

*Full Length Research Paper*

# Improving maize productivity through tillage and nitrogen management

Allah Wasaya<sup>1\*</sup>, Muhammad Tahir<sup>2</sup>, Abdul Manaf<sup>1</sup>, Mukhtar Ahmed<sup>1</sup>, Shuaib Kaleem<sup>3</sup> and Ijaz Ahmad<sup>4</sup>

<sup>1</sup>Department of Agronomy, PMAS-Arid Agriculture University Rawalpindi, Pakistan.

<sup>2</sup>Department of Agronomy, University of Agriculture Faisalabad, Pakistan.

<sup>3</sup>Agriculture Adaptive Research Complex, Dera Ghazi Khan, Pakistan.

<sup>4</sup>Soil Conservation, Agriculture Complex, Jail Road Gujrat, 50400, Pakistan.

Accepted 4 November, 2011

Continuous cultivation of fields with same implement (cultivator) creates a hard pan in the subsoil which adversely affects crop productivity. In addition to tillage, nitrogen management is a key factor for better crop growth and yield. Impact of different tillage systems and nitrogen management on yield attributes and grain yield of hybrid maize was evaluated by conducting experiments at the Agronomic Research Area, University of Agriculture, Faisalabad during 2008 and 2009. The experiment comprised of three tillage systems viz. conventional tillage, tillage with mould board plough followed by 2-cultivations (with cultivator), tillage with chisel plough followed by 2-cultivations (with cultivator) and three nitrogen levels (100, 150 and 200 kg ha<sup>-1</sup>). Different tillage systems and nitrogen levels significantly influenced the maize yield and yield components. Chisel ploughed plots resulted to heavier cobs, higher 1000-grain weight and grain yield in comparison with other tillage systems. Maize yield with chisel tilled plots was 18 and 9% higher than mould board ploughed and conventionally tilled plots, respectively. Generally, differences between different nitrogen application rates were more pronounced; increasing nitrogen rate resulted in increased yield and yield components of maize. Significantly, highest grains weight per cob, 1000-grain weight and grain yield was recorded with 200 kg ha<sup>-1</sup> nitrogen application. Maize yield with 200 kg ha<sup>-1</sup> nitrogen application was 17 and 8.50% higher than 100 and 150 kg ha<sup>-1</sup> nitrogen application, respectively. Therefore, it may be concluded that maize hybrids should be grown with 200 kg ha<sup>-1</sup> nitrogen application by preparing the field with chisel plough followed by cultivator.

**Key words:** Maize productivity, chisel plough, conventional tillage, nitrogen.

## INTRODUCTION

Maize (*Zea mays* L.) is one of the most widely grown cereals in the world and has great significance as human food, animal feed and raw material. In most developing countries, about 50 to 55% of the total maize production is consumed as food (Kumar et al., 2007). It is the third most important cereal crop of Pakistan after wheat and rice and is grown both in autumn as well as spring season in Pakistan. In Pakistan, maize is grown on an area of 0.95 m. ha with an annual production of 3.49 m.

tons and average yield of 3.67 t ha<sup>-1</sup> (Anonymous, 2009). Nitrogen plays a vital role in nutritional and physiological status of plants and stimulates changes in mineral composition of plants (Mengel and Kirkby, 1982). Nitrogen is the integral part of chlorophyll molecule; a deficiency of N will result in a chlorotic condition of the plant. Nitrogen is also a structural constituent of cell walls (Schraeder, 1984). Soil fertility and crop productivity is increased by nitrogen fertilization. It results in increased grain yield (43 to 68%) and biomass (25 to 42%) in maize (Ogola et al., 2002). It also contributes 18 to 34% increase in soil residual nitrogen (Yang et al., 2007). Nitrogen fertilization in nitrogen deficient soil results in increased maize grain yield. Increase in yield occurs up

\*Corresponding author. E-mail: [wasayauaf@gmail.com](mailto:wasayauaf@gmail.com). Tel: +92-3006765024.

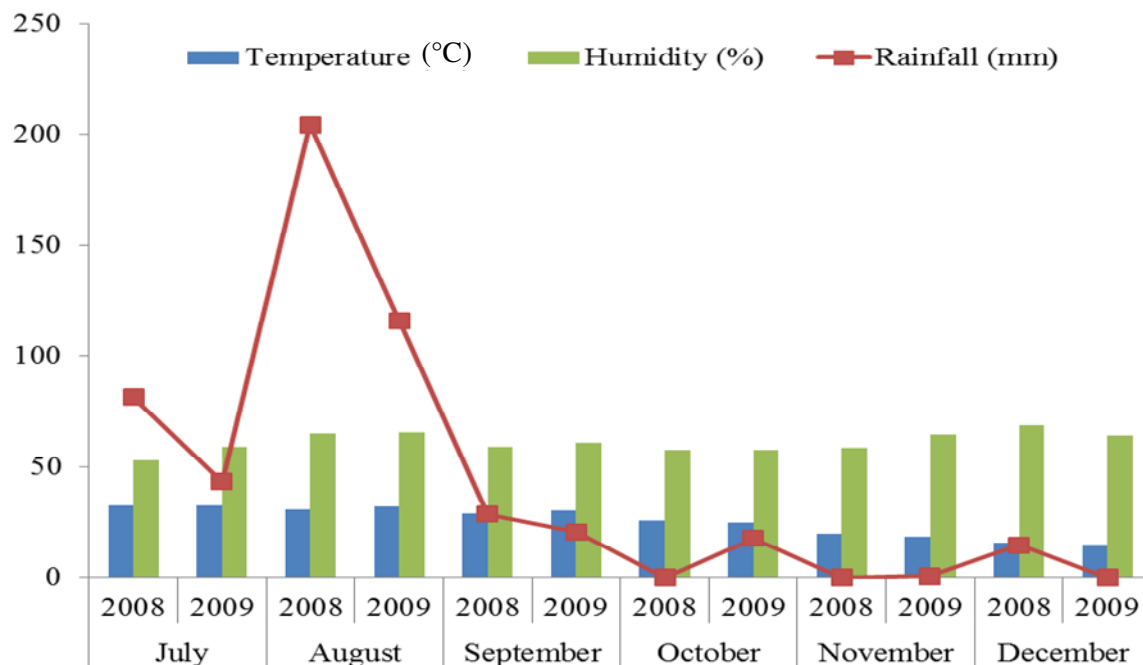


Figure 1. Meteorological data for whole crop growing season for the year 2008 and 2009.

to a certain limit after which further nitrogen application either has no effect or causes reduction in yield (Nagy, 1997).

