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COMBINING ABILITY AND GENE ACTION FOR CUREDLEAF YIELD, ITS COMPONENTS AND QUALITY TRAITS IN BIDI TOBACCO (*Nicotianatabacum* L.)

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Abstract: Eleven parents were crossed in line x tester fashion comprising four cytoplasmic male sterile lines and seven diverse pollinators to estimate combining ability for curl (Curd) leaf yield, its components and quality traits in bidi tobacco.The analysis of variance revealed that the mean square values due to genotypes, parents and hybrids were significant, which suggested differences among themselves for all the characters under study. The significance value of parent *vs* hybrids for all the characters except days to maturity also indicated difference between parents and hybrids. The magnitude of both the components of genetic variance, their potence and predictability ratio revealed preponderance of additive genetic variance for inheritance of cured leaf yield, days to flowering, number of leaves per plant, plant height, leaf length, leaf width, days to maturity and total reducing sugar content; whereas, both additive and non-additive genetic variances with prime role of non-additive genetic variance were important for leaf thickness and nicotine content. The estimates of general combining effect suggested that parents GT 7, ABD 101 and GP 53 were found good general combiners for cured leaf yield and its related attributes. The parents GT 4 and Line 479-1-5-40 were found to be good general combiner for quality characters, whereas parents A 119 and Line 2-1 were good general combiner for earliness and leaf thickness. The estimates of specific combining ability effect indicated that cross combinations GT 7 x Line 6-2-18-69, GT 7 x GP 53 and A 199 x San and local were significant and positive for cured leaf yield. Among these, cross GT 7 x GP 53 had the highest significant and positive sca effects for quality characters. These crosses showing significant sca effect are expected to through off transgressive segregations. Therefore, these crosses combinations could be utilized for further use in breeding programme for amelioration of cured leaf yield of bidi tobacco.

Keywords: Line x Tester, Combining ability, Gene action, Cured leaf yield and Bidi tobacco.

Introduction

Tobacco is one of the most important crops among the chief cash crops in India. Tobacco was introduced in the Indian sub-continent by Portuguese. ‘The Golden leaf’ is a member of *Solanaceae* family and belongs to genus *Nicotiana.* It is self-pollinated allopolyploid species.

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It is an amphidiploids (2n=48) of *Nicotianasylvestris* (2n=24) and *Nicotianatomentosa* (2n= 24). The haploid chromosome number of genus *Nicotiana* varies from n=12 to n=24. Out of 66 species described in the genus, only two species *viz., N. tabacum* L. and *N. rustica* L. are economically important and the farmers grow predominantly in India.

The major tobacco producing countries in the world are USA, China, Brazil, India, Turkey and Bulgaria. India is the only country where, because of the diverse climate conditions different types of tobacco, *viz*., flue cured virginia (FCV), burley, natu, cigar filler, cigar wrapper, cheroot, snuff, hookah, bidi and chewing are grown under different agro-climatic conditions. India is world's third-largest producer of leaf tobacco. It is also a very large consumer of tobacco products. It makes a significant contribution to the Indian economy in terms of employment, income and government revenue. In India, tobacco cultivation is mainly concentrated in Andhra Pradesh, Gujarat, Karnataka, Uttar Pradesh, West Bengal, Maharashtra and Tamil Nadu. In Gujarat, cultivation of tobacco is mainly concentrated in Anand, Kheda, Ahmedabad, Mehsana and Vadodara districts.

In spite of considerable export potential as well as large scale domestic uses, tobacco cultivation is discouraged world over due to alleged health hazards. The major thrust of tobacco research is to improve productivity along with quality in respect of demand in National and International markets. To enhance the present yield levels, it is essential a systemic varietal improvement through hybridization and exploitation of generated variabilitythrough recombination breeding. The line x tester analysis approach as proposed by Kempthorne (1957) provides systemic approach for identification of superior parents and crosses, which identify basic material on which success of plant breeding programme rest. Combining ability is a powerful tool to select good combiners and thus selecting the appropriate parental lines for hybridization programme. In addition information on nature of gene action will be helpful to develop efficient crop improvement programme.General combining ability is due to additive and additive x additive gene action and is fixable in nature while specific combining ability is due to non-additive gene action which may be due to dominance or epistasis or both and is non-fixable. The presence of non-additive genetic variance is the primary justification for initiating the hybrid breeding programme (Cockerham, 1961). Cured leaf yield and its contributing characters lack stability due to strong environmental influence suggesting the need for breeding for specific environment. Therefore, the present investigation was planned and executed to assess the nature of gene action involved and combining ability of parental genotypes for various traits for evolving productive varieties in bidi tobacco.

