INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
17–0232/2017/19–5–1149–1155
DOI: 10.17957/IJAB/15.0403
http://www.fspublishers.org

***Full Length Article***

# Infestation of Cotton Leaf Curl Virus in two Bt Cotton Cultivars under Different Sowing Methods and Plant Spacing Systems

**Fida Hussain[1], Riaz Ahmad[1], Abdul Jabbar[1] and Ghulam Murtaza[2]**
[1]*Department of Agronomy, University of Agriculture, Faisalabad-38040, Pakistan*
[2]*Institute of Soil and Environmental sciences, University of Agriculture Faisalabad-38040, Pakistan*
[*]For Correspondence: fida_51214@yahoo.com

## Abstract

Cotton production is integral to economic development of Pakistan. However, cotton leaf curl virus (CLCuV) infestation affects the growth and productivity of cotton, and has been causing serious yield losses for the last two decades. Transgenic Bt varieties have resistance against CLCuV and can produce the high yield. This experiment was conducted to evaluate the effect of different sowing methods (flat sowing and bed sowing) and plant spacing (22.5 and 30 cm) on CLCuV infestation, whitefly population and growth and yield of two Bt cultivars viz. AA-703 and FH-113 during 2010 and again in 2011. The experiment was laid out in a split-split plot design with three replications. The average of the two years' results showed that there was 78% CLCuV incidence in 30 cm spacing as compared to 85% incidence in 22.5 cm spacing. However, cotton crop grown at narrow spacing with higher plant population (44444 plants ha$^{-1}$) produced 17% higher seed cotton yield than wider spacing with lower plant population (33333 plants ha$^{-1}$). The sowing methods did not significantly affect the disease incidence nonetheless the seed cotton yield of bed sown crop was 21% higher than the flat sown cotton crop. Cultivar AA-703 produced 14% higher seed cotton yield than cultivar FH-113 due to low disease infestation, higher boll weight and more number of bolls. The net profit (Rs. 102577 ha$^{-1}$) and benefit cost ratio (1.65) indicated that cotton cultivar AA-703 sown on beds at plant spacing of 22.5 cm could produce the maximum seed cotton yield. © 2017 Friends Science Publishers

**Keywords:** Cotton leaf curl virus; Number of enations; Number of whitefly; Plant spacing; Sowing methods

## Introduction

Cotton (*Gossypium hirsutum* L.) is the main cash crop of Pakistan which contributes substantially to the national economy. However, several problems, particularly the cotton leaf curl virus (CLCuV) is severe threat to the growth and productivity of cotton crop (Farooq *et al.,* 2014). In Punjab, the highest losses due to Begomovirus were observed during 1992 (Iqbal *et al*., 1997). During the last decade, about 60-90% of cotton fields in Pakistan were infested with CLCuV (Iqbal and Khan, 2010); moreover, CLCuV caused the cumulative losses of $1.2 billion in Punjab (Hussain *et al.,* 2012). From 1988 to 2002, more than 7.7 million bales of cotton were lost due to CLCuV attack (Akhtar *et al*., 2005). The major symptoms of CLCuV are leaf-curling either towards lower side or upper side, swallowing of midribs and veins, color darkening, stunted growth and occasionally the development of tiny leaf structure "enation" on the lower side of leaf (Briddon and Markham, 2001; Qazi *et al.,* 2007).

Different management practices and development of resistant or tolerant cultivars reduces the CLCuV induced yield losses (Akhtar *et al.,* 2004). For example, the use of resistant cultivars, control of whitefly, eradication of weeds and proper nutrient management might be the viable options to reduce the CLCuV attack in cotton (Narula *et al.,* 1999).

Different plant spacings also affect the CLCuV incidence; its infestation is increased at plant spacing of 45 cm (Singh *et al.,* 2012). In this context, Iqbal and Khan (2010) reported that increased plant spacing for early sown cotton and decreased plant spacing under late-sown conditions was effective for the management of CLCuV. In another study, the number of whitefly was decreased from 4 to 3 per leaf with increase in plant spacing from 23 to 30 cm (Arif *et al.*, 2006). In a study, cotton grown in plant spacing of 23 cm produced better yield than 30 and 38 cm (Khan *et al*., 2005).

The changing temperature and precipitation patterns cause shift in some pests (white fly) from one population to other population thus affecting the epidemiology of CLCuV disease (Farooq *et al.,* 2014). The low temperature during growing season and wind speed have adverse effect, while sunshine has a positive impact on the whitefly population (Khan *et al.,* 2010). On the other hand, the morphological characteristics of the host plants like_hair density and hair length on midrib vein and lamina enhance the_population of

**To cite this paper:** Hussain, F., R. Ahmad, A. Jabbar and G. Murtaza, 2017. Infestation of cotton leaf curl virus in two Bt cotton cultivars under different sowing methods and plant spacing systems. *Int. J. Agric. Biol.,* 19: 1149–1155

whitefly (Bashir *et al.,* 2001).

Bt cotton is boll worm resistant and have no risk to soil-ecosystem function (Sarkar *et al*., 2009). In a study, more number of whitefly was observed in Bt cotton than non-Bt cotton cultivars (Jeyakumar *et al.,* 2008). Bt cotton is cultivated on 70% of cotton area in Pakistan but CLCuV is a continuous threat for it production (Carroll, 2009).

