

*Full Length Research Paper*

# High plant density by narrow plant spacing ensures cotton productivity in elite cotton (*Gossypium hirsutum* L.) genotypes under severe cotton leaf curl virus (CLCV) infestation

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This study was conducted to compare the seed cotton yield and cotton leaf curl virus (CLCV) infestations of newly evolved cotton genotypes (MNH-886, MNH-814 and CIM-496) under different plant spacings (15.0, 22.5, 30.0, 37.5 and 45.0 cm) at Cotton Research Station (CRS), Multan (71.43°E, 30.2°N and 122 m above sea level), Pakistan, during two consecutive years, that is, 2008 and 2009. The results indicate that cotton sown with 15 cm spaced plants resulted in maximum seed cotton yield only due to highest plant density (88,888 plants ha<sup>-1</sup>), as cotton sown with 30 and 45 cm spaced plants (44,444 and 29630 plants ha<sup>-1</sup>, respectively) had more number of bolls per plant in both years. Plant spacing had non-significant effects on boll weight and CLCV infestations. Genotypes (MNH-886 and MNH-814) resulted in the highest boll weight, number of bolls per plant and higher seed cotton yield compared with CIM-496 because of about 20% lower CLCV attack. Plant population was statistically similar for all cotton genotypes. In summary, cotton genotypes MNH-886 and MNH-814 resulted in higher seed cotton yield when sown with 15 cm plant spacing.

**Key words:** Cotton, genotypes, plant spacing, seed cotton yield, cotton leaf curl virus (CLCV).

## INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is not only the principal cash crop of the world that is primarily grown as fiber and oilseed crop (Dong et al., 2010), but it is also the most important cash crop of Pakistan having prime share in national export earnings (GOP, 2009 to 2010). It is a dual purpose crop as it provides fiber as well as edible oil. Pakistan not only earns 55% of its total foreign exchange earnings by exporting lint and value added cotton products, but cotton provides uncooked material for its textile and ghee manufacturing industry as well, and it accounts for 8.6% of value added in agriculture and 1.8% in gross domestic product (GDP) of the country

(GOP, 2009 to 2010). Although lot of fertile land suitable for cotton production is available but unluckily Pakistan had 48, 6, 44 and 8% less per hectare seed cotton yield than China, USA, Brazil and Egypt, respectively (GOP, 2009 to 2010). The reason is the poor agronomic practices like low plant population, imbalanced use of fertilizers, use of low quality seed, conventional sowing methods, high weeds infestation, boll shedding due to high temperature late in the season, flare up insect pressure and high cotton leaf curl virus (CLCV) infestation (Nadeem et al., 2010; GOP, 2009 to 2010).

CLCV is one of the most caustic diseases of cotton limiting vegetative growth and cotton productivity as well (Iqbal and Khan, 2010). Plants affected with CLCV showed stunted growth and produced fewer numbers of bolls with condensed boll weight that ultimately results in

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yield penalty (Tanveer and Mirza, 1996). Developing CLCV resistant cotton genotypes is the most valuable tool to curtail the yield losses but still no cotton genotype resistant to CLCV (especially against Burewala strain) has been reported (Iqbal and Khan, 2010). Therefore the only available option to maximize the seed cotton yield is to adjust the management practices (Iqbal and Khan, 2010). Amid various management factors to boost up per acre yield of cotton, apposite genotype selection, optimal sowing time and higher plant density toning the ecological conditions of the region is the most important (Ali et al., 2004; Nadeem et al., 2010).

Cotton growth and development are greatly influenced by environmental circumstances, as well as seasonal management practices (O'Berry et al., 2008). One of the options to maximize yield per unit area is to maintain optimum plant population per unit land area that also varies from variety to variety in cotton (Ali et al., 2009). Plant spacing has a key role in managing optimum plant density according to the requirement of variety under consideration to boost cotton productivity especially under irrigated conditions (Nadeem et al., 2010). Usually farmers adopt plant spacing and plant density according to their traditional methods of planting rather than variety requirement that results in yield penalty in cotton. Cotton genotypes and the field conditions that produce short stature plants can generally tolerate higher plant density without incurring significant yield reduction. Higher planting density with ultra-narrow rows cotton production system proved a viable cotton production system compared with conventionally grown cotton system with wider rows and low plant density in different cotton genotypes (Nicholas et al., 2004; Witten and Cothren, 2000).

Nonetheless, the revolution in seed development era which includes various transgenic, seed treatment technologies with higher price of the cotton seed around the globe made more vital to determining the optimum plant density and spacing to harvest maximum returns per unit area (Bednarz et al., 2006; Pettigrew and Johnson, 2005; Siebert and Stewart, 2006; Siebert et al., 2006). There are many reports available that highlighted the importance of optimum plant population and spacing that varies across different environments and cotton genotypes to realize maximum seed cotton yield along with improved fiber quality (Ali et al., 2009; Siebert and Stewart, 2006; Siebert et al., 2006; Iqbal and Khan, et al., 2010; Nadeem et al., 2010).

Different cotton genotypes behave differently with respect to seed cotton yield and resistance against diseases like CLCV in different ecological conditions and management practices (Iqbal and Khan, 2010). Therefore, suitable genotype selection according to the prevailing conditions of the region along with suitable management practices is even more vital for cotton production, although high yield potential is a principal concern (Nichols et al., 2004). Iqbal et al. (2007) reported

that higher plant density can be used as an effective tool to realize optimum seed cotton yield in cotton genotypes that are severely affected by CLCV. Recently, Iqbal and Khan (2010) quoted that narrow plant spacing (higher plant density) is very effective in managing CLCV infestation especially in late sown cotton.

