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RESEARCH PAPER

Physiological studies in cotton hybrids differing in morpho- physiological traits

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Abstract: Field experiment were conducted during *kharif* season of 2013-14 and 2014 -15 at Agriculture Research Station, Dharwad to study the "Physiological studies in Cotton hybrids *G.hirsutum* L. differing in morpho-physiological traits". The experiment consisted of thirty hirsutum x hirsutum cotton hybrids and their twenty three parents laid out in randomized block design with three replications on medium black soil and worked out heterosis. Hybrids and their heterosis were assessed for yield, Number of bolls, boll weight, total dry weight, leaf area, plant height and specific leaf weight. Seed cotton yield differed significant among the hybrids. It ranged from 1178.2 kg ha^{-1} to 2184.9 kg ha^{-1}. Among the hybrids, RGR x SG-4 recorded highest seed cotton yield (2184.9 Kg ha^{-1}). Higher seed cotton yield was mainly attributed to its close association with total dry matter (0.727), leaf area (0.720.) and medium plant height (0.130) and specific leaf weight (0.509). Heterosis for seed cotton yield was maximum in RGR x SG-2 (72.3%), but total dry matter, leaf area, plant height and specific leaf weight it was recorded more in RGR x RGR-4 (44.5 %), RGR x SG-2 (1047.6%), SG x RGR-5 (35.3 %) and SG x RGR-2 (152.9 %). These traits possibly increase the number of bolls per plant (32.1) and boll weight (5.99). There by it increase seed cotton yield in RGR x SG-4.

Key words: Heterosis, Leaf area, Plant height, Seed cotton yield, Total dry matter

Introduction

India is the first country in the world to exploit heterosis commercially in cotton and now interspecific and intraspecific hybrids are being grown widely throughout the country. Lot of work has been done on genetic and other morphological characters, very few attempts have been made on genetics of physiological characters (Marani and Avieli, 1973).

There are different milestones in the history of Indian cotton which have acted as turning points to a significant impact on development of cotton.

Studies on cotton hybrid research at Dharwad focused on evaluation a large number of crosses over years, constantly observing the most potential crosses and attempting to infer about the causes of high heterosis. Answers were searched for why some combinations are potential, what would be the probable causes for high potentiality revealed by specific crosses? Attempts were made to understand the mechanism of complementation between parents for plant type and physiological mechanism leading to high heterosis. On the basis of the information generated on these lines heterotic groups were formed and these groups are being constantly revised by adding new genotypes to these groups, arranging genotypes of a groups in the order of combining ability (refining them) *etc.,* (Patil., 2012).

This exercise of grouping genotypes done over years has revealed some broader groups of genotype such as compact group, High RGR group, stay green group, robust types with high relative growth rate (RGR) and some smaller groups and even solitary groups consisting of single genotype (Patil., 2009). These groups have shown broadly a definite pattern of combining ability status with other groups of genotypes. The between group crosses of some of them have given rise to some of the most potential hybrids that have proved to be potential. The complementation for physiological processes involved in development of biomass and its partitioning can give rise to potential hybrids. Parents with strong expression for traits contributing to biomass, photosynthetic ability and stay green nature give rise to good hybrid when crossed with two parents.

The pattern of complementation of plant features has given rise to staygreen x compact, robust x compact, robust x RGR and stay green x RGR which in general give rise to high yielding hybrids.

Following these line of expectation physiological parameters were considered most important base for evaluation of these heterotic groups and present study were carried out according to this expectation and some of the genotypes belonging to different heterotic groups were evaluated for morphological parameters.