Soil nutrient status and application of fertilizer are the essential factors on which maize yield depend and it varies from location to location and variety to variety (Shanti et al., 1997). Application of nitrogen had a significant effect on number of grains per cob and 1000-grain weight (Fedotkin and Kravtsov, 2001; Mahmood et al., 2001). In addition to plant nutrition, soil condition also plays a significant role in crop establishment, growth and yield. In improving soil condition, tillage is a key factor and plays a significant role in improving maize growth and grain yield. A compacted soil layer, because of its high strength and low porosity, confines the crop roots in the top layer and reduces the volume of soil that can be explored by the plants for nutrients and water (Lipiec et al., 2003). Due to compaction, availability of soil N to roots is also reduced, which results in decreased shoot number.

Tillage as practice in crop production systems can affect soil environment components that are important to plant growth. Tillage operations and soil disturbance generally can cause an increase in soil aeration, organic N mineralization and the availability of N for plant use (Halvorson et al., 2001; Dinnes et al., 2002). Tillage pans occur in many sandy-loam agricultural soils due to repeated tillage practices at the same depth and hardening in no-tilled soils, and must be removed by using deep tillage to maximize yields. Deep tillage of the soil results in increased corn grain yields with the greatest yield always being obtained with tillage depth of 90 cm (Varsa

et al., 1997). Deep tillage results in lower penetration resistance by soil loosening and manipulating of the deeper soil layer (Jabro et al., 2010). Although very little study had been done previously on tillage in maize, its results are contradictory. Hence, this study was designed with an objective to evaluate the impact of different tillage systems and nitrogen rates on yield attributes and grain yield of hybrid maize.

## MATERIALS AND METHODS

### Experimental site

A two-year study was carried out at the Agronomic Research Area, Department of Agronomy, University of Agriculture, Faisalabad (Pakistan) on a sandy clay loam soil under the semi-arid and subtropical climatic conditions (longitude 73° East and latitude 31° North). The altitude of site is 135 m above the sea level.

### Meteorological data

The rainfall, humidity and temperature data for the whole growing period of the crop under study (2008 and 2009) was collected from the Department of Crop Physiology, University of Agriculture, Faisalabad Pakistan as shown in Figure 1.

### Experimental design

The experiments were carried out in a randomized complete block design with split plot arrangement and replicated three times. A net plot size of 4.5 m × 10 m was used. The tillage treatments were randomized in the main plots and nitrogen levels in the subplots.

Main plot treatments comprised of three tillage systems viz. conventional tillage, tillage with mould board plough followed by 2-cultivations (with cultivator) and tillage with chisel plough followed by 2-cultivations (with cultivator) and subplot treatments comprised of three nitrogen levels (100, 150 and 200 kg ha<sup>-1</sup>). Soil was cultivated with the help of tractor-mounted cultivator in the case of conventional tillage. Two cultivations were done followed by planking. In the second treatment, the soil was ploughed with mould board plough followed by cultivations and planking. In the third treatment, the soil was ploughed with chisel plough followed by cultivations and planking. Maize hybrid pioneer-31R88 was sown on August 07, 2008 and August 01, 2009 at a seeding rate of 25 kg ha<sup>-1</sup> with 75 cm row and 20 cm plant spacing by using dibbler. Two seeds were planted per hill and then one plant per hill was maintained by thinning at three leaf stage. P and K were applied at sowing time at the rate of 100 kg ha<sup>-1</sup> each in the form of single super phosphate (SSP) and sulphate of potash (SOP), respectively and nitrogen was applied according to treatments in the form of urea.

### Soil sampling and analysis

The field under experiment was previously cropped with wheat which was harvested three month prior to maize sowing and kept fallow for three months. Before sowing crops, soaking irrigation of four acre inches was applied and field was prepared for maize sowing when it had reached a proper moisture level. The soil samples were collected randomly from the field and were analyzed for different soil physico-chemical properties. The experimental soil was sandy clay loam containing sand (58 and 60%), (silt 20.2 and 18%) and clay (21.8 and 20%) during 2008 and 2009, respectively. The experimental soil consisted of 0.72 and 0.69% organic matter, 6.1 and 6.8 ppm of available phosphorus, 120 and 115 ppm exchangeable potassium, 0.042 and 0.035% available nitrogen, ECe 1.42 and 1.54 dSm<sup>-1</sup> (1:2.5 soil-H<sub>2</sub>O mixture) and pH of 7.9 and 8.0 (1:2.5 soil-H<sub>2</sub>O mixture) during 2008 and 2009, respectively.

Data for different agronomic parameters was collected following the standard procedure. Ten cobs from each subplot were collected and grain rows, grains number, grains weight and cob length were measured and then averaged to find out grains per cob, grain rows per cob, grains weight per cob and cob length. 1000-grains were counted from the cobs of each subplot and weighed to find out 1000-grain weight. Two central rows were harvested from each subplot to find out grain yield in kg per plot and then converted to t ha<sup>-1</sup>.

### Statistical analysis

The data collected were statistically analyzed by using computer software MSTAT-C (Freed and Scott, 1986). Analysis of variance technique was used to test the data and LSD at 5% probability was used to compare the treatment's means (Steel et al., 1997).