Farmers in the cotton growing region continuously need information about appropriate plant spacing to adopt newly evolved cotton genotypes to get optimum seed cotton yield with minimum CLCV infestation. Therefore, this present study was designed to assess the benefits of higher plant density with narrow plant spacing in newly evolved cotton genotypes to attain maximum seed cotton yield under agro-climatic conditions of Multan, Pakistan.

## MATERIALS AND METHODS

### Site description

This present study was to explore the possible role of different plant spacings and cotton genotypes on seed cotton yield and CLCV infestations and was conducted at Cotton Research Station (CRS), Multan (71.43°E, 30.2°N and 122 m above sea level), Pakistan, during two consecutive years, that is, 2009 and 2010. The climate of the region is subtropical to semi-arid (Table 2). The experimental area was quite uniform and soil analysis was done to assess the soil fertility status. The physico-chemical analysis of the soil is given in Table 1.

### Experimental details

The experiment was laid out in randomized complete block design (RCBD) with split plot arrangements having net plot size of 5 × 3 m and replicated three times. Cotton genotypes and plant spacings were kept in main plots and sub plots, respectively. Cotton genotypes included in the study were MNH-886, MNH-814 and CIM-496. Plant spacings included in the study were 15.0, 22.5, 30.0, 37.5 and 45.0 cm. Weather data during both years of study are given in Table 2.

### Crop husbandry

Pre-soaking irrigation of 10 cm was applied prior to seedbed preparation to create conditions favorable for seedbed preparation. When soil reached a practicable moisture level, the seedbed was prepared by cultivating the field for three times with tractor-mounted cultivator each followed by planking. The three cotton genotypes, that is, MNH-886, MNH-814 and CIM-496 were sown on April 15, with five different plant spacings, that is, 15.0, 22.5, 30.0, 37.5 and 45.0 cm. Sowing was done by hand dibbling by keeping row to row distance of 75 cm on irrigated bed-furrows and stomp (Pendimethaline, 33% pre-emergence herbicide) was applied at the rate of 2.5 L ha<sup>-1</sup> to control weeds (*Trianthema portulacastrum* L. and *Convolvulus arvensis* L.) in the field. The furrows were again irrigated with 3 acre inches of water three days after dibbling the seeds, in other to have successful seed germination and emergence. However, a subsequent irrigation was given after one week later on to fill the gaps where seeds were not germinated. Thereafter, the subsequent irrigations were given at 10 days interval up till crop maturity. Fertilizers were applied at the rate of 230, 90 and 62 kg N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O ha<sup>-1</sup>, respectively, by using urea, di-ammonium phosphate (DAP) and sulphate of potash (SOP)

**Table 1.** Pre-sowing physico-chemical soil analysis.

Determination	2009	2010
<b>Physical analysis</b>		
Sand (%)	64.5	63.6
Silt (%)	18.9	18.5
Clay (%)	17.8	16.7
Textural class	Sandy clay loam	
<b>Chemical analysis</b>		
pH	8.30	8.20
EC (dS m <sup>-1</sup> )	6.58	11.12
Organic matter (%)	1.06	1.11
Total nitrogen (%)	0.53	0.57
Available phosphorus (ppm)	10.0	12.0
Available potassium (ppm)	220	245
Saturation (%)	37	38

**Table 2.** Weather data during the course of study.

Month	Mean monthly temperature (°C)		Mean monthly relative humidity (%)		Total monthly rainfall (mm)	
	2009	2010	2009	2010	2009	2010
April	27.35	30.60	60.7	55.4	6.5	2.5
May	34.05	34.35	42.4	43.4	1.5	4
June	34.35	34.70	43.9	40.9	2.0	0.0
July	33.70	34.05	69.7	57.1	18.0	76.5
August	31.25	31.65	71.4	84.7	6.8	127.0
September	30.70	30.95	76.5	75.4	7.0	15.0
October	27.10	28.70	79.5	72.5	0.0	0.0

Agricultural Meteorology Cell, Central Cotton Research Institute, Multan, Pakistan.

as a source. Full dose of phosphorus, potassium and one third dose of nitrogen were applied at the time of sowing. Second 1/3rd dose of nitrogen was top dressed at 2nd irrigation, and remaining nitrogen was applied at flowering stage of a crop. Crop was kept free from insect pest attack through regular sprays of recommended and required pesticides available in the market.

