Advances in Bioresearch
Volume 3 [2] June 2012: 79 - 85
ISSN 0976 – 4585

www.soeagra.com/abr/abr.htm

ORIGINAL ARTICLE

Generation Mean Analysis for Yield, Yield Contributing Characters and Oil Yield in Tobacco

J.N. Patel[1], A.D. Patel[2], Sudeshna Chakraborty[1] and Sasidharan N[1].
[1]Department of Agricultural Botany, Anand Agricultural University, Anand 388110, Gujarat, India
[2]Bidi Tobacco Research Station, Anand Agricultural University, Anand 388110, Gujarat, India
Email:sudi.bot@gmail.com

ABSTRACT
Tobacco is a principle cash crop of India. The present investigation was carried out to study the genetic parameters like gene effects, epistasis and linkages. The scaling test indicated the presence of epistasis for all characters in different crosses except in cross I and days to flower in cross IV, number of leaves per plant in cross I, number of leaves per plant in cross I and number of branches per plant in cross IV. The estimates of gene effects in cross I reflected the involvement of additive gene effect in the expression of days to flower, number of branches per plant, sand leaves yield per plant, number of capsules per plant and seed yield per plant.
Key words: - *Tobacco, epistasis, gene effect, scaling test.*

INTRODUCTION

Tobacco (*Nicotiana tabacum* L.) is one of the important crops among the principal cash crops of India. Tobacco, 'The Golden leaf' is one of the world's leading non-food crops. The major tobacco producing countries in the world are U.S.A., China, Brazil, India, Turkey and Bulgaria. India ranks second in terms of area with 45 lakh hectares and third in terms of production with 700 million kg of Tobacco. In Gujarat, tobacco occupies about 60 thousand area with 155 million kg production [1]. In Gujarat, cultivation of tobacco is mainly concentrated in Anand, Kheda, Ahmedabad, Mehsana and Vadodara districts. The crop is a rich source of chemicals viz., nicotine, solanesol, malic acid and citric acid. Apart from these phytochemicals, edible protein from green tobacco leaf and oil from the seeds are two areas where further research could justify cultivation of tobacco for alternate uses. Tobacco seed contains about 35 to 40 per cent oil and the refined oil is being used for edible purposes in Turkey and Tunisia [2]. Tobacco seed oil is free from nicotine and is better than other commercially available seed oil like groundnut oil, cotton oil etc. as it does not cause any adverse effect on growth on growth and physiology [3] [4]. Yield is the complex quantitative character and depends on yield components. For crop improvement, genetics of the yield and its components needs to be thoroughly understood. The nature of gene action governing the expression of various traits could be helpful in formulating an effective and sound breeding programme. The knowledge of heritability and genetic gain of the characters is necessary to determine the extent to which they can be transmitted from their parents to offsprings and the extent to which they can be improved through selection. Further, the response of selection is determined by the type of gene action involved in the expression of a trait.

MATERIALS AND METHODS

The present study was conducted at the Bidi Tobacco Research Station (BTRS), Agricultural University, Anand. The experimental material for the present study comprised of seven inbred lines viz., GT 7, Jayalakshmi, Anand 145, Kumkumathri, GT 9, Bhagyalakshmi and HDBRG LP 2 their F_1, F_2 and back cross generations (B_1 and B_2). The seeds of F_1 and back crosses (B_1 and B_2) were prepared by hand pollination. For parents and F_2 self seeds were collected. All the crosses alongwith their parents were grown in Compact Family Block Design with four replications. The application of fertilizer in the experimental plot was done at the rate of 180 kg nitrogen per hectare in the form of ammonium sulphate. All the plants were analyzed for characters like days of flower, number of leaves per plant, plant height, number of branches per plant, sand leaves yield, number of capsules, days to capsule maturity, test weight, seed yield, seed oil percentage and seed oil yield. The mean values were used for statistical computation of all the characters studied. The data were

subjected to analysis of variance for Compact Family Design described by Panse and Sukhatme [5]. The crosses showing significant differences among the progenies for the characters was subjected to generation mean analysis for the estimation of gene effects using six parameter model as suggested by Hayman [6] and Mather and Jinks [7]. The scaling test as described by Hayman and Mather [8] was used to test adequacy of additive dominance model for different characters in each cross. Joint scaling test (additive-dominance model or non-epistatic model) outlined by Cavalli [9] was also applied to generations to fit the three parameter model. In presence of non allelic interactions various gene effects were estimated using six parameters model as suggested by Hayman [8].The non significance scaling test indicates absence of non-allelic interactions and for such character the three parameter model as suggested by Jinks and Jones [10] is employed.

RESULTS AND DISCUSSIONS

During the present study all the four crosses depicted significant differences for all the characters studied, indicating appropriate selection of parental materials as well as their cross combinations. The variance due to generations within cross was significant for most of the characters with all the crosses for all the characters under study, suggesting presence of sufficient variation among the generations of the different crosses.

