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Combining Ability Analysis For Cured Leaf Yield And Its Component Traits In Bidi Tobacco *(Nicotiana tabaccum* L.*)*

Achila Singh*, Arvind Kumar Srivastava, C.P. Sachan, Jagdish Kumar, and Sanjay Kumar

Department of Genetics and Plant Breeding,
C.S. Azad University of Agriculture & Technology, Kanpur- 208002 (U.P.), India

ABSTRACT

Combining ability studies were made in bidi tobacco (Nicotiana tabacum L.), comprising a half diallel set of eight parents and their 28 hybrids. Ten important attributes viz; cured leaf yield per plant (g), days to 50% flowering, number of leaves per plant, plant height (cm), leaf length(cm), leaf width (cm), leaf thickness (mg/cm^2), days to maturity, nicotine content (%) and total reducing sugar content (%) were studied. The combining ability analysis exhibited highly significant gca and sca effects for almost all the traits. The magnitude of combining ability variances suggested the prime role of additive gene action for the inheritance of cured leaf yield, days to flowering, a number of leaves per plant, plant height, and leaf thickness whereas, the preponderance of non-additive gene action for leaf width, days to maturity, nicotine content and total reducing Sugar-Parents ABD 101, ABD 111 and GT 7 were identified as a good general combiner for cured leaf yield while SB32, SB27, and Patiyali were good combiners for earliness. Best cross based on per se Performance for cured leaf yield was ABD 101 × ABD 111, followed by ABD 111 × GT 7, ABD 101 × GT 7, GT 9 × GT 7, and ABD 101 × SB 54, respectively, also having significant estimates for at least two important yield contributing traits.

***Keywords**: combining ability, diallel cross, gene action, hybrid, hybridization, Tobacco.*

INTRODUCTION

Nicotiana tabacum L. is the prevailingly cultivated species of the genus *Nicotiana* (Wersnman and Matzinger, 1980) belonging to the family “Solanacea.” It is one of the most important non-edible commercial crops in India. Tobacco is also known as “The Golden Leaf.” It is self-pollinated, amphidiploids (2n=48) of *Nicotiana sylvestris* (2n=24) and *Nicotiana tomentosa* (2n=24), the wild progenitor species (Gerstel, 1963) and believed to be originated in tropical America (Akehurst, 1981). The haploid chromosome number of *Nicotiana* varies from n=12 to n=24. Out of 66 species described in the genus, only two species, *viz*; *N. tobacum* L and *N. rustica* L., are economically important, and the farmers grow predominantly.

The major Tobacco producing countries are the USA, China, Brazil, India, Turkey, and Bulgaria. India is the world’s third-largest producer of leaf tobacco and a very large consumer of tobacco products. In India, bidi consumes the maximum Tobacco. Despite the considerable export potential and large scale domestic uses, tobacco cultivation is discouraged throughout the world due to health hazards associated with its consumption. The major thrust of tobacco research is to improve productivity and quality in respect of demand in national and international markets. It contributes to the Indian economy in terms of employment, income, and government revenue. It generates nearly Rs.20 billion of income per annum.

Tobacco offers a number of alternative uses like pesticides (Nicotine sulfate), pharmaceuticals (Sololenesol, nicotinic acid, nicotinamide), industrial acids (oxalic, citric, and malic), tobacco seed oil (for uses in soap, varnishes, and paint industries), cardboard and paper (of tobacco stalks), etc. Medically, tobacco is a sedative, diuretic, expectorant, discutient, and internal-only as an emetic when all other emetics fail. Externally nicotine is used as an antiseptic. Tobacco produces nicotine sulfate, which is used as an insecticide. Tobacco is claimed to be a miracle crop because of its nature and properties, used for various purposes right from pesticides, narcotics, stimulants, and medicinal uses (Narasimha and Krishnamurthy, 2007).

The major thrust of tobacco research is to improve productivity and quality in respect of demand in National and International markets. To enhance the present yield levels, systemic varietal improvement is essential through hybridization and exploitation of generated variability through recombination breeding. Combining ability is a powerful tool for selecting good combiners and selecting the hybridization program's appropriate parental lines. In addition, information on the nature of gene action will help develop an efficient crop improvement program. The present investigation was planned and executed to assess the nature of gene action involved and combine parental genotypes' ability for various traits for evolving productive varieties of bidi tobacco.

