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Effect of different phosphorus levels on earliness and yield of cotton cultivars

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Abstract

To determine the effect of phosphorus levels on earliness and yield of cotton, three cultivars viz., CIM-496, MNH-786 and FH-901 were grown in field with four phosphorus levels (0, 30, 60 and 90 kg ha^{-1}) following a 3 x 4 factorial arrangement during the year 2008. Cultivars as well as phosphorus levels significantly affected almost all the characters related to earliness and yield. Among the cultivars, FH-901 took minimum days for squaring, appearance of first flower, first boll splition and for boll maturation period. The same variety recorded the lowest node number for first fruiting branch, lowest fruiting branch height and maximum earliness index. Among the phosphorus levels, control took the maximum while 90 kg ha^{-1} took minimum days for all earliness related characters. Earliness index (53.5 %) and seed cotton yield (1879.5 kg ha^{-1}) were highest with 90 kg P ha^{-1}. Production rate index remained unaffected by variety; however it was highest where no phosphorus was added. So, maximum seed cotton yield and earliness in cotton can be achieved by growing a short duration cultivar with higher dose of phosphorus.

Key words: Cotton, cultivars, phosphorus, earliness, yield

Introduction

Cotton (*Gossypium* spp.) is grown in about 76 countries, covering more than 32 million ha, under different environmental conditions world wide and world cotton commerce is about US$20 billion annually (Saranga *et al*., 2001). Cotton growth and maturity are altered by cultivars, seasonal management and environmental conditions (Gwathmey and Craig, 2003). Early maturing cotton cultivars allow timely removal from the field (Faircloth, 2007). Phosphorus is an integral component of several important compounds in the plant cells, including the sugar-phosphate intermediates of respiration and photosynthesis, and the phospholipids that make up plant membranes (Taiz and Zeiger, 2003). Rate of leaf expansion and photosynthesis per unit leaf area reduced due to phosphorus deficiency (Rodriguez *et al*., 1998). Phosphorus is mobile in the plant. Young leaves and developing bolls can be nourished from the P which is available in older tissues of the plant. In cotton crop the critical-P concentration ranges from 0.20 to 0.31% (Crozier *et al*., 2004).

According to report of NFDC (2001), the reasons for low use of P in Pakistan are high prices, lack of promotional activities and reduced availability during peak demand period. High yielding varieties and intensive cultivation is another cause of depletion of P in our soils. About 80 to 90% soils from arid to semi arid regions of the world, including Pakistan are deficient in P (Memon *et al.*, 1992). P deficiency has a large and rapid negative effect on the final growth in a range of crops (Singh *et al.*, 2000). Phosphorus is essential for cell division, development of meristematic tissue and causing a stimulating effect on the number of floral buds and bolls per plant (Katkar *et al.*, 2002). Photosynthesis activity and stomatal conductance were reduced due to P deficiency (Vieira *et al.*, 1998). Phosphorus application can affect lint percentage (Sawan *et al.*, 1997), boll development and time to maturity (Marcus-Wyner and Rains, 1982). Plesnicar *et al.* (1994) concluded that P treated cotton plants had more photosynthetic activity than untreated cotton plants; this indicated that photosynthetic CO_2 fixation decreased in plants suffering from P deficiency. Chiles and Chiles (1991) reported that promotive effect of increased phosphorus rate on earliness percentage may be through an alteration of the nitrogen balance of cotton plant that lead to early maturity of cotton plant. A study indicated that cotton response to P fertilizer at medium or even low soil test P levels was inconsistent (Mitchell, 2000). Five years landscape-scale cotton study

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indicated that P fertilizer response varied by landscape position (Bronson *et al.*, 2001). Field study showed that decreases in seed cotton yield, leaf area and a greater ratio of leaf dry mass to leaf area were found in P deficient cotton plants (Singh *et al.*, 2006). Keeping in view the importance of cotton crop, its earliness and significant response of cotton crop to phosphorus fertilizers, the present study was conducted to identify the cultivar that can fit well in our cotton wheat cropping system owing to its early maturity and to find the best amount of phosphorus for enhancing earliness in cotton without significantly affecting the yield.

