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EFFECT OF SOWING DATES AND PLANT SPACING ON GROWTH AND DRY MATTER PARTITIONING IN COTTON (*GOSSYPIUM HIRSUTUM* L.)

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Abstract

Among agronomic factors, sowing time and plant spacing are considered key management components in any cropping system to harvest a profitable seed cotton yield. Thus, the present studies were conducted to determine the effects of sowing date and plant spacing on growth and yield of cotton under an arid sub-tropical continental climate during 2004-05. Result indicated better yield responses and reproductive vegetative ratio (RVR) in early sown cotton at high plant density. For crop growth rate (CGR) and relative growth rate (RGR), different plant responses were observed. Early sowing showed the highest CGR50 and RGR50 while at late sowings, CGR100 or CGR150 was highest. Correlation analysis and Path analysis were carried out to understand the effect of different plant traits on seed cotton yield under optimum plant spacing (15cm) and sowing dates (10-May). Both conditions indicated highest association of seed cotton yield with number of bolls per plant and reproductive/vegetative ratio. On the other hand boll weight showed negative association with seed cotton yield. However, path analysis showed the highest direct effect of reproductive/vegetative ratio on seed cotton yield under early sowing dates (10-May). Furthermore, highest correlation of boll number with seed cotton yield was also due to indirect effects through RVR. On the other hand, reproductive dry matter showed highest direct effect on seed cotton yield under high plant density (15cm).

Introduction

Optimal dry matter partitioning is an important factor for higher productivity (Rauf & Sadaqat, 2007, 2008). Dry matter partitioning traits were used to work out harvest index and growth rate. High harvest index is an indicative of better translocation and mobilization of food reserve (Rauf & Sadaqat, 2008). Similarly, crop growth rate determines the maturity timing of the crop (Bange & Milroy, 2004). A number of studies have indicated significant differences among the genotypes for the yield due to significant differences in the harvest index and to some extent to growth rate (Wells & Meredith, 1984; Fritschi *et al*., 2003; Bange & Milroy, 2004; Rauf *et al*., 2008). Dry matter partitioning have also been found to be affected by different factors such as temperature, light, nitrogen, fertilizer and irrigation supplies (Wells & Meredith, 1984; Fritschi *et al*., 2003; Rahman *et al*., 2007; Rauf & Sadaqat, 2008). Although, sowing time and plant spacing are the key productivity factors but few studies have been carried out to determine their effects on dry matter partitioning and crop growth rate. Studies undertaken were shown to impact morphological traits (Norfleet *et al*., 1997; Bozbek *et al*., 2006; Wrather *et al*., 2008). Previous results showed that early sowing produced 10% more flowers, 23% more open bolls, 18% more seed cotton yield and 13% more ginning out turn than late sowing (Arshad *et al*., 2007). Conflicting reports are also available challenging the benefits of early sowing. Kittock *et al*., (1981) indicated that seed cotton yield of upland cotton was least affected by sowing dates when compared with pima cotton; Bange *et al*., (2008) was unable to show benefits of early planting in bollgard II cotton. Rahman *et al*., (2007) used early and late planting time for the induction of heat stress. It was shown that reproductive phase of early sown cotton genotypes coincided with the hottest month of the year, which caused serious short falls in the yield.

Results of plant spacing have also shown that it has altered the plant architecture, photosynthetic efficiency of leaves, boll size and fruit production pattern (Sendouka *et al*., 1980; Malik, *et al*., 1998; Samiani *at al*., 1999; Hussain *et al*., 2000; Soomro *et al.*, 2000). It is also important to study the interaction of appropriate sowing date and optimum plant spacing. Studies will help to understand the process of dry matter accumulation under variable agronomic practices. With the same in mind an experiment was carried to under stand the process of dry matter partitioning under variable conditions of sowing date and plant spacings.

Materials and Methods

The studies were carried out under field conditions of an arid sub-tropical continental climate to determine the response of cotton to different sowing dates and plant spacing during two consecutive cotton seasons on silt loam soils having pH; 8.11 and 8.09 sand; 29.5 and 30.0% silt; 56.0 and 54.5% and clay; 14.5 and 15.5% during the years 2004 and 2005 respectively. The experimental site was situated at 30^{o}12 N, 71^{o}28 E and altitude 123 meter (Ahmed & Ali, 1993). Cotton crop was sown on three sowing dates; May 10, June 01 and June 20 with three-plant spacing 15, 30 and 45cm during both the years by using a randomized complete block design with factorial arrangement in three replicates.

The land was prepared in the form of bed-furrows at 75 cm apart and *Pendimethaline* (pre-sowing herbicide) @ 82.5 a.i g ha^{-1} was applied to control weeds in the field. The furrows were irrigated and delinted cotton seeds were dibbled manually on respective sowing dates as per treatment during both the years. The furrows were again irrigated 72 hours after dibbling the seeds to have successful seed germination and emergence. However, later on a subsequent irrigation was given after a week to fill the gaps where seeds were not germinated. There after wards, the subsequent irrigations were given at 10 days interval up till crop maturity.