Sowing methods also influence the seed cotton yield. In a study, Anwar *et al*. (2003) reported 33% higher yield in bed-furrow planting than flat planting. Flat planted cotton produced lower yield than bed planted (Hussain *et al*., 2003). Ali and Ehsanullah (2007) concluded that flat planting with each row earthing up gave the higher seed cotton yield than bed and ridge plantings.

Although, various approaches viz. grafting inoculation (Mahmood *et al*., 2002), genetic transformation and regeneration of cotton using somatic embryogenesis (Chaudhary *et al*., 2004), crossing and selections from the parental donors of the resistance gene (Tahir and Mahmood, 2005; Ahuja *et al*., 2007; Baluch, 2007), development of resistance using pathogen derived resistance (PDR) based on cross protection and antisense approach (Broderson *et al*., 2008) and artificial micro RNA technology (Ali *et al*., 2013) have been used to control the CLCuV. However, very little is known regarding the interactive effect of different sowing methods and plant spacing on CLCuV infestation and productivity of Bt cotton cultivars. Therefore, the present study was conducted to investigate the influence of different sowing methods and plant spacings on the incidence of CLCuV, white fly population, growth/yield, and net return of two Bt cotton cultivars.

## Materials and Methods

### Site and Soil

This study was carried out at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan, during 2010 and 2011. The geographical location of the site was Latitude 31°.25' N and Longitude 73°.09' E. The soil at experimental site belongs to Lyallpur soil series and was sandy loam with pH (8.4), electrical conductivity (2.3 dS $m^{-1}$) and soil organic matter (0.78%). The meteorological data such as daily mean air temperature (°C), rainfall (mm) and humidity, during the both experimental years are presented in Fig. 1.

### Experimental Design and Treatments

The experiment treatments (each replicated three times) were randomized complete block design in a split-split plot arrangement. The sowing methods were allocated to main plots, plant spacings to sub-plot and the cotton cultivars to sub-sub-plots with a net plot size of 6 m × 8 m.

The experimental land was cultivated with double chisel plough. Seed bed preparation was done with the help of a tractor-mounted cultivator (twice) followed by the same number of plankings. Bed shaper was used to prepare the beds, and manual operated dibbler was used for sowing. Flat sowing was done manually using a local hand drill. Beds size as well as row spacing in flat sown crop was kept at 75 cm. Bt cotton cultivars (AA-703 and FH-113) were sown using delinted seed at a rate of 25 kg $ha^{-1}$ for flat sowing and 10 kg $ha^{-1}$ for bed sowing. The crop was sown on May 28, during both years of experimentation. In flat sowing, thinning was done to maintain the plant density. Fertilizer was applied at 120-60-60 kg $ha^{-1}$ N, $P_2O_5$ and $K_2O$, respectively. Urea, di-ammonium phosphate and sulphate of potash, were used as source of N, P and K. Whole of P and K, while 1/3 of N were applied as a basal dose. The remaining N was applied as split dose at 30 days after sowing and at flowering stage. Six irrigations were applied, in addition to a 100 mm of the average rainfall during the entire growth period of crop. In case of bed sowing, the pesticide Dual Gold was applied at 2000 mL $ha^{-1}$ to control the weeds, while in flat sown crop, manual weeding was done to control weeds. During both years of study, the first picking was done manually during the second week of October, while the last picking was done during the third week of November.

### Observations and Measurements

Data regarding the number of whitefly per plant were recorded 30 and 150 days after sowing (DAS) and are presented in Fig. 2. Disease incidence percentage, number of infected leaves per plant, and number of enations per plant were recorded fortnightly after the appearance of first disease symptoms (45 DAS). The highest values of disease incidence percentage and number of enations per plant were statistically analyzed. Infected leaves percentage is shown in Fig. 3. Leaf area index and crop growth rate were recorded fortnightly (starting from 30 DAS to and 150 DAS) according to the formulae proposed by Watson (1947) and Hunt (1978), respectively. Leaf area was measured with the help of leaf area meter. For measuring the crop growth rate, plants were harvested, sun dried, oven dried and weighed for the calculation of crop growth rate. Number of bolls of five plants of each treatment was counted and averaged; five bolls (lint) of each treatment were weighed on electric balance and their average was taken out. Seed cotton yield of each plot was weighed and later converted into kg $ha^{-1}$. The benefit cost ratio was calculated by dividing the gross income over the total cost (Joseph *et al*., 2009) and the net returns were estimated by subtracting the total cost of production from the gross income of each treatment (CIMMYT, 1988). Disease incidence was calculated on basis of infected and total plants according to the formula of Naveed *et al*. (2007). Data were analyzed to confirm its variability following the analysis of variance technique using the statistical software (Statistics 8.1). The differences between treatments were separated using HSD Tukey's test at 5% probability level in each year.