Material and methods

Field experiment were conducted during *kharif s*eason of 2013-14 and 2014 -15 in Agriculture research station, Dharwad on medium black soil. Experiments were located at $15^0$26 N latitude and $76^0$71 E longitude having an elevation of 678 m above mean sea level. The experiment consisted of thirty hirsutum x hirsutum cotton hybrids and their twenty three parents laid out in randomized block design with three replications. From each plot, three plants were selected randomly, cut at base and each plant was partitioned into different parts *viz.,* stem, leaf and reproductive parts at different growth stages. The samples were dried at 80^0C till a constant weight was achieved and expressed as g per plant. From these observations, the total dry matter production per plant and its distribution in stem, leaf and reproductive parts was worked out, which was used further for computing other growth parameters.

The leaf area was worked out by disc method. For this purpose, a leaf punch having diameter of 1.0 cm was used to remove 20 discs randomly at different positions of the plant and the discs were dried in the oven at 80^0C. The average plant height of five tagged plants was recorded at harvest from base of the plant to the growing tip and is expressed in centimeters.

The specific leaf weight or the leaf thickness was determined by the following formula and expressed as g per dm^2.

$$SLW = \frac{\text{Leaf dry weight (g)}}{\text{Leaf area (dm}^2\text{)}}$$

It is the total seed cotton yield of all the pickings from five tagged plants averaged and expressed as yield per plant in grams. Seed cotton obtained from net plot area from various pickings were considered for computation of cotton yield per hectare and expressed as kilograms per hectare.

Total number of bolls picked from the five tagged plants counted and the average was worked out. Seed cotton obtained from 20 bolls selected randomly from the net plot covering top to bottom were weighed and mean boll weight was worked out. Heterosis over mid parent is calculated by using the following formula (Panse and Sukatame, 1967).

$$\text{Heterosis} = \frac{F_1 - MP}{MP} \times 100$$

Where, F_1 = hybrid

MP = Mid- parent value

Results and discussion

The pooled data of 2013-14 and 2014-15 on yield and yield components of cotton hybrids and genotypic variation in yield and yield components and its per cent heterosis (mid parent) in cotton hybrids recorded at harvest is presented in Table 1. There was significant difference among the cotton genotypes. The hybrid, RGR x SG-4 recorded significantly higher yield (58.0 kg plant^{-1}) followed by RGR x SG-3 (55.5 kg plant^{-1}), while SG x SG-3 recorded the least (34.0 kg plant^{-1}). The highest heterosis for yield was recorded by the hybrid RGR x SG-2 (72.3%) followed by Robust x SG-2 (67.0%) while least was recorded by the hybrid Compact x Robust-1 (2.0%). The hybrid, RGR x SG-4 recorded significantly higher yields (1986.2 kg ha^{-1}) followed by the hybrid RGR x SG-3 (2184.9 kg ha^{-1}), while SG x SG-3 recorded the least (1166.6 kg ha^{-1}). The highest heterosis for yield was recorded

Table 1. Genotypic variation on yield and yield components and its per cent heterosis (mid parent) in cotton hybrids and their parents (pooled data of 2013-14 and 2014-15)