Materials and Methods

Four cytoplasmic male sterile lines were crossed with seven testers in line × tester design at Bidi Tobacco Research Station, Anand Agricultural University, Anand (Gujarat). Here, female lines were maintain by sib matting with corresponding isogenic B line, while male lines were maintain by selfing to get their pure seeds for field experiment. All hybrids along with their eleven parents and a check hybrid (MRGTH 1) were evaluated in a Randomized Complete Block Design in three replications during *kharif*, 2013-14.Each genotype was grown in a single row of 7.5 m length with a spacing of 90 cm between rows and 75 cm between plants. The guard rows were provided on all sides of each block. All recommended agronomical and plant protection measures were followed to raise healthycrop. All plants were topped uniformly by removing three leaves below the bald sucker. Data were recorded on five randomly selected plants from each net plot of parents and F_1s in all the three replications. Mean value on per plant basis were recorded for the ten characters *viz*., cured leaf yield, days to flowering, number of leaves per plant, plant height, leaf length, leaf width, leaf thickness, days to maturity, nicotine content and total reducing sugar content. The observations on days to flowering and days to maturity were recorded on plot basis. Both nicotine content and total reducing sugar content were analyzed biochemically from representative bulk sample (leaf lamina) of each treatment at harvesting stage.The combining ability analysis was performed with data obtained for parents and hybrid according to Kempthrone (1957).

Results and Discussion

The results obtained under the present investigation are presented in Table 1 to 5.The analysis of variance for combining ability (Table 1) revealed that mean square values due to GCA was significant for all the characters, while for SCA it was significant for the characters cured leaf yield, days to flowering, leaf thickness, nicotine content and total reducing sugar content. Prime role of additive genetic variance found for all the characters except nicotine content, as it inherited by effect of non-additive genetic variance and leaf thickness, as it governed by both additive and non-additive genetic variance. Above one value of potence ratio for the characters cured leaf yield, days to flowering, leaf thickness, nicotine content and total reducing sugar content suggested preponderance of additive genetic variance. Whereas, around one value of potence ratio for the attributes leaf thickness and nicotine content indicated equal importance of both the components of genetic variance.

However, about one half value of predictability ratio for leaf thickness and nicotine content indicated importance of both additive and non-additive genetic variances. Whereas, above one half value of predictability ratio for cured leaf yield, days to flowering and total reducing sugar content suggested preponderance of additive genetic variance. The discriminity for the magnitude of gene effects with both potence ratio and predictability ratio for different characters could be differences in weightage of both the variances in their formulas.

