was 1120 m^2. The distance was 0.6 m between two unit plots and 0.6 m between two blocks. The factor (A) was four levels of zinc (0.0, 1.0, 2.0 and 3.0 kg ha^{-1}) and the factor (B) was three levels of boron (0.0, 0.5 and 1.0 kg ha^{-1}).

3.5 Application of Fertilizers

Zinc sulphate and borax acid were applied as the sources of zinc and boron during final land preparation. The full doses of all fertilizers were applied to individual plot during final land preparation. The fertilizers were spread uniformly by hand to each plot. As the amount of zinc and boron for unit plot were small, the fertilizers were mixed with fine sand before application. All treatments along with a blanket dose of N_{20} P_{40} K_{40} kg ha^{-1} in the form of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MOP) were applied in all plots as basal during final land preparation.

3.6 Sowing of Seeds

Green gram seeds were sown in the lines by hand with the rate of 25 kg ha^{-1} on 2 June, 2017 for monsoon season and on 22 September, 2017 for post monsoon season. Seed placement depth was 1.5 cm in the soil. There were six lines in a plot. One line consists of 31 cultivated holes were sown in two seeds per hole.

3.7 Inter-cultivation

After the establishment of the seedlings, or on 5 day after germination, first time of inter-cultivations was done to prevent weed germination and for better growth, better aeration in the root zone, and for well development of green gram. Three times of weeding were done during growing season for each experiment.

Weeding was done firstly to keep the experiment free from weeds and then to prevent the infection of insects, pests and diseases so that to achieve better growth and yield. Weeding was done as necessary during the growing season.

3.8 Water Resource

Water resource for both experiments was under the natural rainfall.

3.9 Thinning

Thinning was done on 7 days after germination. Healthy and erect plant was left and the other plant was removed to get the equal chance for each plant.

3.10 Plant Protection

Experiment was inspected at least two or three days interval during vegetative stage and reproductive stage. Both experiments were infested by insects and pests. Little infestation of Helicovera was especially found in reproductive stage. Cypermethrin 25% EC solution was sprayed in the rate of 20-40 cc per 4 gallon of water three times during the reproductive stage.

3.11 Harvesting, Threshing and Cleaning

Harvesting was done by hand for two times from randomly selected plants at maturity stage. Harvested pods of each plot were bundled separately, labeled, and then carried for threshing. Harvested pods of each plot were cudgeled separately, and then green gram seeds were separated from the husks and cleaned. Dry weight of grains and husks were recorded plot by plot. The stover was sun dried and stover per plot was recorded.

3.12 Data Collection

The data on yield and yield contributing components were collected from 5 randomly selected plants per plot. The following parameters were recorded.

1. Plant height (cm)
2. Number of branches plant^{-1}
3. Number of pods plant^{-1}
4. Number of seeds pod^{-1}
5. 100 seeds weight (g)
6. Yield (kg ha^{-1})
7. Total dry weight (kg ha^{-1})
8. Harvest index (HI)

3.12.1 Plant height (cm)

The plant growth parameter such as plant height was measured starting from 10 days after sowing (DAS) to 45 (DAS) at weekly interval. The plant height was measured as the average of 5 randomly selected plants from the inner rows of each plot. The plant height was measured from the base of the plant (upper the ground) to the apical tip of the plant.

3.12.2 Number of branches plant^{-1}

The branches were counted from the 5 randomly selected plants of each plot at harvested time and mean value was determined.

3.12.3 Number of pods plant^{-1}

The number of pods per plant was collected from 5 randomly selected plants of each plot at harvested time and mean number was expressed per plant basis.

3.12.4 Number of seeds pod^{-1}

The number of seeds were recoded from 5 randomly selected plants of each plot at harvested time and mean number was expressed per pod basis.

3.12.5 Hundred seed weight (g)

One hundred seeds were counted from 5 randomly plants of each plot and weighted by using digital electric balance and expressing in gram (g).

3.12.6 Yield (kg ha^{-1})

Plants within the central 5.58m^2 of the plot were harvested for grain yield. The grains were threshed, cleaned, weighted, and then recorded for each plot. The yield in g plot^{-1} was converted to kg plot^{-1}.

3.12.7 Total dry matter (kg ha^{-1})

Total dry weight was counted from 5 randomly plants of each plot in which consists seed weight, husk weight and stover weight of each plant and mean was expressed per plant basis.

3.12.8 Harvest index (HI)

Harvest index of each treatment was calculated by using the following formula.

$$\text{Harvest Index (HI)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield or yield of total produce (kg ha}^{-1}\text{)}}$$

(Donald & Hamblin, 1976)

3.13 Statistical Analysis

All data were statistically analyzed by using statistix software 8.0 and all treatment means were compared by the least significant difference (LSD) at 5% level of probability (Gomez & Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Field Experiment during Monsoon Season, 2017

4.1.1 Growth Characters

4.1.1.1 Plant height

The mean effect of different rates of zinc fertilizer on the plant height of green gram was not significantly different at 45 DAS (Table 4.1) and was not also significantly different in all stages (Appendix II). However, the tallest plant height (39.48cm) at 45 DAS was obtained from the zinc level (2.0 kg Zn ha^{-1}) and the lowest was recorded from control (Table 4.1). Soil application of Zn activates in auxin production, leading to cell division and elongation. It might be due to the involvement of zinc in protein synthesis, photosynthesis and cell division (Sarwar, 2011).

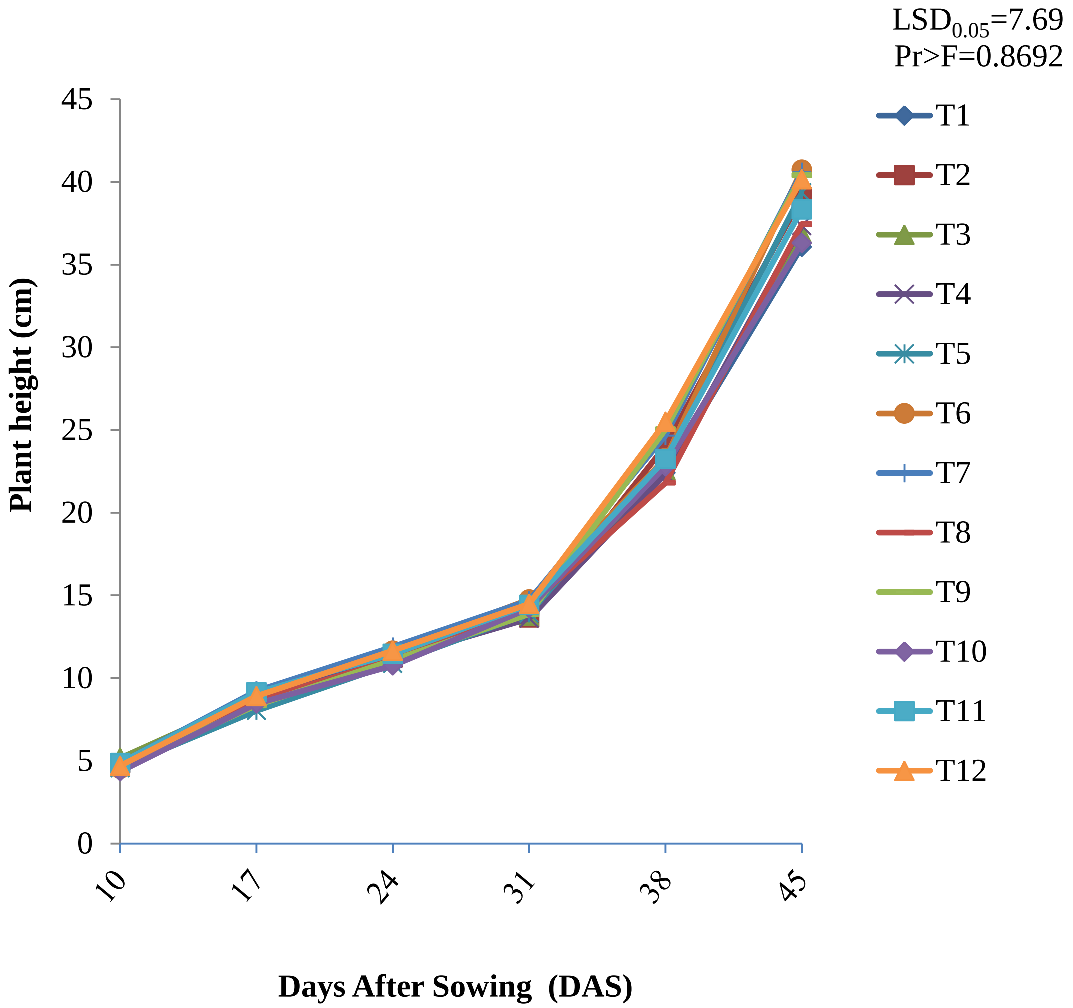
Although no significant mean effect of different rates of boron on the plant height was observed at 45 DAS (Table 4.1), the tallest plant height (39.54 cm) was obtained from the boron level (1.0 kg B ha^{-1}) and the shortest plant height was collected from control. The plant height increased with the application of increasing boron level up to (1.0 kg B ha^{-1}) in all stages (Appendix II). It might be due to the involvement of boron in cell wall development and cell differentiation which supported in elongation of shoots and roots in plant (Vimalan, Gayathri, Thiyageshwari & Prabhaharan, 2017). Quddus et al. (2011) stated that the highest average plant height (45.49 cm) was recorded with (1.0 kg B ha^{-1}) and the lowest value (44.44 cm) was found from the control.

Plant height was continuously increased from 10 DAS to 45 DAS in all treatments (Figure 4.1). Although the interaction effect of zinc and boron was not significant on the plant height of green gram at 45 DAS (Table 4.1), the combined application of zinc and boron gave higher plant height than the single application of zinc or boron. Among the combined application, T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) treatment produced the tallest plant height (40.73cm) which was followed by (40.60 cm) from T_7 (2.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}), and the shortest plant height (36.07 cm) was observed from the control (Figure 4.1). Zinc helps in auxin formation (Hafeez, Khanif & Saleem, 2013) and boron plays an important role in cell division, pod and seed formation (Goldberg and Su, 2007).

Table 4.1 Mean effect of different rates of zinc and boron on the plant height and number of branches plant^{-1} at 45 DAS of green gram in Central Dry Zone during monsoon season, 2017

Treatments	Plant height (cm)	No. of branches plant^{-1}
Zinc (kg ha^{-1})		
0.0	37.33	1.80
1.0	39.13	1.97
2.0	39.48	2.02
3.0	38.26	1.91
$LSD_{0.05}$	**4.44**	**0.55**
Boron (kg ha^{-1})		
0.0	37.58	1.60 b
0.5	38.55	2.00 ab
1.0	39.54	2.18 a
$LSD_{0.05}$	**3.85**	**0.48**
Pr>F		
Zn	0.7522	0.7642
B	0.5789	0.0393
Zn x B	0.8692	0.6708
CV%	**11.78**	**29.51**

Means within a column having same letter (s) are not significantly different at LSD 5% level.