Sl. No.	Treatments	Yield (g plant^{-1})	Yield (kg ha^{-1})	Number of bolls per plant	Boll weight (g boll^{-1})
	RGR types				
	RGR x SG				
1.	RGR x SG-1 (F1)	39.2	1411.3	13.9	3.47
	Heterosis	29.6	42.9	29.7	34.70
2.	RGR x SG-2 (F1)	53.2	2005.0	28.3	4.70
	Heterosis	72.3	89.5	166.0	102.94
3	RGR x SG-3 (F1)	55.5	2090.7	26.0	5.54
	Heterosis	54.0	69.3	109.0	125.57
4.	RGR x SG-4 (F1)	58.0	2184.9	32.1	5.99
	Heterosis	38.0	51.7	73.7	54.38
	SG x RGR				
5.	SG x RGR-1 (F1)	41.6	1570.4	16.8	3.76
	Heterosis	20.8	33.1	34.6	45.96
6.	SG x RGR-2 (F1)	38.5	1437.6	14.0	3.22
	Heterosis	14.7	25.0	0.0	23.09
7.	SG x RGR-3 (F1)	43.8	1621.6	15.3	3.12
	Heterosis	53.1	65.5	74.7	34.72
8.	SG x RGR-4 (F1)	47.1	1694.7	14.1	3.71
	Heterosis	24.3	30.5	12.6	33.84
9.	SG x RGR-5 (F1)	37.5	1348.5	14.0	2.97
	Heterosis	10.3	15.7	19.0	4.87
10.	SG x RGR-6 (F1)	42.2	1517.4	20.5	3.51
	Heterosis	16.2	21.8	55.3	28.48
	RGR x Robust				
11.	RGR x Robust-1 (F1)	49.9	1795.7	18.6	3.22
	Heterosis	65.2	78.3	78.2	42.73
	Robust x RGR				
12.	Robust x RGR-1 (F1)	50.1	1803.5	18.3	3.51
	Heterosis	65.9	74.0	80.1	52.87
	Robust x SG				
13.	Robust x SG-1 (F1)	43.2	1555.5	15.8	3.61
	Heterosis	42.5	50.1	57.4	40.14
14.	Robust x SG-2 (F1)	46.1	1658.4	16.2	3.32
	Heterosis	67.0	75.2	52.3	55.14
15.	Robust x SG-3 (F1)	35.8	1286.2	11.5	3.37
	Heterosis	30.3	40.3	6.1	23.35
16.	Robust x SG-4 (F1)	52.4	1887.2	23.1	4.01
	Heterosis	61.7	70.0	114.7	63.27
17.	Compact x Robust-1 (F1)	34.6	1243.2	11.5	2.62
	Heterosis	2.0	12.9	-1.9	8.44
	RGR x RGR				
18.	RGR x RGR-1 (F1)	42.8	1542.1	16.6	3.71
	Heterosis	18.4	26.3	22.8	33.84
19.	RGR x RGR-2 (F1)	47.6	1712.1	17.2	3.22
	Heterosis	39.2	46.1	32.3	22.15
20.	RGR x RGR-3 (F1)	37.9	1363.9	15.3	3.37
	Heterosis	6.2	13.4	12.5	20.70
21.	RGR x RGR-4 (F1)	36.6	1315.3	11.2	2.97
	Heterosis	7.0	12.2	-13.8	12.67
22.	RGR x RGR-5 (F1)	50.7	1826.3	19.8	3.66
	Heterosis	54.2	68.8	53.7	39.06
	Stay green types				
	SG x SG				

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23. SG x SG-1	34.9	1255.9	10.7	2.82
Heterosis	4.2	9.5	5.7	5.54
24. SG x SG-2 (F1)	40.6	1462.3	15.4	2.82
Heterosis	27.2	34.7	42.6	7.14
25. SG x SG-3 (F1)	32.4	1166.6	9.3	3.51
Heterosis	11.1	16.8	-19.8	39.51
26. SG x SG-4 (F1)	42.5	1528.4	13.9	2.92
Heterosis	54.7	62.2	28.2	6.88
Robust types				
Robust x Robust				
27. Robust x Robust-1 (F1)	36.3	1306.2	17.8	3.32
Heterosis	15.3	21.0	71.2	39.73
28. Robust x Robust-2	39.0	1405.5	15.6	3.47
Heterosis	34.7	41.6	57.9	49.83
29. Robust x Robust-3 (F1)	41.4	1490.1	17.7	3.81
Heterosis	48.9	56.5	99.3	75.09
30. Robust x Robust-4 (F1)	32.7	1178.2	8.8	2.03
Heterosis	3.6	12.9	-30.6	-25.15
Bunny Bt (Check)	58.09	2531.8	35.30	5.50
Mean	35.2	929.7	21.0	11.35
S.Em±	5.32	45.39	2.37	0.41
C.D. at 5%	16.78	128.69	6.46	1.12

by the hybrid RGR x SG-2 (89.5%) followed by the hybrid Robust x SG-2 (75.2%) while least was recorded by the hybrid Compact x Robust-1 (12.9%).