For the cured leaf yield, mean square values due to lines, testers and lines x testers interaction were significant. The variance due to general combining ability was largely attributed to σ^2gca (t), though the σ^2gca (l) was significant. Both σ^2gca and σ^2sca were significant with higher estimate of σ^2gca suggesting preponderance of additive genetic variance. Above one estimate of potence ratio and above one half value of predictability ratio confirmed preponderance of additive genetic variance. The results revealed that the charactercured leaf yield was under prime control of additive genetic variance. The results are in conformity with findings of Krishna Murthy *et al.* (1994), Kara and Esendal (1995), Pathak *et al.* (1996), Kher*et al.* (2001), Patel and Kingaonkar (2006), Patidar (2007) and Rawool (2012), as they reported prime role of additive gene action. Whereas, the results contradicted the findings of Rangaswamy *et al.* (2002) and Makwana (2006), as they reported importance of both additive and non-additive gene actions for the inheritance of the character. For the character number of leaves per plant, mean square values due to lines as well as testers were highly significant. Only σ^2gca was significant with greater magnitude revealing importance of only additive genetic variance. Similar results were also reported by Patel and Kingaonkar (2006), Patidar (2007) and Rawool (2012). For the trait nicotine content, mean square values due to lines as well as testers and their interaction were highly significant. Both the components of genetic variance, σ^2gca and σ^2sca were significant with greater magnitude of σ^2sca, which indicated importance non-additive genetic variance. The value of potence ratio was around unity and predictability ratio was equal to one half, which indicated equal importance of both additive and non-additive genetic variances for inheritance of this character. The results are in accordance with the findings of Makwana (2006) and Vankar (2007), as both reported importance of both additive and non-additive gene action for the inheritance of the character. The results contradicted the findings of Patidar (2007) and Rawool (2012), as they reported predominant role of additive genetic variance.

An overall appraisal of general combining ability effects of parents (Table 2) revealed that for cured leaf yield per plant, from females, GT 7 was good general combiner. Among male parents, testers ABD 101 and GP 53 were good general combiners and Line 479-1-5-40 was average general combiner. The female parent GT 7 was also good general combiner for number of leaves per plant, plant height and leaf length; but it was average general combiner for rest of the characters except days to flowering; while, another female line GT 4 was average general combiner for cured leaf yield but it was good general combiner for days to flowering, leaf width, nicotine content and total reducing sugar content. Though line A 119 was poor general combiner for cured leaf yield and most of the yield component characters, but it was good general combiner for days to flowering, leaf thickness and days to maturity. The male parents, ABD 101 and GP 53 were found good general combiners for cured leaf yield. However, tester ABD 101 was also good general combiner for number of leaves per plant, plant height, leaf length, leaf thickness and total reducing sugar content, but it was poor general combiner for days to flowering and days to maturity; whereas for leaf width and nicotine content it was found average general combiner.

In respect to gca effect of parents involved in a particular cross, crosses could be grouped in to six different categories of parental combinations as G x G, G x A, G x P,A x A, A x P and P x P parents (Table 3). The crosses exhibiting high *per se* performance and significant desirable sca effects for various traits involved either good × good or good × average or average × good or poor × poor combining parents. Thus the cross exhibiting high sca effects did not always involve both good general combiner parents with high gca effect. Hence, the results suggested that interallelic interaction were also important for these characters.

Out of 16 significant F_1s for sca effect, 9 F_1s registered positive values and those were considered as good specific combiners (Table 4). The F_1 GT 7 x GP 53 (0.68) depicted the maximum positive sca effect followed by GT 5 x Line 2-1 (0.56) and GT 4 x Sanand local (0.47). For cured leaf yield, hybrids GT 7 x Line 6-2-18-69, GT 7 x GP 53 and A 119 x Sanand local exerted significant and positive sca effects. High *per se* performance along with high sca effect were recorded with cross GT 7 x GP 53 for cured leaf yield, nicotine content and total reducing sugar content; high sca effect were recorded with cross GT 4 x Line 479-1-5-40 for days to flowering; GT 7 x Line 2-1 for leaf thickness and GT 5 x Line 2-1 for nicotine content and total reducing sugar content.

The top ranking three lines and male parents on the basis of their *per se* performance and general combining ability effects for cured leaf yield per plant and component characters are presented in Table 5. The *per se* performance of parents along with their gca effects could be a better criteria for selection of superior parents in hybridization programme (Rao, 1972). In present investigation, the results revealed that most of the parents had relatively high degree of correspondence between *per se* performance and their gca effects for majority of the characters, which could be ascribed to predominant role of additive and pseudo-additive gene effect for their inheritance. Therefore, in selection of parents for hybridization due weightage should also be given to *per se* performance along with their gca effects.