MATERIALS AND METHODS

The present investigation was conducted at Tobacco Research Station, Araul, C.S.Azad University of Agriculture and Technology, Kanpur (U.P.) during *Kharif* 2014-15. The experimental material consisted of eight inbred lines (ABD 101, ABD 111, SB 54, GT 9, GT 7, SB 32, SB 27, and Patiyali), and their 28 F_1, S developed by diallel mating excluding reciprocals was evaluated in Randomized Block Design with three replications. Each genotype was accommodated in 5 rows of 4.5 m length with the row to row and plant to plant distance of 45 cm. All the recommended agronomic management practices and plant protection measures were adopted timely to raise the healthy crop. The observations on five randomly selected competitive plants were recorded from each entry per replication on eight agro morphological attributes *viz*; cured leaf yield per plant (g.), days to flowering, number of leaves per plant, plant height (cm), leaf length (cm), leaf width (cm), leaf thickness (mg/ cm^2), days to maturity and two quantity traits, i.e., nicotine content (%) and total reducing sugar content (%), Mean values of all the characters were finally subjected to statistical analysis (half diallel analysis). Both nicotine content and total reducing sugar content were analyzed biochemically from the representative bulk sample (leaf lamina) of each treatment at the harvesting stage. Combining ability was performed according to the procedure suggested by Griffing (1956) Method2, Model I.

RESULTS AND DISCUSSION

The analysis of combining ability variances (Table 1) revealed that general combining ability variances were highly significant for all the traits except total reducing Sugar, for which it was significant and negatives; whereas, variance owing to *sca* effects was highly significant for all the characters except cured leaf yield per plant and leaf thickness. This indicated the importance of both additives and non-additive gene actions in the expression of all the attributes. The ratio of *gca* and *sca* variance components (♂^{2} g / ♂^{2} s) was more than unity for the traits *viz*; days to flowering, the number of leaves per plant and plant height indicated that additive type of gene action played a major role in the inheritance of these characters. These findings are akin to the observations of Patel and Kingaonkar (2006), Kuchhadiya *et al.* (2016), and Dave (2012). Around one value of ratio ♂^{2,} g / ♂^{2} s for the attribute leaf length indicated equal importance of both genetic variance components, i.e., additive and non-additive gene action. These results are in agreement with Makwana (2006). The traits leaf width, days to maturity, and nicotine content exhibited the ratio of *gca* and *sca* variance components (♂^{2} g /♂^{2} s) less than unity suggesting preponderance of non-additive genetic variance for the inheritance of these characters. Similar findings were reported by Dave ((2012) and Chaudhari *et al*. (2016).

An examination of Table 1 depicted the significance of the only ♂^{2}gca revealing the importance of only additive gene effects for the inheritance of cured leaf yield per plant and leaf thickness. These results agree with Judeja *et al.* (1984) for leaf thickness and Rawool (2012) for leaf yield per plant. The variances due to both gca and sca effects were noticed as highly significant for reducing sugar content. However, variance due to gca effects was negative, which indicated the preponderance of non-additive type of gene action to express this attribute. The results are similar to those of Dave (2012).

The characters *viz*; cured leaf yield per plant, days to flowering, number of leaves per plant, plant height, and leaf thickness was controlled by the additive gene action type. The pedigree method of breeding can be used to exploit the additive genetic variance in the improvement of such traits. The rest of the attributes were controlled by the non- additive type of gene effects in contrast to it. The predominantly large amount of non-additive gene action would necessitate the maintenance of heterozygosity in the population since this type of gene action is not fixable. Therefore, breeding methods such as heterosis breeding or hybridization (biparental mating) followed by recurrent selection may hasten genetic improvement).