## RESULTS AND DISCUSSION

### Number of grains per cob

Different tillage system did not affect number of grains per cob to significant level in 2008, however, effects reached significant level ( $p \leq 0.05$ ) in 2009 for the same parameter. In 2009, more number of grains per cob (416.3 cm) was recorded when maize was grown by

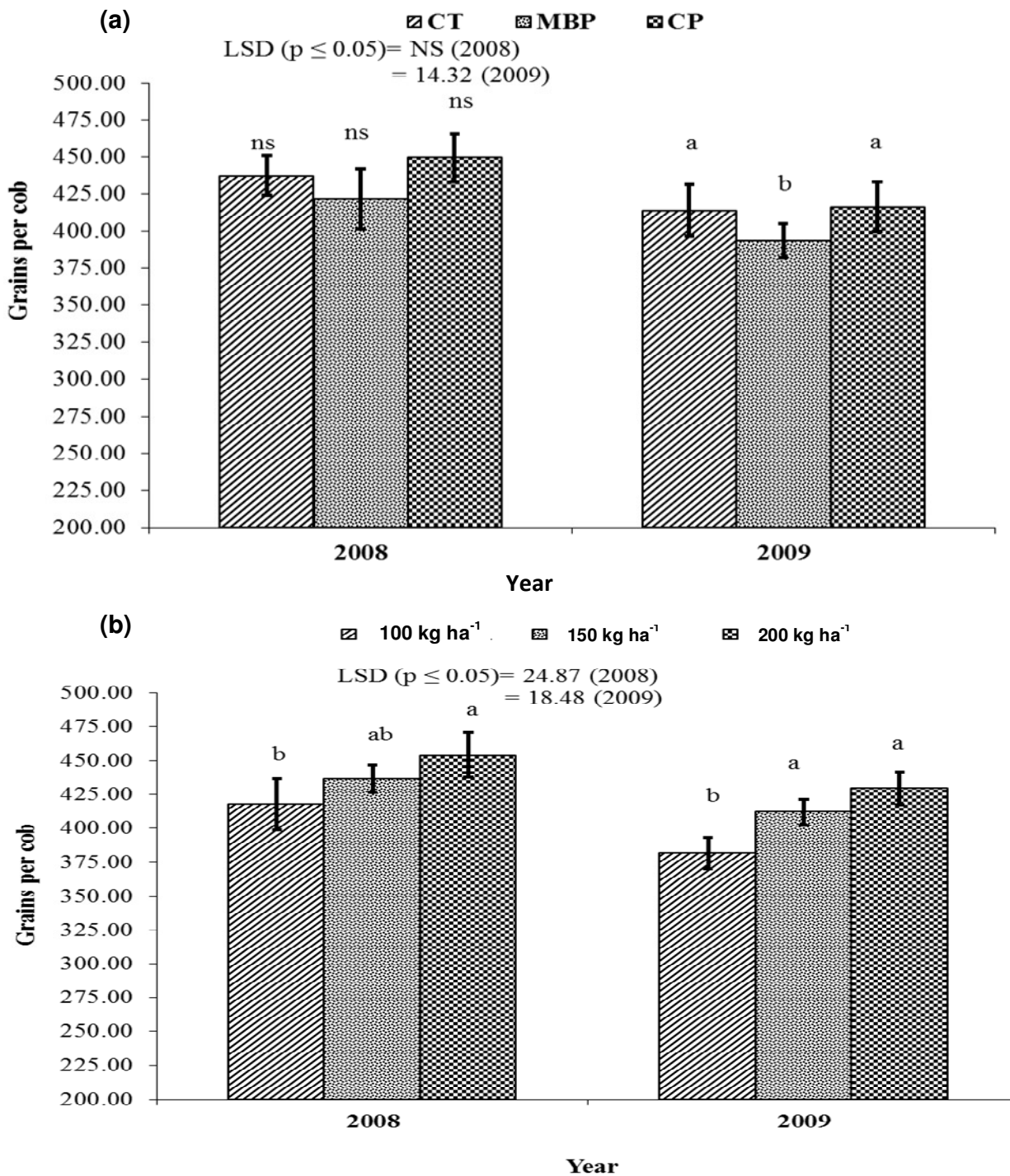
using chisel plough which was at par with the number of grains per cob harvested from the maize plots grown under conventional tillage practices, while least number of grains per cob (393.5 cm) was observed in case of mould board plough (Figure 2). Reduction in grains per cob in mould board plough may be attributed to higher soil bulk density which reduced the soil depth explored by maize roots (Ahadiyat and Ranamukhaarachchi, 2008).

Number of grains per cob was significantly affected ( $p \leq 0.05$ ) in response to different levels of nitrogen application rates. More number of grains per cob (454.3 cm) were obtained with the maize grown by the application of 200 kg ha<sup>-1</sup> N which was at par with the number of grains per cob of maize at 150 kg ha<sup>-1</sup> N. The least number of grains per cob (417.7) was recorded in maize plots fertilized with 100 kg ha<sup>-1</sup> N during 2008. Similarly, different nitrogen rates significantly ( $p \leq 0.05$ ) affected the number of grains per cob in 2009. More grains in the case of 200 kg ha<sup>-1</sup> N was produced due to better growth of maize and healthy cob size as hybrid maize required more nitrogen. Application of N at higher rate delayed growth period of maize, thus resulting to more grains per cob (Amanullah et al., 2009). Likewise greater number of grains per cob by using higher dose of nitrogen was reported by Akmal et al. (2010) and Bakht et al. (2006).

### Grain rows per cob

Grain rows per cob in maize did not differ significantly when grown under different tillage practices during 2008, but differed in 2009. The highest number of rows per cob (16.92) was recorded when maize was grown in chisel tilled plots which was at par with those maize plots grown under conventional tillage practices, while least number of grain rows per cob (16.22) was observed in 2009. The highest number of grain rows per cob in the case of deep tillage followed by shallow tillage was also reported by Rashidi and Keshavarzpour (2007).

In addition, different doses of nitrogen application significantly affected the grain rows per cob during both years of the study. Increase in nitrogen application rate resulted in increased grains rows per cob. Grains' rows per cob produced by maize fertilized with 200 and 150 kg ha<sup>-1</sup> N were not significantly different from each other, but statistically differed from the maize plots treated with 100 kg ha<sup>-1</sup> N. However, significantly ( $p \leq 0.05$ ) greater number of rows per cob (17.52) was observed in maize fertilized with 200 kg ha<sup>-1</sup> N, which was at par with those plots fertilized with 150 kg ha<sup>-1</sup> N. The least number of rows per cob (15.92) was observed where nitrogen was applied at 100 kg ha<sup>-1</sup> during 2008 whereas, maximum number of grains rows per cob (16.89) in maize was obtained when 200 kg ha<sup>-1</sup> N was applied and was at par with 150 kg ha<sup>-1</sup> N in 2009 (Figure 3). However, significantly minimum grain rows per cob (15.52) were observed in plots fertilized with 100 kg ha<sup>-1</sup> N. A slight increase in grain rows per cob with increasing nitrogen