#### Measurements

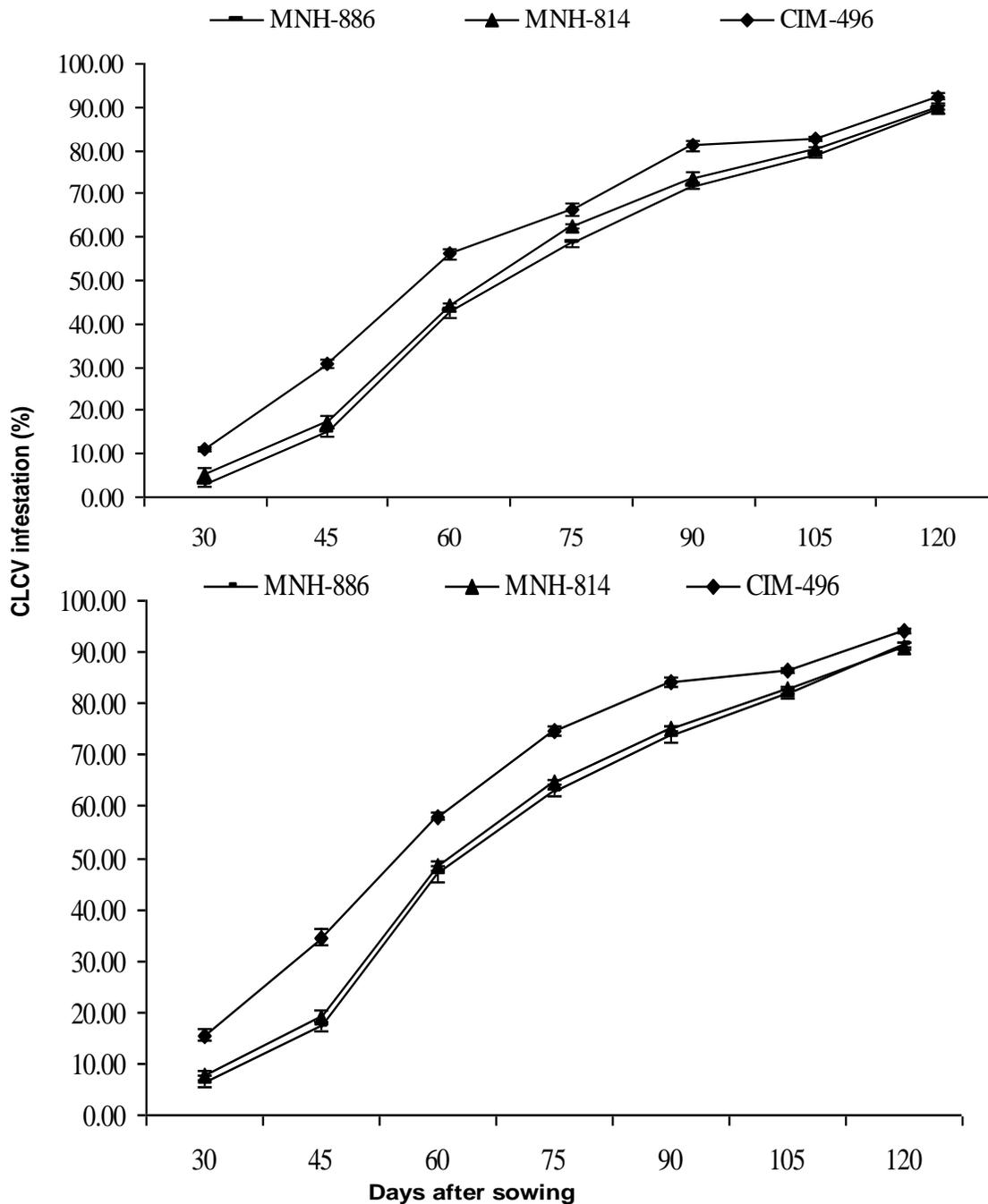
Total number of plants per plot were counted and then converted into m<sup>-2</sup> basis. Total number of bolls of 10 randomly selected plants was counted and averaged to record the number of bolls per plant. To calculate average boll weight, 25 bolls were randomly taken from each plot, weighed by an electronic balance and then averaged. Seed cotton yield was recorded on net plot basis and then converted into kg ha<sup>-1</sup> by unitary method. Total number of virus affected (plants having more than 50% parts affected with CLCV were termed affected while others termed as normal) and normal plants were counted at a regular interval of 15 days and the percentage of virus affected plants was computed. The sampling started on the 15th of June and terminated on 15th of September.

#### Statistical analysis

Data has been presented in the form of line and bar charts made by using Microsoft Excel Program 2003 and  $\pm$  standard error (S.E.) was used to test the significance.

## RESULTS

Cotton genotypes had significant effect on CLCV infestation while different plant spacings had non-significant effect in both years of study (Figures 1 and 2). Cotton genotype MNH-886 and MNH-814 had significantly lower CLCV infestation throughout the growing period than CIM-496 during both years, that is, 2008 and 2009 (Figures 1 and 2). Different plant spacings had significant, while cotton genotypes had non-significant effect on plant density during both years, 2008 and 2009 (Figure 3). Cotton sowing with narrow plant spacing (15 cm spaced plants) had even more than three times higher

