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Evaluation of yield and yield related traits to determine earliness in cotton (*Gossypium hirsutum* L.)

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ABSTRACT : The present research was carried out with the aim to identify short duration cotton from existing germplasm. Bartlett's earliness index showed that the genotype BC 0335 had the highest (0.95) value which was rated as the early genotype followed by BC 0319 and BC 0366 (0.93). Days to first flowering ranges from 49 (BC 0483, SR/L 36) to 68 (BC 0276, BC 0390) days among the genotypes and first boll opening required 100 (BC 0358) to 141 (BC 0074) days. The genotype SR/L 17 produced 1st sympodial branch at the lowest node number of 5.94 followed by BC 0349 (6.22) and BC 0335 (6.31). The highest and the lowest sympodial branches per plant were found in BC 0382 (24.03) and BC 0294 (12.2), respectively. The genotype BC 0318 (35.67) and BC 0374 (35.64) produced the maximum bolls/plant and boll retention percentage was more than 80 per cent in the genotype BC 0366 (85.80%), CB 14 (82.78%), SR/L 17 (81.53%) and SR/L 26 (81.12%). The genotype BC 0314 had the highest single boll weight (5.96g) which was closely followed by Win All 6 (5.93g). The highest 1st picking percentage (84.75 %) was observed in the genotype BC 0335 and the lowest (43.48 %) in BC 0501. The genotype BC 0476 gave the highest ginning outturn percentage (GOT %) of 45.68, which was closely followed by BC 0482 (44.60%), BC 0119 (44%) and SR 15 (44%). Among 100 genotypes BC 0358 gave the highest yield of 2.84 t/ha with minimum days to boll opening (100 days) indicated the earliest high yielding genotype. Positive and significant correlation was observed between plant height, sympodial branches/plant, secondary fruiting branches/plant, bolls/plant and seed cotton yield indicates that these traits are able to enhance the yield.

Keywords: Cotton (*Gossypium hirsutum* L.), earliness index, GOT, short duration, yield

Cotton is the most important natural fibre in the world for textile manufacture, accounting for about 50 per cent of all fibres used in the textile industry. Cotton is currently the leading plant fibre crop worldwide and is grown commercially in the temperate and tropical regions of more than 50 countries. The major countries of production include USA, India, China, the Middle East and Australia. Cotton is one of the important cash crops and the main raw materials of textile industry in Bangladesh. It is commonly known is *kapas tula* in Bangladesh. It is primarily cultivated for its lint, which is spun into yarn. Yarn is used for textile and several industrial uses. Raw cotton is also used for medical and surgical purposes. Around 4-5 per cent of the national requirement is fulfilled through the local production and remaining 95-96 per cent is fulfilled by importing raw cotton from USA (40%), CIS (35%), Australia,

Pakistan, South Africa and other cotton producing countries (25%) (Hamjah and Chowdhury, 2014).

Bangladesh's cotton consumption is expected to almost double by 2022, strongly retaining its position of world's second largest cotton importers. Significantly cotton will contribute in the food security of Bangladesh if there is an increase in production. Short duration cotton variety will enhance production of cotton by enhancing acreage of cotton. Cotton can play major role in the national economy by saving foreign exchange and by generating direct and indirect employment in Agricultural and Industrial sectors. The Cotton Development Board (CDB) supports cotton production by research and testing new technologies, such as imported hybrid seeds, conducting extension services, and supplying quality seeds. In Bangladesh, cotton is generally grown as a rain fed crop. Two types of cotton are grown in Bangladesh namely; Upland cotton (*Gossypium hirsutum*) and Hill cotton (*Gossypium arboreum*). American cotton is cultivated in the South Western region, Northern region and Central region covering more than 32 districts out of 61 plain districts of Bangladesh.

Cotton earliness is a quantitative trait which is mainly affected by genotype and environment of crop (Kassianenko *et al.,* 2003). Various plant characteristics have been used to determine earliness in cotton (Ahmad *et al.,* 2008; Baloch *et al.,* 2014) estimated that one node decrease in sympodial branch matures the cotton crop by approximately 4 to 7 days earlier and determined that short duration cottons set fruits at 4^{th} or 5^{th} nodes while long duration varieties set them at 8^{th} or 9^{th} node. Several other workers (Baloch and Baloch, 2004) have reported strong relationship between early maturity and lower sympodial branch node number and sympodial branch length.

Cotton is mostly cultivated as sole crop, but farmers are intended to grow three or more crops from the same land. Due to long duration (6-7 months) cotton can't be fixed in the exiting cropping pattern. The achievement of earliness is a basic breeding objective in upland cotton (Braden and Smith, 2004). Earliness in cotton can avoid yield losses due to seasonal threat of biotic and abiotic stresses and increase in economic return by reducing input cost (Singh, 2004). Another benefit of growing early maturing cotton varieties is the prerequisite of proper time for rotation of other crops (Ali *et al.,* 2003). Therefore, cultivar selection is the key factor in any cropping system (Nichols *et al.,* 2004).

Short duration cotton varieties are desirable for a number of reasons as they require relatively less input like fertilizer and irrigation and also use less labour. Therefore, early maturing varieties provide comparatively increased economic returns on account of reduced cost of inputs and crop management. Short season cottons are also of immense importance in Bangladesh because other crops succeed cotton, thus fitting very well in cropping pattern. So it is necessary to develop short duration cotton varieties to increase the interest of the farmer and the yield of cotton. Various plant characteristics have been used to determine earliness in cotton. Considering above facts, this research was conducted with the objective to identify and characterize short duration cotton genotypes.

