

YIELD RELATED MORPHOLOGICAL MEASURES OF SHORT DURATION COTTON GENOTYPES

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ABSTRACT

The present studies were aimed to characterize the early maturing cotton genotypes and determine the relationship among earliness, yield and fiber quality traits. Eight upland cotton genotypes viz., CRIS-134, Sadori, Chandi, NIAB-78, AA-802, IR-3701, IR-1524 and FH-113 were included in the studies. The experiment was laid out in a randomized complete block design with four replications during 2012 at Sindh Agriculture University, Tandojam, Pakistan. The mean squares indicated significant ($p < 0.01$) differences among the genotypes for all the traits. The two cultivars i.e. CRIS-134 and Sadori were characterized as early maturing in terms of days to 1st flower, formed sympodial branches at relatively lower nodes, set 1st effective boll on lower sympodia, formed and opened maximum bolls at 90 and 120 days after planting (DAP) and weighed medium size bolls. For yield traits, maximum bolls plant⁻¹, bigger bolls, higher seed cotton yield and more lint percentage were obtained from cultivars CRIS-134, Sadori, IR-3701 and FH-113. Regarding fiber traits, the longer staple with desirable micronaire were recorded by CRIS-134, AA-802 and FH-113. The correlation coefficient showed that sympodial branch length, bolls formed at 120 DAP, bolls plant⁻¹ and seed index were significantly and positively correlated with seed cotton yield. The higher correlations of yield components with yield indicated their reliable use as indirect selection criteria to improve the seed cotton yield. Some important negative correlations of lint percentage with seed index, staple length and micronaire value were also recorded which indicated that a compromise level for lint percentage may be considered while improving staple length and fiber fineness in cotton.

Key words: Short duration cotton, early maturity, seed cotton yield and fiber traits.

INTRODUCTION

Due to varying environmental conditions from north to south (in the southern parts of Punjab province and most parts of Sindh province) in Pakistan, the cotton-wheat-cotton rotation with late maturing cotton cultivars, results in delayed wheat planting that ultimately affects the wheat production. Considerable wheat yield losses occur due to late sowing and the decline in production continues with delay of each day in wheat planting (Chattha *et al.*, 1995; Chaudhary *et al.*, 1995). Delay in sowing of wheat after 10th November may cause 42 kg ha⁻¹ day⁻¹ loss in yield (Khan, 2003), and late maturity of cotton also causes poor fiber quality (Salam *et al.*, 1993). Moreover, the short duration cotton genotypes are economical regarding cost of production because early maturing cultivars evade from biotic and abiotic risks (Rehana *et al.*, 2001).

Cotton earliness is a quantitative trait which is mainly affected by environment and crop genotype (Kassianenko *et al.*, 2003). Therefore, in any cropping system, cultivar selection is the key factor (Nichols *et al.*, 2004). Short duration cotton cultivars can avoid yield losses that occur due to diseases and insect-pest complexes (Singh, 2004). Earliness in cotton is also

important in lessening the late season perils of insect pests (particularly bollworms), diseases, unfavorable weather conditions and increase in economic return by reducing input cost (Anderson *et al.*, 1976). The growing of early maturing cotton cultivars has an advantage of proper time for rotation of other crops allowing timely sowing of wheat in cotton-wheat-cotton cropping system in Pakistan and other countries (Ali *et al.*, 2003).

The damage from pink bollworm (*Pectinophora gossypiella*) can also be avoided by growing early and moderately early cotton cultivars than long season cultivars (Chu *et al.*, 1992a). Similarly, in southern Punjab, which is called the cotton belt of Pakistan, the attack of pink bollworm and white fly during the month of September and first week of October is maximum which damages the cotton crop severely. In addition, high population of *Heliothis* is found in 3rd week of September to 4th week of October (Annual Progress Report, 1999 of CCRI). Thus, keeping in view the suggestions of Chu *et al.* (1992b) and Singh (2004), the cotton crop could be secured through breeding early maturing cultivars. The cultivation of early cotton cultivars will not only minimize the use of pesticides, but the expenses incur on the other inputs like irrigation water and fertilizers will also be condensed down. Early maturing cotton cultivars are more suitable for farming community and textile

industry because it can bump-up the cotton production by diminishing the late-season risks allied to insect intimidation and adverse weather conditions along with saving irrigation in critical environmental conditions (Neil, 1991).

Early maturing cotton cultivars complete most of their life cycle during weather conditions most favourable to the crop, thus, mature before the damage caused by unfavourable weather conditions. For breeding early maturing cotton, in many countries, the cotton breeders must establish some reliable characterization based on early maturing plant traits so that early maturing cultivars could easily be developed without encountering some other confounding effects. Kairon and Singh, (1996) proposed a number of indicators that determine earliness in cotton viz., reduction in monopodia, profuse flowering, higher boll setting and opening at earlier stages of crop growth, less and smaller leaves, shorter internode length, semi-determinate types, lower sympodial node number, short sympodial branches, cluster fruit bearing types, medium boll size, sub-okra types and dwarf stature plants.

About earliness of cotton plant, the past information is limited, however, whatever exists reveal that earliness in cotton is a complex trait which is appraised by determining many traits. Ray and Richmond (1966) reported that first fruiting branch node, number of monopodia, and bolls per vegetative branches are the important attributes, while Godoy (1994) emphasized on measuring the plant height, days to first flower and first open boll for assessing the cotton genotypes for earliness. The measures on first sympodial node number, sympodial branch length, internode length, and percent first pick were used to assess the earliness in cotton (Baloch and Baloch, 2004). The *G. hirsutum* L. genotypes showed highly significant genotypic differences for node of 1st fruiting branch, days to 1st boll opening, earliness index and seed cotton yield, however, their findings revealed that none of the single criterion seems to be adequate for measuring the earliness in cotton genotypes (Shakeel *et al.*, 2008). In cotton genotypes, the traits days to squaring and flowering, vertical flowering interval, horizontal flowering interval, days to first boll opening, boll maturity period, node number for first fruiting branch, height of the first fruiting branch, mean maturity date and earliness index were used for measuring earliness (Shakeel *et al.*, 2012a). However, Babar *et al.* (2002) had mentioned that first sympodial branch node number and days to open first flower are the trustworthy characters for envisaging the earliness in cotton. Date of peak flower and node at which first sympodial branch is borne are index of earliness as well (Iqbal *et al.*, 2003; Basbag *et al.*, 2007; Shakeel *et al.*, 2008). First internode length is contributing in early maturity when it has low value, and the cultivar CIM-554 was early maturing because of having minimum first internode length (2.12 cm) and the

maximum was recorded in cultivar CIM-496 (2.47 cm) (Batool *et al.*, 2010). In the past studies, it was concluded that the earliness traits i.e. days to appearance of first flower and first sympodial node number, could reliably be considered the measures of earliness in upland cotton (Panhwar *et al.*, 2010; Habib *et al.*, 2013). However, Rehana *et al.* (2001) found that main stem node number bearing first sympodial branch, days to attain 5-NAWF (nodes above white flower), and appearance of first sympodial branch were the key factors for assessing earliness in upland cotton.