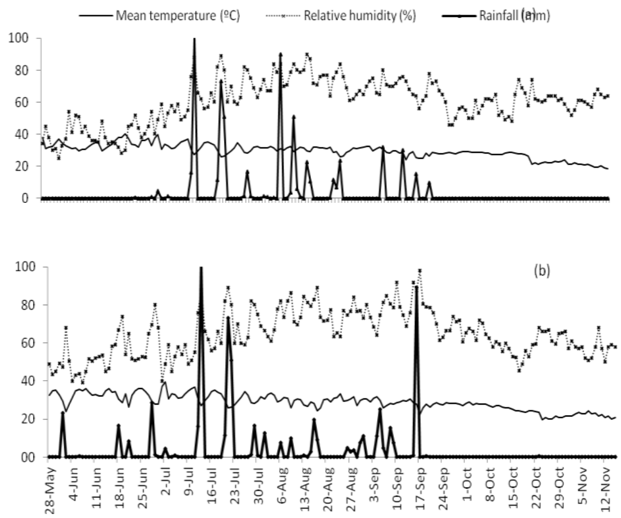


**Fig. 1:** Meteorological data of both experimental years (a): 2010 and (b): 2011. Agro Meteorological Cell, Department of Agronomy, University of Agriculture, Faisalabad (R.H. = relative humidity)

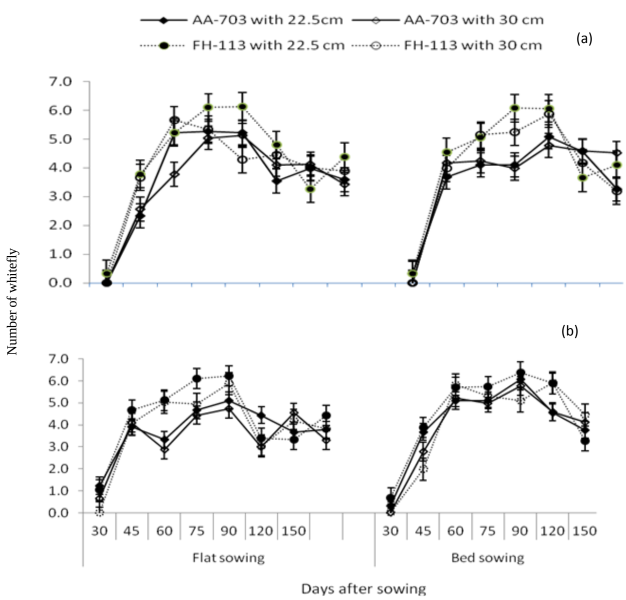


**Fig. 2:** Effect of sowing methods and plant spacing on number of whitefly in two cotton cultivars (a) 2010 (b) 2011 (mean ± standard error)

## Results

### White Fly Population and CLCuV Infestation in Cotton

During entire growth period of crop, continuous fluctuation in number of whitefly was observed (Fig. 2). Pest attack started at 30 DAS and its intensity increased (6 per leaf) at 90 DAS of cotton crop. Averaged across different sowing methods, crop growth stages and plant spacing, the cotton crop sown at 30 cm plant spacing had 9% less number of white fly per leaf than the crop sown at 22.5 cm spacing. Cultivar AA-703 had 8% less number of white fly population than cultivar FH-113.

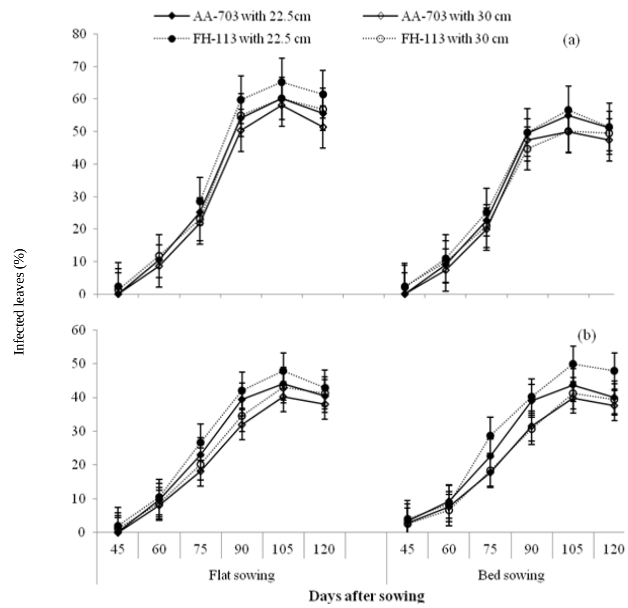


**Fig. 3:** Effect of sowing methods and plant spacing on infected leaves percentage in two cotton cultivars (a) 2010 (b) 2011. Error bars above means reveal the standard error of three replicates

First disease symptom (curling of leaf) appeared early in cultivar FH-113 at 45 DAS than the cultivar AA-703, when sown at plant spacing of 22.5 cm (Fig. 3). The disease symptoms got very severe (65%) at 105 DAS and then were reduced afterward. Less number of infected leaves (4%) was observed in the plants sown under wider plant spacing (30 cm) than the plants sown under narrow spacing (22.5 cm) during the both experimental years. Cultivar AA-703 had 4% lower percentage of disease infected leaves than the cultivar FH-113 at 105 DAS (Fig. 3).

Wide spacing (30 cm) had 10% less disease incidence than narrow spacing (22.5 cm) during the both experimental years (Table 2). Likewise, cultivar AA-703 was 7% less damaged by whitefly than the cultivar FH-113. Sowing method did not significantly affect the disease incidence (Table 1); however, the interactive effect of plant spacing and cultivar was significant during 2010, and non-significant during 2011 (Table 4). Cultivar AA-703 sown at 30 cm plant spacing had the lowest disease infestation (73%).

There was a 30% reduction in number of enations per plant when crop was sown in wider spacing (30 cm) than crop sown in narrow spacing (22.5 cm) (Table 2). In case of cotton cultivars, the cultivar AA-703 showed 32% less enations than the cultivar FH-113. Sowing methods as well as interactions among different factors had non-significant effect on number of enations per plant during both years of study.

