Pak. J. Bot., **42(5): 3569-3576, 2010.**

EARLY AND RAPID FLOWERING COUPLED WITH SHORTER BOLL MATURATION PERIOD OFFERS SELECTION CRITERIA FOR EARLY CROP MATURITY IN UPLAND COTTON

M. KAUSAR NAWAZ SHAH[1*], SAEED A. MALIK[2], NAVEED MURTAZA[3], IHSAN ULLAH[4], H. RAHMAN[5] AND UZMA YOUNIS[6]

[1]Department of Plant Breeding & Genetics, PMAS-Arid Agriculture University, Rawalpindi, Pakistan
[2]Department of Botany, Institute of Pure and Applied Biology, Bahauddin Zakariya, University, Multan, Pakistan, [3]Department of Plant Breeding and Genetics, BZU, Multan, Pakistan
[4]Agricultural Biotechnology Research Institute, Faisalabad, Pakistan
[5]Free Lance Consultant, Agriculture Research & Development, Pakistan
[6]Institute of Pure and Applied Biology, Bahauddin Zakariya, University, Multan, Pakistan

Abstract

In upland cotton, crop maturity is influenced by a number of physiological, phenological, morphological and environmental factors. Selection for this complex trait in segregating populations may be misleading if proper understanding of the direct and indirect effects of these traits is not appropriately understood. Correlation and path analysis techniques were utilized to construct selection criteria to identify early maturing segregants. Results depicted higher genotypic correlations as compared to the phenotypic ones suggesting substantial environmental influence. Earliness index was observed to be negatively correlated with all the traits evaluated except with number of fruiting points on the longest sympodia. Based on path analysis two selection criteria for earliness were evident. First; early and rapid flowering coupled with shorter boll maturation period and the second; low node number of first sympodia coupled with lower number of main stem nodes. Simultaneous improvement in seed cotton yield and earliness of crop maturity required a compromise and determination of a critical point where seed cotton yield and earliness could be maximum.

Introduction

Early crop maturity in cotton is a complex trait influenced by a number of morphological, physiological, phenological and environmental attributes. Since environmental interaction induces a substantial influence on its phenotypic expression, appropriate indirect selection criteria become necessary to facilitate selection procedures in theoretically, every breeding program involving different genotypes, genotypic and external environment. In a breeding population, several interactions including genetic effects of individual genes among themselves and that with external (physical) environment may modify the expression of a particular polygenic trait like early crop maturity. At another level, interaction (direct and indirect effects) of genes controlling several physiological and agronomic traits modifies the phenotypic expression of each other through their relative contributions. The necessity of the present study was further imperative due to the fact that some phonological traits have not been thoroughly investigated under local conditions. For evaluating the nature and magnitude of association between two variables, considered to be interdependent, correlation analysis is used (Steel *et al*., 1997). Further partitioning of correlation coefficients into direct and indirect effects for a certain set of relationships through path analysis can be very helpful to find a casual mechanism lying behind a perceived biological relationship (Kozak *et al*., 2008).

*E-mail: knshah@uaar.edu.pk

Cotton cultivars are classified as early, intermediate or late maturing on the basis of phenological and yield parameters (Solis *et al*., 1989). The major components of earliness included days from sowing to standard flowering date (DSF), vertical flowering interval (VFI), days from sowing to practical flowering date (DPF), plant height, sympodia per plant and the first pick in cotton harvest (PCH1). Plant height, DSF, DPF and sympodia per plant were significantly correlated with each other, and negatively correlated with PCH1 whereas days to 1st flower from sowing provided a reliable estimation of earliness of maturity and the mean maturity date gave the best yield estimate (Chen *et al*., 1991). Shi (1998) indicated that height of the first sympodial node could be used to select for earliness in cotton. Many workers (Iqbal *et al.,* 2003; Wang *et al*., 2004) have reported higher magnitude of genotypic correlation compared to corresponding phenotypic correlation. Soomro *et al*., (2008) indicated positive correlation of yield with bolls per sympodia and sympodia per plant in upland cotton.

The present study was undertaken to determine the correlation mechanism, cause-effect relation and direct and indirect effects which provide the relative importance of each of the causal character to construct selection criteria to identify better early maturing combinations from segregating populations.