The term earliness is particular to crop production that refers to harvest the crop as early as possible without incurring significant yield losses. Average vegetative growth period of cotton throughout the world is found to be 135-150 days (Baloch and Veesar, 2007). Short duration and high yielding cultivars are always required for better fiber quality and production. Early maturing crops avoid disease and insect pest epidemics due to which plant breeders have positioned adequate pressure on the development of early maturing crop plants (Singh, 2004). The present research was therefore, designed to characterize the existing popular cotton cultivars for early maturity and determine the interrelationship between early maturing, yield and fiber quality traits.

MATERIALS AND METHODS

The research was conducted during 2012 at the Sindh Agriculture University, Tando Jam, Pakistan. Eight upland cotton genotypes namely; CRIS-134, Sadori, Chandi, NIAB-78, AA-802, IR-3701, IR-1524 and FH-113 were included in the studies to characterize for earliness based on their phenotypic characters. The experiment was laid-out in a randomized complete block (RCB) design with four replications. The plants and rows spacing were kept at 30 and 75 cm, respectively. Fertilizer at the rate of 125:75 kg N:P ha⁻¹ was applied in the form of Urea and DAP. Full dose of phosphorus with 1/3rd of nitrogen was applied at the time of land preparation while remaining nitrogen was applied in three equal split doses with first irrigation, peak flowering and boll setting stages. Other inputs like irrigation and insecticides were applied at proper time and as when required. All other cultural practices including weeding were uniformly adopted in whole experiment throughout the growing period to minimize the environmental variations. Ten plants were randomly tagged per genotype from each replication for recording the data on earliness and yield related traits including days to first flower, first sympodial branch node number, sympodial branch bearing 1st effective boll, sympodial branch length (cm), bolls formed at 90 days after planting (DAP), bolls opened at 90 DAP, bolls formed at 120 DAP, bolls opened at 120 DAP, bolls plant⁻¹, boll weight (g). The

same plants were harvested individually and ginned on single plant roller gin machine to record the data on seed cotton yield plant⁻¹ (g), lint percentage, seed index / 100-seed weight (g), and fiber quality variables i.e. staple length (mm) and micronaire ($\mu\text{g}/\text{inch}$). The data were analyzed according to Gomez and Gomez (1984) for determining statistical differences among genotypes for various traits. The correlation coefficients (r) were determined through procedures developed by Raghavrao (1983).

RESULTS AND DISCUSSION

The mean squares from the analysis of variance (Table 1) indicated significant ($p < 0.01$) differences among the genotypes for all the traits viz., days to first flower, first sympodial branch node number, sympodial branch bearing 1st effective boll, sympodial branch length, bolls formed at 90 DAP, bolls opened at 90 DAP, bolls formed at 120 DAP, bolls opened at 120 DAP, bolls plant⁻¹, boll weight, seed cotton yield plant⁻¹, lint percentage, seed index, staple length and micronaire value. Similarly, significant differences have also been reported among cotton genotypes for node number of first fruiting branch and days taken to first flower in upland cotton (Habib *et al.*, 2013). Significant variations were reported among cotton genotypes for various earliness traits in upland cotton (Ali *et al.*, 2003; Iqbal *et al.*, 2003; Baloch and Baloch, 2004; Panhwar *et al.*, 2010; Shakeel *et al.*, 2008, 2011).

Mean performance of cotton cultivars for earliness, yield and fiber quality traits

Days to first flower: Days to first flower is not directly considered as yield component but days taken to first flower after planting of the crop would ultimately influence the opening of bolls, thus helps in determining the earliness in maturity (Baloch and Veesar, 2007). For days to first flower, the cultivar Sadori took minimum days (47.35 days) being earliest maturing while IR-3701 took maximum days to 1st flower (51.00 days) being late maturing, yet other cultivars like CRIS-134 and IR-1524 ranked average to initiate the first flower, hence considered as moderately early maturing (Fig. 1). Appearance of first flower is easily recognizable and can be used with more accomplishment. Lesser the days to first flower from sowing date, the earlier would be the cotton cultivar maturity (Saleem *et al.*, 2009). In a study of 13 upland cotton genotypes, the cultivars differed significantly for all the traits, and the strain VH-144 and VH-156 exhibited great potential for earliness and yield by taking minimum days to first flower and more boll opening percentage at 120 DAP (Ahmad *et al.*, 2008). The genotypes NIAB-884/188 and NIAB-111 were confirmed as early maturing by taking less number of days to first flower (41 and 45 days, respectively) (Habib

et al., 2013). The cultivars viz., CRIS-342 and Shahbaz were rated as early maturing genotypes which took 41.7 days to appearance of first flower followed by CRIS-121 and H-151 by taking 42.7 days to first flower (4.5) (Panhwar *et al.*, 2010). In fourteen cotton cultivars, less number of days to first flower were taken by cultivar CIM-443 followed by CIM-240, while more days were recorded in CIM-1100 and CIM-443 (Ali *et al.*, 2003). Dhivya *et al.* (2014) observed cotton genotypes with minimum (50 days) and maximum days (65) to first flowering, respectively, among fifty four cotton genotypes, and selection was made for early maturing genotypes to use in the future breeding program.

First sympodial branch node number: Appearance of first sympodial branch at lower node determines the early maturity of cotton plant. Among the cultivars evaluated, Sadori set the lowest 1st sympodial branch at node number 3.70 followed by CRIS-134 (5.08), NIAB-78 (5.24), AA-802 (5.53) and Chandi (5.58), while IR-3701 formed the 1st sympodial branch at the highest node number of 8.16 (Fig. 1). Theoretically, it is assumed that lower node number which form 1st sympodial branch is highly correlated with earliness and heat tolerance (Baloch and Veesar, 2007). Node number for the first fruiting branch is one of the most reliable and practical morphological measure of earliness in cotton genotypes. The earliness of crop maturation is affected more by the position of first branch than by other morphological characters (Iqbal *et al.*, 2003). The strong relationship between early maturity and lower sympodial branch node number was reported in previous studies (Baloch and Baloch, 2004). In cotton, one node decrease in sympodial branch matures the crop by approximately 4 to 7 days earlier (Ahmed and Malik, 1996). The short duration cottons set fruits at 4th/5th node while long duration cultivars set them at 8th/9th node (Kairon and Singh, 1996). Kerby *et al.* (1990) had reported strong relationship between early maturity and lower sympodial branch node number and sympodial branch length. In previous studies, cv. CIM-443 produced lowest main stem node number of first sympodial branch followed by CIM-240 and Karishma, while the highest main stem node bearing first sympodial branch number was recorded in cultivar CIM-1100 (Ali *et al.*, 2003). In present studies, among the eight cultivars, CRIS-134, Sindh-1 and CRIS-9 produced 1st sympodial branch at lower nodes ranging from 4.7 to 6.7, hence these cultivars are characterized as early and medium-early maturing. The past studies revealed that the range of variation for nodes to 1st fruiting branch was between 6.05 to 11.04, while for days to 1st boll opening ranged from the range was 91.17 to 106.83 days (Shakeel *et al.*, 2011). As regards to second earliness parameter, it was observed in past studies that CRIS-121 was the earliest genotype which gave 4.2 first sympodial node number followed by