A critical examination of *per se* Performance of parental genotypes and their *gca* effects revealed a positive relationship (Table 2). Estimates of *gca* effects showed that none of the parents was found good general combiner for all the traits. Three parents, namely ABD 101, ABD 111, and GT 7, appeared as good general combiners for cured leaf yield and two to three other important yield contributing characters, while parents SB 32, SB 27, and Patiyali were noted as good combiners for earliness. Only parent SB 54 was noticed as a good combiner for nicotine content. The genotypes, as mentioned earlier, are of immense value for simultaneous improvement of desirable attributes. Therefore, these genotypes may be utilized in hybridization programs for improving quantitative and qualitative traits of Tobacco.

Breeder's interest normally rests in obtaining transgressive segregants through crosses to produce homozygous lines in an autogamous crop like Tobacco. It is evident from Table 3 that in the present investigation, none of the cross combinations expressed good combining ability for all the traits. Out of 28 hybrids, thirteen for days to flowering, three for plant height, twelve for leaf length, seven for leaf width, five for days to maturity, three for nicotine content, and eight for total reducing sugar content were noted depicting significant and desirable *sca* effects. The number of leaves per plant is one of the important yield contributing traits in bidi tobacco. The *parents' gca effec*ts, i.e., ABD 101 and ABD 111, were significantly positive in a favorable direction. Among the 28 hybrids, five of the hybrids exhibited significant positive sca effects. Similar observations were recorded by Aleksoska and Aleksoski (2012) and Ramachandra *et al.* (2015), and Ganachari et al. (2019). Considering the *gca* effects of parents involved for exerting the *sca* effect in a particular hybrid, the significant crosses may be grouped into 6 categories *viz*; good x good, good x average, good x poor, average x average, average x poor, poor x poor parents (Table 4) in which parents belonged to either of the categories. However, the crosses involving high *sca* effects did not always involve parents with high *gca* effects, thereby suggesting intra-allelic gene interactions.

The top cured leaf yielding cross combination ABD 101 × ABD 111 followed by ABD 111 × GT 7 and ABD 101 × GT 7 exhibiting high *per se* performance could be placed in the first category as both the parents had significant and desirable *gca* effects for cured leaf yield per plant (Table 5). These crosses are valuable because of the presence of additive × additive type of gene interaction. Therefore, it is desirable that a biparental mating programme on the model of design III presented by Comstock and Robinson (1948) may be followed to get transgressive segregants from such crosses involving high × high combiners. These crosses may be effectively utilized inappropriate breeding programs for the improvement of cured leaf yield.

The crosses GT 9 × GT 7 and ABD 101 × SB 54 involved at least one parent showing a significant gca effect and could be placed in a high × average category. In such a cross, additive gene action is present in a good combiner and complementary epistatic gene action present in the average combiner. They acted in a complementary fashion to minimize desirable effects that could be exploited by selecting desirable homozygous lines among the progenies derived from the cross. Recurrent selection procedure with random mating is expected to offer tremendous potential for improving the tobacco crop population. Hence, these crosses could be successfully exploited for the commercial cultivation of Tobacco.

CONCLUSION

The above discussion concluded that the parent's ABD 101, ABD 111, and GT 7 have emerged as a good general combiner for cured leaf yield, and two to three yield other important yield contributing traits. The hybrids ABD 101 × ABD 111, ABD 111 × GT 7 and ABD 101 × GT 7, GT 9 × GT 7, and ABD 101 × SB 54 showing high *per se* performance for cured leaf yield could be exploited for commercial cultivation of bidi tobacco.

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Table I. Analysis of variance for combining ability of cured leaf yield and its components in bidi tobacco.

Source of Variance	df	Cured leaf yield per plant (g)	Days to flowering	Number 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 (%)
Gca	7	4739.11**	237.14**	17.00**	899.35**	25.99**	18.75**	1.39**	181.13**	0.61**	0.18**
Sca	28	301.53	14.86**	2.21**	75.10**	7.64**	6.93**	0.21	61.13**	0.49**	0.25**
Error	72	203.13	0.92	0.33	30.12	1.24	1.57	0.24	1.33	0.16	0.03
♂^{2} *gca*		460.53**	20.11**	1.36**	82.99**	1.89**	1.23**	0.12**	12.97**	0.008**	-0.010**
♂^{2} *sca*		93.27	13.93**	1.83**	43.59**	5.46**	5.38**	0.01	61.34**	0.35**	0.26**
Potency Ratio (♂^{2} *g* / ♂^{2} *s*)		___	4.99	2.86	7.45	1.15	0.88	___	0.81	.071	___
Predictability Ratio (♂^{2} *g* /♂^{2} *s*)$^{0.5}$		___	0.70	0.59	0.77	0.35	0.32	___	0.29	0.03	___