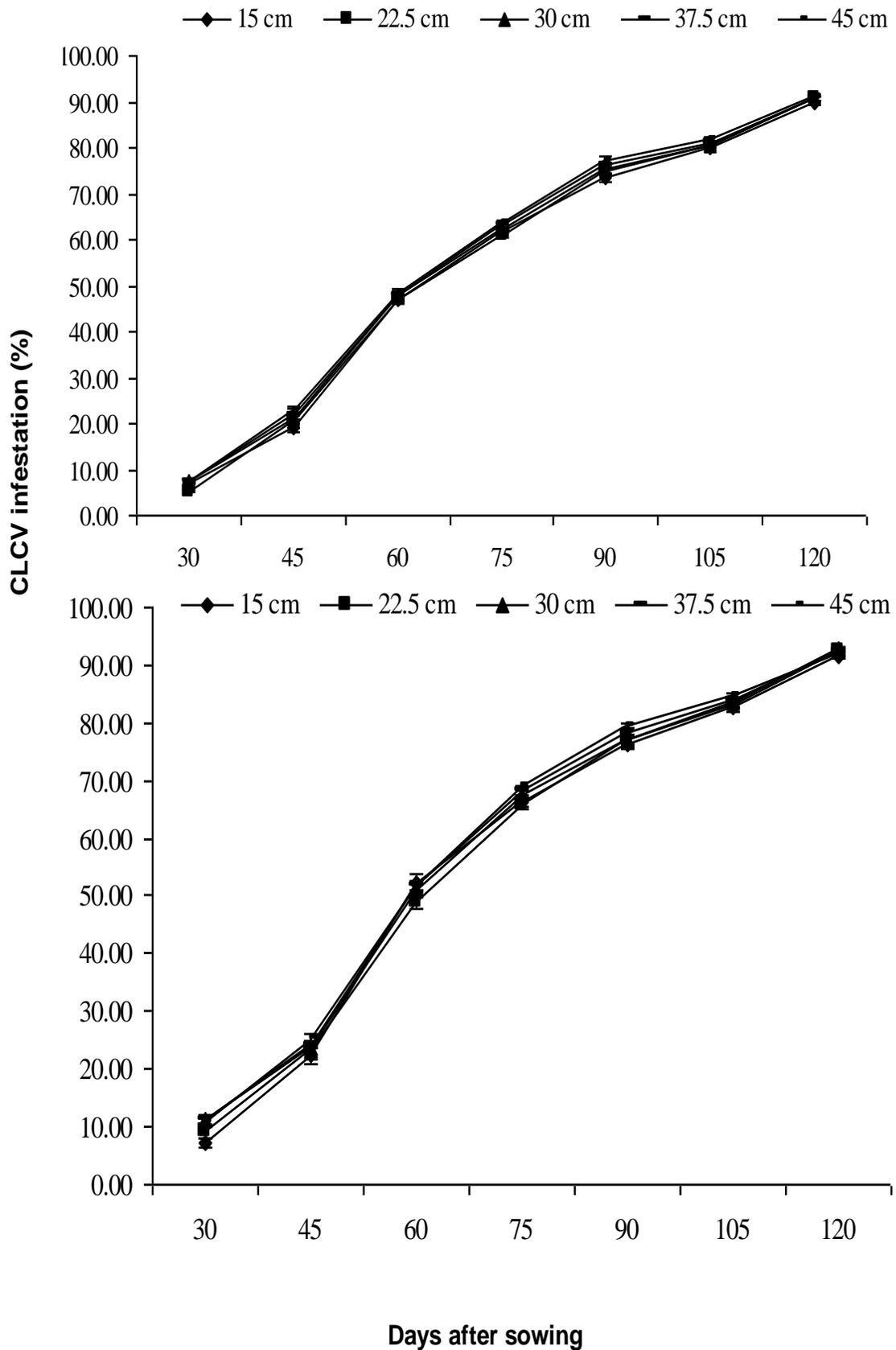


**Figure 1.** Effect of cotton genotypes on CLCV infestation in cotton (%) during 2008 and 2009, respectively  $\pm$  S.E.

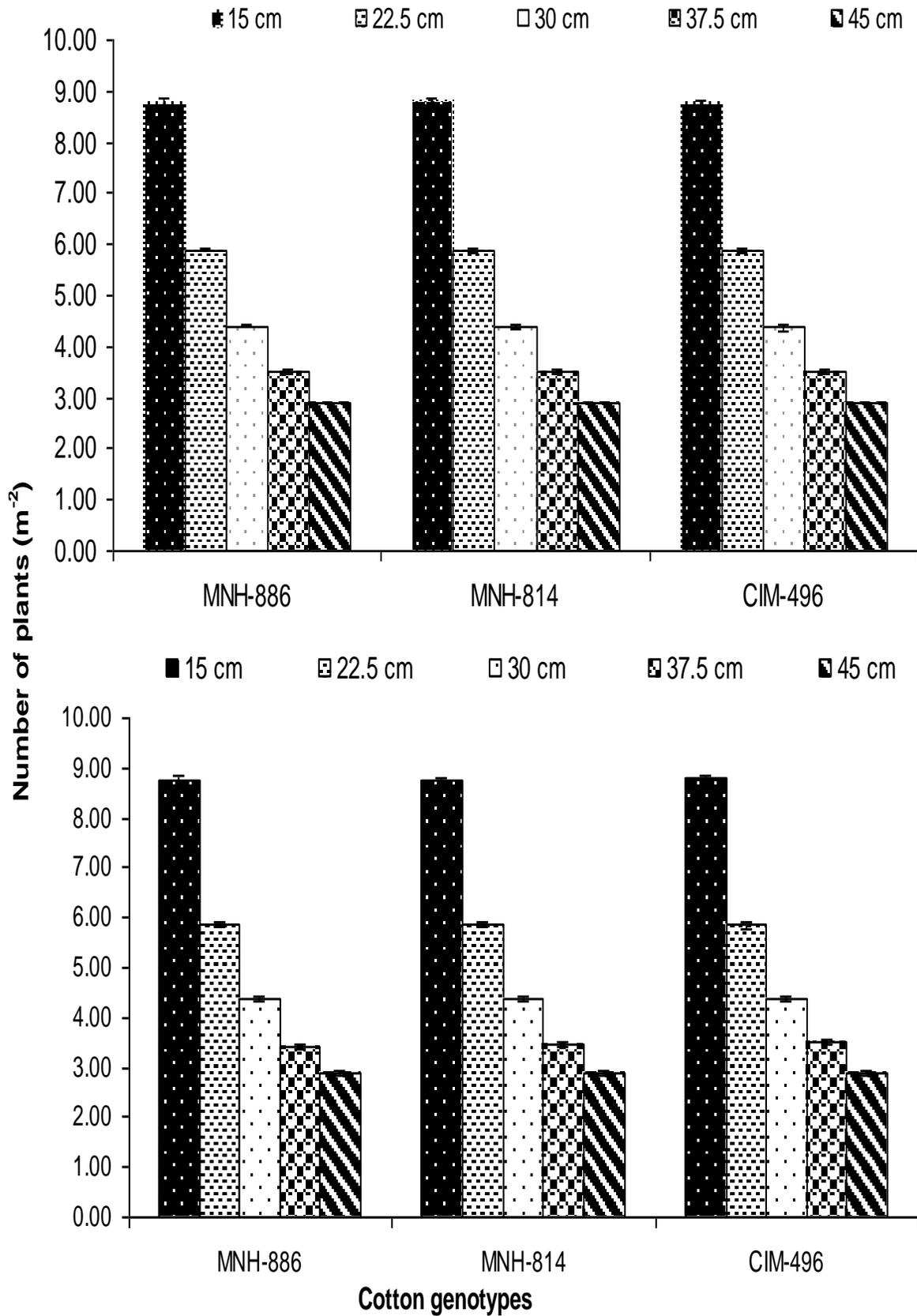
plant density (per ha) than wider plant spacing (45 cm spaced plants) (Figure 3).