Shahbaz (4.4) and CRIS-342 (4.5) (Panhwar *et al.*, 2010). In previous findings, the genotype NIAB-884/188 and NIAB-111 produced first fruiting branch at lower node number of 7.2 and 7.6, respectively, and were designated as early maturing (Habib *et al.*, 2013)

Sympodial branch bearing 1st effective boll: Setting up the 1st effective boll at lower sympodial branch is well thought-out as one of the unique traits related to early maturity in cotton. Results depicted significant differences among the cultivars for this trait. The sympodial branch setting-up the 1st effective boll varied from 6.78 to 9.0 nodes (Fig. 1). It is also implicit that closer distance between the 1st sympodial branch node with 1st effective boll's branch will lead a cultivar to be early maturing (Baloch and Baloch, 2004). Present results revealed that cv. Sadori set the 1st effective boll at 6.78 node number followed by cultivars CRIS-134 (7.20), IR-1524 (7.20), AA-802 (7.28) and NIAB-78 (7.97) being early and medium maturing, while IR-3701 set effective boll at 9th node and was considered as late maturing cultivar. Godoy (1994) observed that number of nodes to first fruiting branch, plant height and days to first flower were the most efficient criteria to identify the early maturing cotton cultivars. The boll setting on lower nodes would be measured as early maturing cultivars (Baloch and Baloch, 2004; Kairon and Singh, 1996). Several other breeders have also reported strong relationship between lower sympodial branch node number and the early maturity in cotton (Kerby *et al.*, 1990; Panhwar *et al.*, 2002).

Sympodial branch length: Results showed that cultivar IR-3701 recorded shorter sympodial branches measuring 13.58 cm as desirable trait for earliness and high yielding, while seven other cultivars produced longer sympodial branches ranging from 21.22 to 29.79 cm (Fig. 2). However, contrary to the assumptions that cultivars with shorter sympodial branches are early maturing, such assumptions surely contradicted with present findings. The shorter sympodial branches were indicative of early maturing cultivars, yet our results suggested that sympodial branch length may not be recommended as solid criterion for earliness in cotton cultivars (Umar *et al.*, 2005; Chang *et al.*, 2005a). In past research, among thirteen cotton genotypes, the cultivars CIM-448, VH-142 and VH-144 produced relatively shorter fruiting branches with values of 14.2, 15.2 and 17.0 cm, respectively, respectively (Ahmad *et al.*, 2008). The cotton breeders have succeeded in developing early maturing genotypes with short fruiting branches and also rated cultivars with short fruiting branches as early maturing ones (Kairon and Singh, 1996; Baloch and Baloch, 2004; Rauf *et al.*, 2005). In earliness studies of cotton cultivars the cv. CRIS-9 was one of the early maturing cultivars mainly because of its characters of developing its sympodial branches at lower position on

the main stem (Baloch and Veesar, 2007). Jatoi *et al.* (2012) also noted that cotton cultivars with shorter fruiting branches were the early maturing.

Bolls formed at 90 days after planting: Setting maximum number of bolls at earlier growth period will eventually lead to early maturity, consequently early picking. The cultivar CRIS-134 formed maximum bolls (30.91) at 90 DAP, followed by cv. Sadori which produced 29.62 bolls at 90 DAP (Fig. 2). In previous studies, the formation of maximum number of bolls between 75 and 90 days after sowing was reliable indicator for predicting the earliness in cotton genotypes at early stage of the crop development for early maturing and high yielding cultivars (Soomro *et al.*, 2002; Azhar *et al.*, 2004; Umar *et al.*, 2005; Chang *et al.*, 2005b). Results revealed that cultivars CRIS-134 and Sadori may be utilized as early maturing cultivars. In other previous studies, the node for 1st fruiting branch (Godoy, 1994; Baber *et al.* 2002; Baloch and Baloch, 2004), days to 1st boll opening (Godoy, 1994; Godoy and Palomo, 1999), and earliness index (Rauf *et al.* 2005) were used as effective selection criteria for the appraisal of earliness in upland cotton.

Bolls opened at 90 days after planting: More number of boll openings at earlier growth period is also considered as an important criterion to enumerate the cotton cultivars for earliness. According to earliness classification, the short duration cotton crop matures in 125 to 145 days, medium duration (145 to 165 days) and long duration matures in 170 to 190 days (Kairon and Singh, 1996). In our conditions, the cotton crop is normally harvested in 150 to 165 DAP with about 90% of the bolls opened, however, these cottons cause some delay in wheat sowing if cotton crop is left for 2nd or 3rd picking. The cultivars expressed significant differences in boll opening at 90 DAP yet, the cultivar Sadori opened the maximum bolls (8.70) at 90 DAP followed by CRIS-134 which opened (8.24) bolls at 90 DAP (Fig. 2). However, other six cultivars opened least number of bolls at 90 DAP ranging from 3.02 to 7.37 bolls. Thus, the former two cultivars could be considered as early maturing ones. Boll opening percentage at specified period of time is main criteria for developing early maturing genotypes (Ray and Richmond, 1966; Godoy, 1994; Kairon and Singh, 1994; Godoy and Palomo, 1999).

Bolls formed at 120 days after planting: The cultivars showed significant differences for bolls formed at 120 days after planting. The cultivars Sadori (35.75) and IR-3701 (35.41) formed the maximum bolls at 120 DAP followed by CRIS-134 (33.99) and FH-113 (33.24) (Fig. 3). From these results, it can be inferred that Sadori, IR-3701, CRIS-134 and FH-113 may be utilized as early maturing and high yielding cultivars in hybridization programs for the development of early maturing cultivars

with good yield potential. Similar findings about earliness and number of bolls opened at specific time have been reported previously in upland cotton genotypes (Saira *et al.*, 2002). In previous studies, seven early and one full season cotton cultivars were studied for earliness, and found that number of node of the first fruiting branch, plant height, first square date, date of first flower and date of first open boll can be used for efficient selection of earliness in upland cotton (Godoy, 1994).