**Table 1:** Analysis of variance for the effect of sowing methods, plant spacing, and cultivars and their interactions on disease incidence, growth and yield of cotton during 2010 and 2011

| SOV | DF | Disease incidence (%) | | Enations per plant | | Max. LAI | | Mean CGR | | Opened bolls per plant | | Boll weight (g) | | Seed cotton yield (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2010 | 2011 | 2010 | 2011 | 2010 | 2011 | 2010 | 2011 | 2010 | 2011 | 2010 | 2011 | 2010 | 2011 |
| Sowing methods (SM) | 1 | 3.26 ns | 3.18ns | 1.33ns | 1.18ns | 0.07** | 0.51ns | 0.85ns | 0.05* | 3.66ns | 5.20* | 0.32* | 0.24ns | 346.38* | 352.67* |
| Plant spacing (PS) | 1 | 2.52** | 4.28* | 0.48* | 0.76* | 0.13** | 0.28ns | 0.35* | 0.39ns | 1.65** | 3.75* | 0.18** | 0.20* | 266.68** | 277.44** |
| Cultivar (Cv) | 1 | 0.86*** | 2.13** | 0.22*** | 0.38** | 0.17** | 0.18** | 0.21*** | 0.23*** | 1.23** | 2.27** | 0.20** | 0.14* | 76.97** | 214.41** |
| SM × PS | 1 | 4.02ns | 4.31ns | 1.40ns | 1.37ns | 0.14ns | 0.56ns | 0.91ns | 0.40ns | 3.95ns | 6.26ns | 0.36ns | 0.30ns | 426.88ns | 438.17* |
| SM × Cv | 1 | 3.30ns | 3.47ns | 1.34ns | 1.20ns | 0.18ns | 0.52ns | 0.86ns | 0.24ns | 3.76ns | 5.46ns | 0.36ns | 0.27ns | 349.44ns | 394.051ns |
| PS × Cv | 1 | 2.66** | 2.45ns | 0.53ns | 0.85ns | 0.21ns | 0.33ns | 0.41ns | 0.46ns | 2.05ns | 4.36ns | 0.27ns | 0.25ns | 277.17ns | 349.17ns |
| SM × PS × Cv | 8 | 4.14ns | 4.23ns | 1.05ns | 1.22ns | 0.26ns | 0.45ns | 0.68ns | 0.47ns | 4.43ns | 7.65ns | 0.37ns | 0.30ns | 456.15ns | 625.07ns |

*= significant at $p \leq 0.05$, **= significant at $p \leq 0.01$, ***= significant at $p \leq 0.001$, ns: non-significant, Max. LAI: maximum leaf area index, CGR: crop growth rate; DF= degree of freedom; SOV= sources of variation

**Table 2:** Effect of different sowing methods and plant spacing on disease incidence, enations per plant, leaf area index and crop growth rate of two Bt cotton cultivars

| Treatments | | Disease incidence (%) | | | Enations per plant | | | Max. LAI | | | Mean CGR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2010 | 2011 | Mean | 2010 | 2011 | Mean | 2010 | 2011 | Mean | 2010 | 2011 | Mean |
| Sowing methods | Flat sowing (c) | 81 a | 75 a | 77.76 | 2.58 a | 1.83 a | 2.21 | 3.99 b | 4.15 a | 4.07 | 3.94 a | 5.02 b | 4.48 |
| | Bed sowing | 79 a | 78 a | 78.27 | 2.05 a | 1.63 a | 1.84 | 4.21 a | 4.51 a | 4.36 | 4.12 a | 5.38 a | 4.75 |
| Plant spacing | 22.5 cm (c) | 84 a | 80 a | 81.89 | 2.66 a | 2.11 a | 2.39 | 3.89 b | 4.24 a | 4.07 | 3.74 b | 5.24 a | 4.49 |
| | 30 cm | 76 b | 73 b | 74.15 | 1.97 b | 1.36 b | 1.67 | 4.12 a | 4.42 a | 4.27 | 4.32 a | 5.16 a | 4.74 |
| Cultivars | AA-703 | 78 b | 75 a | 76.45 | 1.88 b | 1.42 b | 1.65 | 3.96 b | 4.13 b | 4.05 | 3.69 b | 4.86 b | 4.28 |
| | FH-113 (c) | 81 a | 83 b | 82.08 | 2.75 a | 2.08 a | 2.42 | 4.24 a | 4.52 a | 4.38 | 4.36 a | 5.55 a | 4.96 |

Two means sharing same case letter for a parameter during an experimental year did not differ significantly at $p \leq 0.05$; Max. LAI= maximum leaf area index; CGR= crop growth rate; c= control

**Table 3:** Effect of different sowing methods and plant spacing on opened bolls per plant, boll weight and seed cotton yield of two Bt cotton cultivars

| Treatments | | Opened bolls per plant | | | Boll weight (g) | | | Seed cotton yield (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2010 | 2011 | Mean | 2010 | 2011 | Mean | 2010 | 2011 | Mean |
| Sowing methods | Flat sowing (c) | 19.15 a | 18.12 b | 18.64 | 2.53 b | 2.71 a | 2.62 | 1859 b | 2018 b | 1939 |
| | Bed sowing | 21.50 a | 21.64 a | 21.57 | 2.89 a | 2.73 a | 2.81 | 2195 a | 2497 a | 2346 |
| Plant spacing | 22.5 cm (c) | 18.32 b | 17.81b | 18.07 | 2.53 b | 2.47 b | 2.56 | 2240 a | 2449 a | 2345 |
| | 30 cm | 22.63 a | 22.71 a | 22.67 | 2.90 a | 2.94 a | 2.93 | 1815 b | 2066 b | 1941 |
| Cultivars | AA-703 | 21.78 a | 22.15 a | 21.97 | 2.91 a | 2.88 a | 2.90 | 2137 a | 2432 a | 2285 |
| | FH-113 (c) | 19.17 b | 18.46 b | 18.82 | 2.54 b | 2.56 b | 2.55 | 1918 b | 2083 b | 2001 |