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})

T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})

T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})

T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})

T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

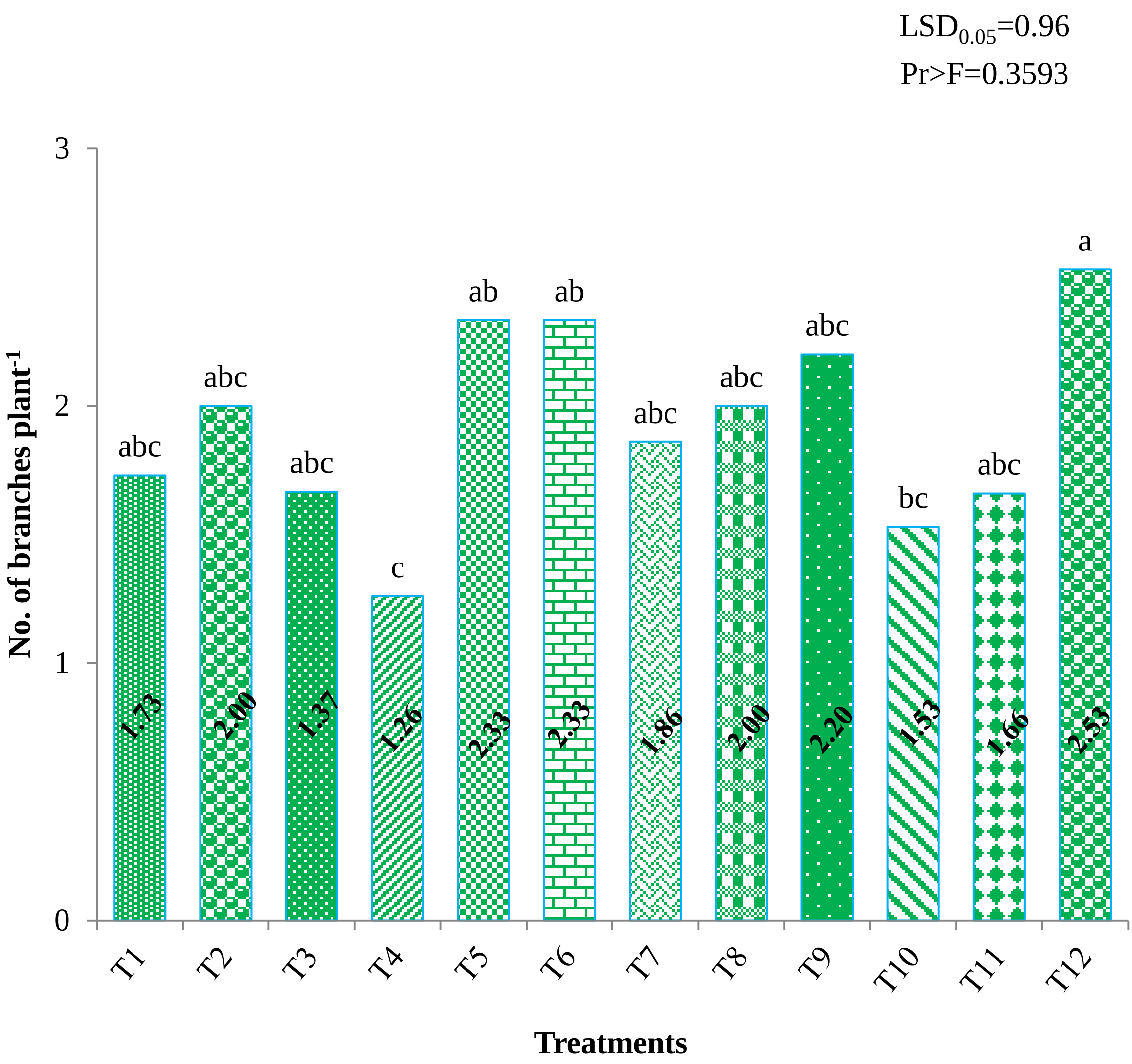
Figure 4.1 Mean values of plant height as affected by different rates of combined application of zinc and boron in Central Dry Zone during monsoon season, 2017

4.1.1.2 Number of branches plant^{-1}

The mean effect of different rates of zinc on the number of branches per plant was not significantly different at 45 DAS (Table 4.1). However, the maximum number of branches plant^{-1} (2.02) was observed from the zinc level (2.0 kg Zn ha^{-1}) followed by (1.97) from (1.0 kg Zn ha^{-1}) and (1.91) from (3.0 kg Zn ha^{-1}), which produced higher number of branches over the control (1.80) (Figure 4.2). Zinc application increased the number of branches plant^{-1} because it extended to more vegetative growth in the zinc treated plant in deficient soil condition (Roy, Lakshman, Narwal. Malik & Saha, 2017).

There was significant difference in the number of branches plant^{-1} due to the application of different rates of boron at 45 DAS (Table 4.1). The maximum number of branches (2.18) was observed from the boron level (1.0 kg B ha^{-1}) followed by (2.00) from the boron level (0.5 kg B ha^{-1}) which were higher than the control. Rahman and Alam (1998) observed that application of (1.5 kg B ha^{-1}) produced significant (10.17%) higher branches plant^{-1} over the control in groundnut.

The interaction effect of zinc and boron on the number of branches plant^{-1} was not significantly different as shown in (Table 4.1). The combined application of zinc and boron produced higher number of branches plant^{-1} than the single application of each one. Among the treatments, T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) produced the maximum number of branches plant^{-1} (2.53) which was followed by (2.33) from T_5 (1.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) and T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}). The minimum number of branches plant^{-1} (1.26) was obtained from T_4 (1.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}) (Figure 4.2). Boron induces positive effect on growth and development, nitrogen assimilation and root growth (Qamar, Rehman, Ali, Qamar, Ahmed & Raza, 2016).



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})

T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})

T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})

T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})

T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.2 Mean values of number of branches plant^{-1} as affected by different rates of combined application of zinc and boron in Central Dry Zone during monsoon season, 2017

4.1.2 Yield and Yield Component Characters

4.1.2.1 Number of pods plant^{-1}

Although the mean effect of different rates of zinc fertilizer was not significant on the number of pods plant^{-1} of green gram, zinc application was greater than the control (Table 4.2). The results showed that the maximum number of pods plant^{-1} (27. 62) was observed from the application of zinc level (3.0 kg Zn ha^{-1}) which was followed by (26.29) from (2.0 kg Zn ha^{-1}), and (25.78) from (1.0 kg Zn ha^{-1}). The variation of the pods number might be due to different levels of Zn fertilizer application. Higher number of pods plant^{-1} could be due to zinc application increased the the development of flower into pods (Praveena, Ghosh & Singh, 2018). Quddus et al. (2014) reported that the maximum number of pods plant^{-1} was found with Zn level (3.0 kg Zn ha^{-1}) which was statistically identical with Zn level (2.0) and (1.0 kg Zn ha^{-1}) but it was significantly different from control.

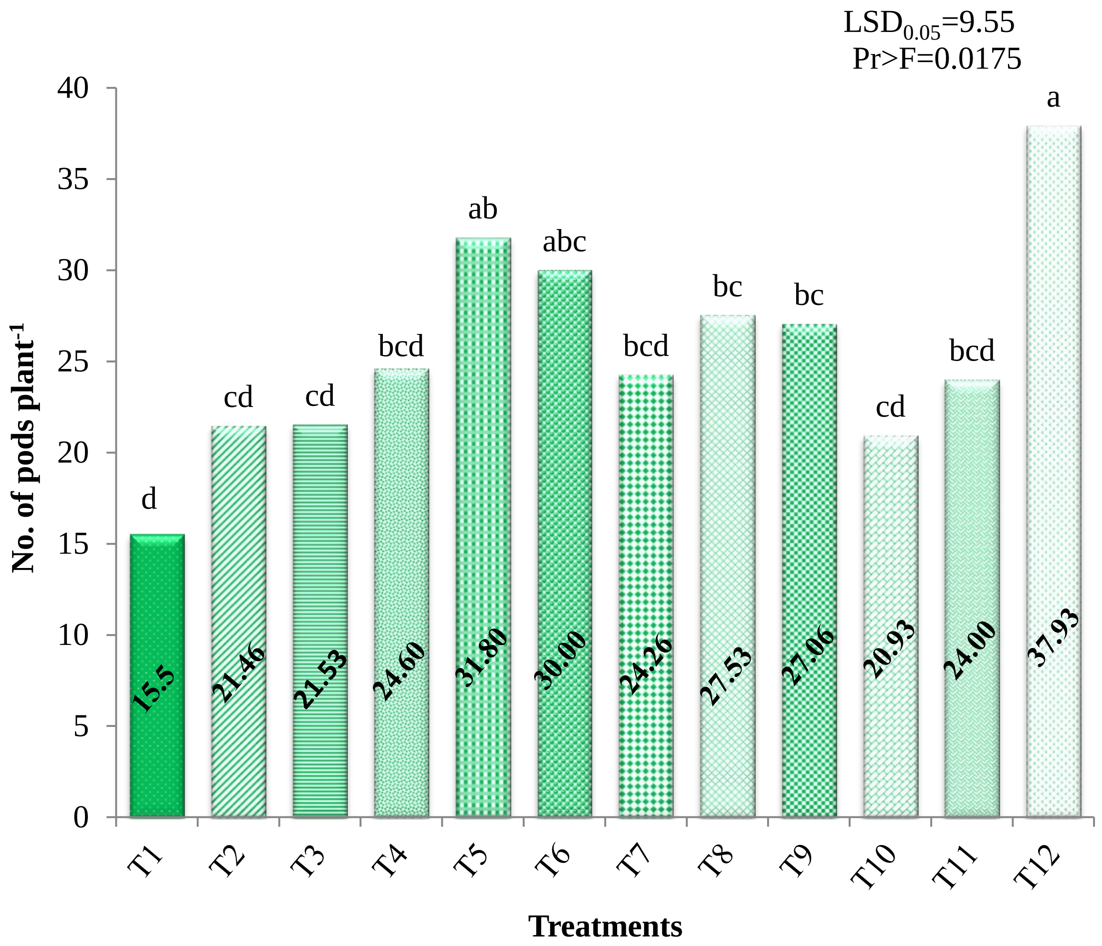
There was significantly different in the mean number of pods plant^{-1} due to the application of different rates of boron fertilizer (Table 4.2). The maximum number of pods plant^{-1} (29.13) was found from the application of boron level (1.0 kg B ha^{-1}) which was followed by (26.2) from (0.5 kg B ha^{-1}). Boron application was significantly higher in number of pods than that of control. This might be due to the different levels of B application which affected on the mean number of pods plant^{-1} in green gram. Boron enhances flower production and retention, pollen tube elongation and germination, and seed and fruit development. The results obtained from this study were in agreement with the finding of Dutta, Uddin & Rahman. (1984) stated that application of (1.0 kg B ha^{-1}) increased the number of pods plant^{-1} in green gram.

The interaction effect between Zn and B on the number of pods plant^{-1} was significantly different (Table 4.2). The maximum number of pods plant^{-1} (37.93) was recorded from the T_{12} treatment (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) which was followed by (31.80) from T_5 (1.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) and (30.00) from T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) which were significantly higher than that of control and single application of each one (Figure 4.3). This might be due to the combined application of Zn and B. Zinc helps in auxin formation (Hafeez et al., 2013) and boron plays an important role in cell division, pod and seed formation (Goldberg & Su, 2007).

Table 4.2 Mean effect of different rates of zinc and boron on the number of pods plant^{-1}, number of seeds pod^{-1}, 100seeds weight, and yield of green gram in Central Dry Zone during monsoon season, 2017

Treatments	No. of pods plant^{-1}	No. of seeds pod^{-1}	100 seeds weight (g)	Yield (kg ha^{-1})	Yield increased over control (%)
Zinc (kg ha^{-1})					
0.0	22.53	12.44	4.60	1438.7	-
1.0	25.78	12.64	4.63	1511.1	5.03
2.0	26.29	12.56	4.66	1521.9	5.78
3.0	27.62	12.56	4.74	1554. 1	8.02
$LSD_{0.05}$	**5.52**	**0.43**	**0.33**	**151.36**	**-**
Boron (kg ha^{-1})					
0.0	21.33 b	12.50	4.57	1480.5	-
0.5	26.20 a	12.58	4.62	1485.7	0.35
1.0	29.13 a	12.57	4.78	1553.1	4.90
$LSD_{0.05}$	**4.78**	**0.37**	**0.29**	**131.01**	**-**
Pr>F					
Zn	0.2939	0.8117	0.8304	0.4617	-
B	0.0092	0.8847	0.2966	0.4532	-
Zn x B	0.0175	0.7621	0.8343	0.2174	-
CV%	**22.09**	**3.47**	**7.30**	**10.28**	**-**

Means within a column having same letter (s) are not significantly different at LSD 5% level.