Bolls opened at 120 days after planting: Early boll opening means early harvesting of the crop. It is an important attribute to compare the cotton cultivars for short season cotton. Significant differences were existed among the cultivars for bolls opened at 120 DAP (Fig. 3). It was observed that the cultivar IR-3701 opened the maximum bolls (32.95) at 120 DAP followed by Sadori (31.16) in prescribed DAP followed by CRIS-134 (30.70). However, other five cultivars opened least number of bolls at 120 DAP ranging from 22.12 to 26.39. It can be concluded that opening of maximum bolls at 120 DAP can positively affect the production of seed cotton yield and cultivars IR-3701 and Sadori may be successfully utilized in breeding programs for development of high yielding and early maturing cotton cultivars. The time of first square, open flower, or the nodal position of the first fruiting branch are important measures of earliness in cotton. Several other researchers also evaluated earliness through boll opening at various stages of crop development and concluded that the boll opening percentage at various stages play crucial role in exploring the earliness of cotton genotypes (Anjum *et al.*, 2002; Saira *et al.*, 2002; Soomro *et al.*, 2002; Soomro *et al.*, 2004). In previous studies, the cultivar NIAB-111 took minimum days for squaring, appearance of first flower, first boll formation and boll maturation and recorded the lowest node to the first fruiting branch (Saleem *et al.*, 2009).

Bolls per plant: The total number of bolls formed by the each plant determines the yield potential of a cultivar and is considered as major yield component and having strong relationship with seed cotton yield. It is generally believed that an increase in boll number would ultimately increase the seed cotton yield. The cultivar Sadori (40.92) and IR-3701 (40.34) produced the maximum number of bolls per plant followed by cv. CRIS-134 (39.28), while cultivar AA-802 formed minimum number of bolls (29.31) (Fig. 3). It may be suggested that cultivars Sadori, IR-3701 and CRIS-134 may be utilized in breeding programs for exploiting number of bolls per plant. The production of earlier cotton might result from increasing the number of early bloom or from broadening the peak flower for the number of boll set (Baloch and Baloch, 2004; Khan, 2013). In the past studies (Panhwar *et al.*, 2002), the cultivar DNH-49 significantly opened its first flower earlier than the other strains, hence, was observed

as early maturing cultivar. In previous studies (Jatoi *et al.*, 2012), the mean performance revealed that cultivar Sindh-1 took minimum days to set first square and also opened maximum bolls at 80 days after sowing while CRIS-134 produced fruiting branches at lower node number of 4.7 and formed 1st effective boll at 6.7 node number, and considered early maturing whereas cv. Sadori was though late maturing, yet recorded maximum seed cotton yield. In previous studies, the less days to flowering were observed in cultivar CIM-554, and its involvement in F₁ hybrids viz., CIM-506 × CIM-554, CIM-473 × CIM-554, CIM-554 × CIM-496, CIM-554 × CIM-707 and CIM-446 × CIM-554 showed early maturity with significant higher bolls per plant, boll weight and eventually seed cotton yield (Bibi *et al.*, 2011a, b; Khan *et al.*, 2011; Gul *et al.*, 2014).

Boll weight: Boll weight has direct influence on seed cotton yield because it is assumed that as the boll weight increases, the seed cotton yield would also increase. Medium bolls weighing 3.71 g were produced by cultivar Chandi (Fig. 4) followed by CRIS-134 (3.26 g) while the genotype AA-802 produced smaller bolls (2.82 g). Present results suggested that medium bolls are the characteristics of early maturing cotton cultivars. Our results suggested that cultivars Chandi and CRIS-134 could be used as potential parental material to evolve the early maturing cotton cultivars with desirable boll size. In past studies of 13 cotton genotypes, majority of the genotypes had boll weight of around 3.00 g and indicated potential for high yield (Ahmad *et al.*, 2008). Early maturing cottons although had comparatively smaller or moderate bolls but produced better yields, may be due to setting and picking more number of bolls at early stages of boll opening as compared to late maturing cotton cultivars (Tunis *et al.*, 2002; Baloch and Baloch, 2004). Singh (2004) also reported that moderate boll weight (3.5 to 4.0 g) is a reliable criterion for developing early maturing cotton cultivars with desirable seed cotton yield. Hence, cotton breeders had always made compromise to evolve cultivars with medium boll size, still having an acceptable level of crop maturity and yield (Ahmad *et al.*, 2008). The cultivar CIM-506 with medium boll weight and early maturity, revealed maximum seed cotton yield, sympodia plant¹ and short stature plants as compared to seven other upland cotton cultivars (Batool *et al.*, 2010). In a study of eight upland cotton genotypes and their 56 F₂ populations, the highest genetic variability was found for boll weight and bigger bolls were noticed in F₂ hybrid CIM-554 × CIM-499 (Panni *et al.*, 2012). The consistent performance in terms of boll opening and their effect on seed cotton yield per plant have been reported in upland cotton (Ahmad *et al.*, 2008; Khan *et al.*, 2009a, b)

Seed cotton yield per plant: Shorter season cottons are evolved without compromising on seed cotton yield. The cultivar IR-3701 produced the highest seed cotton yield

plant⁻¹ (129.09 g) followed by cultivars CRIS-134 (128.40 g) and Sadori (127.69 g) (Fig. 4). The two cultivars (CRIS-134 and Sadori) were also identified as early maturing cotton cultivars, bearing medium sized bolls, maximum and comparable bolls plant⁻¹ with IR-3701 and produced higher seed cotton yields. Present results are in consonance with those of Baloch and Veesar (2007), Panhwar *et al.* (2010), Jatoi *et al.* (2012) and Gul *et al.* (2014) who reported that early maturing cotton cultivars also produced better yields. The breeders succeeded in evolving world's earliest maturing and high yielding cotton cultivars with desirable fiber quality traits viz., C-6037, Termez-14, Terme-16, Termez-24 and Karshin-8 (Egamberdiev, 1996). The commonly used definition of earliness is the proportion of the total crop yield that is produced by the time of first picking. Indirect selection for early maturity could be possible by selecting the genotypes having lower node number of 1st sympodial branch, boll maturation period, height of 1st sympodial branch and significant negative correlation with earliness index (Rauf *et al.*, 2005). In another study, Ahmad *et al.* (2008) reported that the strains VH-156 and VH-144 have shown consistent performance in terms of days taken to set first flower, first sympodial branch node number, boll opening and seed cotton yield per plant, and these two strains were early maturing with good yield potential. Positive correlation and positive indirect effects of sympodia, boll number and plant height on seed cotton yield is an indicative that improvement in these traits will enhance the yield (Farooq *et al.*, 2013). Highest genetic variability was observed among parental cultivars and their F₁ hybrids for yield and its components, and yield was positively correlated with yield contributing traits (Khan *et al.*, 2009b; Ahmad *et al.*, 2011; Bibi *et al.*, 2011b; Khan and Hassan, 2011). Therefore, with optimum seed cotton yield, the earliness may be enhanced by decreasing the days to flowering and first boll opening and by lowering the node to the first fruiting branch.