Material and Methods

A field experiment was carried out to determine the effect of phosphorus levels on earliness of cotton cultivars at Agronomic Research Area, University of Agriculture, Faisalabad, during kharif 2008. The soil of the experimental site was sandy clay loam with alkaline pH (8.0), 0.72% organic matter, 0.045% N, 8.80 ppm available phosphorus and 170 ppm available potassium. The experiment was laid out in randomized complete block design (RCBD) with factorial arrangement and replicated thrice. Experimental treatments comprised of three cotton cultivars viz. CIM-496 (V1), MNH-786 (V2) and FH-901 (V3) and four phosphorus levels viz. 0 (P0), 30 (P1), 60 (P2) and 90 (P3) kg ha^{-1}. The length of each plot was 6 m and width was 3 m. Each plot contained four rows of cotton crop. Seedbed was prepared by cultivating the field for two 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 June 2, 2008, with the help of single row hand drill by maintaining 0.75 m row spacing and constant plant to plant distance of 0.30 m was maintained by thinning at third true leaf stage. A basal dose of 120 kg N ha^{-1} and different levels of phosphorus (0, 30, 60, and 90 kg ha^{-1}) were applied. Whole of P was applied at sowing and nitrogen was applied in three splits viz. 1/3 of nitrogen at sowing, 1/3 of nitrogen after 35 days of sowing before the start of flowering and 1/3 of nitrogen after 65 days of sowing at boll formation stage. Overall nine irrigations were applied and weeds were controlled by two hoeings at 30 and 65 days after planting. Insecticides were applied to control the sucking insects (Aphid, Jassid, Whitefly, Thrips and Mites) and bollworms (American bollworm, Pink bollworm and Spotted bollworm). All other agronomic practices were kept normal and uniform for all the treatments. When seedlings were well established, ten guarded representative plants were selected randomly in each plot and marked for identification. These plants were monitored and tagged to provide the following data:

Number of days from planting to first floral bud initiation (DFS)

When first square of a size visible with naked eye appeared on 50% of selected plants, number of days from planting were recorded. Average number of days taken to squaring was calculated.

Number of days from planting to appearance of first flower (DFF)

Number of days from planting to appearance of first flower was noted from the ten selected plants and average number of days taken to appearance of first flower was calculated.

Number of days from planting to first boll splition (DFOB)

Number of days from planting to first boll splition was noted from the ten selected plants and average number of days taken to boll splition was calculated.

Boll maturation period (BMP)

Boll maturation period (days) was calculated by deducting number of days taken to flowering from number of days taken from planting to boll splition.

Node number for the first fruiting branch (NNFFB)

Number of the main stem node at which first fruiting branch arose was determined by designating node immediately above the cotyledonary scars as number two, and counting the successive ascending nodes until the one that gave rise to the first fruiting branch was reached.

First fruiting branch height (FFBH)

Height of first fruiting branch (cm) was measured from pseudonode of ten selected plants and finally average height of first fruiting branch was calculated.

Mean maturity date (MMD)

The procedure to determine the mean maturity date (days) was the one given by the Christidis and Harrison (1955), which is generalized as follows.

Mean maturity date (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 (PRI)

Production rate index (g/days) was calculated from total seed cotton weight divided by the mean maturity days.

Earliness index (%) (EI)

It was measured with the help of following formula given by Singh (2004). This index is referred as maturity coefficient.

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

Seed cotton yield (SCY)

Seed cotton yield (kg ha^{-1}) was computed from seed cotton yield per plot.

Data collected on different parameters were analyzed statistically by using MSTAT-C programme (Anonymous, 1986) for analysis of variance and means were separated using Fisher's protected least significant difference (LSD) test at 5% probability level (Steel *et al*., 1997).

Results

Data pertaining to appearance of first square as influenced by cotton varieties and phosphorus levels are presented in Table 1. Phosphorus had no significant effect on this character while varietal differences were significant. CIM-496 and MNH-786 have statistically same (35.6 and 35.7) but significantly more number of days for squaring than FH-901 (34.9). Linear regression coefficient (R^2), for mean maturity date (days) vs. days to squaring was only 0.219 (Figure 1a). Number of days from planting to appearance of first flower as affected by varieties and phosphorus levels are shown in Table 1. Minimum days to flowering were recorded in FH-901 (42.8) while maximum was recorded in MNH-786 (44.4). Statistically significant differences were found among all phosphorus levels for number of days to first flower. Minimum days to flowering (42.4) were found where P was applied @ 90 kg ha^{-1} and maximum (44.4) in control treatment (0 kg P ha^{-1}). Number of days to first open boll was influenced statistically by varieties (V) and phosphorus levels (P) and their interaction (VxP) was non significant (Table 1). Minimum days to first boll splition were recorded in FH-901 (90.7) followed by CIM-496 and MNH-786. Days taken to open first boll decreased with increasing phosphorus levels recording maximum in control and minimum with 90 kg P ha^{-1}. Linear regression for both parameters showed increasing trend. R^2 values for mean maturity date (days) vs. days to first flower and first boll splition were 0.492 and 0.553, respectively (Figure 1 b and c). Boll maturation period was statistically altered by varieties (V) while P levels and interaction (V x P) showed non significant effect on boll maturation period (Table 2). Among varieties CIM-496 and MNH-786 were at par with each other (48.3 and 48.4) but took significantly more days for boll maturation than FH-901 (47.7) (Table 1). However (R^2) for MMD vs. boll maturation period was 0.258 (Figure 2a).