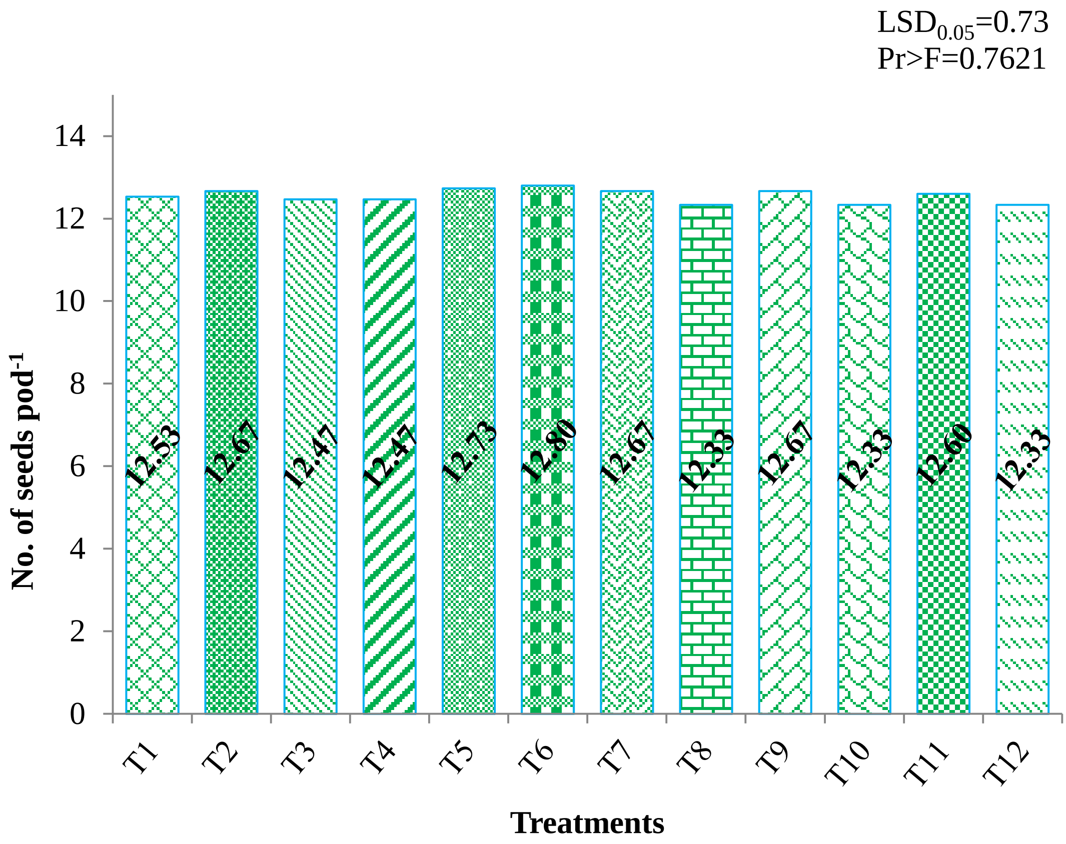
$T_1=Zn_0B_0$= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})	$T_7=Zn_2B_0$= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
$T_2=Zn_0B_1$= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})	$T_8=Zn_2B_1$= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
$T_3=Zn_0B_2$= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})	T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})
$T_4=Zn_1B_0$= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})	T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})
$T_5=Zn_1B_1$= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})	T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})
$T_6=Zn_1B_2$= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})	$T_{12}=Zn_3B_2$= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.3 Mean values of number of pods plant^{-1} as affected by the different rates of combined application of zinc and boron in Central Dry Zone during monsoon season, 2017

4.1.2.2 Number of seeds pod^{-1}

Although the number of seeds pod^{-1} was not significantly affected by the application of different rates of zinc and boron, it tended to be higher in the application of zinc and boron than control (Table 4.2). The number of seeds pod^{-1} was ranging from 12.44 to 12.64 in the zinc application and from 12.50 to 12.58 in the boron application. Increased number of seeds pod^{-1} with zinc application over control might be due to the role of zinc in seed setting (Praveena et al., 2018). Quddus et al. (2011) also reported that the number of seeds pod^{-1} showed no significant variation due to the application of different levels of B in the years of 2008 and 2009. Verma and Mishra (1999) reported that the similar trend.

There was no significant interaction effect between zinc and boron in the number of seeds pod^{-1} (Table 4.2). The micronutrients might have increasing role in seed setting that resulted in improving the number of seeds pod^{-1} (Begum, Swain & Mohanty, 2018).



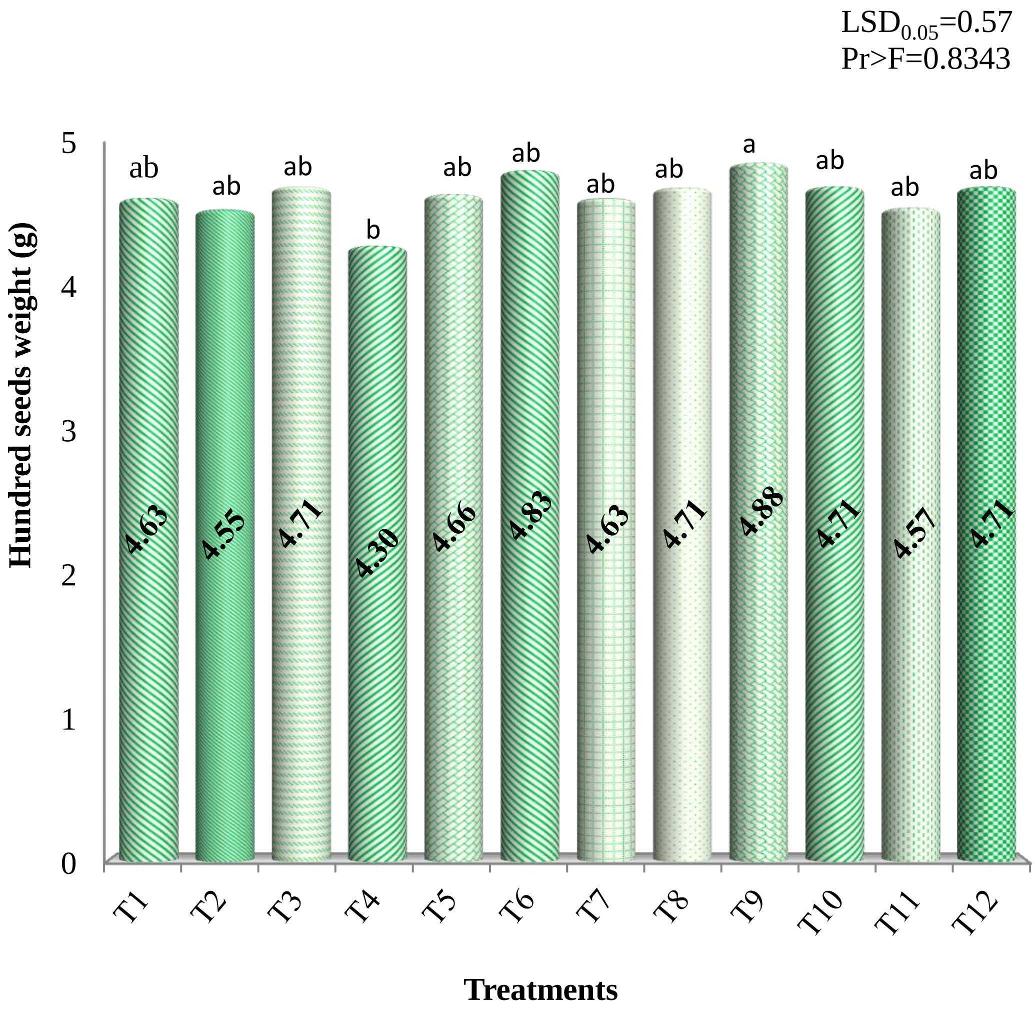
$T_1=Zn_0B_0=$ (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})	$T_7=Zn_2B_0=$ (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
$T_2=Zn_0B_1=$ (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})	$T_8=Zn_2B_1=$ (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
$T_3=Zn_0B_2=$ (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})	$T_9= Zn_2B_2=$ (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})
$T_4=Zn_1B_0=$ (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})	$T_{10}= Zn_3B_0=$ (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})
$T_5=Zn_1B_1=$ (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})	$T_{11}= Zn_3B_1=$ (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})
$T_6=Zn_1B_2=$ (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})	$T_{12}=Zn_3B_2=$ (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.4 Mean values of number of seeds pod^{-1} as affected by different rates of combined application of zinc and boron in Central Dry Zone during monsoon season, 2017

4.1.2.3 Hundred seeds weight

Though the different rates of zinc and boron application were not significantly effective on the 100 seeds weight of green gram, the applications were higher than control (Table 4.2). The 100 seeds weight ranged from 4.60 to 4.74 in zinc application and ranged from 4.57 to 4.78 in boron application. Zinc helps in cell division, sugar and starch formation which provide the seed weight. The optimum dose of zinc sulphate influenced the cell division, sugar and starch formation which increased the seed size and weight (Usman, Tahir & Majeed, 2014). Boron plays structural role in cell wall development, cell division, seed development and hormone development (Ahmad, Niaz, Kanwal, Rahmatullah & Rashed, 2009).

Although the interaction effect between zinc and boron on the hundred seeds weight of green gram was not significantly different (Table 4.2), the seeds weight from combined application was higher than that of single application (Figure 4.5). From the combined application of zinc and boron, the highest 100 seeds weight (4.88) was observed from T_9 (2.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) and the lowest (4.30) was observed from T_4 (1.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}). Rahman (2015) observed that similar trend. Quddus et al. (2011) also reported that 100 seed weight was significantly influenced due to the combined application of Zn and B.



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})

T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})

T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})

T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})

T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

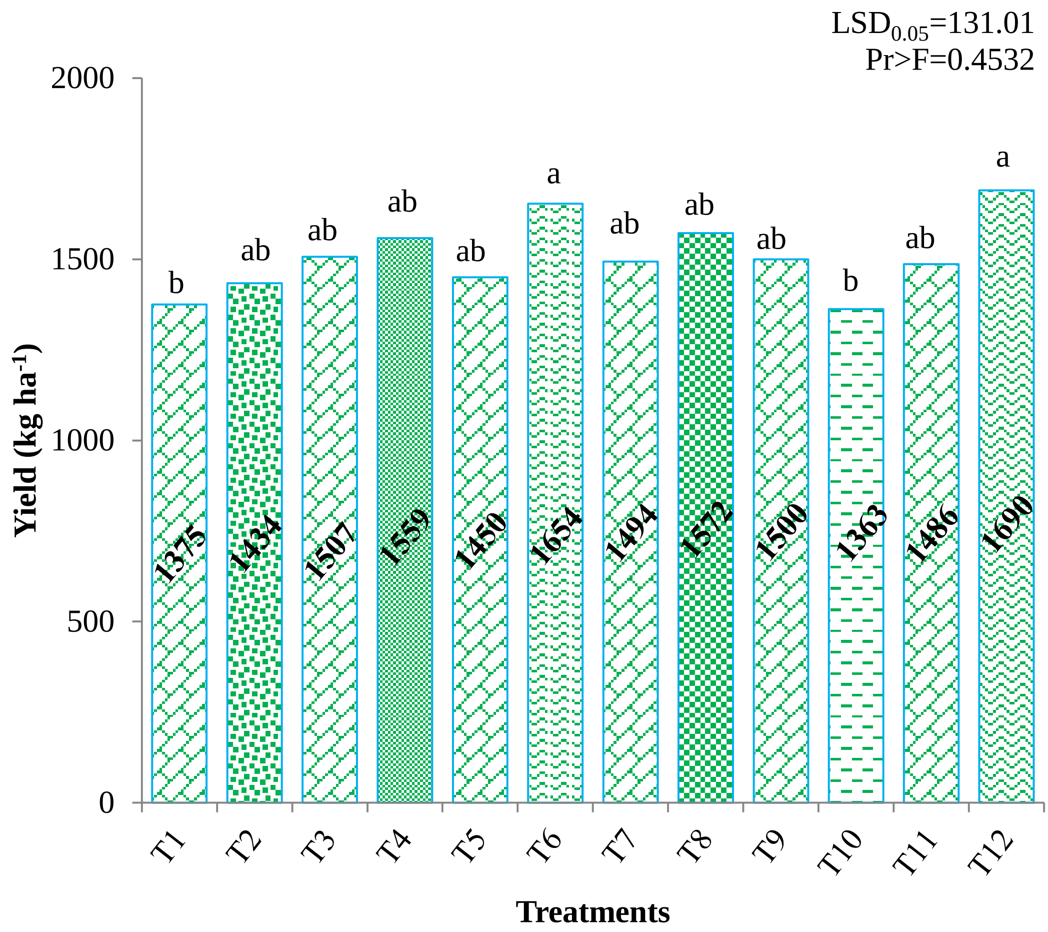
Figure 4.5 Mean values of hundred seeds weight as affected by different rates of combined application of zinc and boron in Central Dry Zone during monsoon season, 2017

4.1.2.4 Yield

Although significant mean effect of different rates of zinc on the yield of green gram was not observed, the grain yield was increased with increasing level of zinc up to (3.0 kg Zn ha^{-1}) (Table 4. 2). The maximum yield (1554.1 kg ha^{-1}) was obtained from zinc level (3.0 kg Zn ha^{-1}) which was followed by (1521.9 kg ha^{-1}) from (2.0 kg Zn ha^{-1}), and (1511.1kg ha^{-1}) from zinc level (1.0 kg Zn ha^{-1}) whereas the minimum yield (1438.7 kg ha^{-1}) was observed from control. The soil application of (3.0 kg Zn ha^{-1}) increased the yield 8.02% over control. Zinc is an important micronutrient in increasing yield of crop productivity. Zinc constitutes one of the essential plant micronutrients and its importance for crop productivity is similar to that of major nutrients (Srivastava & Dawson, 2017).