Lint percentage: Lint percentage (ginning outturn) is a complex polygenic trait which is largely affected by the environmental factors. Primarily, it depends on lint weight, which has the direct effect on seed cotton yield. Selection for higher ginning outturn often results in an increase in the production per plant and per unit area. Results revealed significant differences among the cultivars and it was also observed that the cultivar IR-3701 ginned significantly highest lint percentage (44.31%) followed by FH-113 (42.49%) (Fig. 4), while cultivar NIAB-78 gave the lowest lint percentage (36.25%). The early maturing cotton cultivars viz., CRIS-134 and Sadori ginned almost comparable lint percentage. Present results indicated that IR-3701 and FH-113 could be utilized in breeding programme to improve the lint percentage. Earliness seemed to be the

function of genotypes differing with respect to their maturity period (Ali *et al.*, 2003; Shah *et al.*, 2005). In previous studies (Rauf *et al.*, 2005), the line SL7-9 proved to be an extremely indeterminate cultivar with late maturing growth habit, while lowest earliness index was obtained from cultivar CIM-448 with flowering three days later than parental mean and seven days later boll maturation period. However, Kohel and Benedict (1987) analyzed cotton cultivars with differing growth habits on the basis of yield and lint components and plant growth characters and found that earliest crop produced the lowest seed cotton and lint yields. In F₁ and F₂ populations of upland cotton, Khan *et al.* (2009a), Khan and Hassan (2011), Batool *et al.* (2013), Khan (2013) and Dhivya *et al.* (2014) also observed varying values for lint percentage in upland cotton genotypes, and least seed cotton yield was obtained in the early maturing parental cultivars and their progenies.

Seed index: Seed index is also an important yield component and plays imperative role in increasing the seed cotton yield. Seed index varied from 5.22 to 6.97 g and NIAB-78 (6.97 g) excelled all the genotypes due to having bolder seeds (Fig. 5), however, it was found comparable with two other cultivars IR-1524 (6.40 g) and Chandi (6.30 g). In previous studies (Suinaga *et al.*, 2006; Taohua and Haipeng, 2006; Meena *et al.*, 2007; Khan *et al.*, 2010; Dhivya *et al.*, 2014) the yielding capacity of *G. hirsutum* L. cultivars was studied and variable values were observed for seed index.

Staple length: Staple length is one of major fiber quality traits, which determines the market value of cotton both nationally and internationally. The maximum staple length was measured by CRIS-134 (27.83 mm) which was comparable with FH-113 and IR-1524 with staple length of 27.67 and 27.51 mm, respectively (Fig. 5). The Sadori being an early maturing cultivar, showed relatively medium staple length, however, it was found alike with cultivars IR-3701 and Chandi. The variation in cultivars for staple length might be due to genotypic differences. Significant differences were observed for staple length among different progenies of F₁ and F₂ alongwith their parental cultivars which might be due to varietal differences (Khan *et al.*, 2009c), and significant means squares revealed by various cotton genotypes for staple length (Farooq *et al.*, 2013). The eight genotypes and their fifteen F₁ hybrids through line x tester analysis, revealed that hybrid FH-1000 × LRA-5166 was promising for fiber length and seed cotton yield, while PB-899 × CP-15/2 for fiber fineness, horizontal flowering interval, days taken to first boll opening (Shakeel *et al.*, 2012b).

Micronaire: A micronaire reading is defined as a measurement of the degree of cotton fiber fineness by means of an airflow instrument commercially known as

the Micronaire. The micronaire reading, which indicates the resistance to the passage of air through a 50-gram specimen of fiber compressed to a given volume, made from one or more samples of each bale or test lot of cotton lint. Micronaire readings were divided into ranges, under 2.7 $\mu\text{g}/\text{inch}$ for cotton described as very low in micronaire or say very fine, to over 5.2 $\mu\text{g}/\text{inch}$ for cotton described as very high in micronaire or very coarse fiber. The higher micronaire readings (above 4.9 $\mu\text{g}/\text{inch}$) denote the coarser cottons, while lower readings (below 3.5 $\mu\text{g}/\text{inch}$) denote the finer cottons. The micronaire readings of 3.5 to 4.9 $\mu\text{g}/\text{inch}$ are generally considered as being "average or near average" in micronaire. Results presented in Fig. 5, showed that significant differences were existed among the cultivars for micronaire, yet the cultivar AA-802 recorded the lowest but finer micronaire value (3.92 $\mu\text{g}/\text{inch}$) followed by IR-3701 (4.03 $\mu\text{g}/\text{inch}$), while NIAB-78 measured the highest micronaire value (5.10 $\mu\text{g}/\text{inch}$) and coarser fibers. However, the early maturing cotton cultivars CRIS-134 and Sadori recorded desirable micronaire values. Significant means squares shown by various cotton genotypes for micronaire. Findings of Farooq *et al.*, (2013) and Khan *et al.* (2009c) also revealed significant differences in F_1 and F_2 populations and their parental lines for fiber fineness, however, the selections made in F_2 populations revealed desirable micronaire values in F_3 and F_4 populations. In 54 cotton genotypes, the analysis of variance showed highly significant differences among genotypes for fiber traits i.e. staple length and micronaire and inferred existence of considerable genetic diversity among the genotypes (Dhivya *et al.*, 2014).

Correlations: In earliness traits, significant ($p < 0.05$) positive correlation of days to first flower was observed with bolls formed after 90 DAP ($r = 0.42^*$), bolls opened after 90 DAP ($r = 0.45^*$) and bolls formed after 120 DAP ($r = 0.42^*$), while with staple length its association was significant and negative ($r = -0.55^{**}$) (Table 2). First sympodial branch node number revealed significant positive correlation with sympodial branch bearing 1st effective boll ($r = 0.74^{**}$), and non-significant positive with bolls formed at 90 DAP ($r = 0.27$). Significant positive relationship ($r = 0.55^{**}$) was observed between sympodial branch bearing first effective boll and bolls formed at 90 DAP. Rauf *et al.* (2005) observed significant positive genotypic correlation between boll maturation period and node number of 1st sympodial branch, and between node number of 1st sympodial branch and height of 1st sympodial branch; however, the correlations were negative between the earliness index and other earliness traits in upland cotton. Results further revealed that significant positive correlation of sympodial branch length was observed with bolls formed at 120 DAP ($r = 0.61^{**}$), bolls plant⁻¹ ($r = 0.44^*$), seed cotton yield plant⁻¹ ($r = 0.77^{**}$) while positive with bolls formed

at 90 DAP ($r = 0.37$) and significant negative with boll weight ($r = -0.49^{**}$). Significant correlations were observed between phenological aspects (first square, flower, and open boll) and yield, while most tactical method for measuring maturity was the ratio in early harvests to total seed cotton harvested in upland cotton (Richmond and Radwan, 1962). Significant correlation of days taken to 1st squaring was noted with 1st sympodial branch node number and node number to set 1st effective boll, whereas 1st sympodial branch node was significantly and positively associated with node number to set 1st boll and sympodial branch length, while bolls opened at 80 DAP were positively correlated with sympodial branch length and seed cotton yield (Jatoi *et al.*, 2012).