Phosphorus fertilizer of 60 kg P_2O_5 ha^{-1} in the form of Triple Super Phosphate (46% P_2O_5) was applied at the time of seed bed preparation and nitrogen fertilizer (100 kg N ha^{-1}) in the form of Urea (46% N) was applied in three equal splits i.e., at seed bed preparation, flowering and boll formation. Crop was kept free from insect pest attack through regular sprays of required pesticides available in the market. All other agronomic practices were maintained in the field throughout the crop season.

Measurement of plant traits: Plants were harvested from an area of one square meter from each plot. Plant height was measured with the measuring tape. The plants were separated into its component such as leaves, stem and bolls (along with the burr) and put in the kraft paper bag. All the excised plant material was dried in the oven at 70°C until the weight became constant. In the laboratory, all the bolls were counted for the measurement of number of bolls meter^{-2}. Crop growth rate (CGR) and relative growth rate (RGR) was measured according to formula given by Kandil *et al*., (2004).

Statistical analysis: All data was statistically analyzed using the M-STAT “C” computer software. The estimates of correlation coefficients were worked out using the Mini-Tab program. These correlations were partitioned into path coefficients using the technique outlined by Dewey & Lu (1959).

Results

Analysis of variance indicated significant variation (p≤0.05) due to sowing date, plant spacing and their interaction for all traits. However, variation due to year was either non-significant (p≥0.05) or its magnitude was much lower than that of other sources of variation, therefore it can be considered non-significant (Gomez & Gomez, 1984).

Figures 1-3 show the effect of plant spacing and sowing time on traits related to plant growth and dry matter accumulation. Results indicated that highest productivity was achieved in the form of seed cotton yield (SC), reproductive dry weight (RDW), and reproductive/ vegetative ratio in early sown crop (10-May) and at high plant density (15cm). Contrastingly, early sowing resulted in lowest accumulation of vegetative dry weight (VDW). However, high density (15cm) has accumulated highest VDW as compared to other plant spacing.

Crop growth rate after 50 days of sowing (CGR50) was the highest in crop sown at earlier dates (10-May) as compared to other sowing dates and at high plant density. Non-significant differences (p≥0.05) were observed for crop growth rate after 100 days (CGR100) at all plant spacings and sowing dates except late sowing date (20-June) at high planting density (15cm) that showed significantly lower CGR100 as compared to other sowing dates. Crop growth rate after 150 days (CGR150) was the highest for crop sown on 1st June at high density. However, late sown crop (1-June) showed the highest CGR150 at low plant density (45cm).

Relative growth rate of crop has been shown in Fig. 3. Only early sown crop (10-May) showed the highest relative growth rate after 50 days (RGR50) at high plant density. 20-June, sowing showed the highest relative growth rate (RGR100) at all plant spacings while crop sowing on 1-June showed the highest relative growth rate after 150 days (RGR150) at plant spacing of 15cm.

Correlation and Path analysis was carried out to study the effects of yield component, growth and dry matter partitioning traits on seed cotton yield under optimum sowing date 10-May and high planting density (15cm) (Table 1). Correlation analysis between the plant traits developed under 15cm spacing indicated the highest association of boll number (r=0.98) and RVR (r=0.98) with seed cotton yield. All traits showed significant relationship with seed cotton yield except CGR50. Boll weight and VDW showed negative relationship with seed cotton yield. RVR ratio showed positive association with RDW, CGR50, RGR50 while it showed significant negative relationship with VDW, CGR150 and RGR100 and RGR150 (Table 1).

Correlation between the plant traits under sowing date (10-May) showed that for seed cotton yield maximum relationship was shown by boll number followed by CGR150, RGR150 and RVR (Table 1). All traits showed significant correlation with seed cotton yield except RGR100. Boll weight showed significant (p≤0.01) negative relationship with seed cotton yield. RVR showed highest relationship with RGR50. Plant height, boll number, RDW and CGR50 showed positive and significant (p≤0.05) association with RVR.

Correlation analyses show morasses of relationships, which may be confusing. Alternatively path analyses have been used for better understanding of direct and indirect effect of productivity traits on seed cotton yield (Table 2). Path analysis for high seed cotton under 10-May sowing date showed that RVR had the highest direct effect on seed cotton yield. RVR also showed highest indirect effect on seed cotton yield *via* CGR50.