The mean values of grain yield were not significantly different due to the application of different rates of boron (Table 4.2). The maximum grain yield (1553.1 kg ha^{-1}) was obtained from (1.0 kg B ha^{-1}) probably due to its maximum number of pods per plant while the minimum grain yield (1480.5 kg ha^{-1}) was produced from the control. From this study, the grain yield was increasing with increasing level of boron up to (1.0 kg B ha^{-1}). The result agreed with Quddus et al. (2011), who observed the highest seed yield (2277 kg ha^{-1}) at (1.0 kg B ha^{-1}). The yield increased 4.90% over control with the application of (1.0 kg B ha^{-1}).

Although the interaction effect between zinc and boron on gain yield was not significantly different (Table 4.2), the maximum grain yield (1684.4 kg ha^{-1}) was observed from T_{12} (3.0 kg Zn ha^{-1} + 1.0kg B ha^{-1}), which was statistically similar to T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) (Figure 4.6). The minimum grain yield (1362.6 kg ha^{-1}) was obtained from the control. The treatment T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) increased the yield 21.34% and aslo the treatment T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) increased the yield 23.61% over control. This might be due to synergic effect of Zn and B on the yield of green gram. Application of micronutrients in small quantities (0.5 to 2 kg ha^{-1}) has increased grain yield (Divyashree, Prakash, Yogananda & Munawery, 2018). Quddus et al. (2011) stated that the combined application of zinc and boron showed significant effect on mungbean yield than the single application of Zn and B. The combined application of zinc and boron was more increased in yield than the single application of each one.



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})	T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})	T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})	T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})
T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})	T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})
T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})	T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})
T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})	T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.6 Mean values of yield as affected by different rates of combined application of zinc and boron in Central Dry Zone during monsoon season, 2017

4.1.2.5 Total dry matter

The significant difference of total dry matter was not found among different rates of zinc application at harvest time (Table 4.3). However, the dry matter was increased with increasing the application of zinc level up to (3.0 kg Zn ha^{-1}). The maximum dry matter (6364.30 kg ha^{-1}) was recorded from the zinc level (3.0 kg Zn ha^{-1}) and the minimum dry matter (5036.80 kg ha^{-1}) was observed from no zinc application. This increase might be due to the effect of zinc activities. The effect of Zn application on straw yield of green gram might be due to its direct influence on auxin synthesis, which in turn enhanced elongation processes of plant development (Ranjbar & Bahmaniar, 2007).

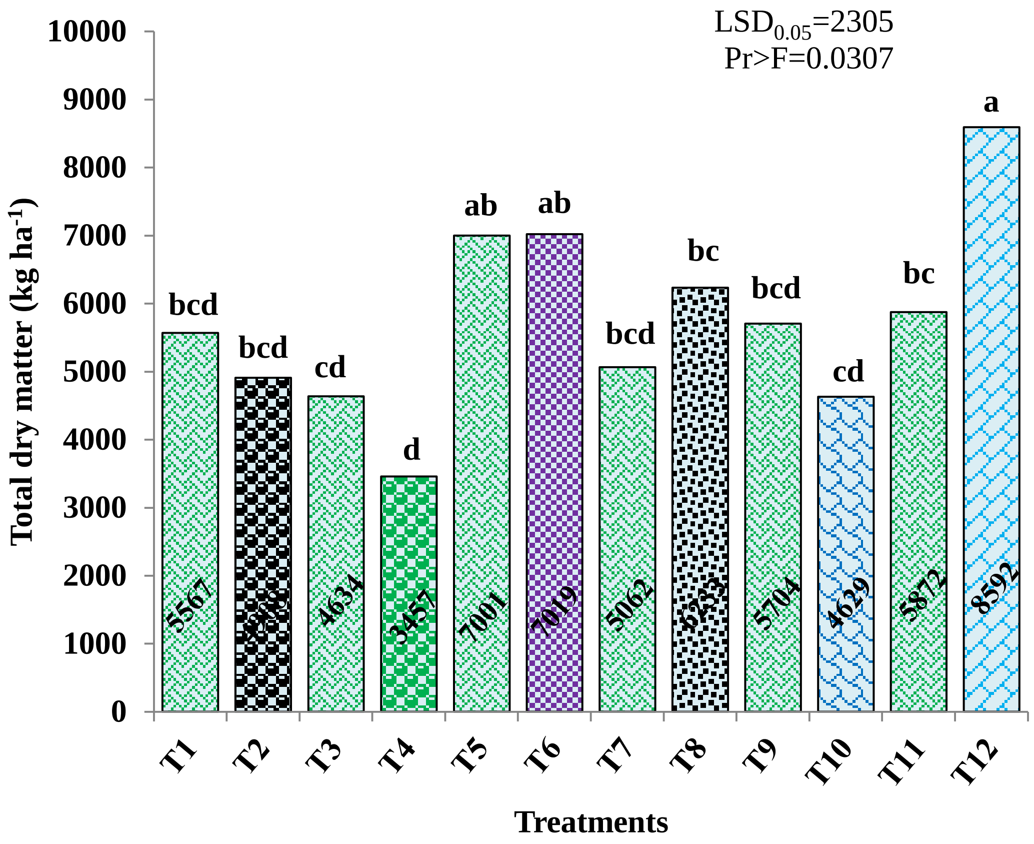
There was significant difference on the total dry matter as affected by different rates of boron application (Table 4.3) and the total dry matter was significantly influenced by different level of boron. The maximum dry matter (6487.50 kg ha^{-1}) was found from (1.0 kg B ha^{-1}) and the minimum dry matter (4679.10kg ha^{-1}) was recorded from no application of boron. This might be due to the effect of boron. Soil-applied boron had more influence on mean dry matter yield, it might be due to the influenced of boron in cell division, cell elongation, pollination, flowering, fruit and seed setting.

The interaction effect of zinc and boron on the total dry matter was significantly different (Table 4.3) which was probably due to its maximum number of pods per plant and number of branches per plant. The maximum total dry matter (8592 kg ha^{-1}) was obtained from T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) which was followed by (7092 kg ha^{-1}) from T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}), T_6 was statistically identical to T_5 (1.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}). The minimum total dry matter (3457 kg ha^{-1}) was observed from T_4 (1.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}) (Figure 4.7). Zinc and boron result synergic effect on the biological yield (Debnath, 2018).

Table 4.3 Mean effect of different rates of zinc and boron on total dry matter and harvest index of green gram in Central Dry Zone during monsoon season, 2017

Treatments	Total dry matter ($kg\ ha^{-1}$)	Harvest index (HI)
Zinc ($kg\ ha^{-1}$)		
0.0	5036.80	0.26
1.0	5825.70	0.30
2.0	5666.40	0.28
3.0	6364.30	0.29
$LSD_{0.05}$	**1331.20**	**0.05**
Boron ($kg\ ha^{-1}$)		
0.0	4679.10 b	0.26 b
0.5	6003.30 a	0.26 b
1.0	6487.50 a	0.34 a
$LSD_{0.05}$	**1152.90**	**0.05**
Pr>F		
Zn	0.3052	0.3305
B	0.0168	0.0024
Zn x B	0.0312	0.0027
CV%	**23.79**	**19.16**

Means within a column having same letter (s) are not significantly different at LSD 5% level.



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})
T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})
T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})
T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})
T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})
T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})
T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

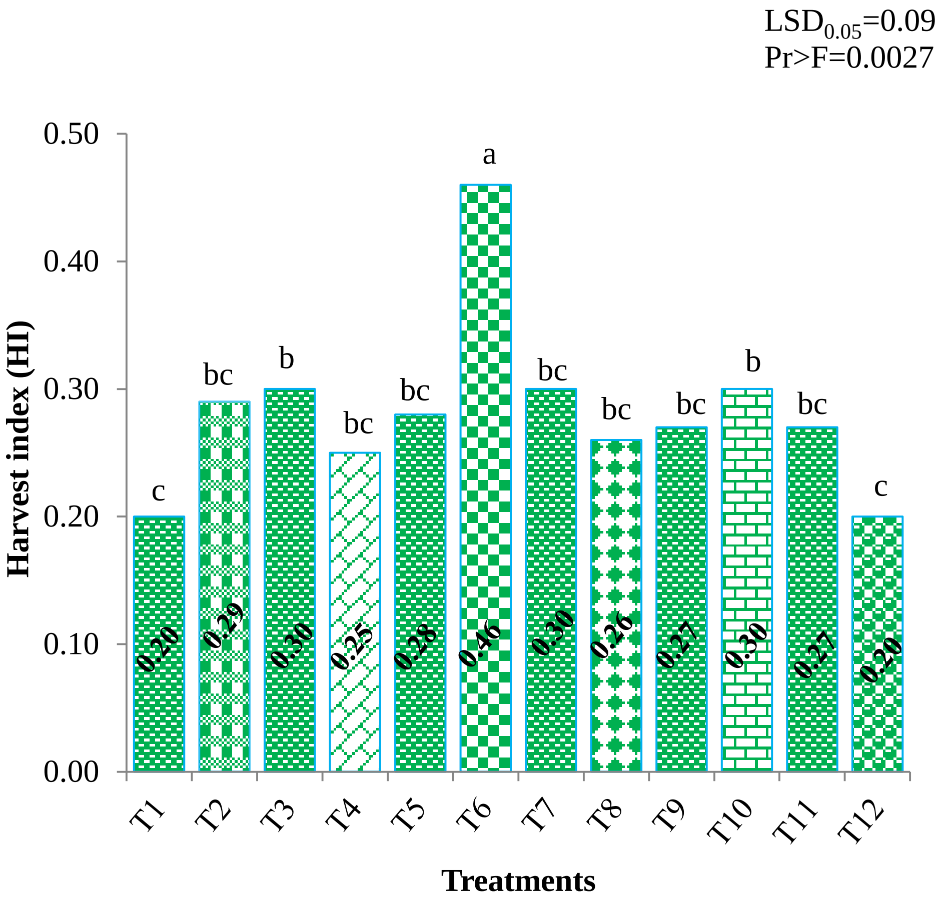
Figure 4.7 Mean values of total dry matter as affected by different rates of combined application of zinc and boron in Central Dry Zone during monsoon season, 2017

4.1.2.6 Harvest Index (HI)

There was no significant difference in harvest index (HI) among different rates of zinc application (Table 4.3). Maximum value of harvest index (0.30) was observed from the zinc level (1.0 kg Zn ha^{-1}) and the minimum value (0.26) was recorded from control. Harvest index determines the amount of photosynthates being translocated to the economic parts of the plant (Usman et al., 2014).

The mean effect of different rates of boron on the harvest index of green gram was highly significant (Table 4.3). This might be due to the significantly affected of boron application on the number of pods $plant^{-1}$. Harvest index was significantly affected by different levels of boron (Hamza, Chowdhury, Rob, Miah, Habiba & Hahman, 2016). The maximum harvest index (0.34) was obtained from (1.0 kg B ha^{-1}) and the minimum harvest (0.26) was resulted from no application of boron. The maximum number of pods per plant in the application of (1.0 kg B ha^{-1}) (Table 4.3) was probably because of the highest harvest index in this treatment (Table 4.4).

The interaction effect between zinc and boron on the harvest index was highly significant (Table 4.3) and the maximum harvest index (0.46) was observed from T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) and the minimum harvest index (0.20) was observed from control which was statistically identical to T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) (Figure 4.8).



$T_1=Zn_0B_0=$ (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

$T_2=Zn_0B_1=$ (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

$T_3=Zn_0B_2=$ (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

$T_4=Zn_1B_0=$ (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

$T_5=Zn_1B_1=$ (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})

$T_6=Zn_1B_2=$ (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

$T_7=Zn_2B_0=$ (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

$T_8=Zn_2B_1=$ (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

$T_9= Zn_2B_2=$ (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})

$T_{10}= Zn_3B_0=$ (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})

$T_{11}= Zn_3B_1=$ (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})

$T_{12}=Zn_3B_2=$ (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.8 Mean values of harvest index as affected by different rates of combined application of zinc and boron in Central Dry Zone during monsoon season, 2017

4.2 Field Experiment during Post-Monsoon Season, 2017

The field experiment was conducted during post-monsoon season (from September to December), 2017 at the same location with the same objective as expressed in the previous season.