In case of yield and its contributing traits, significant ($p < 0.05$) negative correlation ($r = -0.44^*$) was recorded between bolls per plant and boll weight while significant ($p < 0.01$) positive relationship ($r = 0.90^{**}$) was expressed by bolls plant⁻¹ with seed cotton yield plant⁻¹ (Table 2). Positive association between bolls plant⁻¹ and seed cotton yield plant⁻¹ was also observed in upland cotton (Khan *et al.*, 2010; Makhdoom *et al.*, 2010; Ahmad *et al.*, 2011; Farooq *et al.*, 2013) while negative correlation of bolls plant⁻¹ with boll weight is quite common in cotton crop. However, the positive association of bolls plant⁻¹ with seed cotton yield plant⁻¹ suggested that seed cotton yield plant⁻¹ is dependent on bolls plant⁻¹. Association of bolls plant⁻¹ with seed index illustrated significant ($p < 0.01$) positive association ($r = 0.91^{**}$), while boll weight and seed cotton yield plant⁻¹ revealed significant ($p < 0.01$) negative ($r = -0.57^{**}$) relationship. These correlations suggested that increase in boll size reduces the number of bolls plant⁻¹, consequently the seed cotton yield decreases. Highly significant and positive correlation of boll weight with lint percentage ($r = 0.55^{**}$) and seed index ($r = 0.50^{**}$) was observed. Highly significant positive correlation ($r = 0.98^{**}$) was illustrated by seed cotton yield plant⁻¹ with seed index. Significantly negative associations of lint percentage with seed index ($r = -0.55^{**}$), staple length ($r = -0.44^*$) and micronaire ($r = -0.50^{**}$) were observed. Negative correlation between first fruiting node/first effective boll and days to first flower was reported by Gopang (2003). Significant correlations among earliness traits suggested that selection of one trait for earliness can indirectly and simultaneously improve other traits related to earliness and yield (Kerby *et al.*, 1990; Baloch and Baloch, 2004; Baloch and Veesar, 2007). Ahmad *et al.* (2008) reported highly significant positive correlation of days to first flower with sympodial branch, node number with first effective boll, days to first flower with boll opening at 120 DAP, sympodial branch node number with first effective boll and boll opening at 120 DAP, whereas negative correlation was observed between sympodial branch length and boll opening at 120 DAP, boll weight and seed cotton yield.

Table 1. Mean squares for earliness, yield and fiber quality traits in upland cotton.

Characters	Mean squares		
	Replications D.F. = 3	Cultivars D.F. = 7	Error D.F. = 21
Days to first flower	0.45	7.26**	0.45
First sympodial branch node number	1.97	7.53**	1.02
Sympodial branch bearing 1 st effective boll	0.55	2.53**	0.61
Sympodial branch length	41.56	105.32**	13.04
Bolls formed at 90 days after planting	58.33	51.07**	11.87
Bolls opened at 90 days after planting	14.31	17.99**	5.46
Bolls formed at 120 days after planting	111.90	82.44**	15.70
Bolls opened at 120 days after planting	53.59	55.03**	14.74
Bolls per plant	112.59	83.41**	16.01
Boll weight	0.02	0.33**	0.04
Seed cotton yield plant ⁻¹	1535.07	1530.23**	182.53
Lint percentage	17.88	22.94**	3.56
Seed index	0.89	0.85**	0.10
Fiber length	0.18	5.39**	0.74
Micronaire	0.25	0.59**	0.14

** = Significant at $p < 0.01$

Table 2. Correlation coefficients (r) among earliness, yield and fiber quality traits of upland cotton.

Character associations	r value
Days to first flower vs. bolls formed at 90 DAP	0.42*
Days to first flower vs. bolls opened at 90 DAP	0.45*
Days to first flower vs. bolls formed at 120 DAP	0.42*
Days to first flower vs. staple length	-0.55**
First sympodial branch node number vs. symp. branch bearing 1 st effective boll	0.74**
First sympodial branch node number vs. bolls formed at 90 DAP	0.27 ^{NS}
Sympodial branch bearing effective bolls vs. bolls formed at 90 DAP	0.55**
Sympodial branch length vs. bolls formed at 90 DAP	0.37 ^{NS}
Sympodial branch length vs. bolls formed at 120 DAP	0.61**
Sympodial branch length vs. bolls plant ⁻¹	0.44*
Sympodial branch length vs. boll weight	-0.49**
Sympodial branch length vs. seed cotton yield plant ⁻¹	0.77**
Bolls formed after 90 days vs. bolls opened at 90 DAP	0.40*
Bolls formed after 120 days vs. bolls opened at 120 DAP	0.89**
Bolls formed after 120 days vs. seed cotton yield plant ⁻¹	0.90**
Boll plant ⁻¹ vs. boll weight	-0.44*
Boll plant ⁻¹ vs. seed cotton yield plant ⁻¹	0.90**
Boll plant ⁻¹ vs. seed index	0.91**
Boll weight vs. seed cotton yield	-0.57**
Boll weight vs. lint percentage	0.55**
Boll weight vs. seed index	0.50**
Boll weight vs. staple length	-0.31 ^{NS}
Seed cotton yield plant ⁻¹ vs. seed index	0.98**
Seed cotton yield plant ⁻¹ vs. staple length	-0.31 ^{NS}
Lint percentage vs. seed index	-0.55**
Lint percentage vs. staple length	-0.44*
Lint percentage vs. micronaire	-0.50**
Staple length vs. micronaire	-0.02 ^{NS}

** , * = Significant at $p < 0.01$ and $p < 0.05$, respectively; N.S = Non-significant.

It is very common in cotton crop that most of the yield traits like lint percentage were negatively associated

with fiber quality traits i.e. staple length and micronaire value. Staple length with micronaire demonstrated non-significant positive correlation ($r = 0.02^{NS}$) (Table 2). Summing-up the correlation results, it was seen that most of the positive correlations may be used to determine the early maturing cotton cultivars like days to 1st flowering, lower sympodial branch node number, boll setting at lower sympodial branches, bolls formed and opened at earlier days of planting and producing more seed cotton

yield. The days to first flower, sympodial branch number with first effective boll, bolls formation and opening at 90 and 120 DAP have been found the main traits linked with earliness in cotton, and these traits can play imperative role in evolving early maturing genotypes in cotton. The positive correlation of earliness variables with yield related traits revealed that selection of one trait can indirectly improve the seed cotton yield.