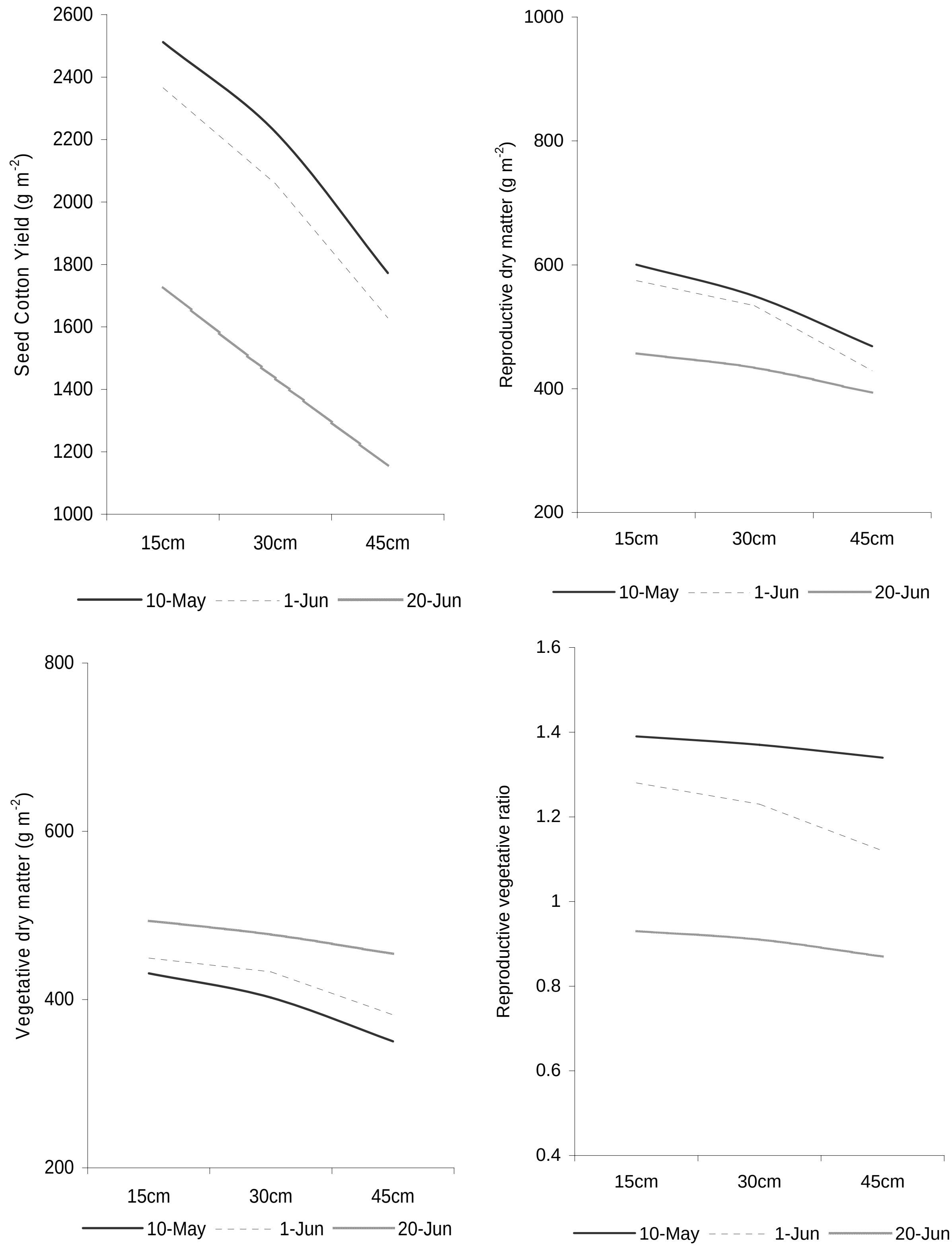

Fig. 1. Effect of sowing dates and plant spacing on seed cotton yield (gm^{-2}), reproductive dry matter ($g\ m^{-2}$), vegetative dry matter ($g\ m^{-2}$), and reproductive/vegetative ratio.

CGR50, CGR150, boll number and boll weight also showed positive direct effect on seed cotton yield. The positive effect of boll number on seed cotton yield was indirectly through RVR and CGR50; while positive effect of boll weight was due to indirect effect of CGR50 and CGR50 was indirectly due to RGR50.

