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EFFECT OF ROW SPACING ON EARLINESS AND YIELD IN COTTON

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Abstract

To determine the effect of row spacing on earliness in cotton, 3 cultivars viz., NIAB-111, CIM-496 and FH-901 were grown with three row spacings of 60, 75 and 90 cm following a 3 x 3 factorial arrangement. Cultivars as well as row spacing significantly affected almost all the characters related to earliness. Among the cultivars, NIAB-111 took minimum days for squaring, appearance of first flower, first boll splition and for boll maturation and recorded the lowest node to the first fruiting branch. Among row spacings, 60 cm apart rows took minimum days for the characters related to earliness. Earliness index was highest (50.9 %) with 60 cm row spacing, production rate index was highest (55.9 g/day) with 90 cm row spacing and seed cotton yield was highest (2603 kg ha^{-1}) with 75 cm row spacing. So, earliness in cotton can be achieved by growing a short duration cultivar and by decreasing the row spacing to a certain limit.

Introduction

Cotton (*Gossypium hirsutum* L.) is the king of natural fibre. Fibre producing plants had played a significant role in the development of modern civilization. Its great value and need for cotton products have made it as one of the world's most widely cultivated and major cash crops. In Pakistan, the area of cotton during 2006-07 was 3.1 million hectares with production of 13 million bales and average yield of 712 kg ha^{-1}. Cotton cultivation engages 1.5 million farming families. It brings annually about 65 % of the foreign exchange for the country by exporting raw material as well as its finished products (Anon., 2007).

Cotton-wheat cropping system is being practiced in cotton belt of Pakistan. The planting of wheat is delayed due to non-availability of land under cotton crop i.e., delayed cotton maturity and according to an estimate, sowing of wheat after November 15, may cause 42 kg ha^{-1} day^{-1} loss in yield (Khan, 2003). Enhancing earliness without sacrificing yield has been the goal in most of the cotton breeding programmes, however it is now clear that several growth and fruiting processes, that can be altered through management practices, determine the earliness of crop maturity. Many morphological characteristics such as days taken to first flower, sympodial branch number with first effective boll and boll opening percentage at 120 days after planting have been found the main traits associated with earliness in cotton and could be helpful in evolving early maturing varieties in cotton (Ahmad *et al*., 2008).

Early maturity helps to fit the crop into double cropping pattern as in cotton growing areas of Pakistan, enables cotton crop to develop during the periods of more favourable moisture, escape losses from late season insect injuries; minimize use of chemical pesticides along with other inputs like irrigation water and fertilizer. As water shortage is a main problem now a days, by reducing the maturity period we can save the quantum of irrigation water required for cotton (Neil, 1991). There are many individual components (nitrogen, row spacing, irrigation management, insect control, growth regulators) that can be managed to contribute earliness (Constable, 1994). Planting before the optimum planting window, does not contribute greatly to earliness and is associated with higher levels of climatic risk (Constable & Shaw, 1988; Hearn, 1995). An early crop can be produced by selecting early maturing cotton cultivars, narrow row spacing or a combination of both (Neil, 1991).

The effect of plant density on earliness may be greater and of more economic importance than yield. Earliness seemed to be function of genotypes (Shah *et al.,* 2005); varieties differ with respect to their maturity period (Ali *et al.*, 2003), DNH-49 significantly opened its first flower earlier than other strains hence was observed as early maturing variety (Panhwar *et al*., 2002). The use of narrow-row, high plant-density systems for cotton production was originally conceived as a means to enhance earliness and to decrease production costs (Buxton *et al*., 1979). Mohammad *et al*., (1982) found that increasing density delayed maturiy, while Smith *et al*., (1979) reported that low plant density delayed maturity. The number of fruiting forms (blooms, squares and bolls) and their location on the plant can change with plant density (Kerby *et al*., 1990) while row width may have positive (Buxton *et al.*, 1979) or no effect (Heitholt, 1994). Mainstem nodes may also decrease as population increases (Kerby *et al*., 1990).