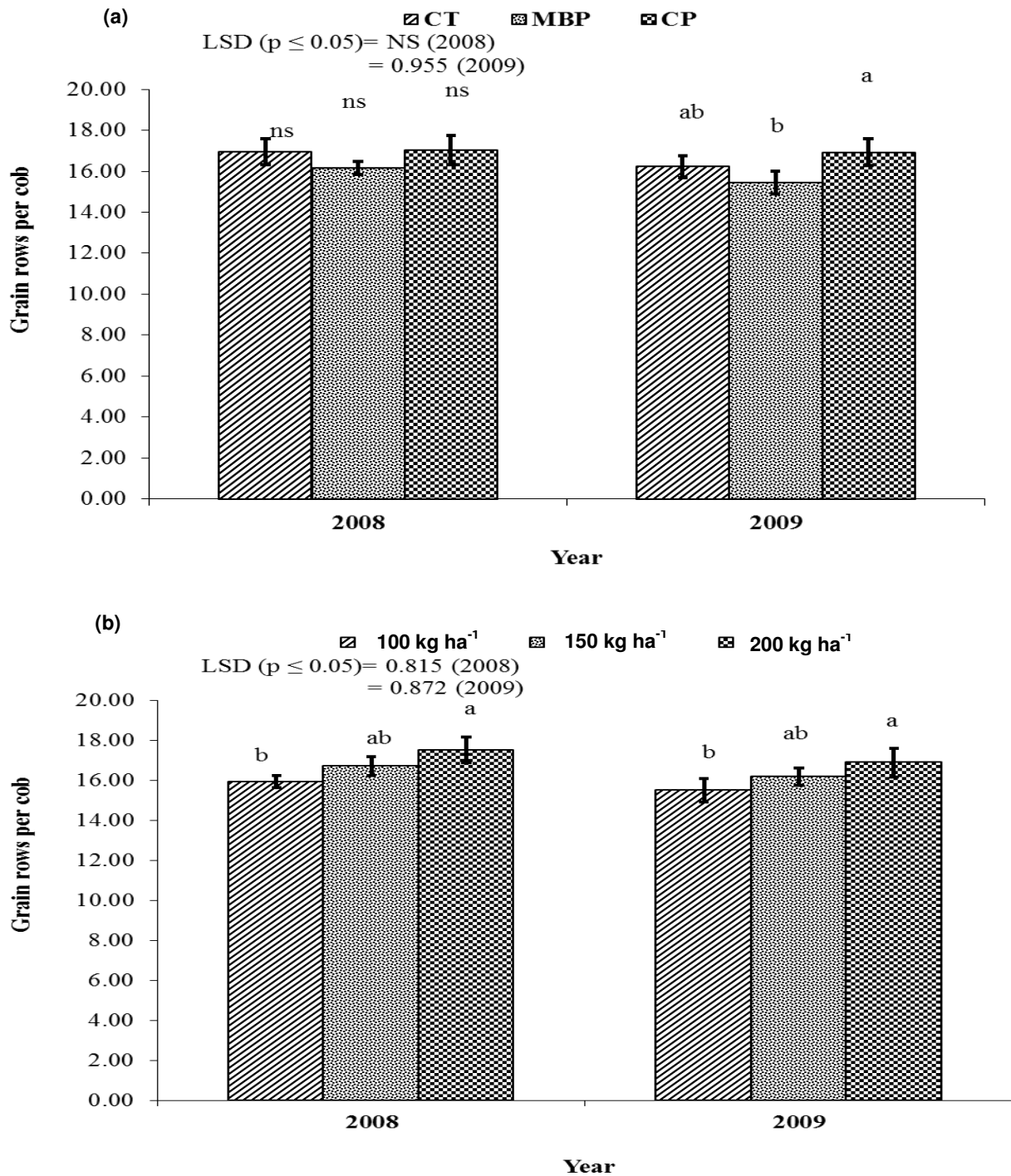


**Figure 2.** Effect of different tillage systems and nitrogen levels on grains per cob in maize during 2008 and 2009. CP, Conventional tillage; MBP, tillage with mould board plough followed by 2-cultivations (with cultivator); CP, tillage with chisel plough followed by 2-cultivations (with cultivator).

levels was observed, but was statistically non-significant (Hokmalipour et al., 2010). These results are also in conformity with the findings of Ali et al. (2002) who observed statistically more grain rows at higher nitrogen application rates.

**Grains weight per cob (g)**

Tillage intensity affected the grains weight per cob significantly ( $p \leq 0.05$ ) as shown in Figure 4. Chisel ploughed plots resulted to heavier cobs which were at par with