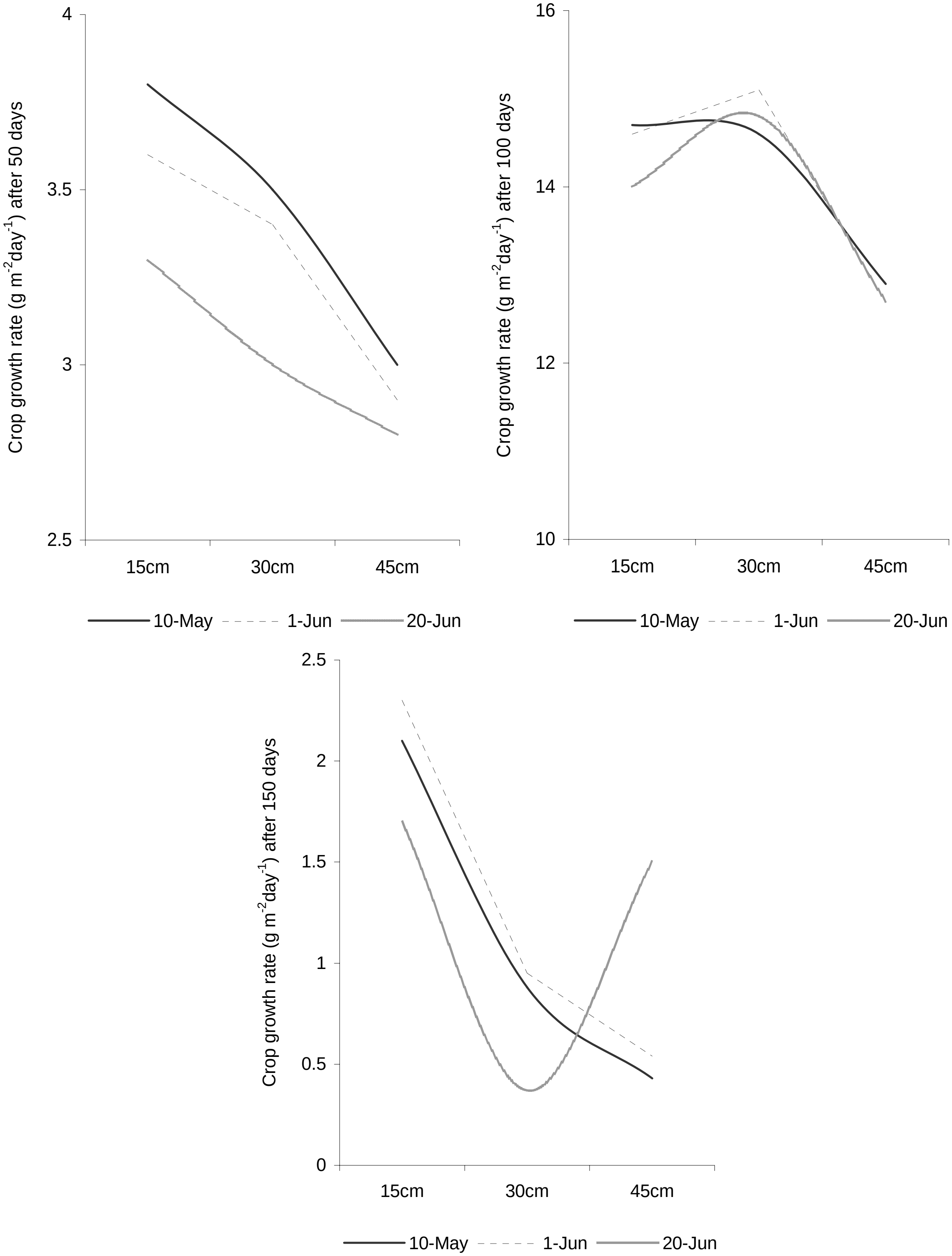

Fig. 2. Effect of sowing dates and plant spacing on crop growth rate (g m^{-2} day^{-1}) after 50, 100 and 150 days of sowing.

Path analysis for high seed cotton yield of high plant density (15cm) is given in Table 3. Highest direct effect was shown by reproductive dry weight. In addition to reproductive dry weight VDW, CGR50 and RGR50 also showed positive direct effect on seed cotton yield. The effect of RDW was also highest and positive *via* BW, RGR50, CGR50 and RVR.