Although previous studies have been conducted to investigate cotton growth and yield response to row spacing, results are often conflicting (Smith *et al*., 1979; Kerby *et al*., 1990; Mohammad *et al.*, 1982). Kasap & Killi (2004) studied the effect of three row spacings (60, 70 and 80cm) and gained highest seed cotton yield with 60 cm row spacing.

The present study was conducted, with the hypothesis that cotton cultivars differ in their earliness and row spacing will significantly influence earliness related characters. The objective of the study was to identify the best cultivar x spacing combination that would lead to early maturity without affecting the economic yield significantly.

Materials and Methods

A field experiment was conducted to determine the effect of row spacing on earliness of cotton cultivars at the Agronomic Research Area, University of Agriculture, Faisalabad during kharif 2006. Experimental treatments comprised of three cotton cultivars viz. NIAB-111 (V_1), CIM-496 (V_2) and FH-901 (V_3) and three row spacings viz., 60 cm (5.55 plants/m^2) (R_1), 75 cm (4.44 plants/m^2) (R_2) and 90 cm (3.70 plants/m^2) (R_3). The experiment was laid out in randomized complete block design (RCBD) with factorial arrangement and replicated thrice. The length of each plot was 7 m and width was variable depending upon row spacing treatments. However, 6 rows of cotton crop were maintained in each plot. Seedbed was prepared by cultivating the field for 2 times with tractor-mounted cultivator each followed by planking. The crop was sown on sandy clay loam soil. Sowing was done on well prepared seed beds on May 24, 2006, with the help of single row hand drill by maintaining variable row spacing. Thinning was done to maintain the proper plant-to-plant distance of 30 cm when the height of plants was 15 cm (20 days after sowing). Nitrogen and phosphorus were applied @ 120 kg and 60 kg ha^{-1}, respectively. Whole of phosphorus and 1/3rd nitrogen was applied at sowing, 1/3rd nitrogen was applied after 35 days of sowing and remaining 1/3rd was applied after 65 days of sowing. Overall 9 irrigations were applied and weeds were controlled by hoeing. Insecticides were applied to control the sucking insects and bollworms. All other agronomic practices were kept normal and uniform for all the treatments. Standard procedures were followed to collect data at various growth stages of the crop. Five plants were selected at random from each plot to record the number of days taken from planting to squaring, appearance of first flower, first boll splition and node number for the first fruiting branch. Number of the main stem node at which first fruiting branch arose was determined by counting the cotyledonary node as 1. Boll maturation period was calculated by deducting number of days taken to flowering from number of days taken to boll splition. Mean maturity days (MMD) were determined using the procedure given by Christidis & Harrison (1955), which is generalized as follows.

$$MMD = \frac{(W1 \times H1) + (W2 \times H2) + \ldots\ldots\ldots + (Wn \times Hn)}{W1 + W2 + \ldots\ldots + Wn}$$

where W = Weight of seed cotton.
H = Number of days from planting to harvest
1, 2,..n = Consecutive periodic harvest number

Production rate index was calculated from total seed cotton weight plot^{-1} divided by the mean maturity date. Earliness index was measured with the help of following formula. This index is referred as maturity coefficient.

$$\text{Earliness index (\%)} = \frac{\text{Weight of seed cotton from first pick}}{\text{Total seed cotton weight from all picks}}$$

Data collected on all parameters were analyzed statistically by using M-stat programme and differences among treatments' means were compared by using the least significant difference (LSD) test at 5 % probability level (Steel *et al*., 1997).

Results

Number of days from planting to first floral bud initiation (squaring) were significantly affected by row spacing while varieties have no significant effect on this character (Table 1). Broader rows (90 cm) took 35.3 days as against minimum of 34.4 days with narrow rows (60 cm). Both 60 & 90 cm row spacing were at par with medium row spacing (75 cm) with respect to parameter under discussion (Table 2). Linear regression coefficient (R^2), for mean maturity days (MMD) vs. days to squaring was -0.053 (Table 4).