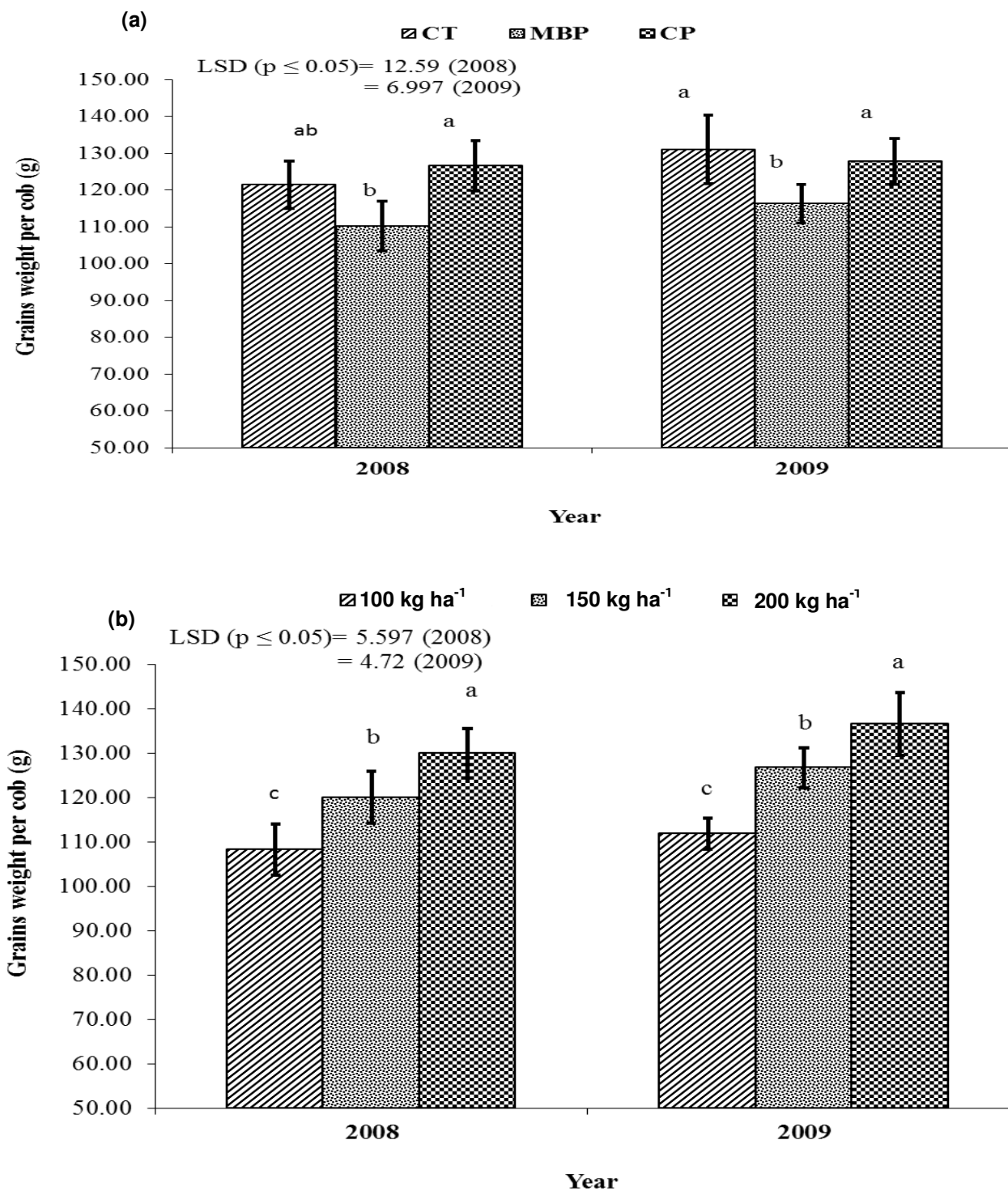


**Figure 3.** Effect of different tillage systems and nitrogen levels on grains rows per cob in maize during 2008 and 2009. CP, Conventional tillage; MBP, tillage with mould board plough followed by 2-cultivations (with cultivator); CP, tillage with chisel plough followed by 2-cultivations (with cultivator).

maize plots cultivated by conventional method. However, significantly lighter cobs were harvested from plots cultivated with mould board plough in 2008. Similar trend in grains weight per cob was observed during the second year of the study (2009). Although mould board plough

helped to loose soil, however, in this study, the less grains weight per cob might be due to soil compaction with more trafficking of agricultural implements.

Nitrogen also affected the grains weight per cob significantly ( $p \leq 0.05$ ) during both years of the study.



**Figure 4.** Effect of different tillage systems (a) and nitrogen levels (b) on grains weight per cob (g) in maize during 2008 and 2009. CP, Conventional tillage; MBP, tillage with mould board plough followed by 2-cultivations (with cultivator); CP, tillage with chisel plough followed by 2-cultivations (with cultivator).

Maize treated with 200 kg ha<sup>-1</sup> N produced heavier cobs, while lighter cobs were produced when 100 kg ha<sup>-1</sup> N was applied to maize during 2008. Similarly, maximum grains weight per cob was observed in 200 kg ha<sup>-1</sup> N fertilized

plots, while minimum cob weight was observed in plots where N was applied at 100 kg ha<sup>-1</sup> N in 2009. These results are in accordance with the findings of Nasser (2009), who reported that statistically more grains weight

per cob was obtained when maize was grown under high level of nitrogen supply.

### 1000-grain weight (g)

1000-grain weight per cob is an important yield contributing parameter that is directly related to yield. Differences in 1000-grain weight were found significant under different tillage treatments (Figure 5). Chisel plough treatment being superior produced heavier kernels as compared to other tillage treatments. Significantly, the lowest 1000-grain weight was recorded in mould board ploughed plots during 2008. In 2009, similar trend was observed and significantly maximum 1000-grain weight was recorded in plots cultivated with chisel plough, which was at par with plots cultivated by conventional methods. However, significantly minimum 1000-grain weight was recorded in plots cultivated through mould board plough. The higher grain weight was due to bigger grain size and healthy grains which might be due to uptake of more nutrients from the deeper soil layer in case of chisel plough as compared to the rest of the treatments. These results correlated with the findings of Diaz-Zorita (2000) who obtained significantly the highest grain weight in deep tillage as compared to no-tillage. Similarly, Khan et al. (2007) reported that significantly higher 1000-grain was obtained when maize was grown under deep tillage, while the lowest 1000-grain weight was observed in both conventional tillage and no-tillage systems.

More also, nitrogen application rates affected 1000-grain weight significantly ( $p \leq 0.05$ ). Data revealed that N at 200 kg ha<sup>-1</sup> produced significantly ( $p \leq 0.05$ ) heavier grains which were at par with 1000-grain weight produced by N at 150 kg ha<sup>-1</sup>. Significantly lighter grains were produced by maize crop treated with 100 kg ha<sup>-1</sup> N in 2008. Increased grain weight with increasing nitrogen was also observed in 2009 and the similar trend was observed in 2008. Increased grain weight with increasing nitrogen levels was due to more leaf area which intercepted more light and produced more carbohydrates in the source which (carbohydrates) then translocated into sink which mostly is the grain in field crops and increased its size. Increased grain weight with increasing nitrogen levels was also reported by Akmal et al. (2010). Khaliq et al. (2009) also reported the same findings but upto a certain limit (300 kg ha<sup>-1</sup> N) after which decline in 1000-grain weight was observed by increasing nitrogen rate. Higher rate of N level increased kernel weight in maize (Miao et al., 2006; Raja, 2003). Increasing N rates increased the enzyme activity in maize which resulted in higher kernel weight (Purcino et al., 2000).