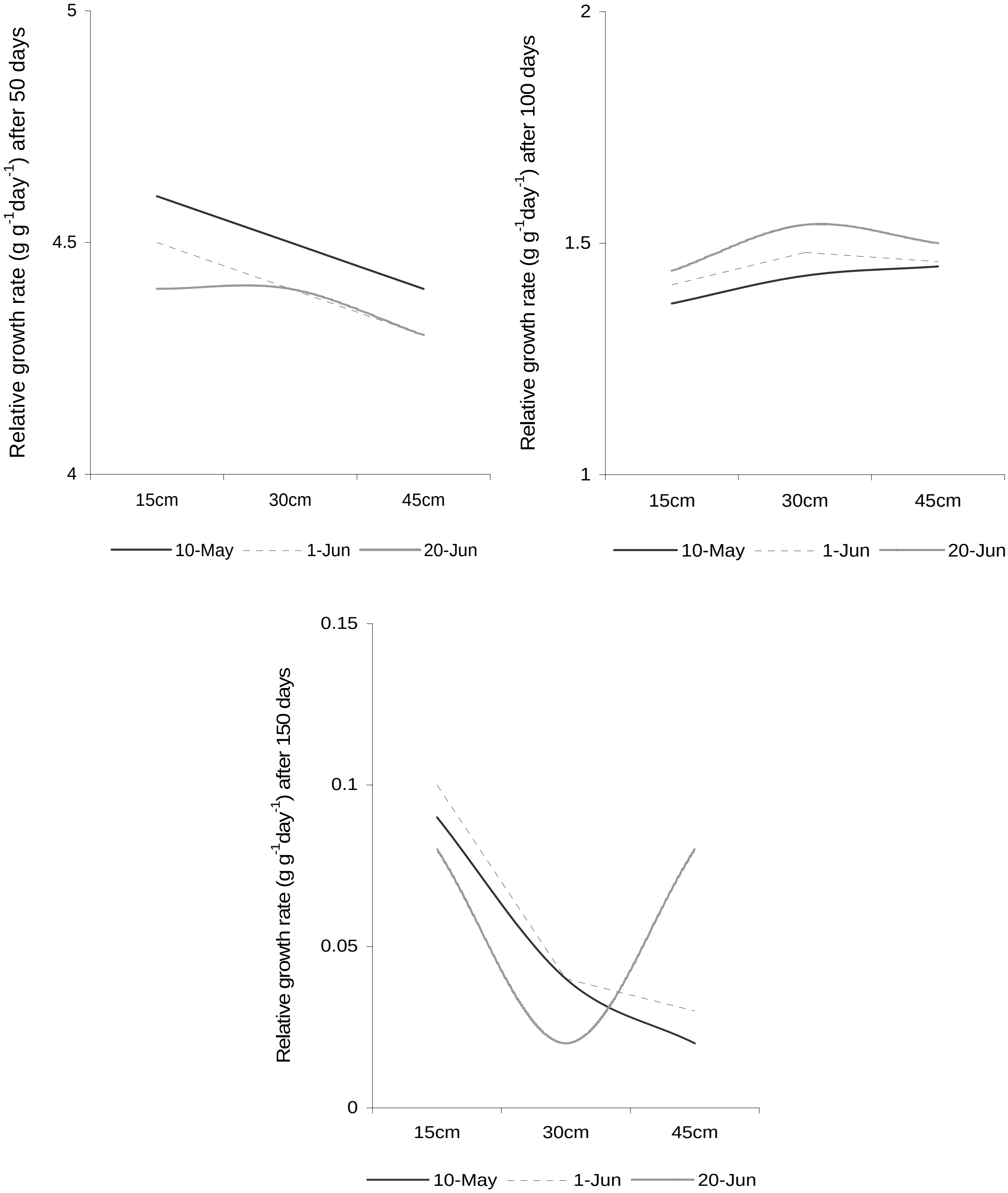

Fig. 3. Effect of sowing dates and plant spacing on relative growth rate (g g^{-1} day^{-1}) after 50, 100 and 150 days of sowing.

Discussion

Better yield responses and reproductive vegetative ratio (RVR) were obtained in early sown cotton at high plant density. Benefits of early sowing have been well documented previously (Norfleet *et al*., 1997; Wrather *et al*., 2008). It was shown that earliest sowing dates have more optimum environmental conditions and allow the plant to gain more plant height and number of bolls (Norfleet *et al*., 1997). Thus, producing more yield than late planting (Wrather *et al*., 2008; Bozbek *et al*., 2006). On the other hand better responses under high plant density may be due to breeder's selection for weak competitor genotypes, allowing them to adopt high plant density production technology.

Table 1. Correlation matrix between the dry matter partitioning and yield components in 15 cm spacing (above diagonal) and 10 May sowing (below diagonal).