Materials and Methods

A field experiment was conducted in 2001 crop season at Cotton Research Institute, Faisalabad. The experimental material included 16 cotton cultivars varying in crop maturity. The experimental design was randomized complete block with three replications. Plot size was three 6-meter long rows, 75cm apart. The plots were hand thinned at the 4 or 5 true leaf stage to maintain uniform crop stand.

Fertilizer was applied @ 150-50-0 (NPK, Kg/ha Full dose of phosphorus was applied at seedbed preparation and nitrogen in three equal splits at seedbed preparation, squaring and flowering. First irrigation was applied after 35days of sowing. Subsequent irrigations continued with 7-15 days interval depending on the weather and crop conditions until the 145^{th} day after sowing. Plant protection measures were adopted as and when necessary. Seed cotton was harvested 130 and 190 days after sowing. At maturity ten competitive plants per plot per treatment per replication were marked at random for data record.

Among Earliness components data were recorded for Earliness Index (%), Days to 50% squaring, Days to 50% flowering, Days to 50% boll opening, Boll maturation period. Among plant morphological traits data were recoded for Height of the main stem (cm), Monopodial branches per plant, Sympodial branches per plant, Fruiting points on longest sympodia, Node of first sympodium, Total nodes on main stem and Height to node ratio. Whereas for yield components data were recorded for Number of bolls per plant, Boll weight (g) and Seed cotton yield per plant (g).

Analysis of genotypic and phenotypic correlation was run following Kwon & Torrie (1964). Genotypic correlation coefficients were tested against their standard errors (Lothrop *et al*., 1985). Phenotypic correlations were tested at n-2 degrees of freedom (df) against the table values of correlation at 5% and 1% level of significance.

Path coefficient analysis was performed according to the method prescribed by Dewey & Lu (1959). The Earliness index was kept as resultant variable (effect) and the remaining fourteen traits as causal variables. The residual effect, which determines how best the causal variables account for the variability of the dependent variable, was estimated following Singh & Chaudhary (1985).

Results

Analyses showed higher magnitude of genotypic correlations as compared to the corresponding phenotypic magnitude (Table 1). Since phenotypic and genotypic correlation coefficients were in a same direction, only genotypic correlation coefficients were the focus of discussion.

Earliness index (EI) showed negative association with all the traits except fruiting points on the longest sympodia (FPLS) though of very low magnitude. High significant negative correlations were exhibited with days to squaring (DSQ), days to boll opening (DBO), days to flowering (DFL), boll maturation period (BMP), number of monopodial branches (MONO), number of main stem nodes (TNOD),), boll weight (BWT) yield per plant (YLD), and bolls per plant (TBOL). Days to flowering (DFL) were positively associated with DSQ, DBO, MONO, YLD, TBOL, BWT, BMP, NNFS, PHT, TNOD and HNR Days to boll opening (DBO) had high positive correlation with BMP, DSQ, MONO, BWT, YLD, TBOL, moderate positive association with TNOD, NNFS and PHT. Days to squaring (DSQ) had moderate to high positive correlations with all the traits studied except for low, negative association with FPLS. Moderate positive correlation coefficients was depicted for BMP with all the traits studied except, negative moderate correlations with FPLS.

Among plant morphological traits, plant height (PHT) showed negative high correlation with earliness index and positive high correlation with TNOD, HNR and YLD. Number of monopodial branches (MONO) had positive correlation with all the traits studied except for negligible negative correlation with FPLS. Number of sympodial branches (SYM) had positive high association estimates with TNOD and PHT whereas it had negative high correlation with earliness index. Node number of first sympodial branch (NNFS) had high positive association with DFL, PHT and negative high correlation with earliness index. Similar correlations were observed for total number of main stem nodes (TNOD), height to node ratio (HNR) and boll weight (BWT). Seed cotton yield per plant (YLD) showed high positive correlation with TBOL, BWT, NNFS, TNOD, MONO, DFL, PHT, DSQ, SYM and HNR.