4.2.1 Growth Characters

4.2.1.1 Plant height

The plant height was measured at weekly interval from 10 to 45 DAS where the plant height continuously increased in all treatment (Figure 4.9).

The mean effect of different rates of zinc on plant height of green gram was significant at 45 DAS (Table 4.4). The tallest plant height (38.62 cm) at 45 DAS was recorded from (3.0 kg Zn ha^{-1}). The plant height was gradually increased in all stages by increasing rate of zinc and was also significantly different at 38 DAS and 45 DAS (Appendix III). The increased plant height may be due to the response of zinc application as its effect in the metabolism of growing plants. Zinc actively supports in auxin production which increase in cell size and number so increases the plant height (Dashadi, Hossein, Radjabi & Babainejad, 2013).

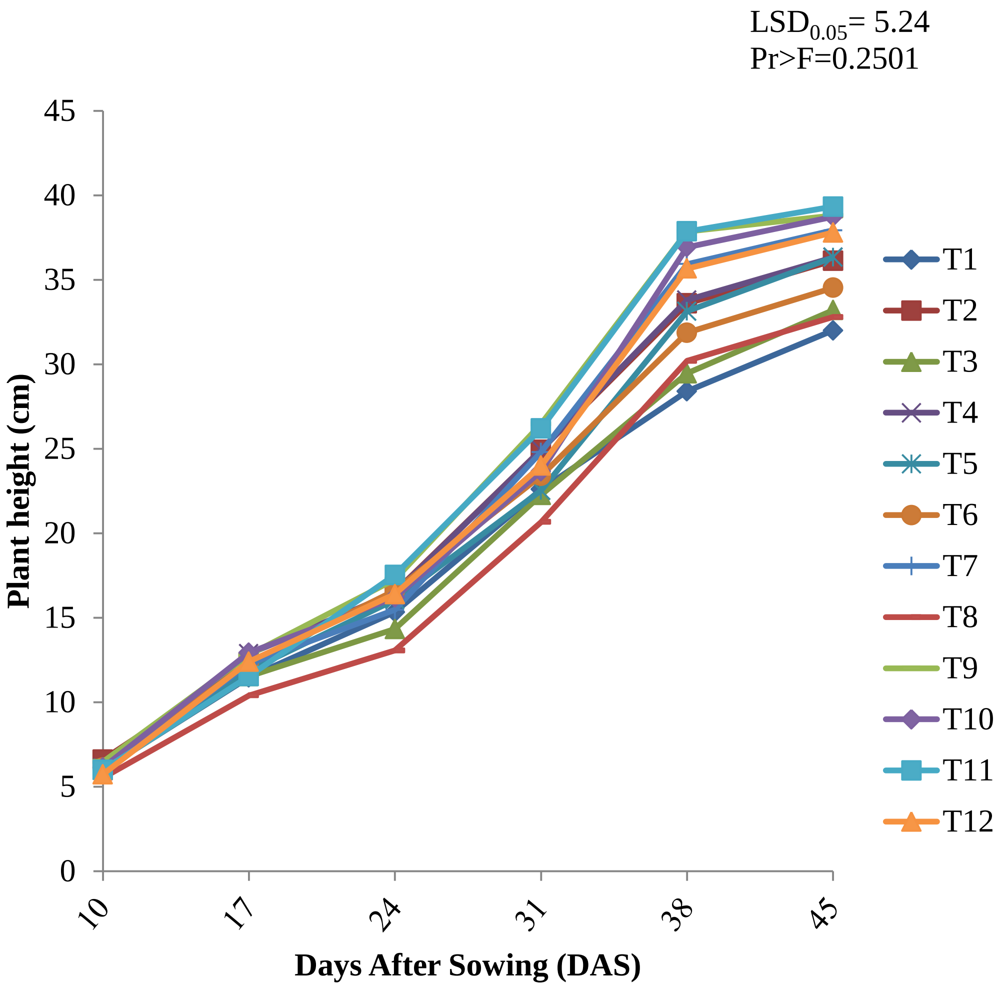
Although the mean effect of different rates of boron on the plant height was no significant at 45 DAS (Table 4.4), the plant height tended to be increasing with increasing rate of boron in all stages (Appendix III). The tallest plant height (36.85 cm) was observed from (1.0 kg B ha^{-1}) and the shortest plant height (36.05 cm) was obtained from control. No significance in plant height among the boron treatments could be due to antagonistic effect between B and N. The result has been agreed with the finding of Padbhushan and Kumar (2015), who stated that there was an antagonistic relationship between B and N which has also been reported by Pal, Jadaun and Raghav (1989) in berseem crop and Leece (1978) in maize crop.

Although the interaction effect between zinc and boron on the plant height of green gram was not significant at 45 DAS (Table 4.4), the tallest plant height (39.33 cm) at 45 DAS was recorded from T_{11} (3.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) treatment which was followed by (38.80 cm) from T_9 (2.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}), (38.73 cm) from T_{10} (3.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}) (Figure 4.9). The shortest plant height (32.00 cm) was observed from control.

Table 4.4 Mean effect of different rates of zinc and boron on the plant height and number of branches plant^{-1} at 45 DAS of green gram in Central Dry Zone during post-monsoon season, 2017

Treatments	Plant height (cm)	No. of branches Plant^{-1}
Zinc (kg ha^{-1})		
0.0	34.57 b	1.00
1.0	35.73 ab	1.22
2.0	36.51 ab	1.33
3.0	38.62 a	0.88
$LSD_{0.05}$	**3.02**	**0.71**
Boron (kg ha^{-1})		
0.0	36.08	1.08
0.5	36.15	1.08
1.0	36.85	1.16
$LSD_{0.05}$	**2.62**	**0.61**
Pr>F		
Zn	0.0486	0.5611
B	0.7997	0.9488
Zn x B	0.2501	0.1064
CV%	**8.51**	**65.38**

Means within a column having same letter (s) are not significantly different at LSD 5% level.



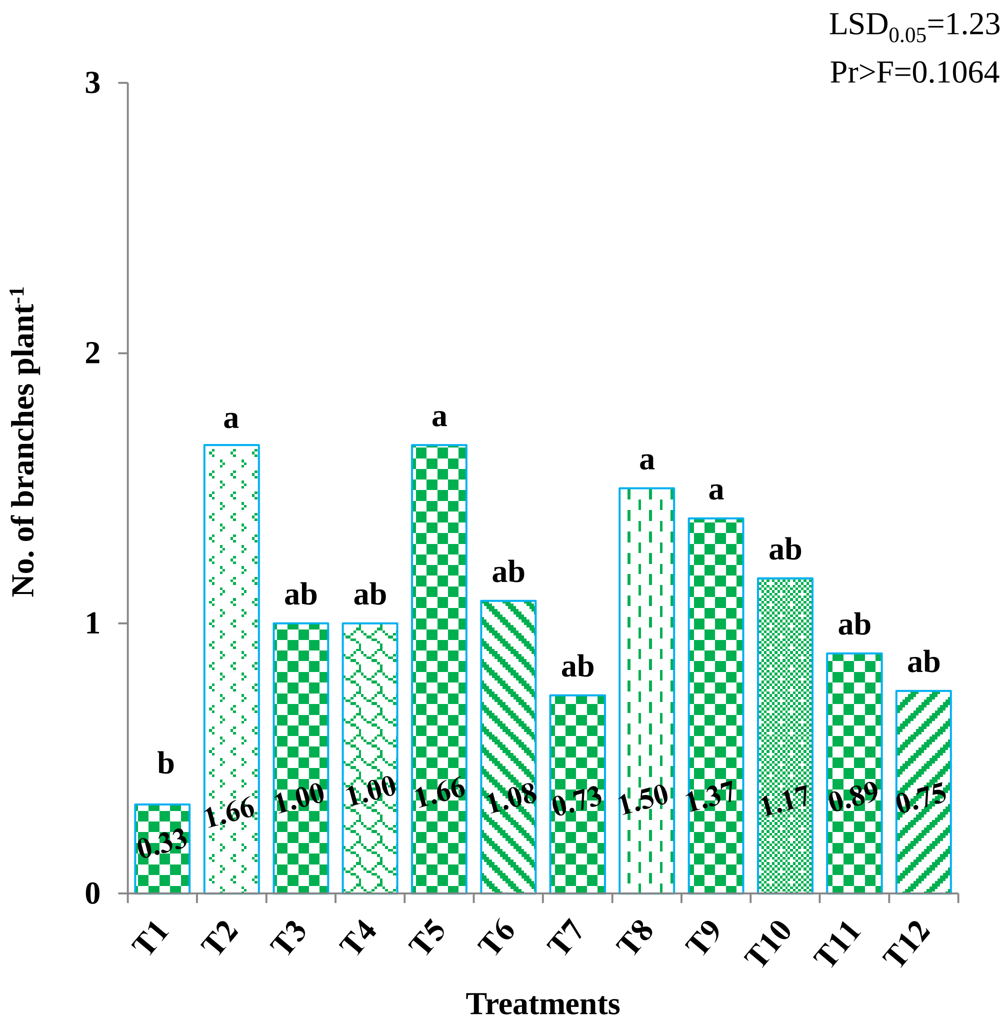
T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})
T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})
T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})
T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})
T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})
T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})
T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.9 Mean values of plant height as affected by different rates of combined application of zinc and boron in Central Dry Zone during post-monsoon season, 2017

4.2.1.2 Number of branches plant^{-1}

The mean number of branches plant^{-1} was not significantly affected by the application of different rates of zinc and boron at 45 DAS (Table 4.4). The number of branches plant^{-1} was ranging from 0.88 to 1.33 in the zinc application and from 1.08 to 1.16 in the boron application. Praveena et al. (2018) reported that the basal application of zinc (control + 2.5 kg Zn ha^{-1}) produced the number of branches plant^{-1} (6.93) but which was not significant different with the control. No significant difference in number of branches plant^{-1} from control might be due to the antagonistic effect of boron with the nitrogen.

There was no significant interaction effect between zinc and boron on the number of branches plant^{-1} (Table 4.4). The maximum number of branches plant^{-1} (1.66) was recorded from T_2 (0.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}), it was statistically similar to T_8 (2.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}), T_9 (2.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}), and T_5 (1.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) (Figure 4.10). The minimum number of branches plant^{-1} (0.33) was observed from control. The number of branches per plant was not influenced by the combined application of zinc and boron but it was higher than the single application.



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})

T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})

T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})

T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})

T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.10 Mean values of number of branches plant^{-1} as affected by different rates of combined application of zinc and boron in Central Dry Zone during post-monsoon season, 2017

4.2.2 Yield and Yield Component Characters

4.2.2.1 Number of pods plant^{-1}

In this season, significant mean effect of different rates of zinc and boron on the number of pods plant^{-1} was observed (Table 4.5). This might be due to the effect of weather because of low intensity and medium amount of rainfall during the growing season. The maximum number of pods plant^{-1} (13.67) was recorded from (3.0 kg Zn ha^{-1}) followed by (11.89) from (2.0 kg Zn ha^{-1}) while the minimum number of pods plant^{-1} (11.00) was observed from control which was statistically similar to (1.0 kg Zn ha^{-1}). Srivastava and Dawson (2017) stated that the maximum number of pods plant^{-1} was significantly recorded by soil application (basal) of (12.5 kg $ZnSO_4$ ha^{-1}) which over the 0.5% foliar spray and fertilized control. Higher number of pods per plant could be due to zinc application increased the realization of flower into pods (Praveena, Ghosh & Singh, 2018).