MATERIALS AND METHODS

The experiment was carried out at the experimental field of Cotton Research, Training and Seed Multiplication Farm, Cotton Development Board (CBD), Sreepur, Gazipur during the cropping season 2015-2016. The experimental field belongs to Salna series representing the Shallow Red Brown Terrace soil within AEZ number 28 in Bangladesh soil classification system which fall under Inceptisols in Soil Taxonomy. The soil was silty clay loam in nature and pH 6.5 in the surface. The experimental site is situated in the sub-tropical climate zone, characterized by heavy rainfall during the months from May to September and scantly rainfall in the rest of the year. The healthy and disease free seeds of 100 genotypes were used as experimental materials, available in the Gene Bank of Cotton Development Board (CDB) for assessing earliness in cotton. The seeds were sown on 30th July 2015 (According to CDB, recommended time for sowing cotton seed is 1st July to 15th August). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The plot size was 12.15 m^2. There were three rows/plot and row to row distance was 90 cm. Each row had 10 plants and plant to plant distance was 45 cm. All intercultural practices were done according to CDB standard. For data collection, sampling was done by selecting random plants from the plots. Data were recorded on the following characters: node number bearing first sympodial branch (NFB), monopodial branches/plant, sympodial branches/plant, secondary fruiting branches/ plant, plant height (cm) was measured during harvesting and leaf shape and colour, days to squaring, days to flowering, days to first boll opening, flowers/plant, bolls/plant, single boll weight, first picking percentage and seed cotton yield/plant (kg) was measured during different growth stages of plants. Earliness index was calculated based on Bartlett's earliness index and ginning outturn (GOT %) [(Weight of lint/ Weight of seed)*100] was measured with LUMUS saw gin in the laboratory CDB, Gazipur. Maturity was defined when plants from all the plots opened cotton bolls and ready for harvesting. The collected data were statistically analyzed. Mean for each character has been calculated and analysis of variance (ANOVA) for each of the character was performed with the help of computer package, Statistix 10. The mean square (MS) at error and phenotypic variances were estimated.

RESULTS AND DISCUSSION

The genotypes of cotton differed significantly for plant height (cm), node number bearing first sympodial branch (NFB), monopodial branches / plant, secondary fruiting branches / plant, days to squaring, days to flowering, days to boll opening, flowers / plant and bolls / plant, single boll weight (g) and seed cotton yield (t/ha) except sympodial branches / plant (Table 1). Mean performance of 100 genotypes of cotton for different agronomic traits related with seed cotton yield and earliness in cotton are discussed character wise as follows:

Plant height (cm) : In cotton, shorter plant height is desirable. In this experiment it was observed that plant height ranged from 107

Table 1. Mean squares for various earliness and yield contributing traits in cotton genotypes

Sources of Variation	df	Plant height	NFB	Monopodial branches (no.)	Sympodial branches (no.)	Secondary FB	Days to squaring	Days to flowering	Days to boll opening	Flower/ plant (no.)	Boll/ Plant (no.)	Single Boll wt.(g)	Yield (t/ha)
Replication	2	616.67	1.258	1.514	44.01	49.50	0.043	5.763	0.653	46.09	27.12	34.43	0.007
Genotype	99	551.31**	0.598**	0.531**	16.95ns	16.63**	47.22**	41.21**	245.58**	58.27**	49.57**	42.66**	0.185**
Error	198	89.40	0.248	0.232	13.12	5.22	6.141	6.178	6.108	25.91	21.03	1.81	0.032

** indicates significant at 1% level of significance; ns= non-significant.

Table 2. Mean performance for 11 important traits related to earliness and yield of 20 selected genotypes of cotton