	PH	BN	BW	RDW	VDW	RVR	CGR50	CGR100	CGR150	RGR50	RGR100	RGR150	SC
PH		0.91^{**}	-0.84^{**}	0.96^{**}	-0.07^{ns}	-0.22^{ns}	0.65^{**}	0.62^{**}	0.75^{**}	0.77^{**}	-0.65^{**}	0.09^{NS}	0.94^{**}
BN	0.72^{**}		-0.89^{**}	0.79^{**}	-0.47^{*}	0.19^{ns}	0.29^{NS}	0.24^{NS}	0.82^{**}	0.46^{*}	-0.34^{NS}	0.46^{*}	0.98^{**}
BW	-0.47^{*}	-0.95^{**}		-0.71^{**}	0.38^{ns}	-0.14^{ns}	-0.34^{NS}	-0.25^{NS}	-0.53^{**}	-0.51^{*}	0.47^{*}	-0.22^{NS}	-0.84^{**}
RDW	0.99^{**}	0.76^{**}	-0.53^{*}		0.14^{ns}	0.42^{*}	0.8^{**}	0.77^{**}	0.74^{**}	0.89^{**}	-0.80^{**}	-0.06^{NS}	0.86^{**}
VDW	0.94^{**}	0.67^{**}	-0.43^{*}	0.99^{**}		-0.86^{**}	-0.90^{**}	0.11^{NS}	-0.75^{**}	0.75^{**}	0.86^{**}	0.09^{NS}	-0.86^{**}
RVR	0.44^{*}	0.80^{**}	-0.78^{**}	0.52^{*}	0.39^{NS}		0.98^{**}	0.30^{NS}	-0.98^{**}	0.96^{**}	-0.61^{**}	-0.81^{**}	0.98^{**}
CGR50	0.97^{**}	0.60^{*}	-0.36^{NS}	0.96^{**}	0.99^{**}	0.87^{**}		0.25^{NS}	0.95^{**}	-0.91^{**}	-0.65^{**}	0.35^{NS}	0.25^{NS}
CGR100	0.99^{**}	0.61^{*}	-0.34^{NS}	0.97^{**}	0.98^{**}	0.36^{NS}	0.98^{**}		0.42^{*}	-0.28^{NS}	0.56^{*}	0.89^{**}	0.42^{*}
CGR150	0.63^{**}	0.93^{**}	-0.89^{**}	0.72^{**}	0.61^{**}	0.27^{NS}	0.52^{*}	0.53^{*}		-0.97^{**}	-0.48^{*}	0.56^{*}	-0.97^{**}
RGR50	0.98^{**}	0.53^{*}	-0.32^{NS}	0.97^{**}	0.99^{**}	0.93^{**}	0.99^{**}	0.99^{**}	0.54^{*}		-0.97^{**}	-0.48^{**}	0.56^{**}
RGR100	-0.37^{**}	-0.23^{NS}	0.21^{NS}	-0.37^{NS}	-0.45^{*}	0.33^{NS}	-0.53^{*}	-0.33^{NS}	-0.17^{NS}	-0.44^{*}		0.57^{*}	-0.44^{**}
RGR150	0.39^{NS}	0.85^{**}	-0.89^{**}	0.49^{*}	0.36^{NS}	0.29^{NS}	0.24^{NS}	0.27^{NS}	0.95^{**}	0.24^{NS}	0.06^{NS}		0.42^{*}
SC	0.69^{**}	1.00^{**}	-0.95^{**}	0.73^{**}	0.64^{**}	0.81^{**}	0.57^{*}	0.58^{*}	0.90^{**}	0.55^{*}	-0.19^{NS}	0.84^{**}	

PH= (Plant height), BN= (Boll number), BW= (Boll weight), RDW= (Root dry matter), VDW= (Vegetative dry matter), RVR (Reproductive vegetative ratio, CGR50=(Crop Growth Rate after 50 days), CGR100=(Crop Growth Rate after 100 days), CGR150= (Crop Growth Rate after 150 days), RGR50= (Relative Growth Rate after 50 days), RG100=(Relative Growth Rate after 100 days), RG150= (Relative Growth Rate after 100 days), SC=(Seed Cotton Yield)

Table 2. Path analysis for high seed cotton yield under 10-May sowing, the values in bold are direct effects of the traits on seed cotton yield.

	PH	BN	BW	RDW	VDW	RVR	CGR50	CGR100	CGR150	RGR50	RGR100	RGR150
PH	**-0.03**	0.30	-0.38	-0.52	-0.27	2.89	-4.82	5.62	1.78	-2.72	1.43	-2.60
BN	-0.02	**0.42**	-0.77	-0.40	-0.18	5.26	3.46	-2.98	2.63	-1.64	0.89	-5.68
BW	0.01	-0.40	**0.81**	0.28	0.12	-5.13	1.79	-1.93	-2.52	0.89	-0.81	5.94
RDW	-0.03	0.32	-0.43	**-0.52**	-0.27	3.42	-4.77	5.51	2.04	-2.69	1.43	-3.27
VDW	-0.02	0.28	-0.35	-0.52	**-0.27**	2.56	-4.92	5.56	1.73	-2.74	1.74	-2.40
RVR	-0.01	0.33	-0.63	-0.27	-0.11	**6.57**	2.46	2.04	-1.24	-0.86	-1.27	-6.21
CGR50	-0.03	0.25	-0.29	-0.50	-0.27	1.64	**5.68**	-2.74	1.47	5.56	2.04	-1.60
CGR100	-0.03	0.25	-0.27	-0.50	-0.27	2.37	-4.87	**-4.97**	1.50	-2.74	1.27	-1.80
CGR150	-0.02	0.39	-0.72	-0.37	-0.17	5.72	-2.59	3.01	**2.83**	-1.50	0.66	-6.34
RGR50	-0.03	0.22	-0.26	-0.50	-0.27	2.04	-4.92	5.62	1.53	**-2.77**	1.70	-1.80
RGR100	0.01	-0.10	0.17	0.19	0.12	2.17	2.64	-1.87	-0.48	1.22	**-3.86**	-0.40
RGR150	-0.01	0.35	-0.72	-0.26	-0.10	6.11	-1.19	1.53	2.69	-0.67	-0.23	**-6.68**

PH= (Plant height), BN= (Boll number), BW= (Boll weight), RDW= (Root dry matter), VDW= (Vegetative dry matter), RVR (Reproductive vegetative ratio, CGR50=(Crop Growth Rate after 50 days), CGR100= (Crop Growth Rate after 100 days), CGR150= (Crop Growth Rate after 150 days), RGR50= (Relative Growth Rate after 50 days), RG100=(Relative Growth Rate after 100 days), RG150= (Relative Growth Rate after 100 days)

Table 3. Path analysis for high seed cotton yield under 15cm spacing, the values in bold are direct effects of the traits on seed cotton yield.