Furthermore, difference for 1000-grain weight between years was statistically significant. Heavier grains in 2009 as compared to 2008 were observed which was due to favourable environment and occurrence of rainfall at

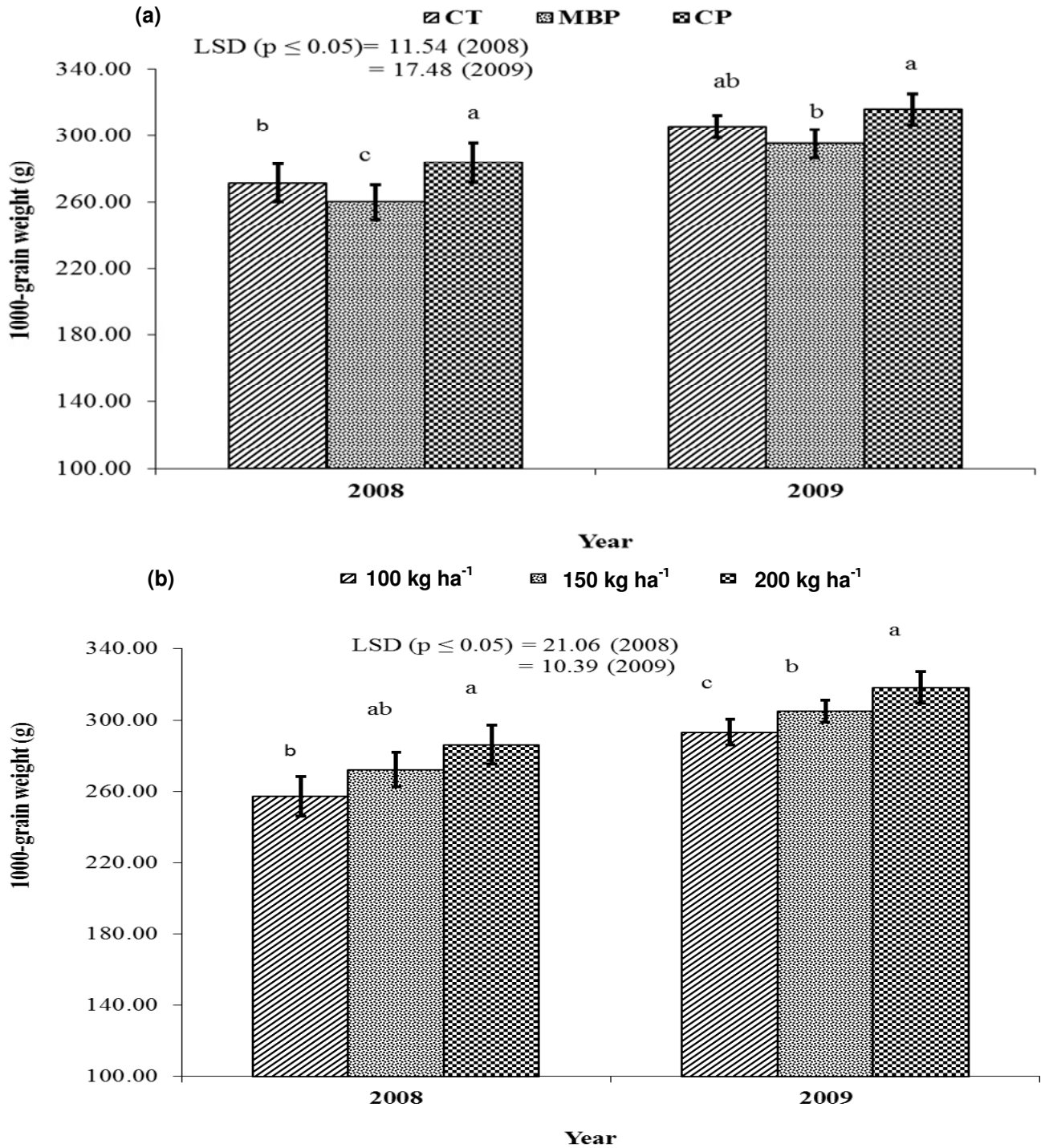
anthesis stage that resulted in healthy grains. However, interaction effect between nitrogen levels and 100-grain weight was found non-significant.

### Grain yield (t ha<sup>-1</sup>)

Tillage systems had a significant effect on grain yield when averaged across nitrogen levels as well as years (Figure 6). Grain yield was significantly ( $p \leq 0.05$ ) greater in chisel plough treatment which was at par with conventional tillage. Significantly ( $p \leq 0.05$ ) lower grain yield was obtained from the maize plots cultivated with mould board plough in 2008. Significantly higher grain yield was recorded in case of chisel plough which was at par with conventional tillage, while yields with mould board plough were statistically lower in 2009. Increase in grain yield under chisel plough treatment was due to more grains weight per cob, as well as 1000-grain weight. Chisel plough breaks the hard pan and resulted in deeper penetration of maize roots for the uptake of nutrients and ultimately resulted in increased grain yield. Significantly greater grain yields were observed under chisel plough as compared to field cultivator, no-tillage and strip tillage (Vetsch and Randall, 2004). About 9% more grain yield was obtained in deep tillage either using chisel plough or mould board plough as compared to no-tillage (Diaz-Zorita, 2000). These results are in agreement with the findings of Astier et al. (2006), who got the highest yield of maize under chisel plough (used as conventional tillage) cultivated plots as compared to zero tillage. Moreover, Marwat et al. (2007) obtained higher maize grain yield in the case of conventional tillage as compared to the reduced tillage.

Nitrogen is an important plant nutrient required for plant growth and development, and plays a significant role in increasing crop yield. Significant effect of nitrogen was observed when averaged across years as well as tillage treatments. Corn grain yield responded positively to nitrogen application. Nitrogen application at 200 kg ha<sup>-1</sup> produced significantly maximum grain yield which was statistically different from other nitrogen treatments and minimum was obtained in 100 kg ha<sup>-1</sup> N treated plots in 2008. Similarly, greater yields were observed in plots fertilized with 200 kg ha<sup>-1</sup> N which was at par with yields obtained from plots treated with 150 kg ha<sup>-1</sup> N. However, lower grain yield was observed in plots where 100 kg ha<sup>-1</sup> N was applied in 2009. Greater grain yield at higher nitrogen rate was probably due to higher grains weight per cob as well as more 1000-grain weight, which was due to better vegetative growth of crop plants at higher nitrogen doses. These results are in line with the findings of Khaliq et al. (2009) who also found that grain yield increased by increasing nitrogen level up to 300 kg ha<sup>-1</sup>. Increase in grain yield by increasing nitrogen level was also reported by Ahmad et al. (2009).