*, ** - indicate levels of significance at 5% and 1%, respectively.
d.f. - degree of freedom

Table II. Estimates of general combining ability (*gca*) effects and *per ser* performance of parents for cured leaf yield and its components in bidi tobacco

Parents	Cured leaf yield per plant (g)		Days to flowering		Number of leaves per plant		Plant height (cm)		Leaf length (cm)		Leaf width (cm)		Leaf thickness (mg / cm^2)		Days to maturity		Nicotive content		Total Reducing Sugar (%)	
	gca	*per se* perform-ance	*gca*	*per se* perform-ance	*gca*	*per se* perform-ance	*gca*	*per se* perform-ance	*gca*	*per se* perform-ance	*gca*	*per se* perform-ance	*gca*	*per se* perfor m-ance	*gca*	*per se* perfor m-ance	*gca*	*per se* perfor m-ance	*gca*	*Per se*
ABD 101	27.12**	251.3	9.43**	86.1	2.13**	24.7	-0.73	100.9	2.18**	63.9	1.81**	27.3	-0.09	8.3	6.61**	170.1	0.19	7.3	-	3.7
ABD 111	22.31**	245.3	1.99**	77.3	1.16**	21.3	8.39**	127.6	-0.23	60.5	-0.07	26.8	-0.36	7.9	5.39**	175.0	-0.11	5.9	-	3.5
SB 54	-3.61	189.6	2.65**	78.1	-0.05*	18.5	8.84**	121.3	-0.63	62.7	-0.89*	25.4	0.31	7.8	0.77*	158.0	0.42*	7.3	-	2.3
GT 9	2.01	214.5	-1.21**	61.9	-0.41**	17.3	3.07	90.9	1.01**	65.8	-0.33	26.8	0.19	8.5	2.11**	160.0	0.22	6.9	-	3.8
GT 7	11.01*	223.0	-1.29**	64.3	-0.13	19.9	2.65	119.4	0.70*	60.3	-0.81*	22.7	-0.16	7.8	-0.13	167.0	-0.07	6.1	-	2.4
SB 32	-23.01**	170.7	-4.18**	55.7	-1.00**	21.1	-18.33**	62.9	-1.00**	61.7	-1.19**	24.9	0.71**	9.1	-6.99**	129.3	-0.21	6.9	-	3.3
SB 27	1.91	241.3	-1.13**	63.3	-0.03	21.9	3.65*	123.3	0.67	63.6	-0.81*	25.7	-0.23**	8.3	-2.86**	160.3	-0.19	6.8	-	2.0
Patiyali	-38.39**	120.3	-6.12**	61.3	-1.70**	17.2	-9.10**	85.3	-3.40**	53.9	2.63**	31.3	-0.47**	7.7	-3.56**	150.3	-0.31**	6.5	-	3.9

*, **- Significance at 5% and 1% respectively
gca effects for total reducing Sugar were not estimated due to non-significant mean square value.

Table III. Estimates of *sca* effects and *per se* Performance of hybrids (crosses) associated for various characters in bidi tobacco