The hybrid, RGR x SG-4 recorded significantly more number of bolls per plant (32.1) followed by the hybrid RGR x SG-2 (28.3), while Robust x Robust-4 recorded the least (8.8). The highest heterosis for number of bolls per plant was recorded by the hybrid RGR x SG-2 (166.0%) followed by the hybrid RGR x SG-3 (109.0%) while least was recorded by the hybrid SG x SG-3 (-19.8%). The hybrid, RGR x SG-4 recorded significantly highest boll weights (5.99 g $boll^{-1}$) followed by the hybrid RGR x SG-3 (5.54 g $boll^{-1}$), while Robust x Robust-4 recorded the least (2.03 g $boll^{-1}$). The highest heterosis for boll weight was recorded by the hybrid RGR x SG-3 (125.57%) followed by RGR x SG-2 (102.94%) while least was recorded by the hybrid Robust x Robust-4 (-25.15%). Yield in cotton is a complex character not readily amenable to genetic analysis. It is dependent on number of traits such as number of bolls, boll weight *etc.* (Sikka and Joshi, 1960). The main yield components like bolls per plant and their size in turn are the product of interaction between physiological processes in development and morphological frame work of the plant.

All the crosses recorded comparatively higher yields. RGR x SG-4 and RGR x SG-3 were high yielding. Results from heterosis studies indicated that all the crosses recorded positive and significant heterosis over mid parent for seed cotton yield. The mid-parent heterosis (89.5%) was recorded by the crosses RAH-4 and DSG-3-5, which produced highest seed cotton yield among the different genotype crosses studied. Major factors attributed for the differences in yield of seed cotton were yield components like boll weight, number of squares and bolls, morphological characters like phenological and physiological characters.

Various yield contributing characters (number of bolls per plant, boll weight and biomass) and yield of cotton recorded in the present investigation were significantly influenced by various hybrids and parents.

The pooled data of 2013-14 and 2014-15 on total dry weight, leaf area, plant height and specific leaf weight of cotton hybrids and its per cent heterosis (mid parent) in cotton hybrids recorded at different growth stages is presented in Table 2. RGR x SG-4 recorded significantly more total dry weight (209.5 g $plant^{-1}$) followed by RGR x SG-2 (190.4 g $plant^{-1}$). While, RGR x RGR-1 recorded the least total dry weight (139.3 g $plant^{-1}$). The highest heterosis for total dry weight was recorded by Robust x SG-2 (51.1%) followed by Robust x RGR-1 (48.1%) while least was recorded by the Robust x Robust-4 (1.0 %). RGR x SG-4 recorded significantly more leaf area (148.41 dm^2 $plant^{-1}$) followed by RGR x SG-3 (141.35 dm^2 $plant^{-1}$). While, SG x SG-3 recorded the least leaf area (5.81 dm^2 $plant^{-1}$). The highest heterosis for leaf area was recorded by RGR x SG-2 (461.3 %) while least was recorded by SG x SG-1 (-72.6 %).

SG x SG-4 recorded significantly more plant height (110.1 cm $plant^{-1}$), followed by SG x RGR-5 (105.0 cm $plant^{-1}$), while RGR x RGR-1 recorded the least (59.7 cm $plant^{-1}$). The highest heterosis for plant height was recorded by SG x RGR-5 (35.3 %), while least was recorded by RGR x RGR-1 (-21.8 %). There was significantly more SLW recorded in SG x SG-3 (7.02 g dm^{-2}) followed by the hybrid SG x SG-1 (6.52 g dm^{-2}), while least was recorded by RGR x SG-3 (0.35 g dm^{-2}). The highest heterosis for SLW was recorded in SG x RGR-2 (152.9 %), while least was recorded by RGR x SG-2 (-90.80 %).