Node number for first fruiting branch was significantly influenced by cultivars and phosphorus levels while interaction was found to be non significant (Table 2). Statistically more value of node number for first fruiting branch was found in MNH-786 (9.5), followed by CIM-496 (9.1) and FH-901 (8.7). Node number on which first fruit branch appeared showed a decreasing trend with increasing phosphorus levels (Table 1). Cultivars and P levels affected the first fruiting branch height while interaction was found to be non significant (Table 3). Varieties differed significantly from each other; MNH-786 produced maximum height of first fruiting branch and FH-901 produced minimum height, while CIM-496 resulted in intermediate first fruiting branch height (Table 4). Among P levels, maximum height of first fruiting branch was recorded with control (no P) and 30 kg P ha^{-1} while 90 kg P ha^{-1} resulted in minimum height of first fruiting branch, although it was at par with that of 60 kg P ha^{-1}. Both the parameters under discussion showed decreasing trend with mean maturity date (days), however R^2 values for MMD vs. node number for 1st fruiting branch and 1st fruiting branch height were 0.597 and 0.325, respectively, as shown in Figure 2 b and c.

Phosphorus levels showed significant effect on mean maturity days (MMD) while varieties and interaction were found to be non-significant for the parameter under discussion (Table 3). Mean maturity period (days) decreased with increasing phosphorus levels; it was lowest with the highest level (90 kg P ha^{-1}), although 60 kg ha^{-1} was at par with that of highest level. Production rate index was influenced by P levels, only (Table 3). All P levels differed significantly from each other with maximum value in control and minimum in higher level (90 kg P ha^{-1}) (Table 3). Linear regression coefficient (R^2) for mean maturity date (days) vs. production rate index was 0.699 (Figure 3a).

Earliness index and seed cotton yield both were influenced by cotton cultivars and P levels; their interaction was found to be non significant (Table 3). Statistically maximum earliness index and minimum seed cotton yield were found in FH-901, while statistically minimum earliness was recorded in CIM-496 (48.8%). MNH-786 achieved maximum seed cotton yield, however this variety was intermediate with respect to earliness index. Phosphorus application rate affected earliness index and seed cotton yield in a similar fashion. Both parameters showed an increasing trend with increasing P levels. Linear regression coefficient (R^2) for mean maturity date (days) vs.

earliness index and seed cotton yield were 0.848 and 0.417, respectively (Figure 3 b & c).

is an estimator of earliness. Regression line drawn to see the dependence of this parameter on mean maturity date

Table 1: Effect of cotton varieties and phosphorus rate on earliness related traits

Treatment	DFS	DFF	DFOB	BMP	NNFFB
Variety					
CIM-496	35.6 a	43.0 b	91.4 b	48.3 a	9.1 b
MNH-786	35.7 a	44.4 a	92.9 a	48.4 a	9.5 a
FH-901	34.9 b	42.8 b	90.7 c	47.7 b	8.7 c
LSD (p=0.05)	0.43	0.44	0.49	0.56	0.36
P rate (kg ha^{-1})					
0	35.4	44.4 a	93.2 a	48.6	9.4 a
30	35.8	43.9 b	92.0 b	48.1	9.3 ab
60	35.3	43.1 c	91.0 c	47.9	8.9 bc
90	35.2	42.4 d	90.4 d	48.0	8.6 c
LSD (p=0.05)	Ns	0.50	0.56	Ns	0.42

Means not sharing a letter in common within a column differ significantly at 5% probability level. ns= Non-significant,
(DFS)= Days to first square**, (DFF)=** Days to first flower**, (DFOB)=** Days to first open boll,
(BMP)= Boll maturation period, **(NNFFB)=** Node number for first fruiting branch,