Sl No.	Accession Number	NFB	Mono-podial branch (no.)	Sym-podial branch (no.)	Plant height (cm)	Days to flowering	Days to boll opening	Bolls/ plant (no.)	Single boll weight (g)	1st Picking (%)	Seed cotton yield (t/ha)	GOT (%)	Earliness Index
1	BC 0002	7.19	1.4	14.9	129.55	52	114	31.2	5.67	66.09	2.37	35.89	0.85
2	BC 0111	8.00	0.4	18	144.72	55	106	28.3	4.51	75.60	1.20	38.50	0.90
3	BC 0119	6.58	1.5	17.8	153.11	52	108	24.4	4.41	72.46	0.85	44.00	0.87
4	BC 0289	6.92	1.8	13.2	130.83	59	114	22.7	5.63	74.77	2.20	33.60	0.90
5	BC-0304	7.31	0.1	14.9	115.80	57	110	20.9	5.66	54.90	2.10	37.39	0.80
6	BC 0305	6.69	0.5	15.9	120.92	56	110	24.9	5.71	51.19	2.25	38.34	0.78
7	BC 0319	6.72	1.2	14.7	113.28	62	114	23.5	4.67	80.88	2.24	37.65	0.92
8	BC 0332	6.56	1.8	14.6	116.19	58	110	19.9	4.91	71.43	2.02	33.77	0.89
9	BC 0333	7.19	0.4	16.7	124.75	57	107	25	5.16	68.52	2.22	39.90	0.88
10	BC 0337	7.19	0.1	17.3	125.86	58	107	28.7	5.62	68.00	2.06	33.49	0.89
11	BC 0349	6.22	1.0	15.6	107.25	52	104	23.6	5.00	72.48	2.24	35.90	0.89
12	BC 0358	7.42	0.9	14.9	114.47	52	100	23.8	5.04	59.42	2.84	35.50	0.79
13	BC 0366	7.31	0.9	15.9	135.44	57	106	35.1	4.69	80.12	2.13	33.54	0.93
14	BC 0378	7.47	0.6	16	129.50	58	101	26.2	5.75	75.00	2.30	40.00	0.89
15	BC 0382	7.08	1.2	24	142.56	60	110	30.2	5.86	67.27	2.26	34.90	0.85
16	BC 0383	6.83	1.0	16.2	130.80	57	104	32.7	5.41	72.90	2.20	34.36	0.88
17	BC 0386	6.58	0.7	15.6	128.53	63	130	26.6	5.87	73.09	2.48	32.15	0.90
18	CB 10	6.58	0.6	14.7	117.31	51	109	26.2	5.70	59.24	1.74	36.46	0.82
19	SR 15	7.31	0.2	17	140.31	55	106	33.3	5.27	47.06	1.75	44.00	0.76
20	Win all 6	7.39	1.0	15.2	121.36	54	124	29.5	5.93	66.12	1.99	44.00	0.87
Mean*	**—**	**7.05**	**0.83**	**15.67**	**131.21**	**55.59**	**117.12**	**25.96**	**5.29**	**65.19**	**2.04**	**38.17**	**0.86**
Max*	—	8.22	2.00	24.03	176.97	68.00	141.00	35.67	5.95	84.75	2.84	45.68	0.95
Min*	—-	5.94	0.10	12.20	107.25	49.00	100.00	16.11	4.33	43.48	0.85	31.00	0.76

* Indicates values taken from mean performance of 100 genotypes

to 177 cm (Table 2). Total range was divided into three intervals whereas, the lowest range (107 to 120 cm) consisted of 20 genotypes was short stature (Table 3). The lowest plant height was observed in BC-0349 (107.25 cm) followed by CB-10 (107.97 cm) and the highest was observed in BC-0369 (176.97 cm) among all the studied genotypes. According to Farooq *et al.,* (2013) plant height had positive correlation and positive indirect effects of on seed cotton yield. Some other scientists (Khan *et al.,* 2009; Batool *et al.,* 2010) also reported positive correlation between plant height and yield and noted that plant height contributed 70 per cent of the total variability for seed cotton yield.

Node bearing first sympodial branch (NFB) : Node number for the first fruiting branch is one of the most reliable and practical morphological measures of earliness in cotton genotypes. The earliness of crop maturation is affected more by the position of first sympodial branch than by other morphological characters (Iqbal *et al.,* 2003a). The genotypes showed variation from 5.94 to 8.22 (Table 2). Among the 100 genotypes SR/L-17 produced 1st sympodial branch at the lowest node 5.94 followed by BC-0349 and BC-0335 with respective value of 6.22 and 6.31, whereas the other genotypes produced first sympodial branch node in the range of 6.4 to 8.2. Theoretically, it is assumed that lower node number which form 1st sympodial branch is highly correlated with earliness (Baloch and Veesar, 2007). Baloch and Baloch (2004) also found strong relationship between early maturity and lower sympodial branch node number. In cotton, one node decrease in sympodial branch matures the crop by approximately 4 to 7 days earlier. Several other workers (Ali *et al.,* 2003; Panhwar *et al.,* 2010; Shakeel *et al.,* 2011 and Habib *et al.,* 2013) have also reported strong relationship between lower sympodial branch node number and early maturity in cotton.

Monopodial branches / plant : Cotton plants grow with a monopodial vegetative, main stem and lateral monopodial and sympodial fruiting branches. Short duration genotypes were characterized by minimum spreading of their vegetative branches. It was observed that mean

Table 3. Performance of 100 genotypes of cotton for plant height (cm)

Sl No.	Range	Accession No.
1.	107 – 120	BC 0113, BC 0231, BC 0232, BC 0292, BC 0293, BC 0301, BC 0304, BC 0306, BC 0319, BC 0332, BC 0349, BC 0358, BC 0475, BC 0483 BC 0496, BC 0505, CB 10, CB 9, SR/L 51, SR/L 56
2.	120.01 – 153	BC 0002, BC 0037, BC 0073, BC 0074, BC 0075, BC 0111, BC 0168, BC 0211, BC 0236, BC 0244, BC 0259, BC 0270, BC 0272, BC 0273, BC 0278, BC 0279, BC 0281, BC 0283, BC 0286, BC 0289, BC 0291, BC 0294, BC 0295, BC 0303, BC 0305, BC 0308, BC 0314, BC 0322, BC 0333, BC 0335, BC 0337, BC 0353, BC 0354, BC 0355, BC 0359, BC 0362, BC 0366, BC 0372, BC 0374, BC 0375, BC 0376, BC 0378, BC 0382, BC 0383, BC 0386, BC 0390, BC 0469, BC 0470, BC 0476, BC 0480, BC 0481, BC 0482, BC 0492, BC 0493, BC 0495, BC 0497, BC 0501, BC 0502, CB 12, CB 13, CB 14, SR/L 14, SR/L 17, SR/L 26, SR/L 30, SR/L 36, SR/L 47, SR/L 55, SR 15, Win all 5, Win all 6
3.	153.01– 177	BC 0112, BC 0119, BC 0276, BC 0312, BC 0316, BC 0318, BC 0331, BC 0369, SR/L 42

monopodial branches / plant ranged from 0.1 to 2.0 among 100 genotypes (Table 2) and usually unproductive in case of cotton. The genotypes BC-3004, BC-0337 and BC-0470 exhibited the lowest (0.1) estimates for vegetative branches / plant (Table 4). Reduced lateral monopodial branches that are formed before sympodial fruiting branches, resulting an earlier onset flowering. On the other hand, monopodial branches / plant and ginning out turn had a negative effect on yield (Iqbal *et al.,* 2003b).