Characters → Crosses ↓	Cured leaf yield per plant (*g*)		Days to flowering		Number 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 (%)	
	sca	Mean	*sca*	Mean	*sca*	Mean	*sca*	Mean	*sca*	Mean	*sca*	Mean	*sca*	Mean	*sca*	Mean	*sca*	Mean	sca	Mean
ABD 101 X ABD 111	-	288.3	1.99**	76.1	2.63**	27.0	0.91	116.7	1.90*	68.7	0.69	31.1	-	7.9	-0.43	178.1	-0.77*	5.8	-0.03	3.5
ABD 101 X SB 54	-	255.9	2.99*	77.9	1.73**	24.1	-3.19	112.3	-0.19	66.6	-0.03	29.8	-	8.8	-1.59	170.6	-0.05	6.9	0.03	3.3
ABD 101 X GT 9	-	246.2	6.01**	76.8	1.27**	23.9	3.70	112.5	4.41**	71.3	1·70	31.9	-	7.6	-2.91**	170.6	0.31	6.9	0.09	3.7
ABD 101 X GT 7		258.7	-3.33**	68.5	-2.17**	19.8	7.01	115.1	1.86*	69.9	7.12**	36.7		7.3	-1.11	170.3	-0.57	6.1	0.71**	3.8
ABD 101 X SB 32	-	236.3	-0.67	68.0	-1.71**	18.5	-4.23	84.7	1.53	66.4	0.28	29.8	-	7.6	10.30**	176.3	0.49	6.8	-0.63**	2.9
ABD 101 X SB 27	-	229.8	-2.01*	71.0	-1.79**	19.5	4.13	113.8	-0.03	66.5	0.61	30.7	-	7.3	-0.47	169.3	-0.33	6.3	-0.61**	2.7
ABD 101 X Patiyali	-	213.3	-5.87**	60.9	-1.89**	18.3	2.27	101.1	1.99*	65.8	-0.13	34.0	-	7.8	3.37**	168.3	0.23	6.7	-0.11	3.1
ABD 111 X SB 54	-	248.7	-1.9*	66.1	-0.31	20.2	1.93	126.9	1.15	66.9	-0.09	28.9	-	7.6	3.17**	170.0	1.27**	7.9	0.23*	3.2
ABD 111 X GT 9	-	251.3	2.55**	66.0	0.83	21.3	-5.77	112.8	1.49	67.4	0.41	29.9	-	7.1	-2.41*	169.7	-0.35	6.1	-0.18*	3.1
ABD 111 X GT 7	-	261.4	-5.13**	58.9	-1.37**	18.8	-8.13	110.7	0.65	65.8	0.89	29.7	-	6.9	-1.69	168.8	0.43	6.3	-0.61**	2.8
ABD 111 X SB 32	-	217.1	0.73	61.8	-1.61**	17.9	6.51	105.3	2.71**	65.9	3.31**	31.8	-	9.1	1.27	160.0	-0.39	6.9	0.17	3.6
ABD 111 X SB 27	-	221.9	0.63	64.5	-0.21	20.1	2.52	127.9	-1.79*	63.0	-2.61*	26.1	-	8.5	2.61**	169.0	0.27	6.3	0.63**	3.8
ABD 111 X Patiyali	-	199.8	-1.71*	59.1	-0.67	17.9	-3.88	103.1	1.71*	62.8	2.71*	34.8	-	7.8	-10.01**	158.7	0.61**	6.7	-0.89**	2.8
SB 54 X GT 9	-	221.7	0.51	63.3	0.14	18.9	4.51	126.1	0.05	67.1	1.23	30.1	-	9.6	-1.03	163.7	0.29	7.1	0.07	3.5
SB 54 X GT 7	-	218.7	-1.04	62.8	-0.29	18.3	-7.35	112.7	2.49**	68.8	-1.11	26.3	-	8.5	-0.61	161.0	0.31	7.1	-0.29**	2.9
SB 54 X SB 32	-	189.9	-1.64*	60.7	-0.71	17.9	3.81	113.9	-0.49	65.5	0.52	29.3	-	9.3	6.83**	161.0	-0.29	7.3	0.29**	3.4
SB 54 X SB 27	-	223.6	0.53	65.1	0.71	19.8	9.41*	130.1	2.53**	68.8	2.21*	29.9	-	8.1	1.03	162.3	-1.63**	5.1	-0.19*	3.1
SB 54 X Patiyali	-	189.7	-4.23**	53.5	-0.53	17.3	-2.73	105.5	1.33	62.5	-0.11	30.6	-	8.0	5.23**	160.3	0.31	6.9	0.27**	3.5
GT 9 X GT 7	-	256.8	-0.63	59.8	2.03**	20.1	11.97**	124.6	1.97*	69.1	-2.51*	25.4	-	8.3	6.53**	172.1	-1.27**	5.1	-1.05**	2.8
GT 9 X SB 32		215.9	-1.21	52.9	-0.45	18.3	17.99**	109.9	0.37	64.9	2.13*	29.3		9.6	4.77**	165.3	0.03	5.9	-0.41**	3.3
GT 9 X SB 27	-	199.8	-4.63**	52.6	-0.19	19.1	-9.21*	104.3	-2.73**	63.5	0.71	28.9	-	7.2	5.67**	171.1	0.23	6.1	0.91**	4.3
GT 9 X Patiyali	-	168.3	-3.11**	51.2	-0.41	16.3	5.93	107.3	-2.03*	60.3	-0.91	30.4	-	7.8	-6.43**	154.3	-0.81*	5.8	0.07	3.5
GT 7 X SB 32	-	211.0	2.89**	60.7	-0.80	17.1	-3.77	91.9	-0.51	64.1	-0.79	26.0	-	9.9	11.71**	168.3	0.31	6.3	0.33**	3.6
GT 7 X SB 27	-	219.3	-3.00**	51.7	-1.39**	17.5	-18.89**	97.3	8.27**	70.1	2.07*	29.7	-	7.3	-24.13**	140.3	1.70**	7.9	0.01**	3.8
GT 7 X Patiyali	-	225.4	3.51**	58.9	1.43**	18.8	6.41	107.7	2.35*	66.3	3.11**	34.3	-	8.0	4.99**	160.3	0.17	6.8	0.07	3.4
SB 32X SB 27	-	186.7	-0.47	55.3	-1.40**	16.7	-9.07*	83.9	0.69	66.2	-1.51	27.1	-	8.9	1.21	153.4	-0.48	6.1	0.07	3.2
SB 32 X Patiyali	-	162.9	-3.23**	50.3	-0.33	16.8	2.63	82.6	-0.51	61.0	1.58	33.0	-	8.4	3.33**	154.2	-0.63*	6.0	-0.13	3.3
SB 27 X Patiyali	-	209.8	-5.92**	50.6	0.47	19.1	2.71	105.9	2.33*	64.8	1.07	32.9	-	7.7	4.65**	159.2	-0.73*	6.0	-0.25**	3.1