Table 2: Mean square values from analysis of variance of earliness related growth parameters of cotton cultivars

S.O.V	d.f.	DFS	DFF	DFOB	BMP	NNFFB
Replication	2	0.51	0.70	0.27	0.07	0.63
Varieties (V)	2	1.99*	9.20*	16.08*	1.80*	2.00*
Phosphorus (P)	3	0.58ns	7.11*	12.76*	0.83ns	1.23*
VxP	6	0.35ns	0.06ns	1.88ns	2.11ns	0.02ns
Error	22	0.26	0.27	0.33	0.44	0.18

ns= Non-significant, * Denotes significance at the 0.05 level of probability. **(SOV)=** Source of variation, **(d.f)=** Degree of freedom,
(DFS)= Days to first square**, (DFF)=** Days to first flower**, (DFOB)=** Days to first open boll,
(BMP)= Boll maturation period, **(NNFFB)=** Node number for first fruiting branch

Table 3: Mean square values from analysis of variance for maturity and yield parameters of cotton

S.O.V	d.f.	FFBH	MMD	PRI	EI	SCY
Replication	2	0.12	6.81	2.28	0.85	24311
Varieties (V)	2	26.71*	11.67ns	6.54ns	42.15*	202420*
Phosphorus (P)	3	2.82*	40.69*	66.86*	56.52*	557323*
VxP	6	1.11ns	1.99ns	2.92ns	0.90ns	42727ns
Error	22	0.38	3.64	2.14	0.34	10207

ns= Non-significant, * Denotes significance at the 0.05 level of probability. **(SOV)=** Source of variation, **(d.f)=** Degree of freedom,
(FFBH)= First fruiting branch height (cm), **(MMD)=** Mean maturity date (days), **(PRI)=** Production rate index (g/days),
(EI)= Earliness index (%), **(SCY)=** Seed cotton yield (kg ha^{-1})

Discussion

Appearance of first floral bud can not be used as an indicator, to estimate the earliness of cotton cultivars (Saleem *et al.,* 2009). In this study, cultivars could not be recognized (early vs late) on the basis of days to squaring. Our finding was not similar to the idea given by Poehlman (1987) he concluded that how early cotton begins to square (days) indicated a very weak positive relationship between two parameters (Figure a). Appearance of first flower can be used as an indicator of early maturing cultivar (Khan *et al.,* 2002). The present data indicated that decrease in the appearance of days to first flower, days to first boll splition, node number for first fruiting branch and first fruiting branch height (cm) were observed at 90 kg P ha^{-1}. High dose of P would provide more nutrients at early growth stages of cotton plant that lead to efficient utilization of other resources like light, water and other nutrients. Linear regression models indicated almost equal dependence of mean maturity date (days) on days to first flower, first boll splition and first fruiting branch height and lower dependence on first fruiting branch height. A cultivar taking less number of days to flowering and first boll splition may be classified as earlier (Godoy and Palomo, 1999).