Total dry matter is the physiological efficiency of a genotype. Leaf area index, leaf photosynthetic rate appeared to be the major determinants of total dry matter (Yoshida, 1972). In the present investigation genotypes showed significant differences in total dry matter production at harvest. Higher total dry matter accumulation was noticed in hybrid compared to parents. Hybrids, RGR x SG-4 recorded more dry matter and also recorded higher yields (Mundas, 1992). Even though the hybrid RGR x SG-3 accumulated moderate total dry matter, the yield was maximum. This may due to increased translocation of assimilates to reproductive parts. This was also true with parent RAH-97. It is not the total dry matter alone which is important but its favorable partitioning into reproductive parts is also important in realizing higher yields (Wells and Meredith, 1984). All other parents produced lower dry matter and yields.

Heterosis studies revealed that all the crosses recorded positive significant heterosis over mid parent, which further confirmed the higher dry matter accumulation in hybrids as compared to parents. Wells and Meredith (1984) observed 32 per cent heterosis for total dry matter prior to last harvest. Similarly, Gupta *et al.* (1980) and Patil (1989) also reported heterosis for total dry matter. Leaf area indicates the size of

Table 2. Genotypic variation in total dry matter (g/plant) and its per cent heterosis (mid parent) in cotton hybrids and their parents (pooled data of 2013-14 and 2014-15)