Year affected grain yield significantly ( $p \leq 0.05$ ) and

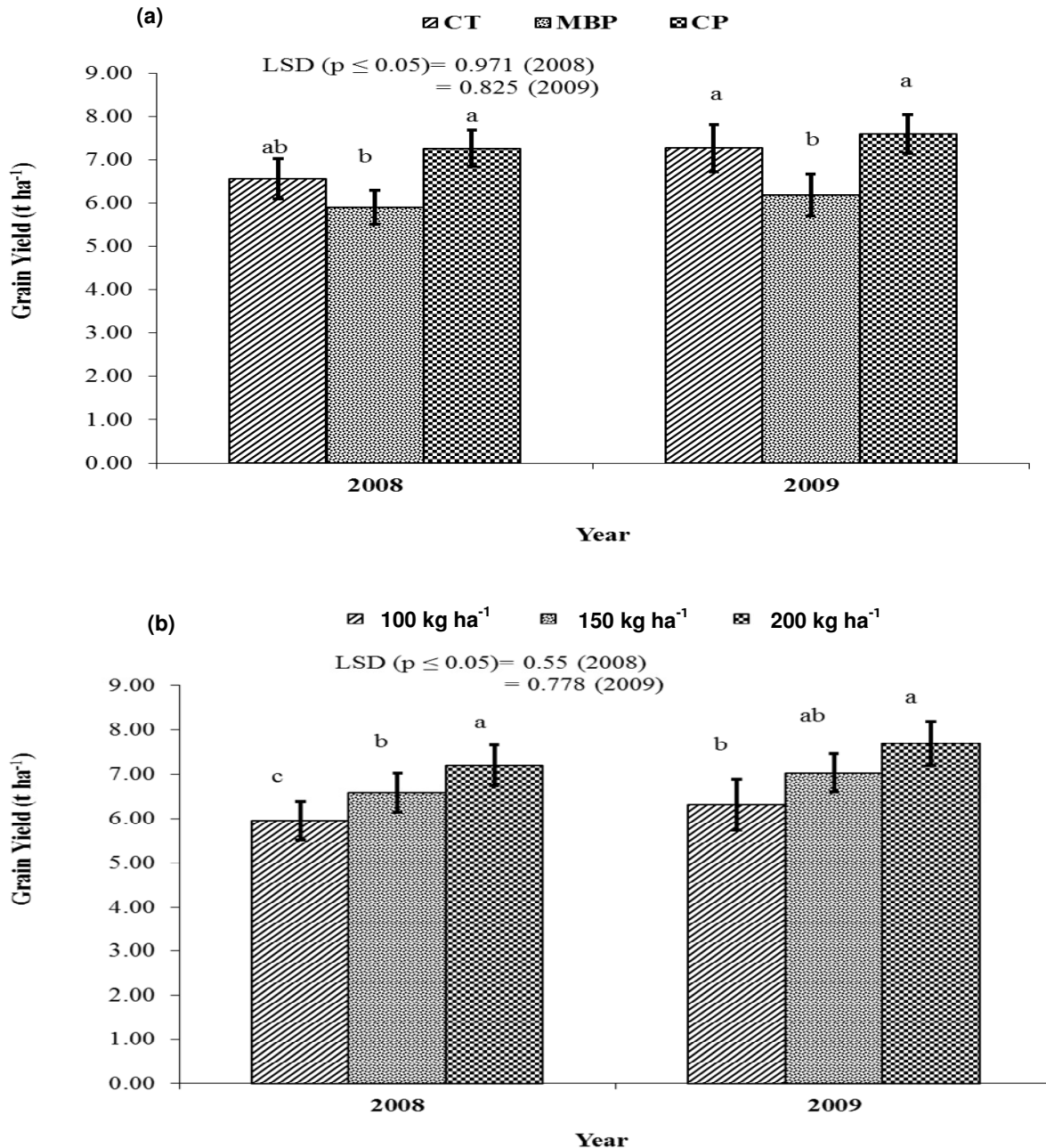


**Figure 5.** Effect of different tillage systems (a) and nitrogen levels (b) on 1000-grain weight in maize during 2008 and 2009. CP, Conventional tillage; MBP, tillage with mould board plough followed by 2-cultivations (with cultivator); CP, tillage with chisel plough followed by 2-cultivations (with cultivator).

statistically, more grain yield was obtained in 2009 as compared to 2008 due to rainfall occurrence at the time of grain formation in 2009, which had positive effect on crop and resulted in increased maize yield. These results

were also supported by the findings of Vetsch and Randall (2004), who reported the significant effect of season on the grain yield of maize. Tillage and nitrogen interaction effect was found to be non-significant.





**Figure 6.** Effect of different tillage systems (a) and nitrogen levels (b) on grain yield ( $t\ ha^{-1}$ ) during 2008 and 2009. CP, Conventional tillage; MBP, tillage with mould board plough followed by 2-cultivations (with cultivator); CP, tillage with chisel plough followed by 2-cultivations (with cultivator).

## REFERENCES

- Ahadiyat YR, Ranamukhaarachchi SL (2008). Effects of tillage and intercropping with grass on soil properties and yield of rainfed maize. *Intern. J. Agric. Biol.* 10(2): 33-139.
- Ahmad I, Iqbal M, Ahmad B, Ahmad G, Shah NH (2009). Maize yield, plant tissue and residual soil N as affected by nitrogen management and tillage systems. *J. Agric. Biol. Sci.* 1(1): 19-29.
- Akmal M, Rehman H, Farhatullah Asim M, Akbar H (2010). Response of maize varieties to nitrogen application for leaf area profile, crop growth, yield and yield components. *Pak. J. Bot.* 42(3): 1941-1947.
- Ali J, Bakht J, Shafi M, Khan S, Shah WA (2002). Effect of various levels of N and P on yield and yield components of maize. *Pak. J. Agron.* 1(1): 12-14.
- Amanullah, Khattak RA, Khalil SK (2009). Plant density and nitrogen effects on maize phenology and grain yield. *J. Plant Nutr.* 32: 246-260.
- Anonymous (2009). Economic Survey of Pakistan, Ministry of food, Agriculture and Livestock (Federal Bureau of Statistics), Islamabad, pp: 11-26.
- Astier M, Maass JM, Etchevers-Barra JD, Pena JJ, Gonzalez FDL (2006). Short-term green manure and tillage management effects on maize yield and soil quality in an Andisol. *Soil Tillage Res.* 88: 153-159.