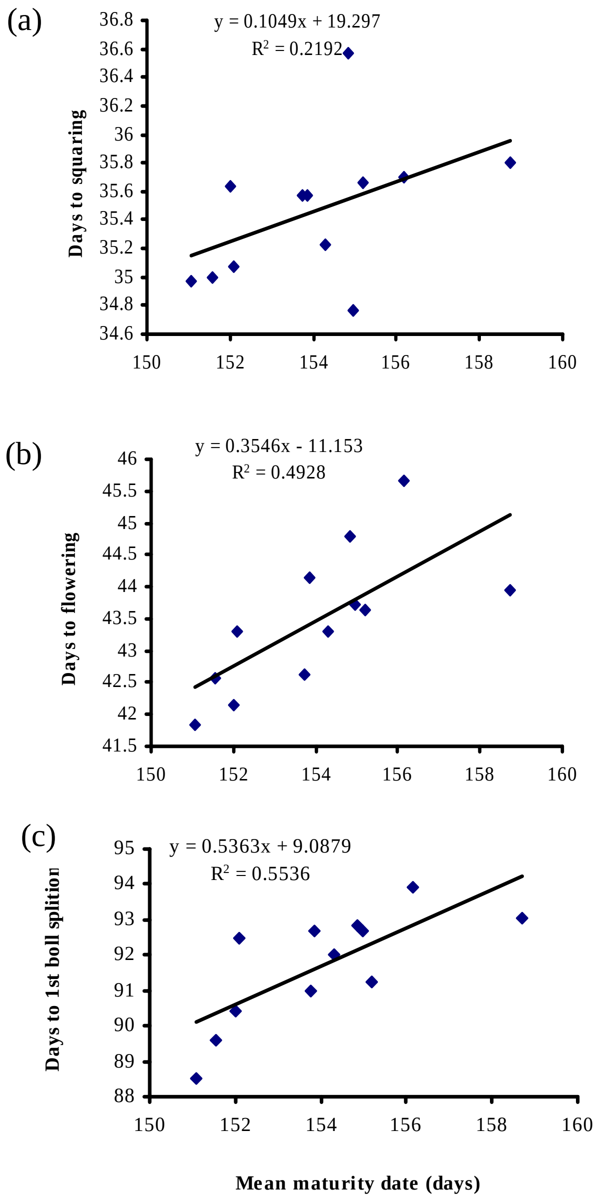

Figure 1: Relationship of some phenological events with mean maturity days of cotton

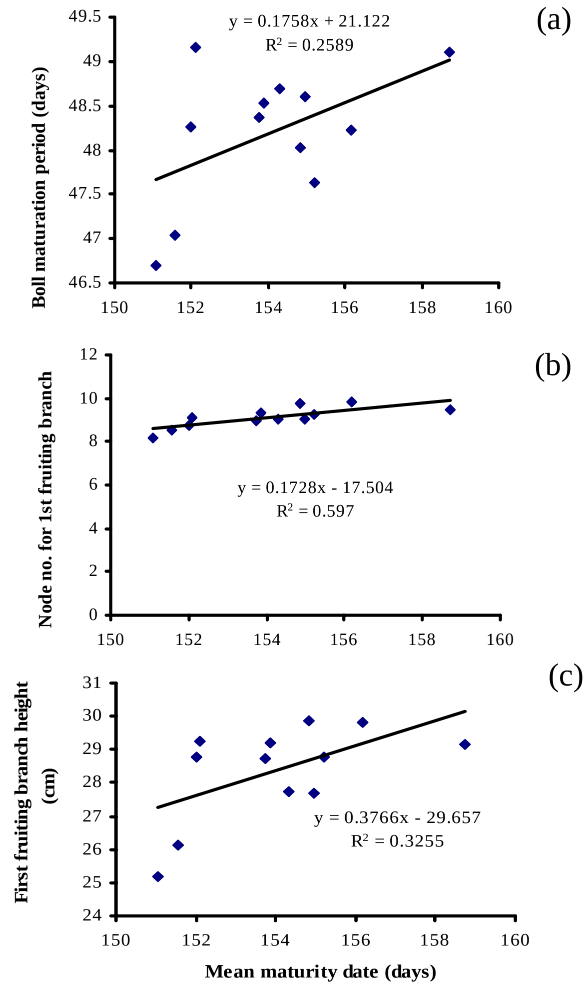

Figure 2. Relationship of boll maturation period, node number for 1st fruiting branch and first fruiting branch height with mean maturity days in cotton

In the present study, boll maturation period was influenced by cultivars. Saeed *et al.* (2005) reported that boll maturation period is used as indirect selection of early maturing cultivars, cultivar having less boll maturation period are early maturing, our results are somewhat similar but linear regression coefficient (R^2) for mean maturity date (days) vs boll maturation period was weak 0.258 (Figure 2a). Craig and Nichols (2005) reported that differences among boll maturation periods were due to the effect of temperature but not due to cultivars. Contrarily, we found that boll maturation period was significantly influenced by cultivars. Gipson and Ray (1970) also confirmed that shorter boll maturation period is the character of early maturing cultivars.

Table 4: Effect of cotton varieties and phosphorus rate on earliness related traits and yield of cotton

Treatment	FFBH	MMD	PRI	EI	SCY
Variety					
CIM-496	28.8 b	154.9	52.8	48.8 c	1639.6 b
MNH-786	29.5 a	154.2	54.0	51.2 b	1810.0 a
FH-901	26.6 c	152.9	52.6	52.5 a	1555.0 b
LSD (p=0.05)	0.52	Ns	ns	0.49	85.53
P rate kg ha^{-1}					
0	28.8 a	156.6 a	56.2 a	47.8 d	1351.4 c
30	28.8 a	154.7 ab	54.3 b	49.8 c	1588.2 b
60	28.0 b	153.0 bc	52.2 c	52.1 b	1853.5 a
90	27.7 b	151.7 c	49.9 d	53.5 a	1879.5 a
LSD (p=0.05)	0.60	1.86	1.43	0.57	98.77