Sl. No.	Treatments	Days after sowing			
		Total dry matter (g plant^{-1})	Leaf area (dm^2 plant^{-1})	Plant height (cm plant^{-1})	Specific leaf weight (g dm^{-2})
	RGR types				
	RGR x SG				
1.	RGR x SG-1 (F1)	166.3	13.86	85.1	3.00
	Heterosis	20.7	25.1	-1.9	-26.31
2.	RGR x SG-2 (F1)	190.4	123.35	92.7	0.39
	Heterosis	36.2	1047.6	3.9	-90.80
3	RGR x SG-3 (F1)	170.2	141.35	89.8	0.64
	Heterosis	37.0	751.5	-11.1	-67.83
4.	RGR x SG-4 (F1)	209.5	148.41	89.1	0.37
	Heterosis	36.8	255.9	14.7	-61.18
	SG x RGR				
5.	SG x RGR-1 (F1)	138.1	20.93	82.5	1.53
	Heterosis	18.2	57.5	-16.1	-36.72
6.	SG x RGR-2 (F1)	149.5	12.74	104.6	3.28
	Heterosis	31.2	-45.0	13.3	152.90
7.	SG x RGR-3 (F1)	165.0	10.17	90.6	4.63
	Heterosis	24.4	75.3	5.0	-25.36
8.	SG x RGR-4 (F1)	173.3	47.07	69.4	0.93
	Heterosis	37.1	74.2	-14.4	-25.19
9.	SG x RGR-5 (F1)	189.1	14.94	105.0	3.15
	Heterosis	47.5	-34.2	35.3	39.49
10.	SG x RGR-6 (F1)	152.3	20.48	95.3	1.85
	Heterosis	20.7	40.0	0.7	-16.67
	RGR x Robust				
11.	RGR x Robust-1 (F1)	169.5	16.07	84.9	2.86
	Heterosis	22.6	63.7	9.5	-37.11
	Robust x RGR				
12.	Robust x RGR-1 (F1)	166.3	13.01	80.4	3.41
	Heterosis	48.1	10.4	23.0	52.84
	Robust x SG				
13.	Robust x SG-1 (F1)	172.9	16.07	97.0	2.89
	Heterosis	29.4	80.3	7.0	-34.99
14.	Robust x SG-2 (F1)	171.6	43.07	88.9	1.03
	Heterosis	51.1	111.1	9.3	-41.30
15.	Robust x SG-3 (F1)	165.8	38.39	99.9	1.18
	Heterosis	37.5	121.9	14.9	-70.71
16.	Robust x SG-4 (F1)	181.8	95.31	95.7	0.54
	Heterosis	35.5	384.7	18.3	-85.68
17.	Compact x Robust-1 (F1)	161.8	15.30	70.7	2.61
	Heterosis	21.3	72.6	-10.4	-44.28
	RGR x RGR				
18.	RGR x RGR-1 (F1)	139.3	15.89	59.7	1.99
	Heterosis	23.6	9.2	-21.8	12.22
19.	RGR x RGR-2 (F1)	142.6	20.48	96.1	1.55
	Heterosis	23.0	69.2	6.0	-39.63
20.	RGR x RGR-3 (F1)	147.2	9.77	89.0	3.58
	Heterosis	31.1	-41.0	1.7	132.09
21.	RGR x RGR-4 (F1)	167.5	8.42	99.9	5.90
	Heterosis	44.5	-30.4	10.1	129.81
22.	RGR x RGR-5 (F1)	178.4	101.03	85.1	0.93
	Heterosis	39.4	541.3	5.5	-49.25
	Stay green types				
	SG x SG				
23.	SG x SG-1	163.9	6.08	76.2	6.52
	Heterosis	20.3	-72.6	-8.1	90.97
24.	SG x SG-2 (F1)	181.8	18.45	82.1	2.58
	Heterosis	33.5	88.3	-14.9	-41.25
25.	SG x SG-3 (F1)	159.3	5.81	85.1	7.02
	Heterosis	28.5	-68.3	-9.6	102.42
26.	SG x SG-4 (F1)	167.9	21.02	110.1	2.25
	Heterosis	39.2	21.5	26.7	-44.15
	Robust types				
	Robust x Robust				
27.	Robust x Robust-1 (F1)	142.4	37.44	92.3	1.04
	Heterosis	8.2	476.0	12.9	-81.33
28.	Robust x Robust-2	177.1	19.26	77.1	2.25
	Heterosis	25.4	129.0	-13.2	-53.40
29.	Robust x Robust-3 (F1)	161.1	40.14	82.1	1.02
	Heterosis	23.6	369.3	14.1	-77.63
30.	Robust x Robust-4 (F1)	141.4	13.55	73.7	2.47
	Heterosis	1.0	-38.5	-19.6	18.58
	Bunny Bt (Check)	154.6	40.7	105.3	1.23
	Mean	112.7	54.91	65.5	1.34
	S.Em±	7.40	1.51	2.60	0.20
	C.D. at 5%	20.98	7.80	7.36	0.62

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assimilatory apparatus of the plant and serves as a primary value for estimation of other growth characters. As early as in 1938, Health and Gregory concluded that, the rate of leaf area expansion has a greater influence on dry matter production. At the harvest the SG x SG-4 (110.1) and SG x RGR-5 (105.0) recorded maximum plant height and were not associated with total dry matter and yield. This variation may be genetically controlled. Patil (1989) also indicated no close relationship between plant height and yield. This may be because increased translocation of stored photosynthates from stem reserves when the current photosynthesis is reduced due to shifting of plant towards senescence particularly during post anthesis period. Specific leaf weight is an integral structure of leaf which indicates the thickness of the leaf and is known to have a positive correlation with photosynthetic rate (Bharadwaj and Singh (1988)). In present study, all the hybrids recorded significantly more SLW which is further confirmed by positive heterosis, for specific leaf weight over mid parent. Bharadwaj *et al*. (1988) observed that increasing SLW from 0.6 to 0.85 was on par with increasing a unit LAI to produce same amount of biomass.

Conclusion

On the basis of the results it was concluded that the Cotton hybrid RGR x SG-4 significantly recorded high boll numbers per plant, boll weight, total dry weight, leaf area, medium plant height and specific leaf weight content, with high seed cotton yield. It was also influenced by its potential parents leading to high heterosis in these cotton hybrid.

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