Conclusion

It is concluded from above discussion, that the character cured leaf and other yield attributes were largely influenced by additive gene effect. Therefore, population improvement may be done through producing transgressive segregants followed by simple selection for the desired traits; whereas the characters like leaf thickness and nicotine content were predominantly influenced by non-additive gene action, which could be improved through some sort of recurrent selection, by way of intermating the most desirable segregants or biparental mating. The female GT 7 in combination with male ABD 101 and GP 53 likely to yield desirable transgressive segregants, from which new hybrids could be developed. The hybrid GT 7 x GP 53 showed high *per se* performance along with high sca effect, while another hybrid GT 7 x ABD 101 showed high *per se* performance but poor sca effect for cured leaf yield could also be further evaluated and exploited for commercial cultivation.

Table 1: Analysis of variance for combining ability, estimates of components of variance for ten characters in bidi tobacco

Sources of variation	d.f.	Cured leaf yield per plant	Days to flowering	No. of leaves per plant	Plant height	Leaf length	Leaf width	Leaf thickness	Days to maturity	Nicotine content	Total reducing sugar content
Replication	2	258.48	12.55	2.01	58.17	33.26	1.89	0.016	13.88	0.10*	0.01
Lines	3	9737.86**	598.19**	56.41**	4049.98**	111.12**	27.02*	6.68**	47.92*	0.19**	0.09**
Testers	6	22770.28**	533.59**	56.48**	1977.81**	56.48**	14.36	1.53**	109.85**	0.94**	0.30**
L x T	18	1519.19**	34.57**	1.50	116.36	15.11	7.72	0.65**	21.59	0.66**	0.26**
Error	54	277.93	13.21	1.58	65.62	13.16	6.51	0.069	14.25	0.03	0.01
Components of Variance											
σ^2 F		391.37**	26.84**	2.61**	187.32**	4.57**	0.92*	0.14**	1.25*	0.00	0.00
σ^2 M		1770.92**	41.59**	4.58**	155.12**	3.45**	0.55	0.07**	7.35**	0.02**	0.00
σ^2 gca		893.02**	32.20**	3.03**	175.61**	4.16**	0.79*	0.12**	3.47**	0.08**	0.004**
σ^2 sca		413.76**	7.12**	0.57	16.91	0.65	0.40	0.20**	2.45	0.16**	0.003**
Potence ratio		5.83	12.22	-	-	-	-	1.64	-	1.36	2.97
Predictability ratio		0.81	0.90	-	-	-	-	0.55	-	0.50	0.69

, * Significant at 0.05 and 0.01 levels, respectively

NOTE - When both GCA and SCA were significant then potence ratio and predictability ratio were calculated

Table 2: Estimates of general combining ability (gca) effects of the parents for ten characters in bidi tobacco

Sr. No.	Parents	Cured leaf yield (g/plant)	Days to flowering	No. of leaves per plant	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Leaf thickness (mg/cm^2)	Days to maturity	Nicotine content (%)	Total reducing sugar content (%)
Lines (Female parents)											
1	**GT 4**	0.65	-4.10**	-1.18**	-19.44**	-0.75	**1.16****	-0.34**	-0.15	**0.13****	**0.09****
2	**GT 5**	-7.54**	5.46**	0.95**	**11.05****	-0.75	0.10	-0.29**	2.13**	-0.11**	-0.07**
3	**GT 7**	**29.04****	3.67**	**1.81****	8.84**	**3.36****	0.30	0.06	-0.58	0.01	-0.01
4	**A 119**	-22.15**	**-5.03****	-1.58**	-0.45	-1.86**	-1.55**	**0.57****	**-1.39***	-0.03	-0.02*
5	**S.E. (gi)**	2.67	0.58	0.20	1.30	0.58	0.41	0.04	0.60	0.03	0.01
6	**CD @ 5%**	9.24	2.01	0.69	4.50	2.01	1.42	0.14	2.08	0.10	0.03
Testers (Male parents)											
1	**Sanand local**	-33.02**	-4.97**	-2.09**	-20.95**	-1.67*	-	-0.15*	2.23**	-0.01	0.01
2	**ABD 101**	**83.23****	11.37**	**3.79****	7.85**	**3.73****	-	**0.63****	4.98**	0.03	0.05*
3	**GP 53**	29.31**	1.50	0.43	**16.95****	0.40	-	-0.42**	0.48	0.03	-0.05*
4	**Line 479-1-5-40**	-2.52	3.33**	1.83**	9.43**	0.90	-	0.06	-1.27	**0.52****	**0.28****
5	**Line 6-2-18-69**	-24.69**	-2.23**	-1.79**	-10.22**	-0.92	-	-0.01	-0.19	-0.07	-0.03
6	**ABD 71**	-9.94**	0.70	-0.62*	-0.27	0.63	-	-0.34**	-1.69*	-0.43**	-0.26**
7	**Line 2-1**	-42.36**	**-9.70****	-1.54**	-2.77	-3.05**	-	0.22**	**-4.52****	-0.06	0.00
8	**S.E. (g_i)**	3.78	0.82	0.28	1.83	0.82	-	0.06	0.85	0.04	0.02
9	**CD @ 5%**	11.65	2.53	0.86	5.64	2.53	-	0.18	2.62	0.12	0.06