Two means sharing same case letter for a parameter during an experimental year did not differ significantly at $p \leq 0.05$; c= control

### Crop Growth and Yield

Leaf area index (LAI) was significantly affected by plant spacing and crop cultivars during the both years of study. Crop grown under wider spacing (30 cm) had the higher (5%) mean LAI than narrow plant spacing (22.5 cm), while cultivar FH-113 had 8% higher mean LAI than the cultivar AA-703. The differences between two sowing methods were non-significant during the second year of experimentation for LAI (Table 2). The mean crop growth rate (CGR) of cotton was 6% higher, when sown under wider plant spacing (30 cm) than narrow plant spacing (22.5 cm). Moreover, bed sowing of cotton produced 6% higher mean CGR than the flat sowing. Cultivar FH-113 had higher mean CGR (14%) than the cultivar AA-703.

Maximum opened bolls (26%) were observed under wide spacing (30 cm) than narrow plant spacing (Table 3). Both cultivars also significantly differed for the number of opened bolls. Nonetheless, AA-703 cultivar had 17% more opened bolls than FH-113. Regarding the sowing methods, the difference were non-significant between the two sowing methods during the first year; while in second year, cotton grown on beds produced 16% higher number of opened bolls per plant than the flat sown cotton.

Cultivars and plant spacing significantly affected the boll weight (Table 3). Sowing methods also significantly affected the boll weight of cotton during 2010 however, effects were non-significant during 2011. At plant spacing of 30 cm, boll weight of cotton was 15% higher than plant spacing of 22.5 cm. Cultivar AA-703 produced 14% more boll weight than FH-113. The two-way and three-way interactions of plant spacing, cultivar and sowing methods were non-significant for the boll weight of cotton.

Cotton grown under narrow plant spacing (22.5 cm) produced 17% higher seed cotton yield than the crop under wider plant spacing (30 cm) during both years. Among the sowing methods, the highest seed cotton yield (21% higher) was recorded in bed sown cotton than flat sowing. Cotton cultivar AA-703 produced 15% higher seed cotton yield than FH-113 (Table 3). The interaction of plant spacing and

**Table 4:** Interactive effects of plant spacing and cultivar on disease incidence during 2010

| Treatments | 22.5 cm | 30 cm | Mean |
|---|---|---|---|
| AA-703 | 82.70 a | 73.10 c | 77.90 B |
| FH-113 | 84.28 a | 78.23 b | 81.25 A |
| Mean | 83.49 A | 75.67 B | |
| HSD (Interaction) value | 1.69 | | |

Means sharing same case letter did not differ significantly at $p \leq 0.05$

**Table 5:** Interactive effects of plant spacing and sowing method on seed cotton yield during 2011

| Treatments | 22.5 cm | 30 cm | Mean |
|---|---|---|---|
| Bed sowing | 2796 a | 2166 b | 2497 A |
| Flat sowing | 2122 b | 2039 b | 2018 B |
| Mean | 2449 A | 2066 B | |
| HSD (Interaction) value | 355 | | |

Means sharing same case letter did not differ significantly at $p \leq 0.05$

sowing methods indicated that the maximum seed cotton yield (2796 kg $ha^{-1}$) was achieved when crop was grown on beds with narrow spacing of 22.5 cm; the lowest of 2039 kg $ha^{-1}$ was obtained with flat sowing under 30 cm plant spacing (Table 5).

Cultivar AA-703 gave maximum net return of Rs. 117849 $ha^{-1}$ and Rs. 87305 $ha^{-1}$ when sown on beds during 2010 and 2011, respectively (Table 6). During both years, the cultivar AA-703 sown on bed gave the maximum benefit cost ratio (BCR) as compared to cultivar FH-113. Whereas, flat sowing of cultivar FH-113 produced the minimum BCR.

## Discussion

Plants sown under wider spacing (30 cm) showed a considerable decrease in disease incidence (10%), number of infected leaves (6% at 90 DAS) and number of enations per plant (30%) than the plants sown at narrow spacing (22.5 cm) during the both experimental years. This less disease incidence, less number of infected leaves and the lower number of enations in wider spaced plants (less leaf canopy) was due to more light penetration which resulted in more photosynthesis and enhanced assimilation of the carbohydrates (Andries *et al.,* 1969).

As a result, the plants remained healthy and showed tolerance to disease. Less plant density of cotton had lower incidence of disease than the higher plant density (Arshad *et al.,* 2009; Iqbal *et al.,* 2007; Iqbal and Khan, 2010). Under more light penetration, the plants become vigorous and resistant to disease, as was observed in this study. Contrarily, narrow plant spacing may also show less disease infestation, as the higher number of plants in narrow spaced planting system result in lower number of vector (white fly) per leaf and lower disease incidence (Baluch, 2007). During the both experimental years, the disease incidence, number of enations per plant, and number of infected leaves were 7, 32 and 4%, respectively, lower in cultivar AA-703 compared with FH-113. These variations were due to the differences in the genetic makeup of both cultivars (Akhtar *et al.,* 2002; Tahir and Mahmood, 2005). The cultivar AA-703 had a thick cuticle wax layer which restricts the disease infestation by avoiding the attack of whitefly.