Both varieties and row spacing significantly affected the number of days taken for appearance of first flower and taken to first boll splition (Table 1). Both parameters showed increasing trend with increase in row spacing. Significantly highest days (46.1 for appearance of first flower & 89.9 for first boll splition) were recorded with 90 cm row spacing and lowest with 60 cm spacing. NIAB-III took significantly less days for the appearance of first flower or for first boll splition than CIM-496 and FH-901 which were at par with respect to parameters under discussion (Table 2). Values of R^2 for MMD vs. days to first flower and first boll splition were 0.781 and 0.701, respectively (Table 4). Varieties differed with respect to boll maturation period, NIAB-III took minimum days (42.4) but was at par with CIM-496, FH-901 took maximum days (44.6) but was also at par with CIM-496. Row spacing showed no significant effect on boll maturation period (Table 1), however it varied between 42.9 to 43.9. R^2 for MMD vs. boll maturation period was 0.423 (Table 4). Node number for first fruiting branch differed significantly among different varieties and row spacings (Table 1), the highest value (7.1) was noted with 90 cm row spacing followed by 75 cm and minimum (6.5) was recorded with 60 cm row width. First fruiting branch appeared on 6.5th node in NIAB-111, 6.8th node on CIM-496 and 7.1st node in FH-901 (Table 2). R^2 for MMD vs. node number for first fruiting branch was 0.732 (Table 4).

Table 1. Mean square values from analysis of variance of earliness related growth parameters of cotton cultivars grown with different row spacing.

S.O.V	d.f.	Days to squaring	Days to 1st flower	Days to 1st boll splition	Boll maturation period	Node no. for 1st fruiting branch	1st fruiting branch height	Mean maturity days
Varieties (V)	2	0.65^{ns}	3.15*	24.97*	11.37*	0.88*	2.92*	51.43*
Row spacing (S)	2	1.69*	12.51*	24.01*	1.88^{ns}	0.75*	3.61*	6.73*
V x S	4	0.09^{ns}	0.44^{ns}	0.71^{ns}	0.30^{ns}	0.03^{ns}	1.16^{ns}	0.23^{ns}
Error	16	0.33	0.32	2.64	2.51	0.03	0.87	0.65

* = Significant at 0.05 probability
ns = Non-significant

Table 2. Effect of row spacing on earliness related parameters of cotton cultivars.

Treatments	Days to squaring	Days to appearance of 1st flower	First boll splition (days)	Boll maturation period (days)	Node no. for 1st fruiting branch	First fruiting branch height (cm)
Varieties (V)						
NIAB-111 (V_1)	34.9	44.2 b	86.5 b	42.4 b	6.5 c	24.2 b
CIM-496 (V_2)	35.1	45.2 a	88.5 a	43.4 ab	6.8 b	25.2 a
FH-901 (V_3)	34.6	45.2 a	89.8 a	44.6 a	7.1 a	25.2 a
LSD (5 %)	NS	0.56	1.62	1.58	0.18	0.93
Row spacing (R)						
60 cm (R_1)	34.4 b	43.7 c	86.7 b	42.9	6.5 c	24.3 b
75 cm (R_2)	34.9 ab	44.8 b	88.3 b	43.5	6.8 b	24.7 ab
90 cm (R_3)	35.3 a	46.1 a	89.9 a	43.9	7.1 a	25.6 a
LSD (5%)	0.58	0.56	1.62	NS	0.18	0.93

Means not sharing the same letters differ significantly from each other at 5 % probability.

Table 3. Mean square values from analysis of variance of production rate index, earliness index, and seed cotton yield of cotton cultivars grown with different row spacings

S.O.V	d.f.	Production rate index	Earliness index	Seed cotton yield
Varieties (V)	2	4.57^{ns}	177.8*	11093.6*
Row spacing (S)	2	83.89*	17.4*	147591.8*
V x S	4	1.08^{ns}	0.27^{ns}	6341.3^{ns}
Error	16	3.02	1.16	2652.6

* = Significant at 0.05 probability
ns = Non-significant

Table 4. Linear regression coefficient (r^2) between mean maturity days (MMD) vs. selected earliness components and seed cotton yield of cotton.