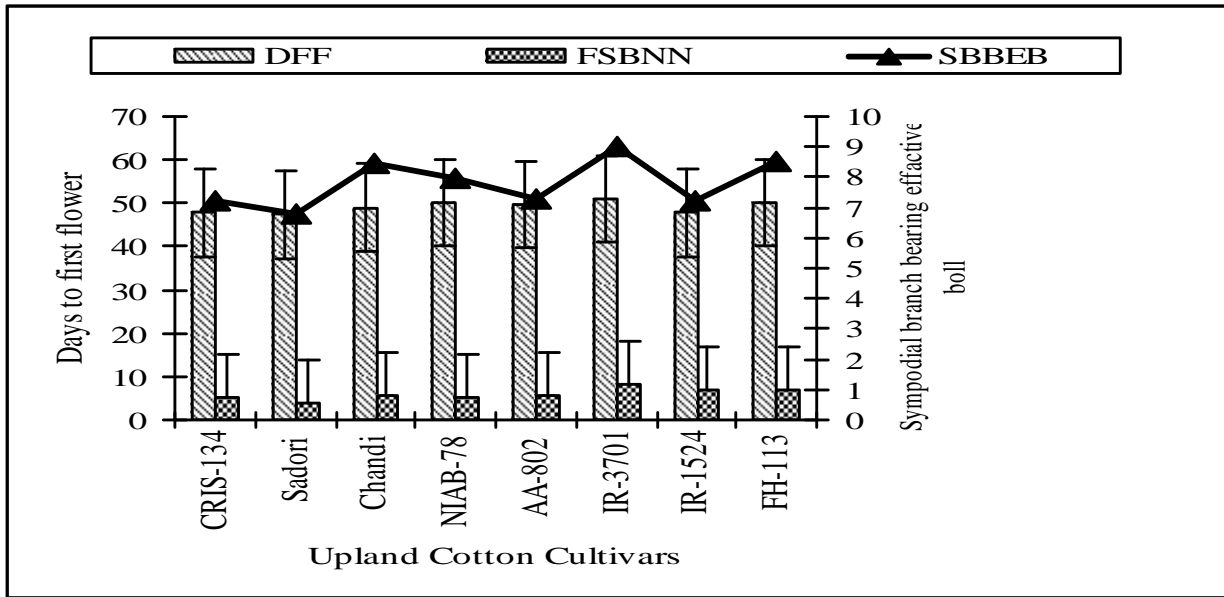


Fig 1. Mean values of the cotton genotypes for days to first flower (DFF), first sympodial branch node number (FSBNN), sympodial branch bearing effective boll (SBBEB)

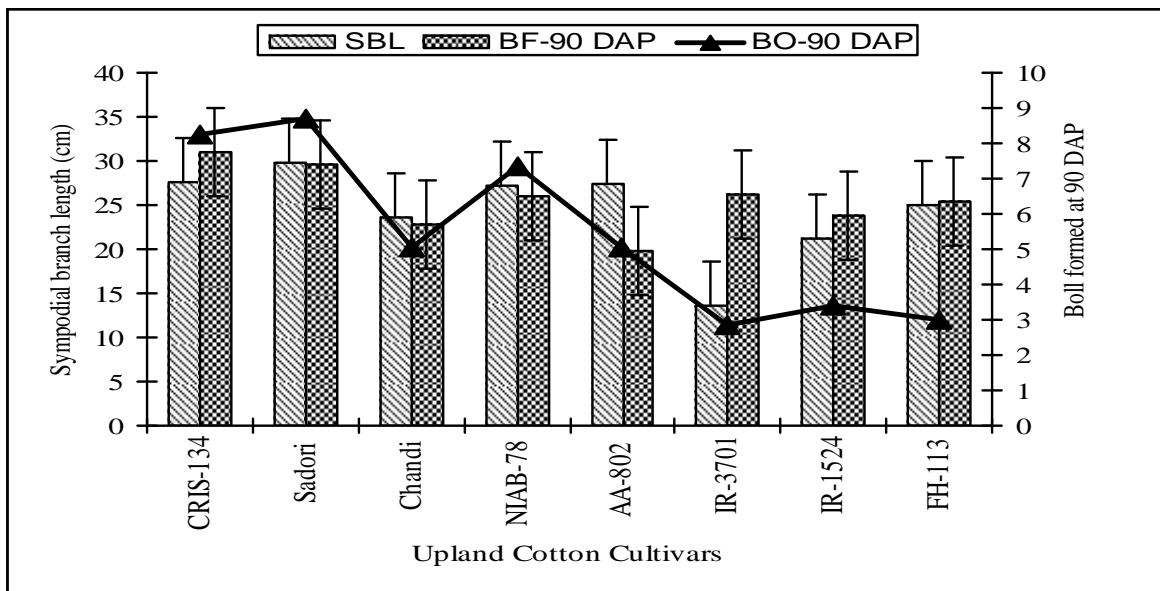


Fig 2. Mean values of the cotton genotypes for sympodia branch length (SBL), bolls formed at 90 days after planting (90 DAP) and bolls opened at 90 days after planting (BO-90 DAP)

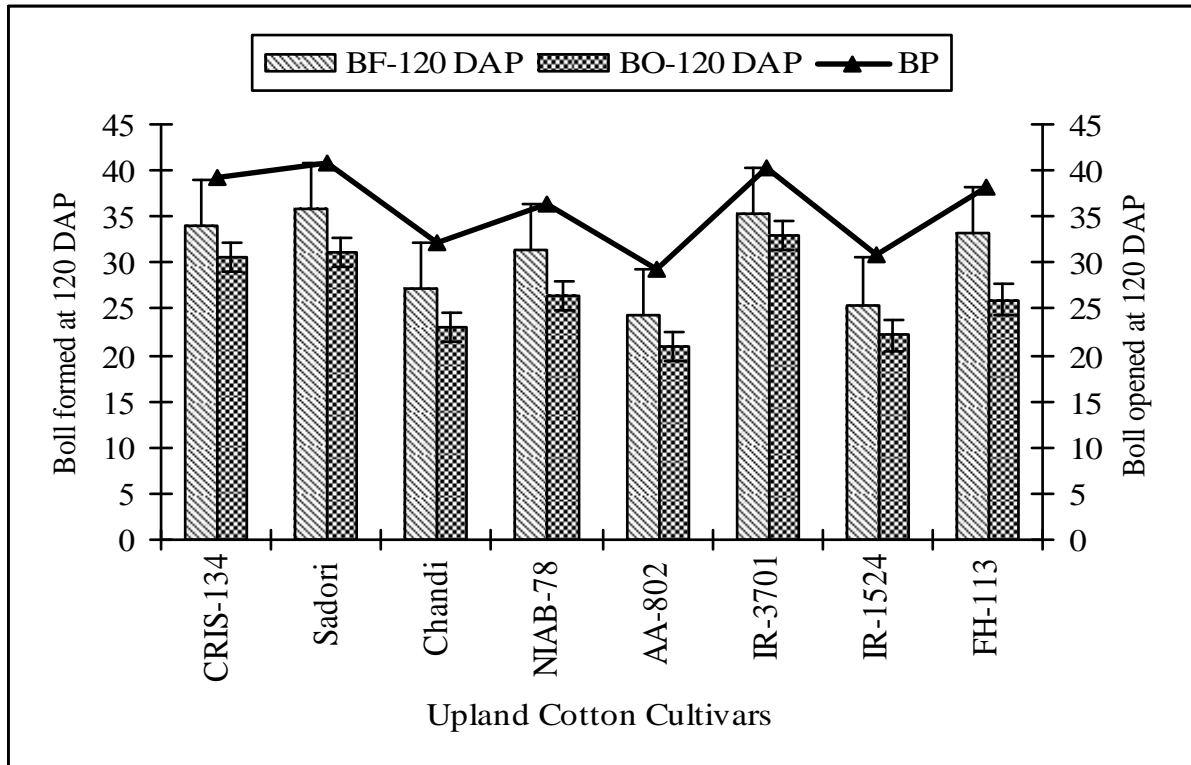


Fig 3. Mean values of the cotton genotypes for bolls formed at 120 days after (BF-120 DAP), bolls opened at 120 days after planting (BO-120 DAP) and bolls plant⁻¹ (BP)