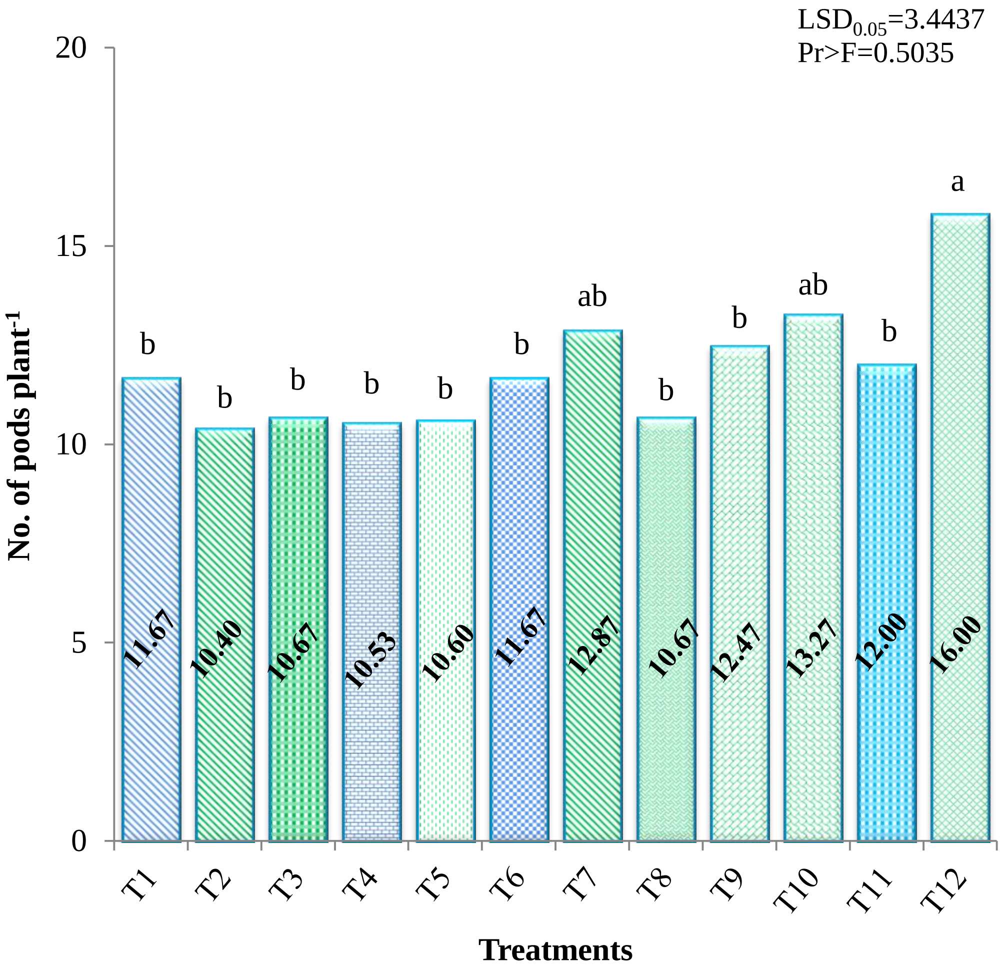
By applying different rates of boron, the maximum number of pods plant^{-1} (12.67) was obtained from (1.0 kg B ha^{-1}) followed by (12.17) from (0.5 kg B ha^{-1}) treatment while the minimum number (10.83) was observed from no application of boron (Table 4.5). Increasing in number of pods plant^{-1} by applying increased level of boron up to (1.0 kg B ha^{-1}) might be due to the effect of boron in flower formation, pollen tube growth and then leading to pod formation. Boron is more important for pollen germination and pollen tube growth (Singh, Khan & Srivastava, 2014).

The interaction effect of zinc and boron on the number of pods plant^{-1} was not significantly different (Table 4.5). However, the maximum number of pods plant^{-1} (16.00) was recorded from T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) followed by (13.27) from T_{10} (3.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}), (12.87) from T_7 (2.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}) while the minimum number of pods plant^{-1} was observed from (10.40) from T_2 (0.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) treatment (Figure 4.11).

Table 4.5 Mean effect of different rates of zinc and boron on number of pods plant^{-1}, number of seeds pod^{-1}, 100seeds weight, and yield of green gram in Central Dry Zone during post-monsoon season, 2017

Treatments	No. of pods plant^{-1}	No. of seeds pod^{-1}	100seeds weight (g)	Yield (kg ha^{-1})	Yield increased over control (%)
Zinc (kg ha^{-1})					
0.0	11.00 b	10.93	4.49	376.70 b	-
1.0	11.00 b	11.07	4.54	451.23ab	19.78
2.0	11.89 ab	11.24	4.57	413.74 b	9.83
3.0	13.67 a	11.31	4.72	536.06 a	42.30
$LSD_{0.05}$	**1.99**	**0.45**	**0.36**	**88.22**	-
Boron (kg ha^{-1})					
0.0	10.83 b	11.10	4.60	420.10	-
0.5	12.17 ab	11.12	4.65	429.63	2.26
1.0	12.67 a	11.20	4.72	483.57	15.10
$LSD_{0.05}$	**1.72**	**0.39**	**0.32**	**76.40**	**-**
Pr>F					
Zn	0.0344	0.3113	0.4500	0.0076	-
B	0.0464	0.8495	0.7473	0.2012	-
Zn x B	0.5035	0.2744	0.4582	0.8828	-
CV%	**17.10**	**4.11**	**8.02**	**20.30**	-

Means within a column having same letter (s) are not significantly different at LSD 5% level.



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})

T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})

T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})

T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})

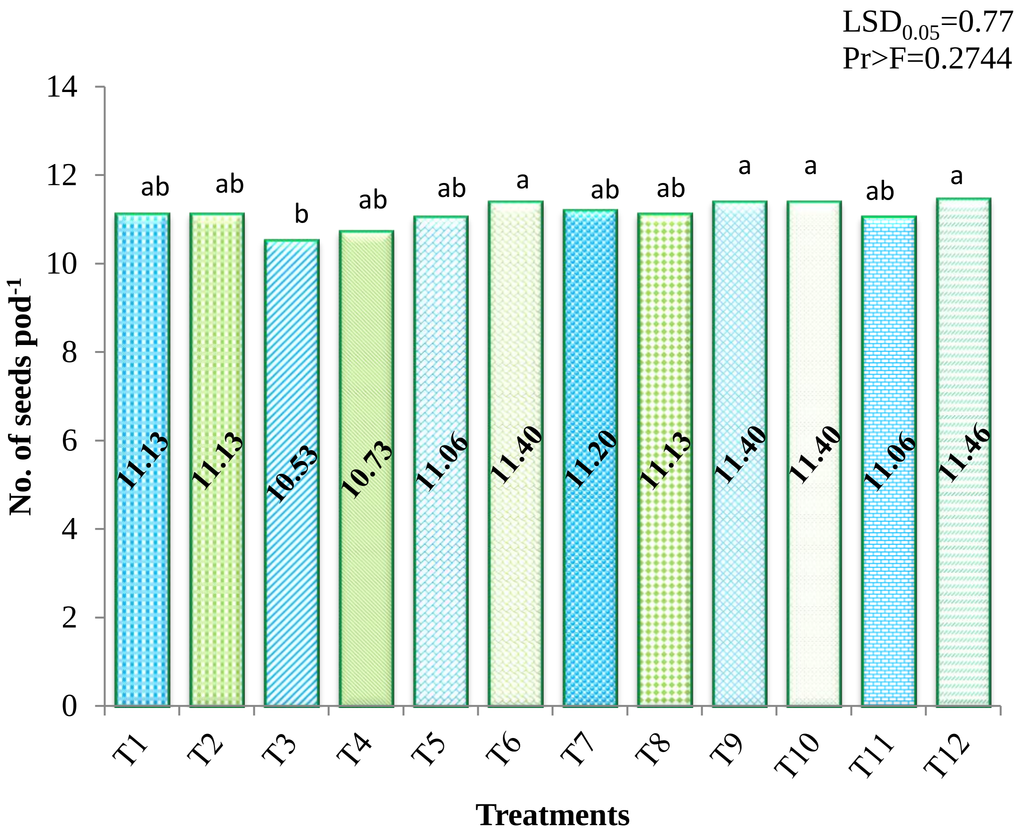
T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.11 Mean values of number of pods plant^{-1} as affected by different rates of combined application of zinc and boron in Central Dry Zone during post-monsoon season, 2017

4.2.2.2 Number of seeds pod^{-1}

Although the mean number of seeds pod^{-1} was not significantly different among the application of different rates of zinc and boron, the application of Z and B produced higher seeds number than the control (Table 4.5). The number of seeds pod^{-1} was ranging from 10.93 to 11.31 in zinc application and from 11.10 to 11.20 in boron application. The maximum number of seeds pod^{-1} (11.31) and (11.20) were produced from (3.0 kg Zn ha^{-1}) and (1.0 kg B ha^{-1}), respectively. Praveena et al. (2018) reported that seeds per pod were increased by zinc application over control because of role of zinc in seed setting. Quddus et al. (2011) reported that the number of seeds pod^{-1} in green gram was not significantly different due to the application of different levels of boron.

There was no significant interaction effect between zinc and boron on the number of seeds pod^{-1} (Table 4.5). The maximum number of seeds pod^{-1} (11.46) was obtained from T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) treatment followed by (11.40) from T_{10} (3.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}) which was statistically similar to T_9 (2.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) and T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}). The minimum number (10.53) was observed from T_3 (0.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) (Figure 4.12). This result was agreed with the finding of Quddus et al. (2011), who observed that the number of seeds pod^{-1} was not significantly influenced due to the combined application of zinc and boron. The combined application was more effective than the single application of zinc and boron.



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})

T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})

T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})

T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})

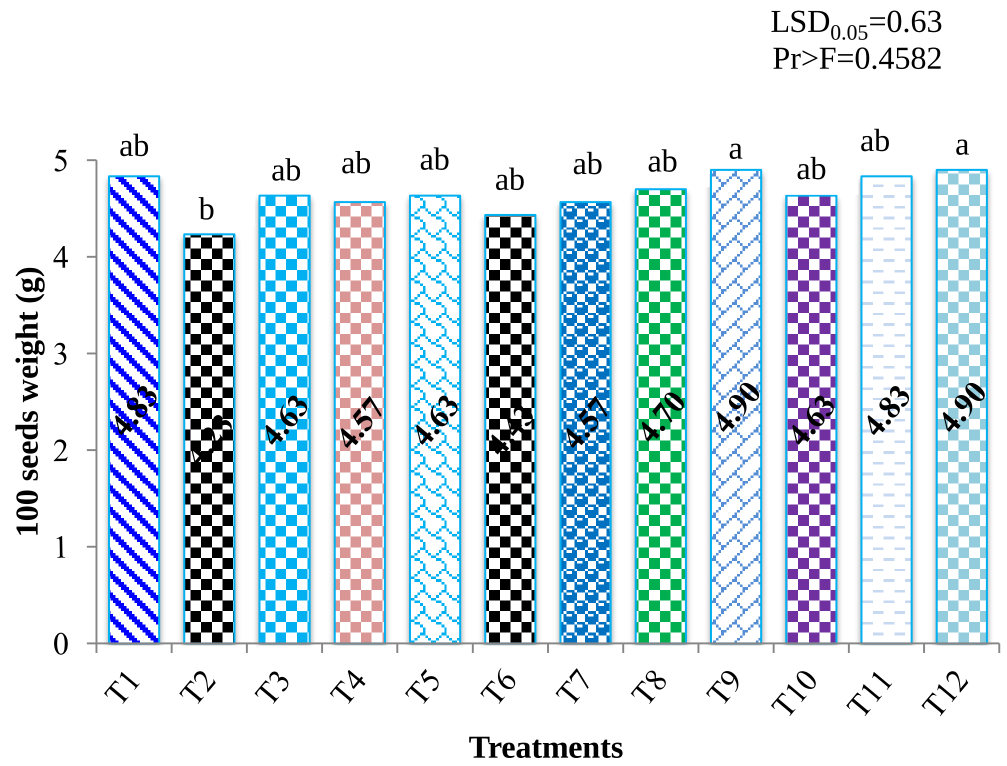
T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.12 Mean values of number of seeds pod^{-1} as affected by different rates of combined application of zinc and boron in Central Dry Zone during post-monsoon season, 2017

4.2.2.3 Hundred seeds weight

Although the mean number of hundred seed weight was not significantly affected by the application of different rates of zinc and boron, it tended to be higher in the application of zinc and boron than the control (Table 4.5). It was ranging from 4.49 to 4.72 in the zinc application and from 4.60 to 4.72 in the boron application. The maximum 100 seeds weight (4.72) was obtained from (3.0kg Zn ha^{-1}) and (4.72) observed from (1.0kg B ha^{-1}). Quddus et al. (2011), who mentioned that 100 seeds weight was not significant variation and boron application was not significant effect on the 100 seeds weight.