Sympodial branches / plant : Sympodial branch is one the most important yield contributing parameters as cotton boll is produced on that branch. Sympodial branches / plant ranged from 12 to 24 among the genotypes (Table 2). The highest range after dividing whole range into three was found 17 to 24 which consisted of 14 genotypes (Table 5). The highest and the lowest primary fruiting branches / plant were found in BC 0382 (24.03) and BC 0294 (12.2), respectively. Positive correlation and positive indirect effects of sympodials indicate that this trait will enhance the seed cotton yield (Farooq *et al.,* 2013). Higher sympodial branches / plant and boll weight had the highest positive direct effect on yield (Iqbal *et al.,* 2003b).

Days to first squaring : It is assumed that a variety which takes minimum days to set 1st square will also be earlier in bolls setting and opening thus will be the early maturing variety. The days taken to set 1st squaring ranged from 35 to 54 days. However, BC-0481, SR/L-26 took minimum of 35 days followed by BC-0493, SR/L-14 and SR/L-56 (36 days) to set 1st square whereas BC-0390 took a maximum of 54 days (Table 2). Baloch and Veesar (2007) reported that early squaring and boll setting contributed significantly towards early maturity.

Days to first flowering : Days to first flower is not directly considered as yield component but days taken to first flower after planting of the crop would ultimately influence the opening of bolls, thus helps in determining the earliness in maturity (Baloch and Veesar, 2007). Saeed and Kausar (2005) also reported that earliness was measured in terms of flowering

Table 4. Performance 100 genotypes of cotton for monopodial branch

Sl No.	Range	Accession No.
1.	0.1 0.5	BC 0037, BC 0075, BC 0111, BC 0270, BC 0273, BC 0303, BC 0304, BC 0305, BC 0306, BC 0308, BC 0322, BC 0333, BC 0337, BC 0353, BC 0374, BC 0376, BC 0469, BC 0470, BC 0483, SR/L 14, SR/L 42, SR/L 47, SR/L 51, SR/L 55, SR/L 56, SR 15
2.	0.6 1.0	BC 0113, BC 0168, BC 0231, BC 0236, BC 0259, BC 0272, BC 0278, BC 0279, BC 0283, BC 0291, BC 0292, BC 0293, BC 0294, BC 0295, BC 0301, BC 0316, BC 0331, BC 0349, BC 0354, BC 0355, BC 0358, BC 0362, BC 0366, BC 0369, BC 0372, BC 0378, BC 0383, BC 0386, BC 0390, BC 0475, BC 0476, BC 0480, BC 0481, BC 0495, BC 0497, BC 0501, BC 0502, BC 0505, CB 10, CB 12, CB 13, CB 14, CB 9, SR/L 17, SR/L 26, SR/L 30, Win all 5, Win all 6
3.	1.1 2.0	BC 0002, BC 0073, BC 0074, BC 0112, BC 0119, BC 0211, BC 0232, BC 0244, BC 0276, BC 0281, BC 0286, BC 0289, BC 0312, BC 0314, BC 0318, BC 0319, BC 0332, BC 0335, BC 0359, BC 0375, BC 0382, BC 0482, BC 0492, BC 0493, BC 0496, SR/L 36

Table 5. Performance of 100 genotypes of cotton for sympodial branch

Sl No.	Range	Accession No.
1.	24 17	BC 0073, BC 0111, BC 0112, BC 0119, BC 0270, BC 0312, BC 0316, BC 0318, BC 0331, BC 0337, BC 0369, BC 0374, BC 0382, SR 15
2.	16.9 15	BC 0037, BC 0074, BC 0075, BC 0168, BC 0211, BC 0231, BC 0232, BC 0272, BC 0276, BC 0279, BC 0281, BC 0286, BC 0291, BC 0292, BC 0295, BC 0303, BC 0305, BC 0306, BC 0308, BC 0314, BC 0322, BC 0333, BC 0335, BC 0349, BC 0353, BC 0354, BC 0359, BC 0362, BC 0366, BC 0372, BC 0375, BC 0376, BC 0378, BC 0383, BC 0386, BC 0390, BC 0475, BC 0476, BC 0482, BC 0493, BC 0497, CB 12, CB 14, SR/L 14, SR/L 17, SR/L 26, SR/L 30, SR/L 36, SR/L 42, SR/L 47, SR/L 55, Win all 5, Win all 6
3.	14.9 12	BC 0002, BC 0113, BC 0236, BC 0244, BC 0259, BC 0273, BC 0278, BC 0283, BC 0289, BC 0293, BC 0294, BC 0301, BC 0304, BC 0319, BC 0332, BC 0355, BC 0358, BC 0469, BC 0470, BC 0480, BC 0481, BC 0483, BC 0492, BC 0495, BC 0496, BC 0501, BC 0502, BC 0505, CB 10, CB 13, CB 9, SR/L 51, SR/L 56