- Bakht J, Ahmad S, Tariq M, Akber H, Shafi M (2006). Response of maize to planting methods and fertilizer N. *J. Agric. Biol. Sci.* 1(3): 8-14.
- Diaz-Zorita M (2000). Effect of deep-tillage and nitrogen fertilization interactions on dry land corn (*Zea mays* L.) productivity. *Soil Tillage Res.* 54: 11-19.
- Dinnes DL, Karlen DL, Jaynes DB, Kaspar TC, Hatfield JL, Colvin TS, Cambardella CA (2002). Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. *Agron. J.* 94: 153-171.
- Fedotkin IV, Kravtsov IA (2001). Production of grain maize under irrigated conditions. *Kukuruza-I-Sorgo.* 3: 5-8.
- Freed RD, Scott DE (1986). MSTAT-C. Crop and Soil Sci. Dept. Michigan State University, Michigan, USA.
- Halvorson AD, Wienhold BJ, Black AL (2001). Tillage and nitrogen fertilization influence grain and soil nitrogen in an annual cropping system. *Agron. J.* 93: 836-841.
- Hokmalipour S, Shiri-e-Janagard M, Darbandi MH, Peyghami-e-Ashenaee F, Hasanzadeh M, Seiedi MN, Shabani R (2010). Comparison of agronomical nitrogen use efficiency in three cultivars of corn as affected by nitrogen fertilizer levels. *World Appl. Sci. J.* 8(10): 1168-1174.
- Jabro JD, Stevens WB, Iversen WM, Evans RG (2010). Tillage depth effects on soil physical properties, sugarbeet yield and sugarbeet quality. *Communic. Soil Sci. Plant Anal.* 41: 908-916.
- Khaliq T, Ahmad A, Hussain A, Ali MA (2009). Maize hybrids response to nitrogen rates at multiple locations in semiarid environment. *Pak. J. Bot.* 41(1): 207-224.
- Khan AUH, Iqbal M, Islam KR (2007). Dairy manure and tillage effects on soil fertility and corn yields. *Bioresour. Tech.* 98: 1972-1979.
- Kumar MAA, Gali SK, Hebsur NS (2007). Effect of Different Levels of NPK on Growth and Yield Parameters of Sweet Corn. *Karnataka J. Agric. Sci.* 20(1): 41-43.
- Lipiec J, Medvedev VV, Birkas M, Dumitru E, Lyndina TE, Rousseva S, Fulajtar E (2003). Effect of soil compaction on root growth and crop yield in Central and Eastern Europe. *Int. Agrophy.* 17: 61-69.
- Mahmood MT, Maqsood M, Awan TH, Sarwar R (2001). Effect of different levels of nitrogen and intra-row plant spacing on yield and yield components of maize. *Pak. J. Agric. Sci.* 38: 48-49.
- Marwat KB, Arif M, Khan MA (2007). Effect of tillage and zinc application methods on weeds and yield of maize. *Pak. J. Bot.* 39(5): 1583-1591.
- Mengel K, Kirkby EA (1982). Principles of plant Nutrition. Publ. Int. Potash Instit. pp. 335-368.
- Miao Y, Mulla DJ, Robert PC, Hernandez JA (2006). Within field variation in corn yield and grain quality responses to N fertilization and hybrid selection. *Agron. J.* 98: 129-140.
- Nagy J (1997). The effect of fertilization on the yield of maize (*Zea mays* L.) with and without irrigation. *Cereal Res. Commun.* 25: 69-76.
- Nasser KBE (2009). Effect of nitrogen rate and plant density on agronomic nitrogen efficiency and maize yields following wheat and faba bean. *Am. Eur. J. Agric. Environ. Sci.* 5(3): 378-386.
- Ogola JBO, Wheeler TR, Harris PM (2002). Effects of nitrogen and irrigation on water use of maize crops. *Field Crop Res.* 78: 105-117.
- Purcino AAC, Silva MRE, Andrade SRM, Bebele CL, Parentoni SN, Santos MX (2000). The effect of N nutrition on the activities of N assimilating enzymes in the pedicel placenta chalaza region. *Maydica.* 45: 95-103.
- Raja V (2003). Effect of N rates and plant population on yield and quality of super sweet corn. *Ind. J. Agron.* 46: 246-249.
- Rashidi M, Keshavarzpour F (2007). Effect of different tillage methods on grain yield and yield components of Maize (*Zea mays* L.). *Int. J. Agric. Biol.* 9(2): 274-277.
- Schrader LE (1984). Functions and transformation of nitrogen in higher plants. In: Nitrogen in Crop Production. R.D. Hauck (ed.), ASA, CSSA and SSSA, Madison, WI. pp. 55-56.
- Shanti KVP, Rao MR, Reddy MS, Sarma RS (1997). Response of maize (*Zea mays* L.) hybrid and composite to different levels of nitrogen. *Ind. J. Agric. Sci.* 67: 424-425.
- Steel RGD, Torrie JH, Dickey DA (1997). Principles and Procedures of Statistics. A biometrical approach. McGraw Hill Book Co., New York, USA. pp. 400-428.
- Varsa EC, Chong SK, Abolaji JO, Farquhar DA, Olsen FJ (1997). Effect of deep tillage on soil physical characteristics and corn (*Zea mays* L.) root growth and production. *Soil Tillage Res.* 43: 219-228.
- Vetsch JA, Randall GW (2004). Corn production as affected by nitrogen application timing and tillage. *Agron. J.* 96: 502-509.
- Yang JY, Huffman EC, Jong RD, Kirkwood V, MacDonald KB, Drury CF (2007). Residual soil nitrogen in soil landscapes of Canada as affected by land use practices and agricultural policy scenarios. *Land Use Policy.* 24: 89-99.