Although the interaction effect of zinc and boron on the 100 seeds weight of green gram was not significant (Table 4.5), the maximum 100 seed weight (4.90) was observed from T_9 (2.0kg Zn ha^{-1} + 1.0 kg B ha^{-1}) which is statistically similar to T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) followed by (4.83) from T_{11} (3.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) which is also statistically similar to control, the minimum (4.23) was recorded from T_2 (0.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) (Figure 4.13). The combined application was more effective than the single application of zinc and boron.



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})

T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})

T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})

T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})

T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

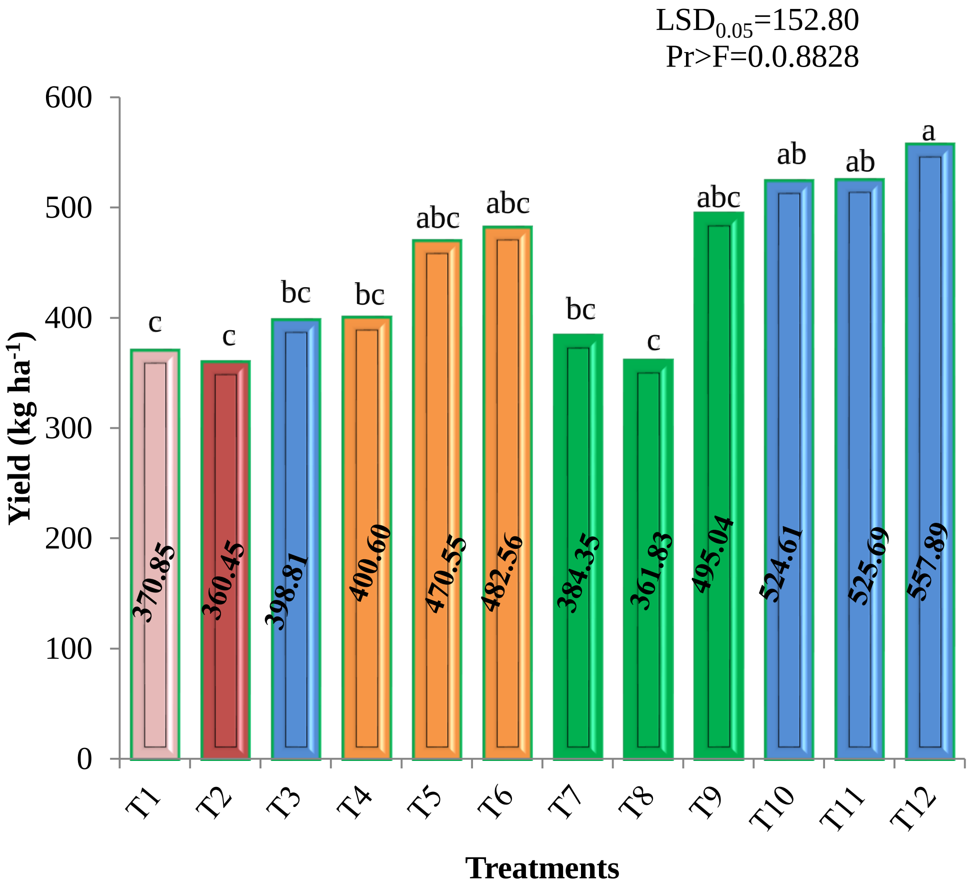
Figure 4.13 Mean values of hundred seeds weight as affected by different rates of combined application of zinc and boron in Central Dry Zone during post-monsoon season, 2017

4.2.2.4 Yield

The mean effect of different rates of zinc on the yield of green gram was highly significantly different (Table 4.5). The maximum yield (536.06 kg ha^{-1}) was obtained from the (3.0 kg Zn ha^{-1}) followed by (451.23 kg ha^{-1}) from (1.0 kg Zn ha^{-1}), (413.74 kg ha^{-1}) from (2.0 kg Zn ha^{-1}) while the minimum (376.70 kg ha^{-1}) was recorded from the no application of zinc. This variation of yield might be due to the effect of different rates of zinc. Zinc performs an important role in metabolic process which increase straw and grain yield (Lokhande et al., 2018). Zinc has its role in various enzymic reactions, growth processes, hormone production and protein synthesis and also the translocation of photosynthates to reproductive parts thereby leading to higher yield of the crops (Keerthi, Babu, Joseph & Amuhta, 2015).

Although no significant mean effect of different rates of boron on the yield of green gram was observed, the maximum yield (483.57 kg ha^{-1}) was found from the (1.0 kg B ha^{-1}) followed by (429.63 kg ha^{-1}) from (0.5 kg B ha^{-1}), however the minimum yield (420.10 kg ha^{-1}) was recorded from the non-application of boron. Yield increase was found by applying with increasing rates of boron. This trend might be due to the influenced of boron on the yield of green gram. This finding was agreed by Quddus et al. (2011), who reported that the grain yield of mung bean was no significant variation due to the application of boron.

There was no significant interaction effect between zinc and boron on the mean yield of green gram (Table 4.5). However, among the treatments, the maximum yield (557.89 kg ha^{-1}) was obtained from T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) followed by (525.69 kg ha^{-1}) from T_{11} (3.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) and (524.61 kg ha^{-1}) from T_{10} (3.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}) while the minimum yield (360.45 kg ha^{-1}) from T_2 (0.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) which was statistically similar to control (Figure 4.14). The combination of highest level of zinc (3.0kg Zn ha^{-1}) with each of different rates of boron produced the maximum yield higher than the other treatments. This might be increased in significant pods formation due to the effect of different rates of zinc and boron.



$T_1=Zn_0B_0$= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})	$T_7=Zn_2B_0$= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
$T_2=Zn_0B_1$= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})	$T_8=Zn_2B_1$= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
$T_3=Zn_0B_2$= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})	T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})
$T_4=Zn_1B_0$= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})	T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})
$T_5=Zn_1B_1$= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})	T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})
$T_6=Zn_1B_2$= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})	$T_{12}=Zn_3B_2$= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.14 Mean values of yield of green gram as affected by different rates of combined application of zinc and boron in Central Dry Zone during post-monsoon season, 2017

4.2.2.5 Total dry matter

The mean effect of different rates of zinc on the total dry matter was significantly different (Table 4.6). The maximum total dry matter (2106.60 kg ha^{-1}) was recorded from (3.0 kg Zn ha^{-1}) followed by (1953.80 kg ha^{-1}) from (2.0 kg Zn ha^{-1}) while the minimum total dry matter (1691.40 kg ha^{-1}) was observed from (1.0 kg Zn ha^{-1}) which was statistically similar to control. By the time zinc was applied with increasing rates, the total dry matter was still increasing. This might be due to zinc application as its direct influence on the auxin production which enhanced the elongation processes of plant development. It might be due to optimum dose of zinc sulphate, which significantly affected the grain formation and vegetative growth in check pea and thereby increases the biological yield (as cited in Valenciano, Boto & Marcelo, 2010).

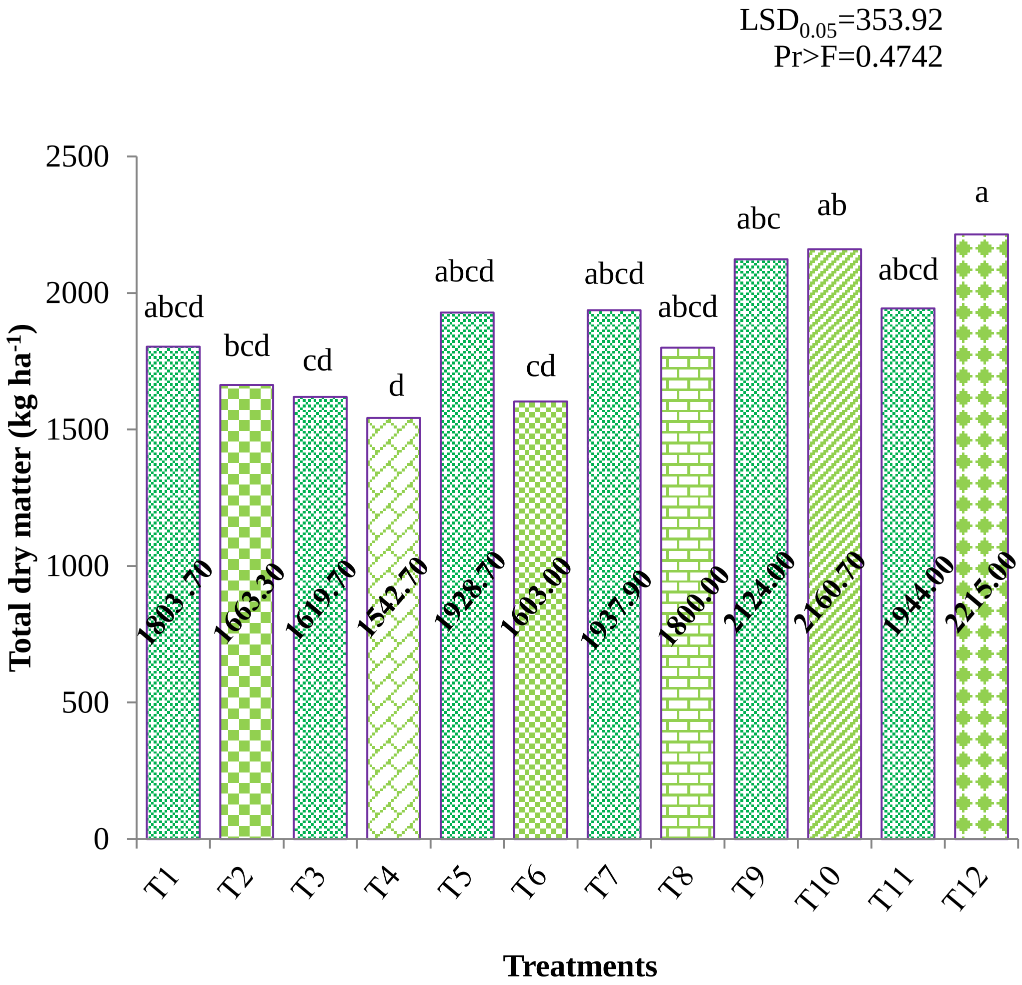
The mean effect of different rates of boron on the total dry matter was not significantly different (Table 4.6). The maximum total dry matter (1890.4 kg ha^{-1}) was recorded from (1.0 kg B ha^{-1}) while the minimum (1834.00 kg ha^{-1}) was obtained from control which was statistically similar to (0.5 kg B ha^{-1}) (1861.0 kg ha^{-1}). This might be due to the effect of boron application as its direct affected on flowering, seed setting, on pod formation and in stabilizing of cell wall and plasma membrane, enhancement of cell division. Padbhushan and Kumar (2015) reported that soil applied B had more influence on mean dry matter yield.

The interaction effect of zinc and boron on the total dry matter of green gram was not significant (Table 4.6). Among the treatments, the maximum total dry matter (2215.00 kg ha^{-1}) was found from T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) followed by (2160.70 kg ha^{-1}) from T_{10} (3.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}) and (2124.00 kg ha^{-1}) from T_9 (2.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}). However, the minimum total dry matter (1542.70 kg ha^{-1}) was recorded from T_4 (1.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}) (Figure 4.15). This might be due to synergistic effect of zinc and boron on the total dry matter. Debnath et al. (2018) indicated that Zn and B gave synergic effect on the biological yield of cowpea.

Table 4.6 Mean effect of different rates of zinc and boron on total dry matter and harvest index of green gram in Central Dry Zone during post-monsoon season, 2017

Treatments	Total dry matter (kg ha^{-1})	Harvest index (HI)
Zinc (kg ha^{-1})		
0.0	1695.6 b	0.22 bc
1.0	1691.4 b	0.27 a
2.0	1953.8 ab	0.21 c
3.0	2106.6 a	0.25 ab
$LSD_{0.05}$	**309.41**	**0.04**
Boron (kg ha^{-1})		
0.0	1834.0	0.22
0.5	1861.1	0.23
1.0	1890.4	0.25
$LSD_{0.05}$	**267.95**	**0.03**
Pr>F		
Zn	0.0259	0.0289
B	0.9094	0.1920
Zn x B	0.4742	0.8426
CV%	**17.00**	**18.24**

Means within a column having same letter (s) are not significantly different at LSD 5% level.