time of cotton. The observed data ranges from 49 to 68 days for flowering. Dhivya *et al.,* (2014) also observed cotton genotypes with minimum (50 days) and maximum days (65) to first flowering, respectively, among 54 cotton genotypes which is close to results found in this experiment. Total range was divided into three intervals and the lowest range was 49-53 days which consisted of 30 among 100 genotypes (Table 2). The genotypes BC 0483 and SR/L-36 took minimum days (49) to first flower followed by BC 0281, BC 0481, and SR/L 56, which set first flower 50 days after sowing (Table 6).

According to Habib *et al.,* (2013) the genotypes were considered as early maturing which take less days to first flower (41 and 45 days). It is normally assumed that fewer the days taken to produce first flower the earliest is the boll setting and opening hence earlier the variety. Lesser the days to first flower from sowing date, the earlier would be the cotton cultivar maturity (Saleem *et al.,* 2009). Ali *et al.,* (2003) also reported positive linkage between first flower and earliness. Several other workers (Ali *et al.,* 2003a; Ahmad *et al.,* 2008; Panhwar *et al.,* 2010) have also reported strong relationship between days to first flowering and earliness in cotton.

Days to first boll opening : Boll opening is also considered as an important character to quantify cotton varieties for earliness. Days to first ball opening required 100 to 141 days among all the genotypes (Table 2). According to Shakeel *et al.,* (2011) days to 1st boll opening for early genotypes ranged from 91.17 to 106.83 days. Again, for easy understanding total range was divided into three intervals. The lowest range (100-110 days) consisted of 25 genotypes and the highest range consisted of 39 genotypes (Table 7). Among them the top ranker BC 0358 needs minimum (100) days to ball opening, followed by BC 0354, BC 0359, BC 0369 and BC 0378, each of which required 101 days to open boll after sowing. Thus, these five genotypes could be considered as early maturing. The consistent performance in terms of boll opening and their effect on seed cotton yield / plant have been reported in upland cotton. In a study of 13 upland cotton genotypes, the strains which

exhibited great potential for earliness and yield, have more boll opening percentage at 120 DAP (Ahmad *et al.,* 2008).

Bolls / plant : The total bolls formed by the each plant determines the yield potential of a genotype and is considered as major yield component and having strong relationship with seed cotton yield. Among the yield components, bolls / plant are the key independent component and play prime role in managing seed cotton yield. Open bolls had the highest direct effect on lint yield/plant. The genotype BC 0318 (35.67) and BC 0374 (35.64) produced the maximum bolls / plant followed by SR/L 30(34.78) and SR 15 (34.28), while genotype SR/L 51 formed minimum bolls (16.11). The production of earlier cotton might result from increasing the early bloom or from broadening the peak flower for the boll set (Baloch and Baloch, 2004). Positive correlation and positive indirect effects of boll number on seed cotton yield is an indicative that improvement in these traits will enhance the yield (Farooq *et al.,* 2013). Rao and Mary (1996) evaluated different *G. hirsutum* cultivars for yield and other economic traits and observed significant variations for boll number and observed direct positive impact on yield. Khan *et al.,* 2009 also reported that variable bolls / plant in upland cotton genotypes and exhibited very high positive correlation with seed cotton yield.

Per cent boll retention : Percentage of boll retained was calculated from the flowers and bolls / plant. The flowers / plant ranged from 50.88 to 85.80 among 100 genotypes (Table 2). Boll retention percentage was more than 80 per cent in the genotype BC 0366 (85.80%), CB 14 (82.78%), SR/L 17 (81.53%) and SR/L 26 (81.12%).

Single boll weight (g) : Boll weight is second major yield component after bolls / plant and have a greater contribution in enhancement of yield. This trait has direct influence on seed cotton yield because it is assumed that as the boll weight increases, the seed cotton yield would also increase. A significant positive correlation was observed between the average bolls / plant, mean boll weight and seed cotton yield / plant (Zende *et al.,* 2003). The observed data showed that single boll weight ranges from 4.33 to 5.96g among different 100 genotypes (Table 2). Total range was again divided into three intervals. The highest interval of range was 5.50 to 5.96 g that consists of 35 genotypes (Table 8). The genotype BC 0314 has the highest single boll weight of 5.96 g among 100 genotypes followed by Win All 6 (5.93 g) and BC 0386 (5.87 g). The genotype BC 0113 has the minimum single boll weight of 4.33g. Fan *et al.,* (1989) found that boll size; boll weight and fibre properties were positively correlated with flowering date and boll retention. Soomro *et al.,* (2008) also observed significant variations for boll weight and revealed highly positive effect on yield.