Path coefficient analysis: Path analysis (Table 2) revealed highest positive direct effect of DBO on earliness index followed by SYM and NNFS. These traits, therefore, appeared facilitating in selecting early maturing genotypes in the present cotton material. TNOD exerted highest negative direct effect on earliness index followed by BMP and DFL.

Days to 50% squaring and earliness index: With significantly negative genotypic correlation coefficient with EI, its direct effect was also negative but low in magnitude. The negative indirect contribution of DSQ towards earliness came through BMP, TNOD and DFL remained predominant despite the positive indirect effects it received through DBO, SYM, NNFS and PHT.

Days to 50% flowering and earliness index: The days to 50% flowering had negative high direct effect on earliness index. It was due to high indirect negative effect through BMP and TNOD despite high positive indirect effect exhibited via DBO, NNFS, SYM, PHT and BWT.

Days to 50% boll opening and earliness index: The genotypic correlation coefficient was significantly high and negative despite high positive direct effect exerted by the days to 50% boll opening on earliness. But the relationship was altered due to high negative indirect effect exhibited via BMP, DFL and TNOD.

Table 1. Estimates of genotypic (upper) and phenotypic correlation coefficients among earliness, yield, and morphological traits.

Parameter	EI	DFL	DBO	DSQ	BMP	PHT	MONO	SYM	FPLS	NNFS	TNOD	HNR	TBOL	BWT	YLD
E.I.	1	-0.96	-0.84	-0.96	-0.87	-0.57	-0.99	-0.59	0.16	-0.60	-0.71	-0.36	-0.77	-0.74	-0.80
		-0.73	-0.80	-0.87	-0.69	-0.54	-0.82	-0.51	0.12	-0.55	-0.64	-0.32	-0.69	-0.63	-0.70
DFL		1	1.097	0.97	1.32	0.53	1.03	0.34	-0.47	0.497	0.49	0.495	0.748	0.896	0.74
			0.83	0.85	0.54	0.38	0.74	0.15	-0.18	0.51	0.37	0.32	0.59	0.53	0.67
DBO			1	0.96	1.06	0.47	0.93	0.24	-0.36	0.44	0.397	0.48	0.64	0.72	0.65
				0.83	0.92	0.40	0.75	0.16	-0.36	0.37	0.30	0.41	0.54	0.67	0.59
DSQ				1	1.07	0.51	0.98	0.597	-0.21	0.37	0.59	0.396	0.63	0.80	0.67
					0.65	0.48	0.79	0.48	-0.11	0.40	0.54	0.33	0.55	0.66	0.61
BMP					1	0.49	0.97	0.19	-0.33	0.46	0.38	0.54	0.65	0.69	0.68
						0.34	0.61	0.14	-0.41	0.20	0.20	0.39	0.40	0.64	0.42
PHT						1	0.53	0.64	0.68	0.72	0.80	0.90	0.69	0.78	0.699
							0.48	0.64	0.56	0.62	0.77	0.84	0.66	0.69	0.63
MONO							1	0.53	-0.27	0.74	0.75	0.29	0.87	0.99	0.95
								0.51	-0.10	0.57	0.65	0.23	0.82	0.64	0.78
SYM								1	0.62	0.40	0.87	0.33	0.49	0.71	0.58
									0.58	0.34	0.87	0.24	0.47	0.54	0.44
FPLS									1	0.13	0.47	0.65	0.06	0.34	0.09
										0.25	0.53	0.34	0.10	0.07	0.06
NNFS										1	0.81	0.46	1.01	0.81	0.97
											0.76	0.29	0.86	0.61	0.87
TNOD											1	0.47	0.87	0.90	0.91
												0.32	0.78	0.69	0.76
HNR												1	0.39	0.54	0.38
													0.37	0.49	0.35
TBOL													1	0.95	1.02
														0.71	0.95
BWT														1	0.94
															0.80
YLD															1

Table 2. Direct (shaded) and Indirect effects of 14 traits related earliness, yield, and morphology.