Means not sharing a letter in common within a column differ significantly at 5% probability level. ns= Non-significant, **(MMD)=** Mean maturity date (days),**(PRI)=** Production rate index (g/days), **(EI)=** Earliness index (%), **(SCY)=** Seed cotton yield (kg ha^{-1})

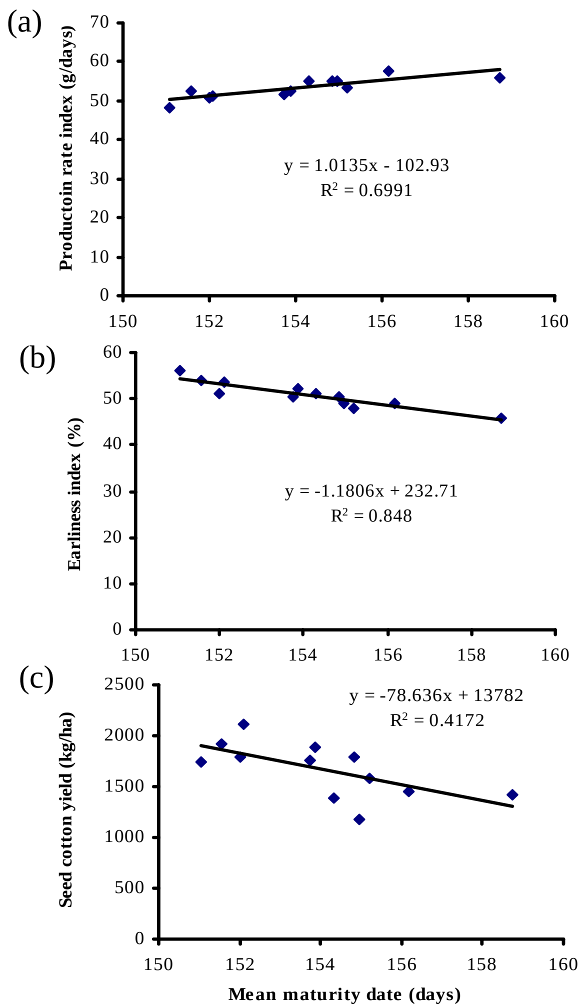

Figure 3: Relationship between production rate index, earliness index and seed cotton yield with mean maturity days in cotton

Node number for first fruiting branch and first fruiting branch height are the morphological measures of earliness in cotton (Joham, 1979). In the present study, node number for first fruiting branch and first fruiting branch height both were altered by the cultivar and P levels. Figure 2 a+c showed a considerably strong association between mean maturity date and node number for first fruiting branch. Cultivar matured earlier approximately 4 to 7 days by decrease in one node number of first fruiting branch (Ahmed and Malik, 1996). Above discussed parameter was also confirmed by the finding of Babar *et al*. (2002) who reported that lower the level of fruiting branch node on the main stem the earlier is the variety.

Mean maturity date and production rate index both were affected by the P levels and cultivars. Significant positive correlation coefficient was found between mean maturity days and production rate index (R^2 =0.699) (Figure 3a), data showed that with increase in mean maturity days, production rate index also increased; earlier maturity with lower production rate index is well documented (Borland *et al.*, 2001). Our data further indicated that production rate index and mean maturity days of cotton decreased with increase in P rate, which is a true reflection of specific role of phosphorus described by Singh (2003) that it enhances early maturity.

Sezener *et al*. (2006) reported that varieties varied significantly for seed cotton yield. Early maturing cultivars produced more seed cotton yield at first picking; earliness index (Jenkins *et al.*, 1990); as after the first bloom these varieties partition a greater portion of photosynthates to fruit growth than to new vegetation (Bang and Milroy, 2004). Our results also indicated a strong association between earliness index and mean maturity days (R^2 =84.6%) as against the findings of Richmond and Ray (1996) that percentage of first picking in the multiple harvests is a poor estimate of earliness. Increased seed cotton yield per plant, seed cotton yield per hectare, lint yield per hectare as well as earliness in cotton was achieved with increasing phosphorus levels (Sawan *et al.,* 2008; Aslam *et al.*, 2009); same was reported in our studies.

Conclusion

Among the three varieties under test, FH-901 proved to be the earliest however, its seed cotton yield was lowest. Higher phosphorus dose (90 kg ha^{-1}) was best for achieving more seed cotton yield and early maturity than its lower application rates.

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