Hence, cotton breeders had always made compromise to evolve cultivars with medium boll size, still having an acceptable level of crop maturity and yield. In past studies, majority of the genotypes had boll weight of around 3.00 g and indicated potential for high yield (Ahmad *et al.,* 2008). Early maturing cottons although had comparatively smaller or moderate bolls but produced better yields, may be due to setting and picking more bolls at early stages of boll opening

Table 6. Performance of 100 genotypes of cotton for days to flowering

Sl No.	Range	Accession No.
1.	49-53	BC 0002, BC 0037, BC 0073, BC 0119, BC 0232, BC 0259, BC 0270, BC 0272, BC 0273, BC 0281, BC 0349, BC 0354, BC 0358, BC 0369, BC 0476, BC 0481, BC 0482, BC 0483. BC 0492, BC 0493, BC 0497, CB 10, CB 13, CB 14, SR/L 17, SR/L 26, SR/L 30, SR/L 36, SR/L 42, SR/L 56
2.	54 - 57	BC 0074, BC 0075, BC 0111, BC 0113, BC 0168, BC 0211, BC 0231, BC 0236, BC 0244, BC 0283, BC 0293, BC 0295, BC 0301, BC 0305, BC 0333, BC 0355, BC 0359, BC 0362, BC 0366, BC 0374, BC 0375, BC 0376, BC 0383, BC 0469, BC 0470, BC 0475, BC 0480, BC 0495, BC 0496, BC 0501, BC 0502, BC 0505, BC 3004, CB 12, CB 9, SR/L 14, SR/L 47, SR/L 51, SR/L 55, SR 15, Win all 5, Win all 6
3.	58 - 68	BC 0112, BC 0276, BC 0278, BC 0279, BC 0286, BC 0289, BC 0291, BC 0292, BC 0294, BC 0303, BC 0306, BC 0308, BC 0312, BC 0314, BC 0316, BC 0318, BC 0319, BC 0322, BC 0331, BC 0332, BC 0335, BC 0337, BC 0353, BC 0372, BC 0378, BC 0382, BC 0386, BC 0390

Table 7. Performance of 100 genotypes of cotton for days to boll opening

Sl No.	Range	Accession No.
1.	100 - 110	BC 0111, BC 0119, BC 0281, BC 0291, BC 0304, BC 0305, BC 0332, BC 0333, BC 0337, BC 0349, BC 0353, BC 0354, BC 0358, BC 0359, BC 0366, BC 0369, BC 0376, BC 0378, BC 0382, BC 0383, CB 10, CB 12, CB 13, CB 14, SR 15
2.	111 - 120	BC 0002, BC 0113, BC 0168, BC 0231, BC 0232, BC 0236, BC 0244, BC 0259, BC 0270, BC 0272, BC 0278, BC 0279, BC 0283, BC 0286, BC 0289, BC 0292, BC 0293, BC 0294, BC 0295, BC 0301, BC 0303, BC 0306, BC 0308, BC 0312, BC 0314, BC 0316, BC 0318, BC 0319, BC 0322, BC 0335, BC 0355, BC 0362, BC 0372, BC 0374, BC 0375, CB 9
3.	121 - 141	BC 0037, BC 0073, BC 0074, BC 0075, BC 0112, BC 0211, BC 0273, BC 0276, BC 0331, BC 0386, BC 0390, BC 0469, BC 0470, BC 0475, BC 0476, BC 0480, BC 0481, BC 0482, BC 0483, BC 0492, BC 0493, BC 0495, BC 0496, BC 0497, BC 0501, BC 0502, BC 0505, SR/L 14, SR/L 17, SR/L 26, SR/L 30, SR/L 36, SR/L 42, SR/L 47, SR/L 5,1 SR/L 55, SR/L 56, Win all 5, Win all 6

as compared to late maturing cotton cultivars (Baloch and Baloch, 2004). Singh (2004) also reported that moderate boll weight (3.5 to 4.0 g) was a reliable criterion for developing early maturing cotton cultivars with desirable seed cotton yield.

First picking percentage : Data in Table 9 present mean performances of 1st picking percentage of different genotypes. The observed data showed that 1st picking percentage ranged from 43.48 to 84.75 per cent. After dividing the total range into three intervals it was found that, the highest range (71.00 to 84.75 %) consisted of 26 genotypes and the lowest range (43.48 to 57.24%) consisted of 19 genotypes.

Earliness index : As per the Bartlett's earliness index, the higher the value of the index the earlier would be the genotype. Earliness index was calculated based on Bartlett's earliness index formula —

$$\text{Earliness index} = \frac{P_1 + (P_1+P_2) + (P_1+P_2+P_3)}{n\,(P_1+P_2+P_3)}$$

Where;

P_1 = Weight of seed cotton at first picking

P_2 = Weight of seed cotton at second picking

P_3 = Weight of seed cotton at third picking

n = Total picking.

The data obtained from the analysis showed that the genotype BC 0335 had the highest (0.95) value of earliness index indicated that this genotype rated as the early genotypes followed by BC 0319 and BC 0366 (0.93). The genotype SR 15 was observed as late genotype among the all the genotypes having the lowest value (0.76) of earliness index (Table 2).

Ginning outturn (GOT %) : Ginning outturn percentage (GOT %) among 100 genotypes ranged from 31 to 45.68 per cent (Table 2). The genotype BC 0476 gave the highest GOT (%) of 45.68, which was closely followed by BC 0482 (44.60%), BC 0119 (44%) and SR 15 (44%). The lowest GOT was found in BC 0301 (31%). Ginning outturn range from 33 40 per cent in American cotton genotypes. Comparing with this statement, present experimental materials showed better performance. On the other hand, Iqbal *et al.,* (2003b) reported that ginning outturn had a negative effect on yield.