	DFL	DBO	DSQ	BMP	PHT	MONO	SYM	FPLS	NNFS	TNOD	HNR	TBOL	BWT	YLD	r_g
DFL	-10.1827	27.9801	-0.2742	-18.4033	1.0834	0.1021	3.4179	-0.2136	4.1724	-8.8660	-0.7482	0.7017	1.0032	-0.7293	-0.9565
DBO	-11.1734	25.4954	-0.2701	-14.7478	0.9559	0.0921	2.2989	-0.1658	3.7157	-7.1203	-0.7266	0.6402	0.8080	-0.6470	-0.8448
DSQ	-9.8726	24.2892	-0.2828	-14.9405	1.0414	0.0979	5.9508	-0.0945	3.1428	-10.5270	-0.5990	0.5986	0.8974	-0.6609	-0.9592
BMP	-13.4776	26.9691	-0.3039	-13.9043	0.9889	0.0970	1.8796	-0.1506	3.8771	-6.7514	-0.8098	0.6126	0.7729	-0.6724	-0.8728
PHT	-5.4322	11.9680	-0.1450	-6.7708	2.0308	0.0530	6.3357	0.3130	6.0053	-14.4500	-1.3629	0.6974	0.8763	-0.6915	-0.5729
MONO	-10.4435	23.5301	-0.2781	-13.5543	1.0819	0.0995	5.2852	-0.1229	6.2576	-13.4360	-0.4382	0.8225	1.1345	-0.9356	-0.9973
SYM	-3.4941	6.0715	-0.1689	-2.6237	1.2917	0.0528	9.9609	0.2830	3.3624	-15.5400	-0.4979	0.4887	0.7941	-0.5750	-0.5945
FPLS	4.7385	-9.1874	0.0582	4.5615	1.3848	-0.0266	6.0306	0.5923	1.1099	-8.5050	-0.9808	0.0829	0.3831	-0.0865	0.1555
NNFS	-5.0652	11.2637	-0.1036	-6.4270	1.4640	0.0875	3.9930	0.0607	8.3878	-14.4650	-0.6997	0.9582	0.9046	-0.9623	-0.6033
TNOD	-5.0287	10.0842	-0.1658	-5.2288	1.6346	0.0745	8.6221	0.2416	6.7581	-17.9530	-0.7099	0.8220	1.0342	-0.8973	-0.7122
HNR	-5.0417	12.2255	-0.1121	-7.4514	1.8488	0.0289	3.2818	0.2979	3.8840	-8.4335	-1.5111	0.3673	0.6271	-0.3717	-0.3602
TBOL	-7.6152	16.3315	-0.1793	-9.0196	1.4075	0.0867	4.8837	0.0295	8.5255	-15.6280	-0.5878	0.9443	1.0581	-1.0110	-0.7741
BWT	-9.1275	18.3550	-0.2267	-9.5295	1.5901	0.0988	7.0819	0.1796	6.7790	-16.2040	-0.8235	0.8927	1.1192	-0.9289	-0.7438
YLD	-7.5026	16.6206	-0.1888	-9.4459	1.4314	0.0941	5.7865	0.0526	8.1553	-16.2760	-0.5674	0.9649	1.0639	-0.9898	-0.8012

Boll maturation period and earliness index: BMP showed negative high direct effect on earliness index. Negative indirect effects were mainly inflicted on earliness index through DFL and TNOD despite positive high indirect effect shown via DBO, NNFS and SYM.

Height of main stem and earliness index: Plant height had significant negative genotypic correlation coefficient with earliness index. The direct effect of plant height on earliness was positive but low in magnitude. The positive indirect effect of sizable magnitude via DBO, SYM and NNFS dominated high negative indirect effects via TNOD, BMP, DFL and HNR.

Monopodial branches per plant and earliness index: The MONO showed very low positive direct effect on earliness index despite it had very high, significant and negative genotypic correlation with earliness index. The positive indirect effects contributed via DBO, NNFS, SYM, PHT and BWT were countered well by the negative indirect effects exhibited via BMP, TNOD and DFL.

Sympodial branches per plant and earliness index: The genotypic correlation coefficient between the traits was negative and significant. The direct effect exhibited by SYM on earliness index was positive. Positive indirect effects were mainly exhibited via DBO, NNFS and PHT but all were suppressed by the negative indirect effects exhibited through TNOD, DFL and BMP.