*, ** Significant at 0.05 and 0.01 probability levels, respectively

Table 3: Classification of parents with respect to general combining ability (gca) effect for ten characters in bidi tobacco

Sr. No.	Parents	Cured leaf yield	Days to flowering	No. of leaves per plant	Plant height	Leaf length	Leaf width	Leaf thickness	Days to maturity	Nicotine content	Total reducing sugar content
Lines (Female parents)											
1	GT 4	A	**G**	P	P	A	**G**	P	A	**G**	**G**
2	GT 5	P	P	**G**	**G**	A	A	P	P	P	P
3	GT 7	**G**	P	**G**	**G**	**G**	A	A	A	A	A
4	A 119	P	**G**	P	A	P	P	**G**	**G**	A	P
Testers (Male parents)											
1	Sanand local	P	**G**	P	P	P	A	P	P	A	A
2	ABD 101	**G**	P	**G**	**G**	**G**	A	**G**	P	A	**G**
3	GP 53	**G**	A	A	**G**	A	A	P	A	A	P
4	Line 479-1-5-40	A	P	**G**	**G**	A	A	A	A	**G**	**G**
5	Line 6-2-18-69	P	**G**	P	P	A	A	A	A	A	A
6	ABD 71	P	A	P	A	A	A	P	**G**	P	P
7	Line 2-1	P	**G**	P	A	P	A	**G**	**G**	A	A

G, **A** and **P** indicates Good, Average and Poor General Combiners, respectively.

Table 4: Estimates of specific combining ability (sca) effects for yield and its components in bidi tobacco

Sr. No.	Hybrids	Cured leaf yield	Days to flowering	Leaf thickness	Nicotine content	Total reducing sugar content
1	GT 4 x Sanand local	-12.40	-1.23	-0.28**	**0.47****	0.19**
2	GT 4 x ABD 101	1.35	2.70	0.21*	0.01	-0.03
3	GT 4 x GP 53	-2.74	0.77	0.34**	0.20**	0.15**
4	GT 4 x Line 479-1-5-40	3.10	**-4.47****	**0.48****	-0.05	-0.07*
5	GT 4 x Line 6-2-18-69	3.60	0.23	-0.99**	0.16*	0.07*
6	GT 4 x ABD 71	6.18	1.77	0.06	-0.10	0.03
7	GT 4 x Line 2-1	0.93	0.23	0.18	-0.69**	-0.32**
8	GT 5 x Sanand local	22.79**	2.94*	**0.83****	0.09	0.08**
9	GT 5 x ABD 101	-7.46	-0.73	-0.10	0.09	0.06*
10	GT 5 x GP 53	17.79**	**-3.33***	0.08	-0.88**	-0.67**
11	GT 5 x Line 479-1-5-40	-16.38*	-1.63	-0.37**	0.05	0.03
12	GT 5 x Line 6-2-18-69	-20.55**	0.94	0.36**	-0.08	0.02
13	GT 5 x ABD 71	0.04	1.14	-0.08	0.18*	0.21**
14	GT 5 x Line 2-1	3.79	0.67	-0.72**	**0.56****	**0.28****
15	GT 7 x Sanand local	-37.45**	**-5.94****	-0.54**	0.11	0.08**
16	GT 7 x ABD 101	-5.04	-2.07	0.13	-0.07	-0.01
17	GT 7 x GP 53	**27.21****	3.86**	-0.37**	**0.68****	**0.41****
18	GT 7 x Line 479-1-5-40	-13.62*	7.36**	-0.06	-0.45**	-0.12**
19	GT 7 x Line 6-2-18-69	**32.88****	-1.47	0.38**	-0.19**	-0.03
20	GT 7 x ABD 71	4.80	0.40	0.00	-0.49**	-0.53**
21	GT 7 x Line 2-1	-8.79	-2.14	**0.47****	0.41**	0.20**
22	A 119 x Sanand local	**27.07****	4.23**	-0.01	-0.67**	-0.35**
23	A 119 x ABD 101	11.15	0.10	-0.24*	-0.02	-0.01
24	A 119 x GP 53	-42.26**	-1.30	-0.05	0.01	0.11**
25	A 119 x Line 479-1-5-	**26.90****	-1.27	-0.04	0.45**	0.16**