Both cotton genotypes and different plant spacings had significant effect on number of bolls per plant (Figure 4). Cotton genotypes MNH-886 and MNH-814 produced more number of bolls per plant compared with cotton genotype CIM-496 in both years. Likewise, cotton sown with 45 cm spaced plants resulted in maximum number of

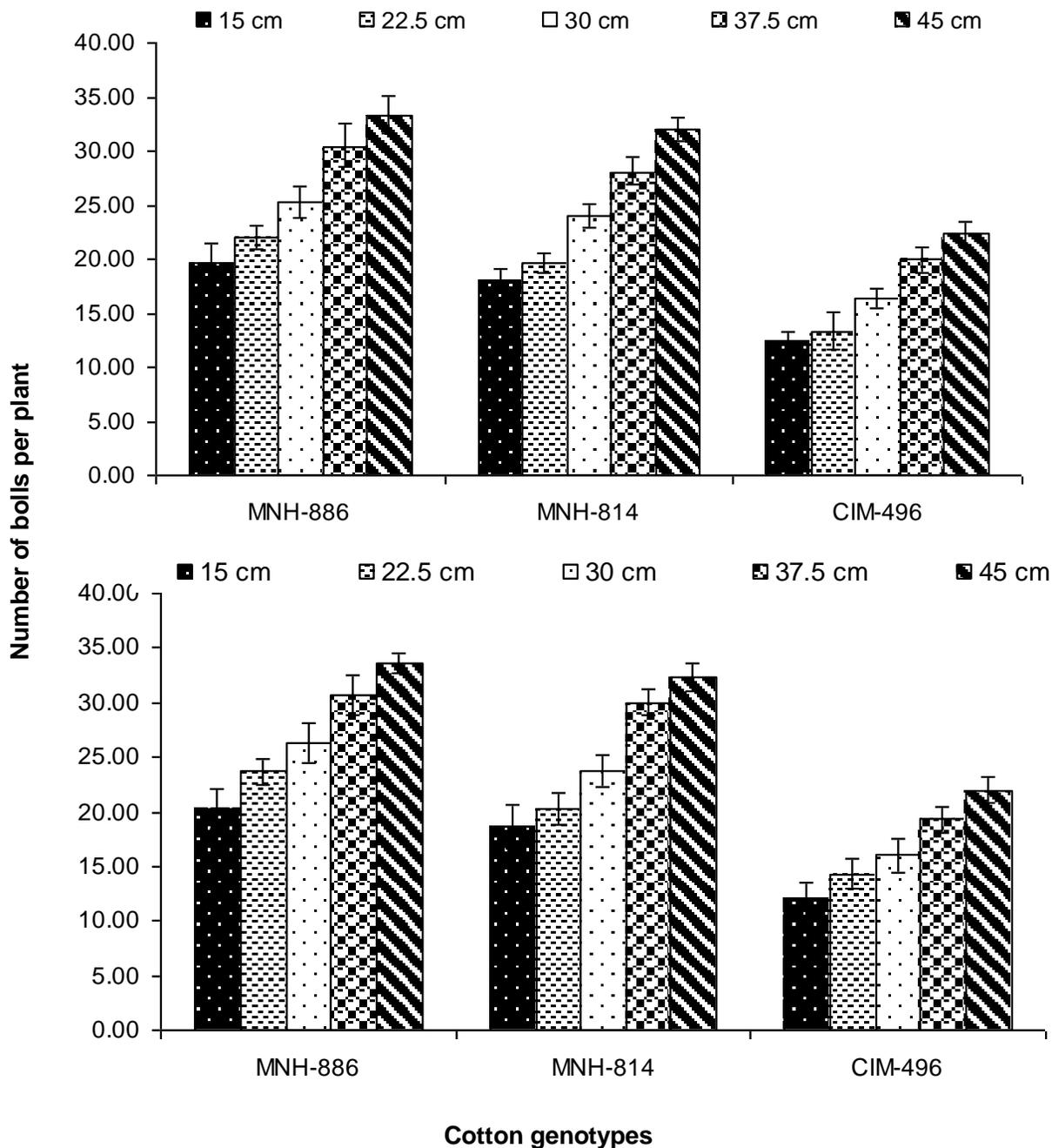
bolls per plant in all three cotton genotypes during 2008 and 2009, while cotton sown with 15 cm spaced plants resulted in minimum number of bolls per plant in all three cotton genotypes during both years, 2008 and 2009 (Figure 4). With respect to average boll weight, cotton genotypes had significant effect while different plant spacings had non-significant effect in both years, 2008 and 2009 (Figure 5). Cotton genotypes MNH-886 and



**Figure 2.** Effect of plant spacings on CLCV infestation in cotton (%) during 2008 and 2009, respectively  $\pm$  S.E.



**Figure 3.** Effects of plant spacing on plant population ( $m^{-2}$ ) in different cotton genotypes during 2008 and 2009, respectively  $\pm$  S.E.



**Figure 4.** Effects of plant spacing on number of bolls per plant in different cotton genotypes during 2008 and 2009, respectively  $\pm$  S.E.