	PH	BN	BW	RDW	VDW	RVR	CGR50	CGR100	CGR150	RGR50	RGR100	RGR150
PH	**0.02**	-1.85	1.19	3.82	-0.02	0.13	0.26	-1.34	0.63	-1.01	-0.80	-0.08
BN	0.02	**-2.03**	1.26	3.14	-0.14	-0.11	0.12	-0.52	0.68	-0.60	-0.42	-0.41
BW	-0.01	1.81	**-1.42**	-2.82	0.12	0.08	-0.14	0.54	-0.44	0.67	0.58	0.19
RDW	0.02	-1.60	1.01	**3.98**	0.04	0.25	0.32	-1.67	-1.17	0.62	-0.98	0.05
VDW	0.00	0.95	-0.54	0.56	**0.31**	0.57	0.27	-1.60	-0.29	-0.71	-0.70	0.81
RVR	0.00	-0.39	0.20	-1.67	-0.29	**-0.60**	-0.35	1.95	0.09	0.99	0.92	-0.76
CGR50	0.01	-0.59	0.48	3.18	0.21	0.52	**0.40**	-2.12	0.25	-1.29	-1.18	0.54
CGR100	0.01	-0.49	0.35	3.06	0.23	0.54	0.39	**-2.16**	0.21	-1.25	-1.12	0.57
CGR150	0.01	-1.67	0.75	2.94	-0.11	-0.07	0.83	-0.54	**0.12**	-0.55	-0.34	-0.49
RGR50	0.01	-0.93	0.72	3.54	0.17	0.45	0.39	-2.06	-1.32	**0.35**	-1.19	0.42
RGR100	-0.01	0.69	-0.67	-3.18	-0.17	-0.45	1.23	1.97	-0.23	1.28	**-0.39**	-0.50
RGR150	0.00	-0.93	0.31	-0.24	-0.28	-0.52	-0.24	1.41	0.47	0.63	0.70	**-0.88**

PH= (Plant height), BN= (Boll number), BW= (Boll weight), RDW= (Root dry matter), VDW= (Vegetative dry matter), RVR (Reproductive vegetative ratio, CGR50=(Crop Growth Rate after 50 days), CGR100=(Crop Growth Rate after 100 days), CGR150= (Crop Growth Rate after 150 days), RGR50= (Relative Growth Rate after 50 days), RG100=(Relative Growth Rate after 100 days), RG150= (Relative Growth Rate after 100 days)

For crop growth and relative growth rate, different plant responses were observed. Early sowing showed highest CGR50 and RGR50 while at late sowings, CGR100 or CGR150 was highest. Similar trends were observed for RGR100 and RGR150. It means that early sowing date achieved higher growth rate during earlier plant growth phases. Rauf & Sadaqat (2007) indicated that differential growth rates were achieved due to differential production of plant growth regulator such as cytokinins. Therefore, earlier sowing dates may have induced higher cytokinins than other sowing dates.

Correlation analysis and Path analysis indicated the highest association of seed cotton yield with number of bolls per plant, reproductive/vegetative ratio. On the other hand boll weight showed negative association with seed cotton yield. Therefore, high seed cotton yield under early sowing and high plant density may be due to higher number of bolls per plant rather than size of boll. Positive and the highest impact of number of bolls per plant on seed cotton yield have also been identified in other studies (Azhar *et al*., 1999; Rauf *et al*., 2004).

However, path analysis showed the highest direct effect of reproductive/vegetative ratio on seed cotton yield under early sowing dates (10-May). RVR also showed indirect positive effect *via* CGR50. Although, number of bolls showed highest correlation with seed cotton yield but it failed to show direct effect on yield. This correlation may be due to its indirect effects through RVR and CCGR50. This showed that early sowing date resulted in higher translocation and mobilization photosynthates which were utilized in the production of large number of bolls. Similarly, higher RVR was indirectly achieved through the high CGR50.Karimi & Siddiqui (1991) also showed high crop growth rate during vegetative phase of wheat. Thus high crop growth rate during vegetative resulted in the early onset of reproductive phase.

On the other hand, reproductive dry matter showed highest direct effect on seed cotton yield under high plant density (15cm). Therefore it may be concluded that high plant density was involved in the production of higher reproductive dry matter while early sowing date (10-May) was involved in the mobilization of photosynthates. Previous results also showed that high plant density may increase total dry matter production per unit land area, earliness and more fruiting (Samani *et al*., 1999; Sendouka *et al*., 1980).