*, ** Significant at 5% and 1% level, respectively.
Due to the non-significant value of ♂^{2} sca, the sca effects for cured leaf yield per plant and leaf thickness were not estimated.

Table IV. Classification of parents with respect to *gca* effects for various general combing ability traits in bidi tobacco

Character Parents	Cured leaf yield per plant (*g*)	Days to flowering	Number 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 (%)
ABD 101	G	P	G	A	G	G	A	P	A	-
ABD 111	G	P	G	G	A	A	A	P	A	-
SB 54	A	P	A	G	A	P	A	P	G	-
GT 9	A	G	P	A	G	A	A	P	A	-
GT 7	G	G	A	A	G	P	A	A	A	-
SB 32	P	G	P	P	P	P	G	G	A	-
SB 27	A	G	A	G	A	P	A	G	A	-
Patiyali	P	G	P	P	P	G	P	G	P	-

A= Average general combiner
G= Good general combiner
P= Poor general combiner

Table V. Promising crosses for cured leaf yield per plant and their Performance for other traits in bidi tobacco.

Promising hybrids	*Per se* Performance	*gca* effect		Other characters with significant *sca* effects in the desirable direction
		P_1	P_2	
1. ABD 101 X ABD 111	288.30	27.12**	22.31**	Number of leaves per plant, Leaf length
2. ABD 111 X GT 7	261.40	22.31**	11.01**	Days to flowering
3. ABD 101 X GT 7	258.70	27.12**	11.01**	Days to flowering, Leaf width, Total reducing sugar (0.69**)
4. GT 9 X GT 7	256.80	2.01	11.01	Number of leaves per plant, plant height, leaf length
5. ABD 101 X SB 54	255.90	27.12**	-3.61**	Number of leaves per plant