Characters	Linear regression coefficient (r^2)
MMD vs. days to squaring	-0.053
MMD vs. days to 1st flower	0.781
MMD vs. days to 1st boll splition	0.701
MMD vs. boll maturation period	0.423
MMD vs. node no. for 1st fruiting branch	0.732
MMD vs. 1st fruiting branch height	0.429
MMD vs. production rate index	0.592
MMD vs. earliness index	-0.343
MMD vs. seed cotton yield	-0.096

Both varieties and row spacing affected the height of first fruiting branch significantly (Table 1). Broader rows (90 cm) produced maximum height of first fruiting branch (25.6 cm) and narrow rows (60 cm) resulted in minimum height (24.3 cm), while intermediary spaced rows (75 cm) produced intermediate height of first fruiting branch and it was also at par with those obtained with broader and narrower row spacing (Table 2). R^2 for MMD vs. first fruiting branch height came out to be 0.429 (Table 4). Significance of earliness under mean maturity days, production rate index and seed cotton yield with respect to varieties and row spacing is presented in Table 3.

All the varieties showed similar decreasing trend in earliness index with increasing row spacing (Fig. 1). Statistically highest earliness index (50.9%) was recorded in R_1 (60cm) row spacing, followed by R_2 (75cm) row spacing treatment. Whereas, statistically minimum earliness index (48.1%) was recorded in R_3 (90cm) row spacing. Statistically maximum earliness index (54.3%) was noted in V_1 (NIAB-111), followed by V_2 (CIM-496). Whereas, statistically minimum earliness index (45.6 %) was recorded in V_3 (FH-901). R^2 for MMD vs. earliness index was -0.343 (Table 4).

Mean maturity days and production rate index increased with increasing row spacing in all the cultivars under study (Figs. 2 & 3). Statistically maximum mean maturity days (155) and production rate index (55.9 g/day) were recorded in R_3 (90cm) row spacing, followed by R_2 (75cm) and then R_1 (60 cm) row spacing. The varieties also differed significantly in mean maturity date with maximum mean maturity days (156.1) in V_3 (FH-901) and minimum mean maturity days (151.5) in V_1 (NIAB-111). Non significant differences were recorded among varieties with respect to production rate index. R^2 for MMD vs. production rate index was 0.592 (Table 4).