Higher number of whitefly (9% more) was observed in plant spacing of 22.5 cm than 30 cm during the both experimental years. This was due to less aeration and high temperature in narrow spaced plants, which resulted in more hatching of whitefly (Arif *et al.,* 2006). Cultivar FH-113 showed 8% higher number of whitefly compared with AA-703. This might be attributed to the difficult movement of white fly on hairy cultivar (AA-703) than hairless cultivar (FH-113) (Aslam *et al.,* 2000; Tahir *et al.,* 2004) and vice versa.

Maximum leaf area index and the higher mean crop growth rate were recorded under wider plant spacing than the narrow plant spacing. This might be due to more photosynthetic rate, more mitosis rates, more cell division and more cell enlargement under wider spacing with the availability of plenty of light (Darawsheh *et al.,* 2009). Wider spaced plants produced 26% more number of bolls and 15% more boll weight than the narrow plant spacing during the both years of experimentation. It was due to more nutrients availability and utilization in lower plant population, which resulted in higher number of bolls and more boll weight (Boquet, 2005).

Variations between cultivars were also apparent regarding growth and yield traits; the cultivar FH-113 showed better growth performance owing to its unique characteristics such as long stature, larger leaves, and higher number of leaves per plant; AA-703 performed better in case of yield owing to higher boll size and boll number. These differences in morphological and yield parameters were due to differences in the genetic makeup of the studied cultivars (Bange and Milroy, 2001). In case of sowing methods, cotton grown on beds produced significantly higher seed cotton yield (21%) due to early germination, deeper root proliferation and more roots surface area, which improved the absorption of water and nutrients thus resulting in good stand of crop than the flat sowing.

Cotton grown under narrow plant spacing produced significantly higher seed cotton yield, possibly due to more number of plants in narrow plant spacing. All favorable factors in the form of less disease incidence, less infected leaves percentage, higher boll size and more boll number could not compensate lower plant population in wider spaced crop. Cotton cultivar AA-703 produced significantly higher (14% more) seed cotton yield than FH-113 which indicates the higher yield potential in the form of more boll size and higher number of bolls in cultivar AA-703. The differences in the seed cotton yield between both cultivars might be due to differences in the inherited yield potentials (Ali *et al.,* 2009). Higher seed cotton (2796 kg $ha^{-1}$) yield was achieved when crop was grown on beds with plant spacing of 22.5 cm and lower seed cotton yield was obtained in flat sown crop in 30 cm spaced plants. This was due to

**Table 6:** Effect of sowing methods and cultivar on net returns and benefit cost ratio during 2010 and 2011

| Year | Treatments | | Seed cotton yield (kg $ha^{-1}$) | Seed cotton yield value (Rs. $ha^{-1}$) | Cotton sticks value (Rs.) | Gross income (Rs. $ha^{-1}$) | Total cost (Rs. $ha^{-1}$) | Net return (Rs. $ha^{-1}$) | Benefit cost ratio |
|---|---|---|---|---|---|---|---|---|---|
| 2010 | Flat sowing (c) | AA-703 | 2004 | 200400 | 10000 | 210400 | 145346 | 65054 | 1.45 |
| | | FH-113 (c) | 1711 | 171100 | 10000 | 181100 | 142381 | 38719 | 1.27 |
| | Bed sowing | AA-703 | 2585 | 258500 | 10000 | 268500 | 150651 | 117849 | 1.78 |
| | | FH-113 | 2248 | 224800 | 10000 | 234800 | 147466 | 87334 | 1.59 |
| 2011 | Flat sowing | AA-703 | 2409 | 168640 | 10000 | 178640 | 137764 | 40877 | 1.30 |
| | | FH-113 | 2187 | 153120 | 10000 | 163120 | 141355 | 21765 | 1.15 |
| | Bed sowing | AA-703 | 3132 | 219280 | 10000 | 229280 | 141976 | 87305 | 1.61 |
| | | FH-113 | 2575 | 180240 | 10000 | 190240 | 148471 | 41770 | 1.28 |

more number of plants with well root establishment, and the best water and nutrient utilization by cotton crop on beds.

Cultivar AA-703 gave the maximum net return of Rs. 117849 $ha^{-1}$ and Rs.87305 $ha^{-1}$, when sown on beds during 2010 and 2011, respectively. Although yield during 2011 was more as compared to first year, nonetheless, decrease in net returns during the second year was due to lower cotton rates than the first year. During both years, cultivar AA-703 sown on bed gave the maximum BCR as compared to cultivar FH-113. Flat sown FH-113 produced the minimum BCR. Indeed, the higher seed cotton yield in bed sown cotton enhanced the net returns which ultimately increased the BCR (Nasrullah *et al*., 2011; Irfan *et al.*, 2014).