Seed cotton yield (t/ha) : The observed data on total yield ranges from 1.20 to 2.84 (t/ha) 100 different genotypes under study. After dividing whole range into three it was found that the highest range (2.20 to 2.84 t/ha) consists of 23 genotypes (Table 2). Results showed that among 100 genotypes BC 0358 gave the highest yield of 2.84 t/ha with minimum days to boll opening (100 days) (Table 10). Present results are in consonance with those of Baloch and Veesar (2007) and Panhwar *et al.,* (2010), who reported that early maturing cotton cultivars also produced better yields. It was followed by BC 0386 and BC 0335 which gives seed cotton yield of 2.48 and 2.43 ton/ha respectively. In another study, Ahmad *et al.,* (2008) reported that the strains which showed consistent performance in terms of days taken to set first flower, first sympodial branch node number, boll opening and seed cotton yield / plant were early maturing with good yield potential. Positive correlation and positive indirect effects of sympodials, boll number and plant height on seed cotton yield is an indicative that improvement in these traits will enhance the yield (Farooq *et al.,* 2013).

Cotton earliness is a quantitative trait which is mainly affected by environment and crop genotype (Kassianenko *et al.,* 2003). Development of early maturing cotton varieties now a day has become one of the important objectives of cotton breeders world over because of many reasons, such as short duration cotton cultivars can avoid yield losses that occur due to diseases, insect pest (particularly bollworms) unfavorable and weather conditions (Singh, 2004). The growing of early maturing cotton cultivars has an advantage of proper time for rotation of other crops allowing timely sowing of wheat in cotton-wheat-cotton cropping system in different countries (Ali *et al.,* 2003). Late maturity of cotton also causes poor fiber quality. Moreover, the short duration cotton genotypes are economical regarding cost of production because early maturing cultivars evade from

Table 8. Performance of 100 genotypes of cotton for single boll weight (g)

Sl No.	Range	Accession No.
1.	5.96 – 5.50	BC 0002, BC 0074, BC 0211, BC 0232, BC 0244, BC 0289, BC 0295, BC 0301, BC 0304, BC 0305, BC 0306, BC 0314, BC 0337, BC 0355, BC 0362, BC 0375, BC 0378, BC 0382, BC 0386, BC 0390, BC 0475, BC 0483, BC 0492, BC 0493, BC 0501, BC 0505, CB 10, CB 14, CB 9, SR/L 17, SR/L 30, SR/L 36, SR/L 51, SR/L 56, Win all 6
2.	5.49 – 5.00	BC 0259, BC 0270, BC 0272, BC 0273, BC 0276, BC 0279, BC 0281, BC 0283, BC 0286, BC 0291, BC 0292, BC 0293, BC 0294, BC 0316, BC 0322, BC 0333, BC 0335, BC 0349, BC 0353, BC 0354, BC 0358, BC 0359, BC 0372, BC 0374, BC 0376, BC 0383, BC 0469, BC 0476, BC 0480, BC 0481, BC 0482, BC 0495, BC 0496, BC 0497, BC 0502, CB 12, CB 13, SR/L 14, SR/L 26, SR/L 42, SR 15, Win all 5
3.	4.99 – 4.33	BC 0037, BC 0073, BC 0075, BC 0111, BC 0112, BC 0113, BC 0119, BC 0168,BC 0231, BC 0236, BC 0278, BC 0303, BC 0308, BC 0312, BC 0318, BC 0319 , BC 0331, BC 0332, BC 0366, BC 0369, BC 0470, SR/L 47, SR/L 55

biotic and abiotic risks (Anjum *et al.,* 2001). The commonly used definition of earliness is the proportion of the total crop yield that is produced by the time of first picking. Indirect selection for early maturity could be possible by selecting the genotypes having lower node 1st sympodial branch, boll maturation period, height of 1st sympodial branch and significant negative correlation with earliness index (Rauf *et al.,* 2005). Two preliminary indicators (main stem node first sympodial branch and days taken to open first flower) are reported to be reliable and efficient for predicting the earliness of cotton genotype (Saira *et al.,* 2002). Number of nodes to the first fruiting branch, plant height, days to first square, days to first flower and date of first open boll can be used for efficient selection of early genotypes.

Correlation Coefficient : Plant height showed significant positive correlation with seed cotton yield / plant (Table 11). According to Farooq *et al.,* (2013) plant height have positive correlation with seed cotton yield. Khan *et al.,* (2009) and Batool *et al.,* (2010) also reported positive correlation between plant height and seed cotton yield. The total bolls formed by the each plant determines the yield potential of a genotype and is considered as major yield component and having strong relationship with seed cotton yield. Among the yield components, bolls / plant are the key independent component and play prime role in managing seed cotton yield. Khan *et al.,* (2009) and Akter (2016) also reported that variable bolls / plant in upland cotton genotypes and exhibited very high positive correlation with seed cotton yield. Bolls/plant showed significant positive correlation with seed cotton yield (Table 11). Positive correlation of boll number on seed cotton yield is an indicative that improvement in these traits will enhance the yield (Farooq *et al.,* 2013).