CGR50 and RGR50 have also showed positive direct effect on seed cotton yield. Furthermore, RDW and RVR showed indirect effect on seed cotton yield *via* CGR50 and RGR50. Thus, showing role of CGR50 and RGR50 in the production of high RVR and and RDW.

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References

Arshad, M., A. Wajid, M. Maqsood, K. Hussain, M. Aslam and M. Ibrahim. 2007. Response of growth, yield and quality of different cotton cultivars to sowing dates. *Pak. J. Agric.,* 44(2): 208-212.

Azhar, F.M., A.I. Khan and I. Mahmood. 1999. Path coefficient analysis of some advanced generation progenies of *Gossypium hirsutum* L. *Int. J. Agri. Biol.,* 1(3): 85-87.

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(10): 143-155.

Bange, M.P., S.J. Caton and S.P. Milroy. 2008. Managing yields of fruit retention in transgenic cotton (*Gossypium hirsutum* L.). *Aust. J. Agric., Res.,* 59: 733-741.

Bozbek, T., V., Sezner and A. Unay. 2006. The effect of sowing date and planting density on cotton yield. *J. Agron.,* 5(1):122-125.

Dewey, D.R. and K.H. Lu. 1959. A correlation and path coefficient analysis of components of crested wheat grass and seed production. *Agron. J.,* 51: 515-518.

Fritischi, F.B., A.R. Bruce, R.L. Travis, D.W. Rains and R.B. Hutmacher. 2003. Response of irrigated acala and pima cotton to nitrogen fertilizeration: Growth, Dry matter Partitioning and Yield. *Agron. J.*, 95: 133-146.

Gomez, K.A. and J.H. Gomez. 1984. *Statistical Procedures for Agricultural Research.* John Wiley & Sons.

Kandil, A.A., S., Badawis, A. El-Moursy and U.M.A. Abdou. 2004. Effect of planting dates, nitrogen levels and bio-fertilization treatment on 1: Growth Attributes of sugar beet (*Beta vulgaris*, L.). *Scietif. J. King. Faisal Uni.,* 5(2): 227-237.

Karimi, M.M. and K.H.M. Siddique. 1991. Crop growth and relative growth rates of old and modern wheat cultivars. *Aust. J. Agric. Res*., 42: 13-20.

Kittock, D.L., T.J. Hennebery and L.A. Bariola. 1981. Fruiting of upland and pima cotton with different planting dates. *Agron. J.,* 73: 711-715.

Norfleet, M.L., D.W. Reeves, C.H. Burmester and C.D. Monks. 1997. Optimal planting dates Albama*. Proceedings of the Beltwide Cotton Conference,* 1: 644-647.

Rahman, H.R., S.A. Malik, M. Saleem and F. Hussain. 2007. Evaluation of seed physical traits in relation to heat tolerance in upland cotton. *Pak. J. Bot.,* 39(2): 475-483.

Rauf, S. and H.A. Sadaqat. 2007. Effects of varied water regimes on root length, dry matter partitioning and endogenous plant growth regulators in sunflower (*Helianthus annuus* L.). *J. Plant Interact.,* 2(1): 41-51.

Rauf, S. and H.A. Sadaqat. 2008. Effect of osmotic adjustment on root length and dry matter partitioning in sunflower (*Helianthus annuus* L.) under drought stress. *Acta Agric. Scand. Section B. Soil and Plant Sci*., 58(3): 252-260.

Rauf, S., H.A. Sadaqat and A. Naveed. 2008. Effect of moisture stress on combining ability variation for bird resistance traits in sunflower (*Helianthus annuus* L.). *Pak. J. Bot*., 40(3): 1319-1328.

Rauf, S., T.M. Khan, H.A. Sadaqat and A.I. Khan. 2004. Correlation and path coefficient analysis of yield components in cotton (*Gosspium hirsutum* L.). *Int. J. Agri. Biol.,* 6(4): 686-688.

Samani, M.R.K., M.R. Khajehpour and A. Ghavaland. 1999. Effects of row spacing and plant density on growth and dry matter accumulation in cotton on Isfhan. *Iran. J. Agric. Sci.*, 29: 667-679.

Sendouka, S.G., A.G. Sficas, N.A. Fotiadis, A.A. Gagianas and P.A. Gerakis. 1980. Effect of planting density, planting date, and genotype on plant growth and development of cotton. *Agron. J.*, 72: 347-353.

Wells, R. and W.R. Meredith Jr. 1984.Comparative growth of obsolete and modern cotton cultivars. II. Reproductive dry matter partitioning. *Crop Sci.,* 24: 863-868.

Wrather, J.A., B.J. Phipps, W.E. Stevens, A.S. Phillips and E.D. Vories. 2008. Cotton Planting date and plant population effect on yield and fiber quality in the Mississippi Delta. *J. Cotton Sci.,* 12: 1-7.

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