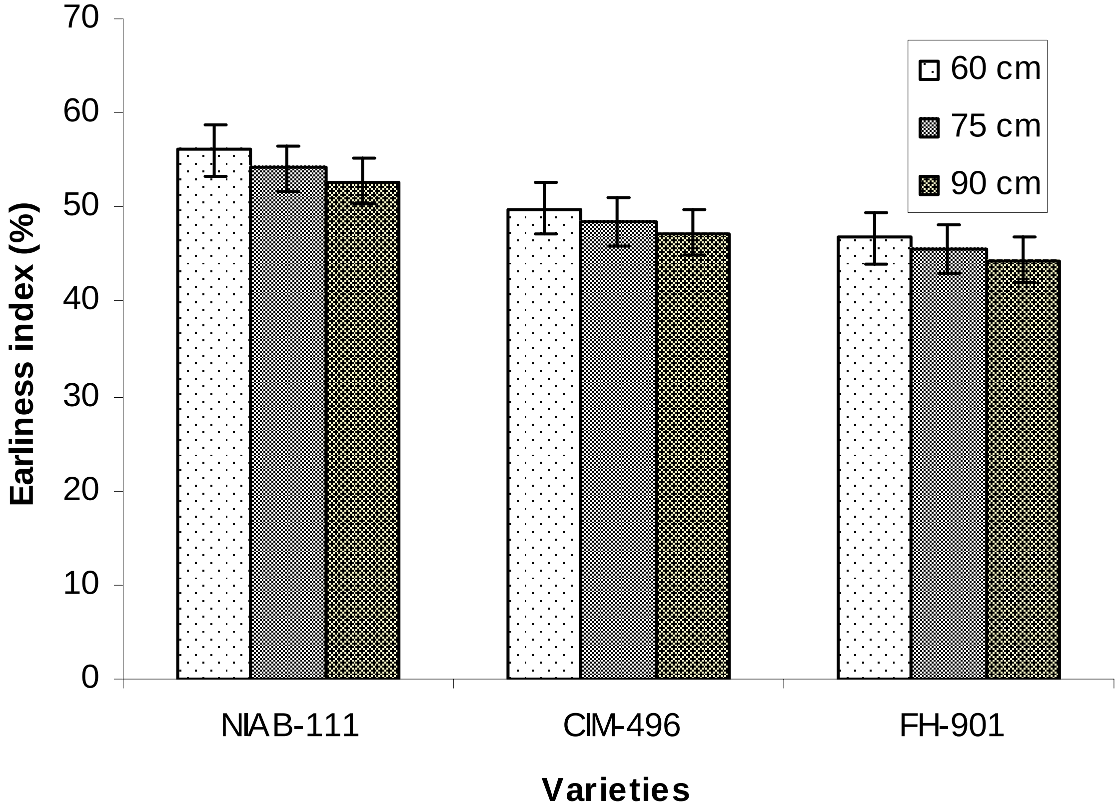

Fig. 1. Effect of row spacing on earliness index of cotton cultivars.