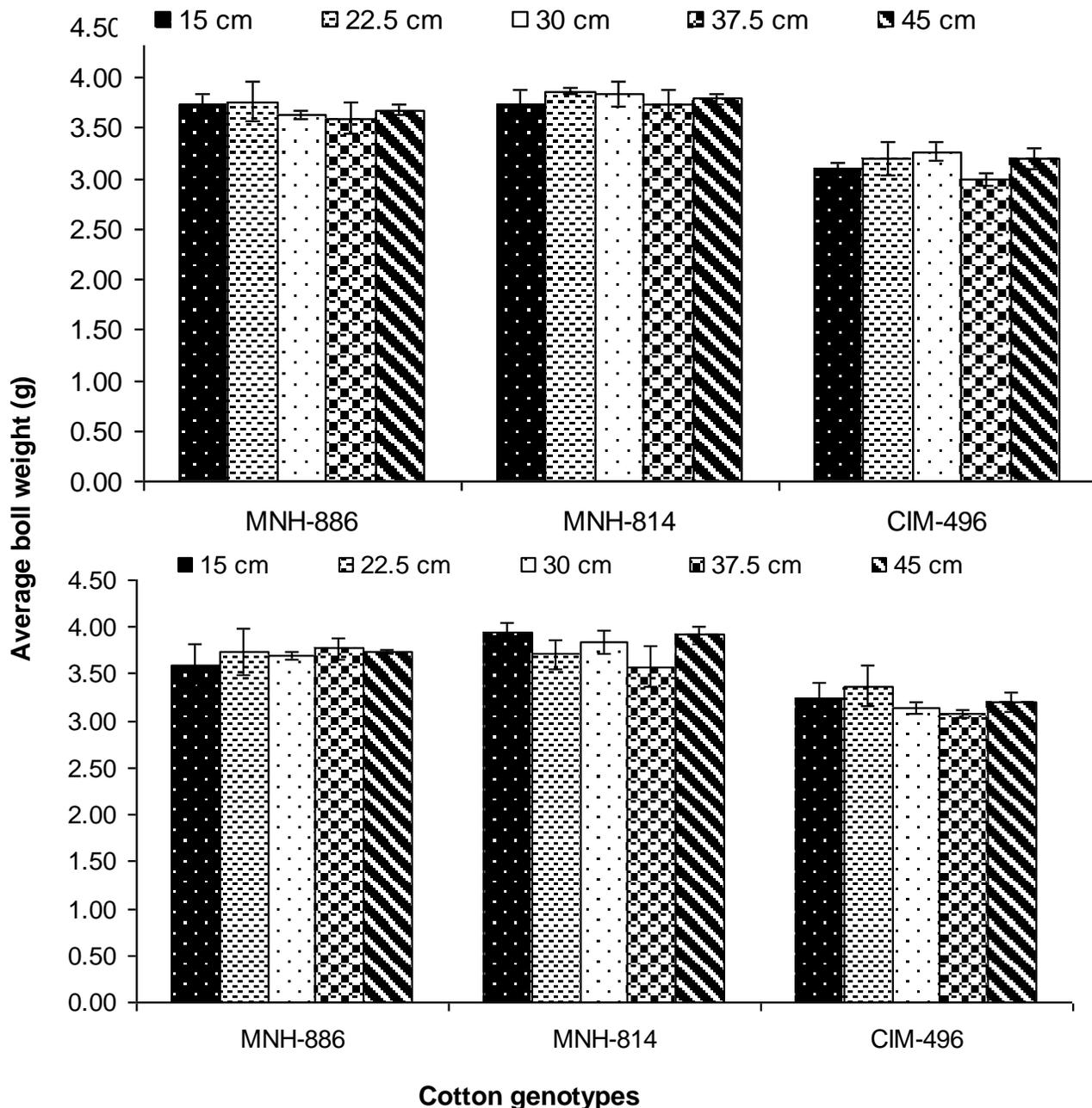
MNH-814 produced bolls with more average weight than cotton genotype CIM-496, which produced bolls with low average weight in both years (Figure 5).

Both cotton genotypes and plant spacings had significant effect on seed cotton yield in both years, 2008 and 2009 (Figure 6). Both cotton genotypes MNH-886 and MNH-814 produced higher seed cotton yield than cotton genotype CIM-496 in both years of study, that is, 2008 and 2009. Likewise, all three cotton genotypes

sown with 15 cm spaced plants resulted in maximum seed cotton yield compared with 30 and 45 cm plant spacing during both years of study, that is, 2008 and 2009 (Figure 6).