## Conclusion

Wider plant spacing (30 cm) minimized the white fly attack and CLCuV infestation in cotton than narrow plant spacing (22.5 cm). However, the crop planted at 22.5 cm produced 2% higher seed cotton yield than those planted at 30 cm, in spite of low disease in wider plant spacing, which indicates that lower disease could not compensate the low plant population in wider spaced crop. Sowing methods did not significantly influence the disease incidence, but seed cotton yield of bed sown cotton was 21% higher than the flat sown cotton. Cultivar AA-703 produced 12% higher yield than FH-113, which was better linked with lower disease incidence and larger size and quantity of bolls. In crux, the maximum net return and benefit cost ratio were achieved for cultivar AA-703 sown at plant spacing of 22.5 cm on beds.

## Acknowledgements

The financial support by Higher Education Commission (HEC), Islamabad in the form of Indigenous Scholarship is highly acknowledged.

## References

Ahuja, S.L., D. Monga and L.S. Dhayal, 2007. Genetics of resistance to cotton leaf curl disease in *Gossypium hirsutum* L. under field conditions. *J. Hered.,* 98: 79–83

Akhtar, K.P., A.I. Khan, M. Hussain and M.S.I. Khan, 2002. Comparison of resistance level to cotton leaf curl virus (CLCuV) among newly developed cotton mutants and commercial cultivars. *J. Plant Pathol*., 1: 179–186

Akhtar, K.P., M. Hussain, A.I. Khan, A.A. Haq and M.M. Iqbal, 2004. Influence of plant age, white fly population and cultivar resistance on infection of cotton plants by cotton leaf curl virus (CLCuV) in Pakistan. *Field Crop Res.,* 86: 15–18

Akhtar, K.P., M. Aslam, M.A. Haq, F.F. Jamil, A.I. Khan and M.T. Elahi, 2005. Resistance to CLCuV in a mutant cotton line. *J. Cotton Sci.,* 9: 175–181

Ali, L. and Ehsanullah, 2007. Water use efficiency of different planting methods in cotton (*Gossypium hirsutum* L.). *J. Agric. Res.,* 45: 299–306

Ali, A., M. Tahir, M. Ayub, I. Ali, A. Wasaya and F. Khalid, 2009. Studies on the effect of plant spacing on yield of recently approved cotton cultivars. *Pak. J. Life Soc. Sci*., 7: 25–30

Ali, M., L. Ali, M. Sattar and M.A. Ali, 2013, Response of seed cotton yield to various plant populations and planting methods. J. Agric. Res., 48: 134–137

Andries, J.A., J.E. Jones, L.W. Sloane and J.G. Marshall, 1969. Effects of okra leaf shape on boll rot, yield, and other important characters of upland cotton, *Gossypium hirsutum* L. *Crop Sci.,* 9: 705–710

Anwar, M.M., M.I. Gill and M.S. Zaki, 2003. Effect of bed-furrow planting on cotton crop. *Pak. Cottons,* 47: 41–46

Arif, M.J., M.D. Gogi, M. Mirza, K. Zia and F. Hafeez, 2006. Impact of plant spacing and abiotic factors on population dynamics of sucking insect pests of cotton. *Pak. J. Biol. Sci*., 9: 1364–1369

Arshad, M., A. Suhail, M.J. Arif and M.A. Khan, 2009. Transgenic-Bt and non-transgenic cotton effects on survival and growth of *Helicoverpa armigera*. *Int. J. Agric. Biol.,* 11: 473–476

Aslam, M., G.A. Herzog and R.B. Chlfant, 2000. Different cotton strains screened for resistance to Heliothis spp. (Lepidoptera: Noctudae) in the field. *Pak. J. Biol. Sci.,* 3: 1290–1291

Bange, M.P. and S.P. Milroy, 2001. Timing of crop maturity in cotton: Impact of dry matter production and partitioning. *Field Crop Res.,* 2: 143–155

Baluch, Z.A., 2007. Recent research advances to combat cotton leaf curl virus disease in Pakistan. Available online at https://wcrc.confex.com/wcrc/2007/techprogram/P1517.HTM (Accessed on June 10, 2017)

Bashir, M.H., M. Afzal, A.M. Sabri and A.B.M. Raza, 2001. Relationship between sucking insect pests and physio-morphic plant characters towards resistance/susceptibility and some new genotypes of cotton. *Pak. Entomol.,* 23: 75–78

Boquet, D.J., 2005. Cotton in ultra narrow row spacing; plant density and nitrogen fertilizer rates. *Agron. J. Louis. State Univ.,* 97: 279–287

Briddon, R.W. and P.G. Markham, 2001. Cotton leaf curl virus disease. *Virus Res*., 71: 151–159

Brodersen, P., L. Sakvarelidze-Achard, M. Bruun-Rasmussen, P. Dunoyer, Y. Y. Yamamoto, L. Sieburth, and O. Voinnet, 2008. Widespread translational inhibition by plant miRNAs and siRNAs. *Science*, 320: 1185–1190

Carroll, J., 2009. *Pakistan annual cotton report (Global Agricultural Information Network Report).* USDA Foreign Agriculture Service, Washington DC, USA

Chaudhary, B., S. Kumar, K.V.S.K. Prasad, G.S. Oinam, B.K. Burma and D. Pental, 2004. Slow desiccation leads to high frequency shoot recovery from transformed somatic embryos of cotton (*Gossypium hirsutum* L. cv. Coker 310 FR). *Plant Cell Rep.,* 21: 955–960

CIMMYT, 1988. *From Agronomic Data to Farmers Recommendations: An Economics Training Manual*. Completely revised edition. Mexico