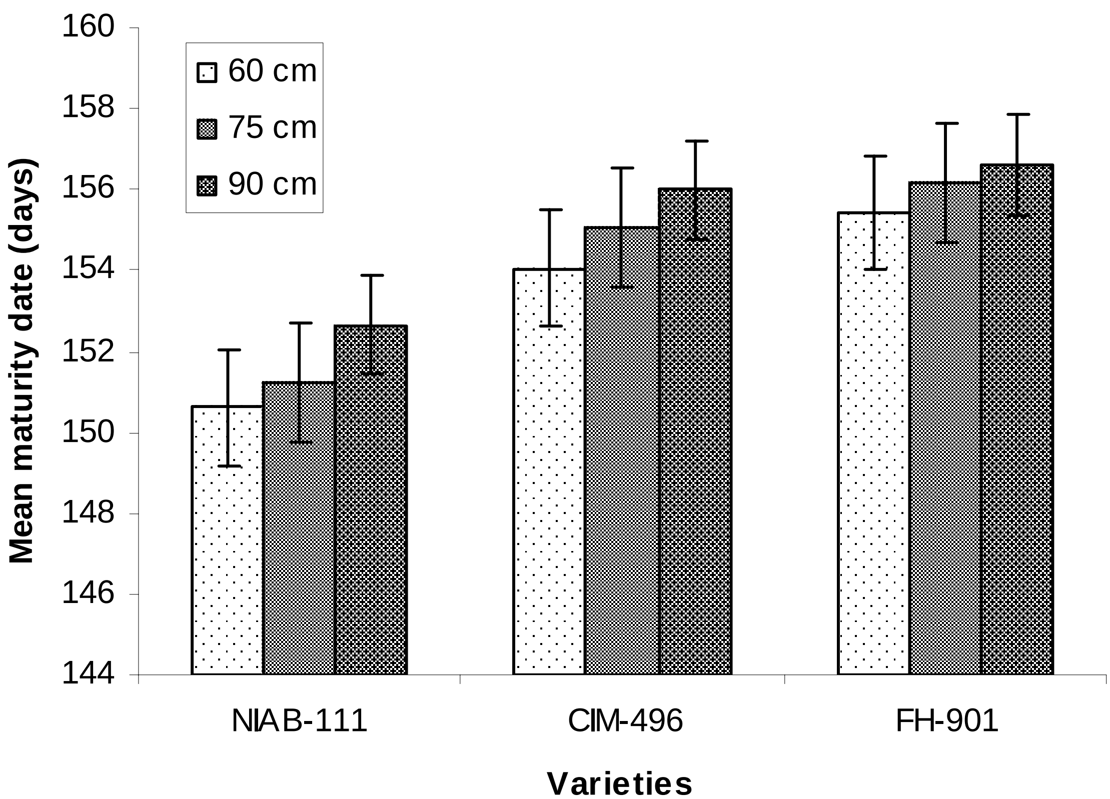

Fig. 2. Effect of row spacing on mean maturity days of cotton cultivars.

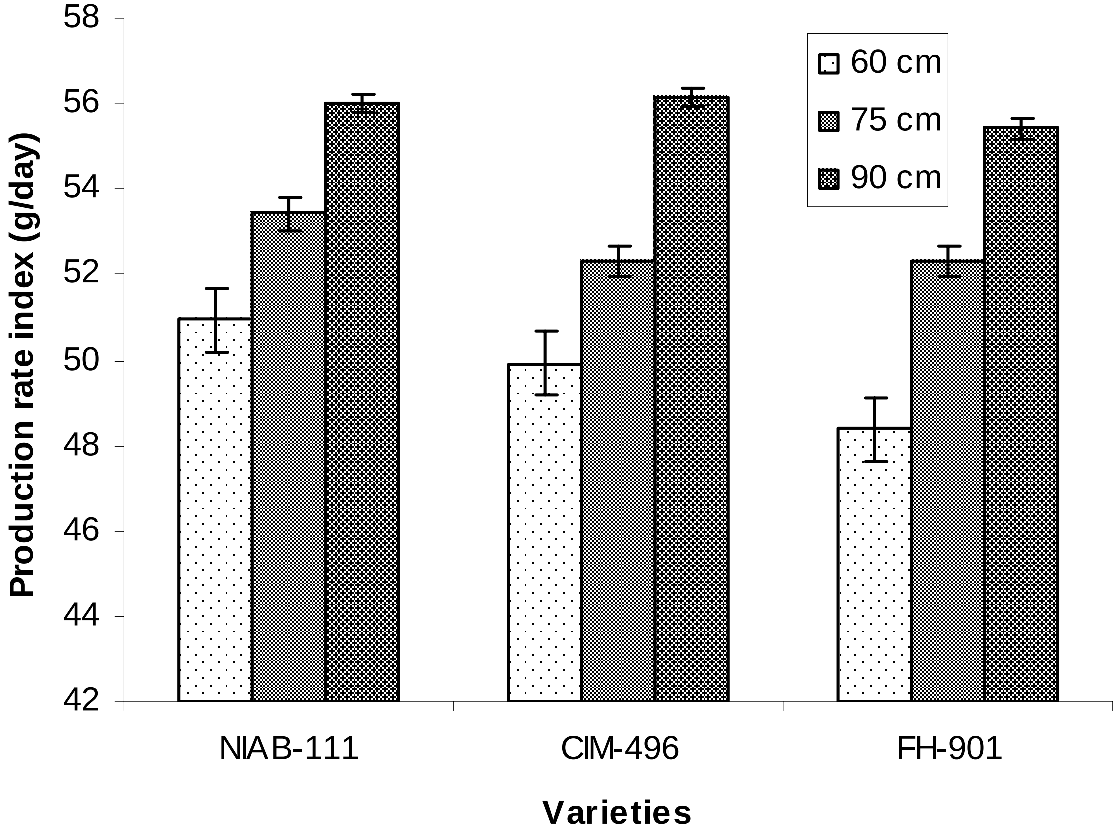

Fig. 3. Effect of row spacing on production rate index of cotton cultivars.