## DISCUSSION

Higher seed cotton yield recorded in narrow plant

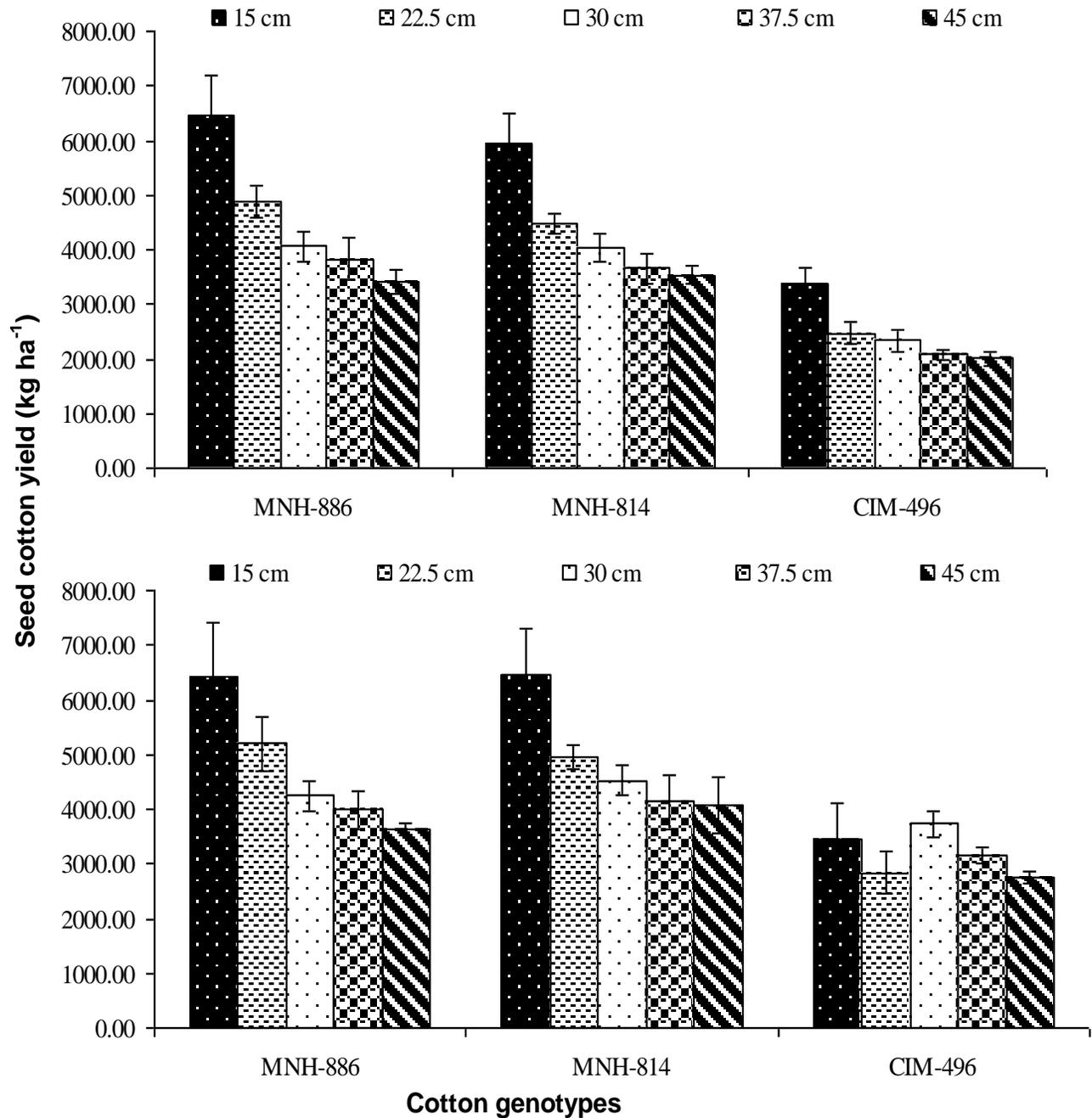


**Figure 5.** Effects of plant spacing on average boll weight (g) in different cotton genotypes during 2008 and 2009, respectively  $\pm$  S.E.

spacings in all three cotton genotypes during both years of study (Figure 6) was the direct result of more than three times higher plant density recorded in narrow plant spacing (15 cm spaced plants), compared with wider plant spacing (45 cm spaced plants) in all cotton genotypes (Figure 3). Likewise, cotton genotypes MNH-886 and MNH-814 resulted in higher cotton productivity and lower CLCV infestation than CIM-496 due to their better genetic makeup in both years (Figures 1 and 6).

Higher plant density by narrow plant spacing was

directly due to reduced spacing between plants as row to row distance was kept constant. Same plant density in three cotton genotypes was due to same seed rate and planting geometry used in all cotton genotypes. Nadeem et al. (2010) and Iqbal and Khan (2010) also reported higher plant density with narrow plant spacing in different cotton genotypes. Lower CLCV infestation in both cotton genotypes compared with CIM-496 during both years might be due to their better genetic makeup (Iqbal and Khan, 2010). Non-significant effect of plant spacing on



**Figure 6.** Effects of plant spacing on seed cotton yield ( $\text{kg ha}^{-1}$ ) in different cotton genotypes during 2008 and 2009, respectively  $\pm$  S.E.

CLCV infestation might be due to the genetic character of genotypes that can not be controlled by plant spacing (Iqbal et al., 2007).

Maximum number of bolls per plant produced in all three cotton genotypes sown with wider plant spacing (45 and 37.5 cm spaced plants) in both years of study might be due to little plant to plant competition compared with narrowly spaced plants (15 and 22.5 cm spaced plants) as row to row distance was kept constant. Reduced

competition among plants along with more available space enabled the plants to uptake more water and nutrients to produce more monopodial and sympodial branches that ultimately resulted in more number of bolls per plant (Muhammad et al., 2002; Wrather et al., 2008; Nadeem et al., 2010). Although, a strong competition existed among plants in narrow plant spacing compared with wider plant spacing but average boll weight remained same in all plant spacings. This might be due to

narrow plant spacing, and number of bolls per plant was too small compared with wider plant spacings that eventually salaried the average boll weight, but in contrary, Muhammad et al. (2002) and Nadeem et al. (2010) reported enhanced average boll weight with increased plant spacing.

Large number of bolls per plant along with higher average boll weight (Figures 4 and 5) produced in both MNH-886 and MNH-814 cotton genotypes compared with CIM-496 during both years might be due to their better genetic makeup (Ali et al., 2009; Iqbal et al., 2007; Iqbal and Khan, 2010), and lower CLCV infestation during the whole growing season (Figure 1). Higher seed cotton yield with narrow plant spacing was the direct result of higher plant density (Figure 3) compared with wider row spacing even having more number of bolls per plant (Figure 4). This higher plant density with narrow plant spacing (more than three times than wider plant spacing) compensated the lesser number of bolls per plant, while average boll weight remained unchanged (Figure 5). Nonetheless, CLCV infestation (Figure 2) remained same during the entire growing season in all plant spacings, normal plants in narrow plant spacings were three times more than wider plant spacing only due to higher plant density that also contributed in final seed cotton yield.