Darawsheh, M.K., E.M. Khah, G. Aivalakis, D. Chachalis and F. Sallaku, 2009. Cotton row spacing and plant density cropping systems II. Effects on seed cotton yield, boll components and lint quality. *J. Food Agric. Environ.,* 7: 262–265

Farooq, J., A. Farooq, M. Riaz, M.R. Shahid, F. Saeed, M.S. Iqbal. T. Hussain, A. Batool and A. Mahmood, 2014. Cotton leaf curl virus disease a principal cause of decline in cotton productivity in Pakistan. *Can. J. Plant Prot.,* 2: 9–16

Hunt, 1978. *Plant Growth Analysis*, Vol. 96, pp: 8–38. The institute Biology's studies in Biology. Edward Arnold (Pub.) Ltd, UK

Hussain, T., Jehanzeb, M. Tariq and B.N. Siddiqui, 2003. Effect of different irrigation levels on the yield and yield components of cotton (*Gossypium hirsutum* L.) under two sowing methods. *J. Biol. Sci.,* 3: 655–659

Hussain, M., F.M. Azhar and A.A. Khan, 2012. Expression of genes controlling the inheritance of resistance to cotton leaf curl virus disease (CLCuD) in *Gossypium hirsutum* L. a quantitative analysis. *Pak. J. Bot.,* 44: 247–254

Iqbal, M.J., N. Aziz, N.A. Saeed, Y. Zafar and K.A. Malik, 1997. Genetic diversity evaluation of some elite cotton cultivars by RAPD analysis. *Theor. Appl. Genet.,* 94: 139–144

Iqbal, M., N.I. Khan, K. Hayat and T. Muhammad, 2007. Management of cotton crop under high leaf curl virus attack. *Asian J. Plant Sci.,* 6: 1125–1130

Iqbal, M. and M.A. Khan, 2010. Management of cotton leaf curl virus by planting time and plant spacing. *AAB Bioflux.*, 2: 25–33

Irfan, M., Ehsanullah, R. Ahmad and A.U. Hassan, 2014. Effect of sowing methods and different irrigation regimes on cotton growth and yield. *Pak. J. Agric. Sci.,* 51: 789–795

Jeyakumar, P., R.K., Tanwar, M. Chand, A. Singh, D. Monga and O.M. Bambawale, 2008. Performance of Bt. cotton against sucking pests. *J. Biopest*: 223–225

Joseph, L.N., R. Maloney and H.P. Possingham, 2009. Optimal allocation of resources among threatened species: a project prioritization protocol, *Conserv. Biol.*, 23: 328–338

Khan, J., A. Abid and J. Ahmad, 2005. Diagnosis, monitoring and transmission characters of cotton leaf curl virus. *Curr. Sci*., 88: 1803–1809

Khan, M.A., W. Akram, H.A.A. Khan, J. Asghar and T.M. Khan, 2010. Impact of Bt cotton on whitefly, *Bemisia tabaci* (genn.) population. *Pak. J. Agric. Sci*., 47: 327–332

Mahmood, T., M. Tahir, H.T. Mahmood and S. Hussain, 2002. Testing of cotton leaf curl virus resistance of candidate varieties/strains through different techniques. *Asian J. Plant Sci.,* 1: 489–491

Narula, A.M., D. Monga, M.S. Chauhan and S. Raj, 1999. Cotton leaf curl virus disease in India-The Challenge ahead. *J. Cott. Res. Dev*., 13: 129–138

Nasrullah, H.M., M.B. Khan, R. Ahmad, S. Ahmad, M. Hanif and W. Nazeer, 2011. Sustainable cotton production and water economy through different planting methods and mulching techniques. *Pak. J. Bot.,* 43: 1971–1983

Naveed, M., M. Nadeem and N. Islam, 2007. AMMI analysis of some upland cotton genotypes for yield stability in different milieus. *World. J. Agric. Sci.,* 3: 39–44

Qazi, J., I. Amin, S. Mansoor, J. Iqbal and R.W. Briddon, 2007. Contribution of the satellite encoded gene $\beta C_1$ to cotton leaf curl disease symptoms. *Virus Res*., 128: 135–139

Sarkar, B., A.K. Patra, T.J. Purakayastha and M. Megharaj, 2009. Assessment of biological and biochemical indicators in soil under transgenic Bt and non-Bt cotton crop in a sub-tropical environment. *Environ. Monit. Assessment*, 156: 595–604

Singh, R., A. Kumar, M.S. Chauhan, J. Beniwal and P.K. Chohan, 2012. Effect of different sowing dates and spacings on the incidence of cotton leaf curl virus disease (CLCuD) under Haryana conditions. *J. Cott. Res. Dev.,* 26: 251–253

Tahir, M., M. Tariq, H.T. Mehmood and S. Hussain, 2004. Effect of sowing dates on the incidence of cotton leaf curl virus on different cultivars of cotton. *Plant Pathol*., 3: 61–64

Tahir, M. and T. Mahmood, 2005. Occurrence of cotton leaf curl virus in the main cotton belt of the Punjab and its impact on yield losses during 2004–05. *Pak. Cotton,* 50: 65–73

Watson, D.J., 1947. Comparative physiological studies in the growth of field crops. I. Variation in net assimilation rate and leaf area between species and cultivars, within and between years. *Ann. Bot.,* 11: 41–76

**(Received 27 February 2017; Accepted 15 June 2017)**