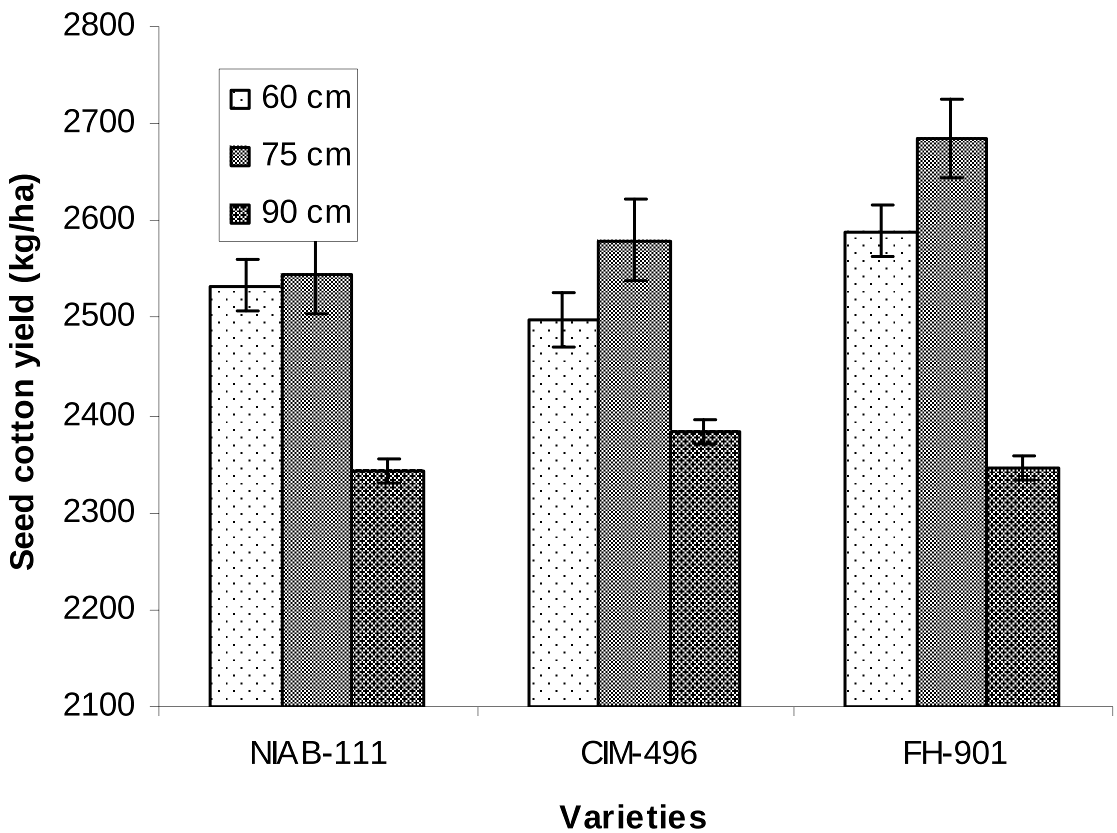

Fig. 4. Effect of row spacing on seed cotton yield of cotton cultivars.

Seed cotton yield as influenced by row spacing and varieties is shown in Fig. 4, which reveals that row spacing significantly influenced the seed cotton yield/ha. Statistically maximum seed cotton yield/ha (2603 kg) was recorded in R_2 (75 cm) row spacing treatment, followed by R_1 (60cm) row spacing treatment. Whereas, statistically minimum seed cotton yield/ha (2357 kg) was observed in R_3 (90 cm) row spacing treatment. The varieties also differed significantly from each other in seed cotton yield/ha. Statistically maximum seed cotton yield/ha (2541 kg) was recorded in V_3 (Fh-901). Whereas, minimum seed cotton yield/ha (2474 kg) was obtained in V_1 (NIAB-111), followed by V_2 (CIM-496). R^2 for MMD vs. seed cotton yield was -0.096 (Table 4).