Fruiting points on longest sympodia and earliness index: There existed a very low significant positive correlation between the traits. The direct effect shown by FPLS on earliness was positive but very low. Positive indirect effects were exhibited via SYM, DFL, BMP, NNFS, and PHT whereas negative indirect effects were produced via DBO and TNOD.

Node of first sympodium and earliness index: A high, significant and negative genotypic correlation was exhibited between the traits under discussion. The direct effect of NNFS on earliness was positive. Positive direct effects were also produced via DBO, SYM and PHT on earliness index. The negative indirect effects produced for NNFS were through TNOD, BMP and DFL that in fact made the relationship negative between node number of first sympodia and earliness index.

Total nodes on main stem and earliness index: The genotypic correlation coefficient between these two traits was negative, high and significant. It was mainly contributed by the negative direct effect of TNOD on earliness index and negative indirect effects shown via BMP and DFL, though the positive indirect effects of reasonable magnitude were exhibited via DBO, SYM, NNFS, PHT and BWT.

Height to node ratio and earliness index: Genotypic correlation coefficient was negative and so was the direct effect exerted by HNR on earliness index. TNOD, BMP and DFL produced the negative indirect effects whereas indirect positive effects were produced through DBO, SYM, NNFS and PHT on earliness index.

Number of bolls per plant and earliness index: Though the genotypic correlation coefficient between these traits was negative, TBOL exerted positive direct effect. The negative indirect effects produced through TNOD, BMP, DFL and YLD on earliness index in-fact overpowered the positive indirect effect produced via DBO, NNFS, SYM, PHT and BWT.

Boll weight and earliness index: There existed a negative genotypic correlation between the two traits. The direct effect produced by boll weight on earliness index was positive similarly positive indirect effect was produced through DBO, SYM, NNFS and PHT. But all positive effects were dominated by the negative indirect effects produced through TNOD, BMP and DFL.

Seedcotton yield per plant and earliness index: Significant negative, high genotypic correlation was observed for EI. The direct effect of YLD on earliness index was also high and negative. It was mainly produced via indirect effect through TNOD, BMP and DFL which overcame the positive indirect effects produced via NNFS, SYM, PHT and B wt on earliness index.

Residual effect: The residual effect determines the extent of causal variables responsible for the variability in dependent variable. Residual effect, around 12 percent, showed that causal factors determined 88% of the variability in EI while and only 12% of the variability in earliness index remained unexplored.

Discussion

The magnitude of genotypic correlation coefficients was comparatively higher than that of phenotypic ones explaining that the traits are under strong influence of environmental factors. Similar findings were also reported by Iqbal *et al*., (2003) and Wang *et al*., (2004). Crop maturity depends on a number of morphological and phenological traits. Cotton plant is indeterminate in growth, hence vegetative and reproductive stages move side by side. Number of days taken to flowering is considered as an important determinant of earliness (Chen *et al*., 1991). Initiation of squares infact, marks the entry of plant into reproductive stage. Continued development of new fruiting branches resulting in production of fruiting sites may possibly affect earliness index. This impact can be minimized if the boll maturation period is shorter as earlier maturing cultivars possessed the shortest boll maturation periods (Bednarz & Nichols, 2005).

Flowering interval also needs consideration. Therefore, early and rapid flowering coupled with shorter boll maturation period will help to enhance earliness index.

Node number of first sympodia is also considered important for early onset of squaring and consequently for earliness in cotton (Iqbal *et al*., 2003). Earliness index exhibited negative correlation with all the parameters studied. On the basis of correlation coefficients, it is concluded that all phenological traits i.e., days to squaring, flowering, boll opening and boll maturation period are important determinants of earliness index. Small cylindrical plants with reduced height, TNOD, MONO, FPLS and NNFS, result in early flowering, lower monopodial bolls, lower yield per plant. The possibility of combining high yield with earliness and quality was explored with some deficiencies in performance (Wilson, 1989). Highest yields were shown by the least determinate and slowest-maturing genotypes; yields generally decreased as determinacy increased and rate of maturity accelerated. Except for date for first open boll, components of earliness showed no association with yield (Godoy & Palomo, 1999). Iqbal *et al*., (2006) emphasized on selection for more no. of bolls and boll weight with lower no. of monopodial branches and node of first fruiting branch for simultaneous improvement of earliness and yield. Boll number and boll weight, which has been, reported as most important yield determining factors in cotton (Soomro *et al*., 2008), showed very small positive direct effects on earliness index. A compromise should be reached between yield and earliness, as it seems unlikely to improve a genotype combining high seed cotton yield with earliness (Kaynak *et al*., 2000).