	40					
26	A 119 x Line 6-2-18-69	-15.93*	0.30	0.25*	0.11	-0.05
27	A 119 x ABD 71	-11.01	**-3.30***	0.02	0.41**	**0.29****
28	A 119 x Line 2-1	4.07	1.23	0.07	-0.28**	-0.16**
	S. E. ±	6.54	1.43	0.10	0.07	0.03
	CD @ 5%	18.54	4.05	0.28	0.20	0.09
	No. of Significant (Total)	12	8	15	16	20
	Positive	6	4	8	9	13
	Negative	6	4	7	7	7

*,**, significant at 0.05 and 0.01 levels of probability, respectively.

Table 5: Top three female and male parents with respect to *per se* performance and gca effects for various traits in bidi tobacco

Characters	Female		Male	
	***Per se* performance**	**gca effect**	***Per se* performance**	**gca effect**
Cured leaf yield	GT 7	GT 7	ABD 101	ABD 101
	GT 5	GT 4	Line 479-1-5-40	GP 53
	A 119	-	GP 53	-
Days to flowering	GT 4	A 119	Sanand local	Line 2-1
	A 119	GT 4	Line 6-2-18-69	Sanand local
	GT 7	-	Line 2-1	Line 6-2-18-69
Number of leaves per plant	GT 7	GT 7	ABD 101	ABD 101
	GT 5	GT 5	Line 479-1-5-40	Line 479-1-5-40
	GT 4	-	GP 53	GP 53
Plant height	GT 5	GT 5	GP 53	GP 53
	GT 7	GT 7	Line 479-1-5-40	Line 479-1-5-40
	A 119	-	Line 6-2-18-69	ABD 101
Leaf length	GT 5	GT 7	ABD 101	ABD 101
	GT 7	-	Line 479-1-5-40	Line 479-1-5-40
	A 119	-	GP 53	ABD 71
Leaf width	GT 5	GT 7	GP 53	-
	A 119	GT 5	ABD 101	-

	GT 7	-	Line 479-1-5-40	-
Leaf thickness	GT 4	A 119	Line 479-1-5-40	ABD 101
	GT 5	GT 7	ABD 71	Line 2-1
	A 119	-	Sanand local	Line 479-1-5-40
Days to maturity	GT 7	GT 5	Line 2-1	Line 2-1
	GT 4	-	ABD 71	ABD 71
	A 119	-	Sanand local	Line 479-1-5-40
Nicotine content	A 119	GT 4	GP 53	Line 479-1-5-40
	GT 7	GT 7	Sanand local	ABD 101
	GT 4	-	Line 2-1	GP 53
Total reducing sugar	A 119	GT 4	GP 53	Line 479-1-5-40
	GT 7	-	Sanand local	ABD 101
	GT 4	-	Line 2-1	Sanand local

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