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})
T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})
T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})
T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})
T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})
T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})
T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})
T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})
T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

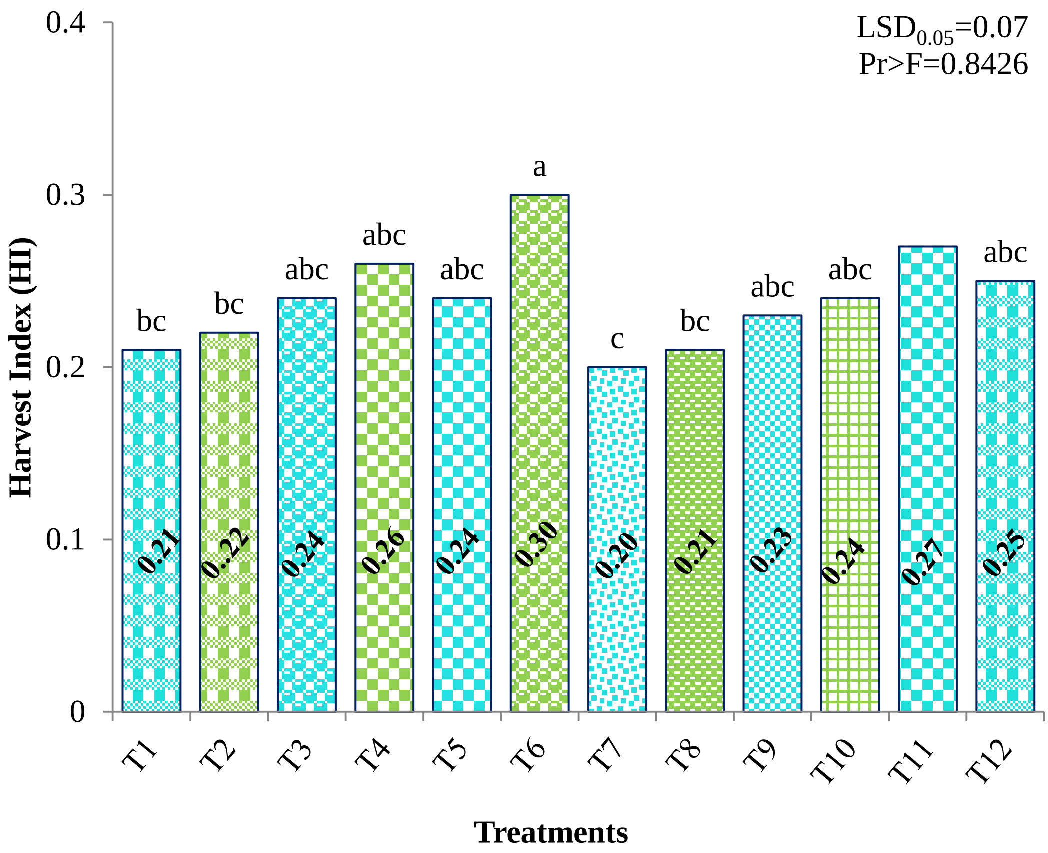
Figure 4.15 Mean values of total dry matter as affected by combined application of zinc and boron in Central Dry Zone during post-monsoon season, 2017

4.2.2.6 Harvest index (HI)

The mean effect of different rates of zinc on the harvest index was significantly different (Table 4.6). The maximum harvest index (0.27) was recorded from (1.0 kg Zn ha^{-1}) followed by (3.0 kg Zn ha^{-1}) whereas the minimum harvest index (0.21) was obtained from (2.0 kg Zn ha^{-1}) which was statistically similar to non-application of zinc. This variation might be due to the influenced of zinc application. Zinc fertilizer had a significant effect on harvest index (Khorgamy & Farina, 2009).

No significant difference in mean effect of different rates of boron on the harvest index was observed (Table 4.6). However, harvest index increased with increased rates of boron application. The maximum harvest index (0.25) was observed from (1.0 kg B ha^{-1}) followed by (0.23) from (0.5 kg B ha^{-1}) while the minimum harvest index was obtained from the non-application of boron. This might be due to the effect of boron throughout the reproductive stage. Harvest index determines the amount of photosynthates being translocated to the economic parts of plant (Usman et al., 2014).

Although there was no significant interaction effect between zinc and boron on the harvest index (Table 4.6), the maximum harvest index (0.30) was recorded from T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) followed by (0.27) from T_{11} (3.0 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) while the minimum harvest index (0.20) was recorded from T_7 (2.0 kg Zn ha^{-1} + 0.0 kg B ha^{-1}) which was statistically similar to control (Figure 4.16).



T_1=Zn_0B_0= (0.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_2=Zn_0B_1= (0.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_3=Zn_0B_2= (0.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_4=Zn_1B_0= (1.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_5=Zn_1B_1= (1.0kgZn ha^{-1} + 0.5kg B ha^{-1})

T_6=Zn_1B_2= (1.0kg Zn ha^{-1} + 1.0kg B ha^{-1})

T_7=Zn_2B_0= (2.0kg Zn ha^{-1} + 0.0kg B ha^{-1})

T_8=Zn_2B_1= (2.0kg Zn ha^{-1} + 0.5kg B ha^{-1})

T_9= Zn_2B_2= (2.0kg Zn ha^{-1}+ 1.0kg B ha^{-1})

T_{10}= Zn_3B_0= (3.0kg Zn ha^{-1}+0.0kg B ha^{-1})

T_{11}= Zn_3B_1= (3.0kg Zn ha^{-1}+0.5kg B ha^{-1})

T_{12}=Zn_3B_2= (3.0kg Zn ha^{-1} +1.0kg B ha^{-1})

Figure 4.16 Mean values of harvest index as affected by combined application of zinc and boron in Central Dry Zone during post-monsoon season, 2017

CHAPTER V

CONCLUSION

The present study emphasized on the effect of different rates of zinc and boron on yield and yield contributing characters of green gram in monsoon and post-monsoon seasons, 2017.

All yield and yield components characters were not significantly affected by the application of zinc fertilizer in monsoon season but yield, plant height, number of pods $plant^{-1}$, total dry matter and harvest index were significantly affected by it in post-monsoon season. The application of Zn level (3.0 kg Zn ha^{-1}) produced the maximum yield in both seasons.

Although the effect of boron application was not significantly different in yield, plant height, number of seeds pod^{-1}, and 100 seeds weight, it was significantly different in number of pods $plant^{-1}$ in both seasons. Number of branches $plant^{-1}$, total dry matter and harvest index were significantly affected by boron application in monsoon season but were not significant in post-monsoon season. The application of boron level (1.0 kg B ha^{-1}) gave the maximum yield in both seasons.

The effect of combined applications of Zn and B was not significantly different in yield, plant height, number of branches $plant^{-1}$, number of seeds pod^{-1}, and 100 seeds weight in both seasons but its effect was significant in number of pods $plant^{-1}$, total dry matter and harvest index in monsoon season. Generally, the combined application was higher in all characters than single application of Zn and B in both seasons. In both seasons, T_{12} produced maximum yield, it was statistically similar to T_6 in monsoon season. Therefore, the treatment T_6 (1.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) was the optimum dose for monsoon season and T_{12} (3.0 kg Zn ha^{-1} + 1.0 kg B ha^{-1}) was also a suitable dose for post-monsoon season for the maximization of green gram yield in the study area.

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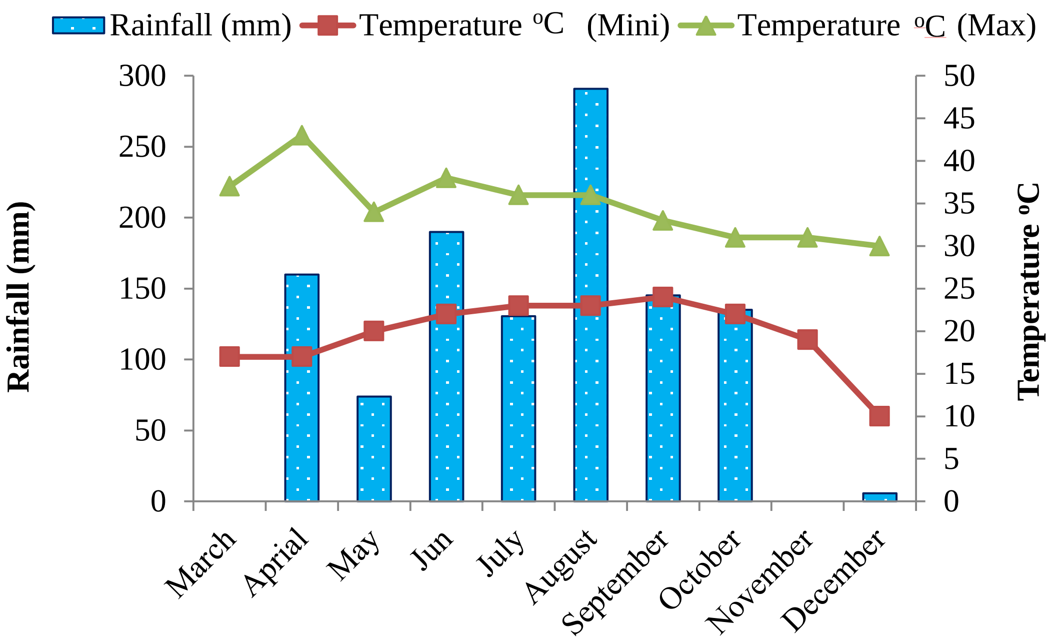
APPENDICES

Appendix I Monthly average rainfall, minimum and maximum temperature of Minbu Township, 2017



Source: Department of Agriculture, Irrigation and Livestock, Minbu Township, Magway Region.

Appendix II Mean effect of different rates of zinc and boron on plant height from 10DAS to 45DAS during monsoon season, 2017

Treatments	Plant height (cm)					
	10DAS	**17DAS**	**24DAS**	**31DAS**	**38DAS**	**45DAS**
Zinc (kg ha^{-1})						
0.0	4.89	8.75	11.27	13.72	23.00	36.07
1.0	4.62	8.64	11.23	14.09	23.46	37.33
2.0	4.75	8.73	11.36	14.31	23.83	40.60
3.0	4.63	8.83	11.28	14.37	23.84	40.15
$LSD_{0.05}$	**0.34**	**0.72**	**0.66**	**1.15**	**2.16**	**4.44**
Boron (kg ha^{-1})						
0.0	4.67	8.78	11.25	14.06	23.05	36.07
0.5	4.76	8.67	11.17	14.09	23.09	39.07
1.0	4.75	8.77	11.44	14.22	24.46	36.87
$LSD_{0.05}$	**0.29**	**0.63**	**0.57**	**0.99**	**1.87**	**3.85**
Pr>F						
Zn	0.3184	0.9616	0.9827	0.6407	0.8340	0.7522
B	0.7935	0.9181	0.6048	0.9384	0.2248	0.5789
Zn x B	0.2924	0.3561	0.3665	0.8878	0.4452	0.8692
CV%	**7.29**	**8.48**	**5.95**	**8.35**	**9.38**	**11.78**

Appendix III Mean effect of different rates of zinc and boron on plant height from 10DAS to 45DAS during post-monsoon season, 2017

Treatments	Plant height (cm)					
	10DAS	**17DAS**	**24DAS**	**31DAS**	**38DAS**	**45DAS**
Zinc (kg ha^{-1})						
0.0	6.20	11.77	15.40	23.26	31.75 b	34.57 b
1.0	6.08	12.28	16.37	23.62	32.93 b	35.73 ab
2.0	5.95	11.82	15.26	23.97	34.40 ab	36.51 ab
3.0	5.95	12.28	16.71	24.62	36.82 a	38.62 a
$LSD_{0.05}$	**0.62**	**1.21**	**1.47**	**2.25**	**3.35**	**3.02**
Boron (kg ha^{-1})						
0.0	6.03	12.38	15.86	24.00	34.71	36.85
0.5	6.03	11.53	15.80	23.58	33.50	36.15
1.0	6.08	12.26	16.15	24.03	33.71	36.08
$LSD_{0.05}$	**0.54**	**1.04**	**1.28**	**1.95**	**2.90**	**2.62**
Pr>F						
Zn	0.8216	0.6602	0.1423	0.6451	0.0286	0.0486
B	0.9760	0.2130	0.8356	0.8691	0.6568	0.9779
Zn x B	0.4858	0.3821	0.0423	0.0436	0.0965	0.2501
CV%	**10.61**	**10.27**	**9.49**	**9.68**	**10.11**	**8.51**

Means within a column having same letter (s) are not significantly different at LSD 5% level.