Discussion

Days to first square can be used as an estimator of earliness (Richmond & Radwan, 1962), however use of this parameter has some disadvantages. Early recognition of first square is difficult and requires to establish a measurement standard when a square can be considered to be recognizable. Moreover young squares abscise in response to environmental stress. In this study, cultivars could not be recognized (early vs late) on the basis of days to squaring. This is against the idea given by Poehlman (1987) that earliness in cotton is greatly influenced by the expression as to how early the cotton plant begins to square. Regression line drawn to see the dependence of this parameter on mean maturity days indicated negative and very weak relationship between the two parameters (regression coefficient value presented in Table 4). Appearance of first flower is easily recognizable and can be used with more success. Lesser the days to flower from sowing date, the earlier would be the variety (Khan *et al*., 2002). Utility of another phenological event, first boll splition, is limited by considerable time needed for scoring plants, by shedding of squares and immature bolls (Richmond & Radwan, 1962). However, regression coefficient values in this study indicate significant dependence of these two parameters on mean maturity days. Varieties taking less number of days to first flower and to open first boll, will be earlier in maturity (Godoy & Palomo, 1999).

Present data indicated delay in appearance of first flower and first boll splition and increase in height of first fruiting branch with increase in space between rows. Wider rows would have decreased the competition and facilitated the cotton plants to utilize light, nutrients etc., more efficiently which led to more vegetative growth and delayed flower and boll opening. Regression models indicated much lower dependence of mean maturity days on first fruiting branch height than on days to first flower or on first boll splition.

Use of boll maturation period as an indicator of maturity is questionable. Morris (1964) suggested that evaluation of boll maturation period may be confounded by the effects of temperature that may tend to negate genotype differences in boll maturation period. Linear regression coefficient for mean maturity days vs boll maturation period indicated that boll maturation period would be less effective than days to first flower or days to first boll splition in determining mean maturity days of a variety.

Utility of production rate index is also limited due to the need to make several periodic harvests. Coefficient of determination (R^2) (for mean maturity days vs production rate index) came out to be 0.592. Relationship between mean maturity days vs earliness index was negative indicating that higher the values of earliness index earlier would be the variety but this relationship was also weak. Our data indicated decrease in earliness index with increase in row spacing.

Node number for the first fruiting branch is one of the most reliable and practical morphological measures of earliness in cotton varieties. The earliness of crop maturation is affected more by the position of first branch than by other morphological characters (Iqbal *et al*., 2003). Genotypes, when entered earlier in reproductive phase, the first fruiting branch was developed at a node on the main stem which caused the development of its fruiting parts relatively earlier (Babar *et al*., 2002; Rehana *et al*., 2001; Aden, 1997; Leghar, 1997; Godoy, 1994).

As population density increase so does the node number of first sympodial branch (Buxton *et al*., 1977; Kerby *et al*., 1990). Our study is in agreement (Table2). R^2 value also indicates a fairly good dependence (73.2%) of this parameter on mean maturity days of crop.

Highest seed cotton yield was achieved with intermediate row spacing (75 cm). Narrow row spacing (60 cm) might have created an environment of competition among plants for nutrients, light, water etc. and with 90 cm row spacing these inputs might not be utilized efficiently. However, this spacing cannot be generalized for all the varieties and for all environments as Oad & Agha (2005) achieved highest seed cotton yield of NIAB-78 with 90 cm row spacing in irrigated plains while Sarkar & Malik (2004) observed that inter-row spacing of 60 cm recorded 7.9 and 11.1 % higher seed cotton yield over both the narrower and wider inter row spacing of 45 and 75 cm, respectively with rainfed upland cotton.

Our study led to the conclusion that earliness in cotton may be enhanced by decreasing the number of days taken for appearance of first flower or first boll splition or by lowering the node to the first fruiting branch. This can be achieved by decreasing the row spacing and/or by growing a short duration cultivar. However, the ultra-narrow row spacing (60 cm) decreased the seed cotton yield significantly over intermediate row spacing (75 cm). While wider row spacing (90 cm) not only delayed maturity but also caused reduction in seed cotton yield.

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