CONCLUSION

Considering earliness and other yield contributing characters 20 cotton genotypes are identified as short duration with high yield potential and need to be further evaluation for future breeding program. The selected genotypes were BC 0002, BC 0111, BC 0119, BC 0289, BC 0304, BC 0305, BC 0319, BC 0332, BC 0333, BC

Table 9. Performance of 100 genotypes of cotton for first picking (%)

Sl No.	Range	Accession No.
1.	84.75 – 71.00	BC 0075, BC 0111, BC 0113, BC 0119, BC 0236, BC 0244, BC 0259, BC 0270, BC 0289, BC 0278, BC 0283, BC 0286, BC 0319, BC 0331, BC 0332, BC 0335, BC 0349, BC 0355, BC 0362, BC 0366, BC 0372, BC 0378, BC 0383, BC 0386, BC 0480, SR/L 47
2.	70.99 – 57.25	BC 0375, BC 0390, BC 0492, BC 0295, BC 0358, BC 0475, BC 0276, BC 0502, BC 0505, BC 0322, BC 0482, BC 0495, BC 0314, BC 0112, BC 0493, BC 0292, BC 0074, BC 0303, BC 0211, BC 0281, BC 0168, BC 0359, BC 0312, BC 0231, BC 0073, BC 0469, BC 0002, BC 0273, BC 0382, BC 0308, BC 0293, BC 0337, BC 0291, BC 0333, BC 0279, BC 0354, BC 0476, BC 0353, BC 0232, BC 0376, BC 0481, BC 0272, BC 0318, SR/L 51, SR/L 17, SR/L 55, SR/L 56, SR/L 30, SR/L 26, Win all 5, Win all 6, CB 9, CB 10, CB 12, CB 14.
3.	57.24 – 43.48	BC 0037, BC 0294, BC 0301, BC 0304, BC 0305, BC 0306, BC 0316, BC 0369, BC 0374, BC 0470, BC 0483, BC 0496, BC 0497, BC 0501, CB 13, SR/L 14, SR/L 36, SR/L 42, SR 15

Table 10. Performance of 100 genotypes of cotton for total seed cotton yield (t/ha)

Sl No.	Range		Accession No.
1.	2.84	2.20	BC 0002, BC 0074, BC 0279, BC 0289, BC 0291, BC 0305, BC 0318, BC 0319, BC 0333, BC 0335, BC 0349, BC 0358, BC 0372, BC 0375, BC 0378, BC 0382, BC 0383, BC 0386, BC 0469, BC 0476, BC 0482, BC 0492, SR/L 26
2.	2.19	2.00	BC 0037, BC 0073, BC 0211, BC 0244, BC 0270, BC 0272, BC 0273, BC 0276, BC 0278, BC 0281, BC 0292, BC 0293, BC 0294, BC 0301, BC 0303, BC 0304, BC 0306, BC 0312, BC 0314, BC 0316, BC 0322, BC 0331, BC 0332, BC 0337, BC 0353, BC 0354, BC 0355, BC 0359, BC 0362, BC 0366, BC 0369, BC 0475, BC 0481, BC 0493, BC 0497, BC 0505, CB 12, CB 13, CB 14, CB 9, SR/L 17, SR/L 30, SR/L 42, SR/L 47, SR/L 51, SR/L 55, Win all 5
3.	1.99	1.20	BC 0075, BC 0111, BC 0112, BC 0113, BC 0119, BC 0168, BC 0231, BC 0232, BC 0236, BC 0259, BC 0283, BC 0286, BC 0295, BC 0308, BC 0374, BC 0376, BC 0390, BC 0470, BC 0480, BC 0483, BC 0495, BC 0496, BC 0501, BC 0502, CB 10, SR/L 14, SR/L 36, SR/L 56,SR 15, Win all 6

0337, BC 0349, BC 0358, BC 0366, BC 0378, BC 0382, BC 0383, BC 0386, CB 10, SR 15 and Win all 6. Further close investigation should be carried out to confirm the earliness of the selected genotypes. Correlation studies indicates that plant height, sympodial branches / plant, secondary fruiting branches / plant, bolls / plant are the yield contributing traits in cotton.

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Table 11. Correlation among 10 important traits related to earliness and yield of short duration cotton genotypes

	DFF	NFB	PH	NMB	SFB	NSB	NBP	DBO	ERI	YPP
DFF	1.00	-0.0703	-0.2248*	0.0564	-0.0122	-0.0775	-0.0994	0.6159	0.1248	-0.3346**
NFB		1.00	0.0831	-0.0424	0.0416	0.0683	0.1027	-0.1774	-0.0252	-0.0087
PH			1.00	0.2190*	0.2328	0.4375	0.2205*	-0.1758	-0.1726	0.4080**
NMB				1.00	0.8030**	0.1059	0.1025	0.0730	-0.0664	0.1499
SFB					1.00	0.2326*	0.2577*	0.0387	-0.1421	0.2796**
NSB						1.00	0.1472	-0.0718	-0.2429*	0.5177**
NBP							1.00	-0.1556	-0.1552	0.2486*
DBO								1.00	0.0621	-0.3067**
ERI									1.00	-0.4300**
YPP										1.00

DFF= Days to first flowering, NFB= Number of fruiting branch, PH= Plant height (cm), NMB= Number of monopodial branches, SFB= Secondary fruiting branches (no.), NSB= Number of Sympodial branches, NBP= Bolls per plant (no.), PFP= % 1st Pick, PSP= % 2nd Pick), PTP= % 3rd Pick,DBO= Days to boll opening, ERI= Earliness index, TCY= Total Yield (Kg), YPP= Yield per plant (g)

DECLARATION

The authors declare that there is no conflict of interest regarding the publication of this paper.

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