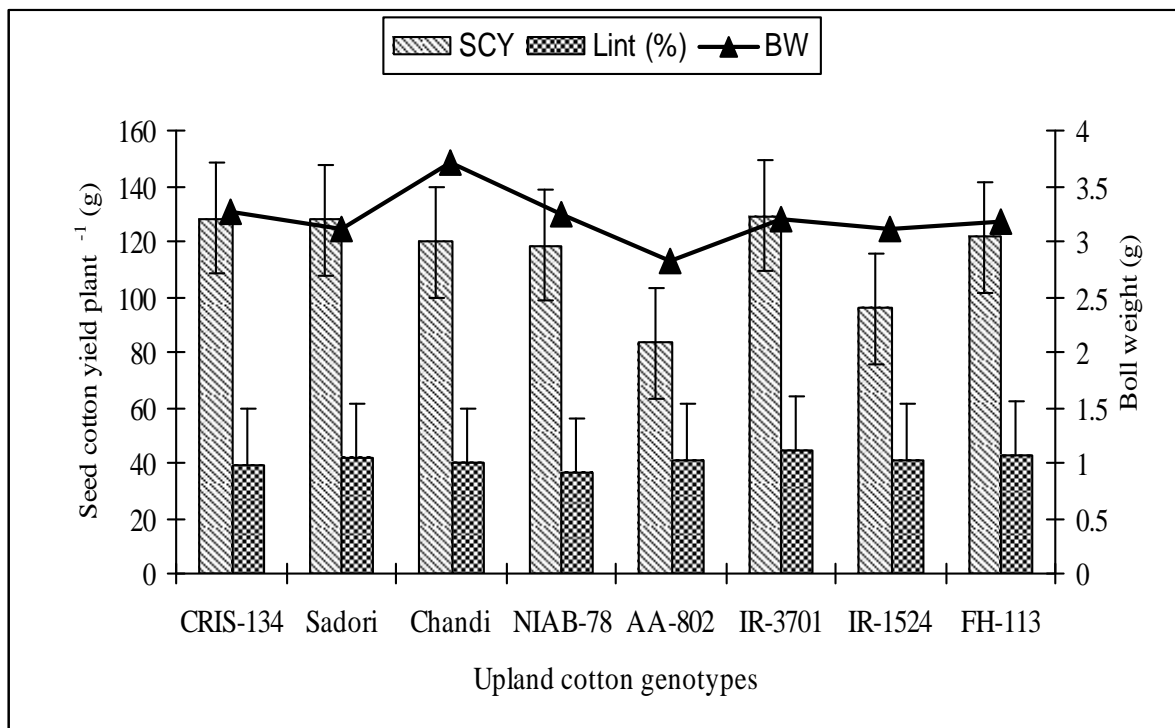


Fig 4. Mean values of the cotton genotypes for boll weight (g) seed cotton yield plant⁻¹ (g) and lint percentage

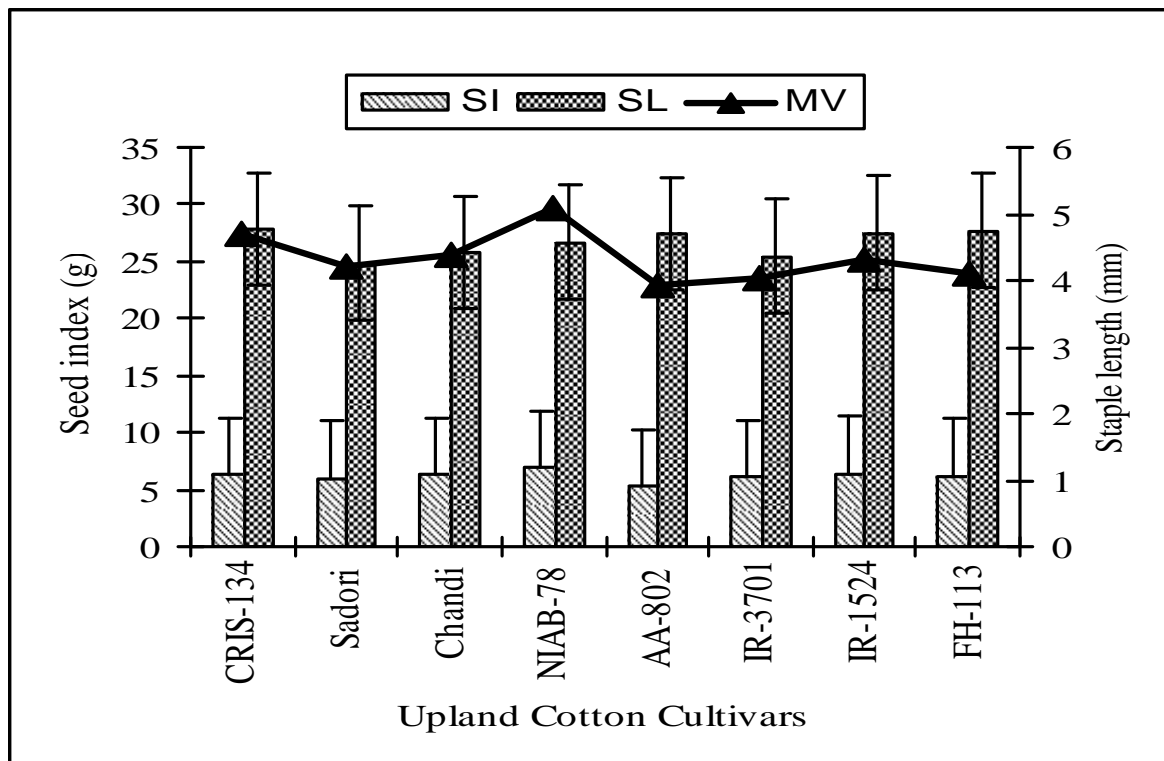


Fig 5. Mean values of the cotton genotypes for seed index (g), staple length (mm) and micronaire value ($\mu\text{g}/\text{inch}$)

Conclusions: While characterizing the cotton cultivars for earliness, the CRIS-134 and Sadori were identified as early maturing with desirable yield and fiber quality traits, and could be utilized in future breeding program. Positive correlation between bolls formed and opened at 90 and 120 DAP and with yield are very encouraging, and early maturity could be achieved without scarifying the yield.

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