Two selection criteria for earliness in cotton were observed to be important. First based early and rapid flowering coupled with short BMP. The second criteria based on low NNFS coupled with less TNOD of the main stem. Iqbal *et al*., (2006) suggested to use reciprocal recurrent selection method or modified back cross or three- way cross for evolving a superior genotype possessing all the three basic characteristics i.e., earliness, high yield and improved fiber quality

References

Bednarz, C.W. and R.L. Nichols. 2005. Phenological and morphological components of cotton crop maturity. *Crop Science*, 45(4): 1497-1503.

Chen, Z.F., Z.W. Zhang, Z.Y. Li and Y.F. Wang. 1991. Study on the correlation between the earliness of Upland cotton and its yield and fibre quality. *China Cottons*, 5: 16-17.

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

Godoy A.S. and G.A. Palomo. 1999. Genetic analysis of earliness in upland cotton (*Gossypium hirsutum* L.). II. Yield and lint percentage. *Euphytica*, 105(2): 161-166.

Iqbal, M., K. Hayat, R.S.A. Khan, A. Sadiq and N. Islam. 2006. Correlation and path coefficient analysis for earliness and yield traits in cotton (*G. hirsutum* L.). *Asian J. Pl. Sciences*, 5(2): 341-344.

Iqbal, M., M.A. Chang, A. Jabbar, M.Z. Iqbal, M. Hassan and N. Isalm. 2003. Inheritance of earliness and other characters in upland cotton. *Online J. Biol. Sci*., 3(6): 585-390.

Kaynak, M.A., A. Unay, I. Ozkan, H. Basal. 2000. Determination of the heterotic effects and phenotypic correlation of earliness, and agronomical and quality characteristics in cotton (*Gossypium hirsutum*). *Turkish Journal of Agriculture and Forestry*, 24(1): 105-111.

Kozak, M., J. Bocianowski and W. Rybiński, 2008. Selection of promising genotypes based on path and cluster analyses. *J. Agric. Sci*., 146: 85-92.

Kwon, S.H. and J.H. Torrie. 1964. Heritability and interrelationship among traits of two soybean population. *Crop Sci*., 4: 196-198.

Lothrop, J.E., R.E. Akins and O.S. Smith.1985. Variability of yield and yield components in IAPIR grain sorghum random mating population means, variance components and heritibilities. *Crop Sci*., 25: 235-240.

Shi, W.J. 1998. Research on the correlation between earliness and agronomic characters of upland cotton in Xinjiang. *China Cottons*, 25(4): 17-18.

Singh, R.K. and B.D. Chaudhary. 1985. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi, India.

Solis, R.O., R.P. Cabangbang and R.F. Bader. 1989. Phenological and product quantity measures of earliness in cotton (Gossypium hirsutum L.). *Philippine Agriculturist*, 72(3): 279-289.

Soomro, Z.A., A.S. Larik, M.B. Kumbhar, N.U. Khan and N.A. Panhwar. 2008. Correlation and path analysis in hybrid cotton. *Sabrao J. Breed. & Genet*., 40: 49-56.

Steel, R.G.D., J.H. Torrie, D.A. Dickey. 1997. *Principles and Procedures of Statistics: A Biometrical Approach*, p: 666. McGraw-Hill, Columbus, USA

Wang, C., A. Isoda and P. Wang. 2004. Growth and yield performance of some cotton cultivars in Xinjiang, China, an arid area with short growing period. *J. Agron. & Crop Sci*., 190: 177-183.

Wilson, F.D. 1989. Yield Earliness, and Fiber Properties of Cotton Carrying Combined Traits for Pink Bollworm Resistance. *Crop Sci*., 29:7-12.

(Received for publication 25 February 2008)