There are many reports available that signify the role of higher plant density with narrow plant spacing in enhancing seed cotton yield (James et al., 2004; O'Berry et al., 2008; Wrather et al., 2008; Nadeem et al., 2010). Likewise, elevated seed cotton yield (Figure 6) recorded in both cotton genotypes (MNH-886 and MNH-814) compared with CIM-496 might be the direct result of higher number of bolls per plant and more average boll weight (Figures 4 and 5), due to their better genetic makeup. Nonetheless, lower CLCV infestation (Figure 1) in both MNH-886 and MNH-814 cotton genotypes compared with CIM-496 during the entire growing season might be due to their better genetic makeup that eventually twisted into more number of bolls per plant with more weight which resulted into higher seed cotton yield. Iqbal et al. (2007) reported that higher plant density can be used as an effective tool to realize optimum seed cotton yield in cotton genotypes that are severely affected by CLCV. Recently, Iqbal and Khan (2010) quoted that narrow plant spacing (higher plant density) was very effective in managing CLCV infestation especially in late sown cotton.

In conclusion, higher plant density under narrow plant spacing (15 cm spaced plants) ensured higher seed cotton yield in all cotton genotypes although the number of bolls per plant were reduced. Moreover, cotton genotypes MNH-886 and MNH-814 resulted in higher seed cotton yield by producing higher number of bolls per plant of heavier weight and lesser CLCV infestation due to their better genetic makeup than CIM-496. Therefore, cotton genotypes MNH-886 and MNH-814 should be sown with 15 cm plant spacing to ensure higher seed

cotton yield under prevailing agro-climatic conditions of Multan, Pakistan.

## REFERENCES

- Ali A, Tahir M, Ayub M, Ali I, Wasaya A, Khalid F (2009). Studies on the effect of plant spacing on yield of recently approved cotton varieties. *Pak. J. Life Soc. Sci.* 7(1): 25-30.
- Ali M, Din QM, Ali MA, Sabir S, Ali L (2004). Cotton yield as influenced by different sowing dates under the climatic conditions of Vehari-Pakistan. *Int. J. Agric. Biol.* 6(4): 644-646.
- Bednarz CW, Nichols RL, Brown SM (2006). Plant density modifies within-canopy cotton fiber quality. *Crop Sci.* 46: 950-956.
- Dong H, Kong X, Li W, Tang W, Zhang D (2010). Effects of plant density and nitrogen and potassium fertilization on cotton yield and uptake of major nutrients in two fields with varying fertility. *Field Crops Res.* 119: 106-113.
- GOP (Government of Pakistan) (2009-10). Economic Survey of Pakistan. Ministry of Food and Agriculture, Islamabad, Pakistan.
- Iqbal M, Islam NU, Hayat K, Muhammad T (2007). Management of cotton crop under high leaf curl virus attack. *Asian J. Plant Sci.* 6(7): 1125-1130.
- Iqbal M, Khan MA (2010). Management of cotton leaf curl virus by planting time and plant spacing. *AAB Bioflux.* 2: 25-33.
- James JM, Wright DL, Wiatrak PJ, Vargas MA (2004). Effect of row width and nitrogen on cotton morphology and canopy microclimate. *Crop Sci.* 44: 707-710.
- Muhammad DM, Anwar M, Zaki MS, Afzal MN (2002). Effects of plant population and nitrogen variables on cotton crop. *Pak. Cottons* 47(1-2): 37-41.
- Nadeem MA, Ali A, Tahir M, Naeem M, Chadhar AR, Ahmad S (2010). Effect of nitrogen levels and plant spacing on growth and yield of cotton. *Pak. J. Life Soc. Sci.* 8(2): 121-124.
- Nichols SP, Snipes CE, Jones MA (2004). Cotton growth, lint yield and fiber quality as affected by row spacing and cultivar. *J. Cotton Sci.* 8: 1-12.
- O'Berry NB, Faircloth JC, Edmisten KL, Collins GD, Stewart AM, Abaye AO, Herbert DA, Haygood JRA (2008). Plant population and planting date effects on cotton (*Gossypium hirsutum* L.) growth and yield. *J. Cotton Sci.* 12: 178-187.
- Pettigrew WT, Johnson JT (2005). Effects of different seeding rates and plant growth regulators on early-planted cotton. *J. Cotton Sci.* 9: 189-198.
- Siebert JD, Stewart AM (2006). Influence of plant density on cotton response to mepiquat chloride application. *Agron. J.* 98: 1634-1639.
- Siebert JD, Stewart AM, Leonard BR (2006). Comparative growth and yield of cotton planted at various densities and configurations. *Agron. J.* 98: 562-568.
- Tanveer M, Mirza MB (1996). Effect of cotton leaf curl virus on the yield components and fibre properties of four commercial varieties. *Pak. J. Phytopathol.* 8: 68-70.
- Witten TK, Cothren JT (2000). Varietal comparisons in ultra narrow row cotton (UNRC). In Proc. Beltwide Cotton Conf., San Antonio, TX. 4-8 Jan. 2000. Natl. Cotton Counc. Am., Memphis, TN. p. 608.
- Wrather JA, Phipps BJ, Stevens WE, Phillips AS, Vories ED (2008). Cotton planting date and plant population effects on yield and fiber quality in the Mississippi Delta. *J. Cotton Sci.* 12: 1-7.