For days to flower, only additive or dominance as well as additive and non-additive gene effects were found to be important in respect to crosses under study. The number of leaves per plant revealed the presence of digenic interactions and higher order interactions in addition to principle gene effects. The estimates of additive gene effect and dominance epistatic were consistent with both the models. The decreasing alleles were preponded with both additive and dominance gene effects. For the character, number of leaves per plant, only additive, additive as well as dominance, additive and digenic interactions and digenic interactions and additive as well as intra and interallelic interactions were observed with various crosses. Regarding the characters, the plant height (cm), inadequacy of additive dominance model was detected and scaling test was significant, which was confirmed by significant value for X^2 of joint scaling test (Table. 2). For the plant height only additive, epistasis, additive and epistasis and epistasis as well as additive, dominance and epistasis gene effects were found to be important. The results revealed that inheritance of plant height was governed by both additive and non additive gene effects. The above results corroborates with the results of several scientists who had worked on these aspects [11], [12], [13], [14]. While negative significant gene effects for days to flowering was also reported in the same plant [15] and also importance of only dominance gene effect of digenic inter interactions and intra and inter allelic interactions where also reported by several worker which contracts with present findings [16], [17].

Number of leaves per plant is a main attribute of sand leaves yield. The presence of additive gene action for this trait in cross II suggested that the characters could be improved by selection and isolation of homozygous recombinants having more number of leaves from segregating generations through pedigree selection would be appropriate breeding method for increasing number of leaves per plant in this population. Several findings have been reported to have significance of only dominance gene effect or additive and dominance gene effects which mismatches with the present work (Table 1) [18], [19].

Number of branches per plant is an important component character for seed yield, though it is undesirable for leaf yield. Numerical comparisons of means of various generations suggested additivity of genes and presence of partial/ complete dominance gene effects for the inheritance of the trait. Among the simple scaling tests in cross I, 'B' and 'C' tests were significant which suggested inadequacy of additive dominance model. Significance of X^2 value of joint scaling test confirmed presence of digenic interactions and linkages. From the above results, it is concluded that only additive, additive and epistasis, only epistasis as well as additive, dominance and various epistasis gene effects were at work for the genetic control of this characters. Also since it is the main attribute for number of capsules per plant, therefore these genes actions suggested cyclic method of breeding could be adopted to increase the desirable genes (Table 3.).

Table 1: Estimates of scaling tests and gene effects for days to flower, number of leaves per plant and plant height in four crosses of tobacco.

Cross	Gene effects													
	Scaling tests				Six parameter model						Three parameter model			X^2 (3)
	A	B	C	D	m	d	h	i	j	l	m	d	h	
DAYS TO FLOWERS														
I	-2.25	-8.10**	-8.30	1.02	79.35**	5.13**	-2.49	2.05	2.92	12.39				11.09**
					83.70**	2.20**	-14.90	-2.05	5.85	12.40				
II	77.60**	12.55**	14.10**	4.50	68.42**	3.35	-16.30*	9.10	10.05**	4.10				29.36**
					77.60**	13.40**	-20.40	-9.10	-20.10**	4.10				
III	2.85	-12.65**	-8.70	0.55	73.49**	3.18	-11.43	-1.10	7.77**	10.90				26.40**
					81.93**	-4.58**	-22.32	-1.10	15.50**	10.90				
IV	-2.10	-2.20	-0.50	1.90							84.34**	-0.41	-8.92**	1.13
NUMBER OF LEAVES PER PLANT														
I	0.50	-0.30	-2.25	-1.23							28.24**	2.33**	-0.77	2.25
II	0.90	0.15	7.50**	3.23**	22.23**	5.25**	-9.77**	-6.45**	0.38	5.40				19.18**
					28.48**	4.88**	-15.17**	-6.45**	0.75	5.40				
III	0.25	-3.70**	-7.90	-2.22	23.94**	0.80	5.12	4.45	1.98	-1.00				21.51**
					21.13**	-1.18**	6.13	4.45	3.95*	-1.00				
IV	-2.75**	-3.45**	-2.95	1.63	27.90**	-4.17**	-4.93**	-3.25	0.35	9.45**				14.13**
					32.73**	-4.53**	-14.38**	-3.25	0.70	9.45**				
PLANT HEIGHT (cm)														
I	-16.00**	-9.55	-39.35**	-6.90*	157.58**	0.30	12.37	13.80	-3.22	11.75				53.95**
					154.33**	3.52**	0.63	13.80	-6.45	11.75				
II	-18.35**	7.25	-44.95**	-16.93*	120.25**	20.72**	39.67**	33.85*	-12.80**	-22.74				26.88**
					94.73**	33.53**	62.42**	33.85*	-25.60**	-22.75				
III	-25.55**	9.55	-25.10**	-4.55	159.9**	-18.13**	5.52	9.99	-17.55**	6.90				51.26**
					158.88**	-0.58	-1.38	9.10	-35.10**	6.90				
IV	-28.15**	-21.35**	-46.10**	1.70	149.36**	-5.13	-2.38	-3.40	-3.40	52.90**				120.02**
					163.76**	-1.73**	-55.28**	-3.40	-6.80	52.90**				

N.B.: *, ** significant at 5% and 1% level of significance, respectively.

Table 2: Estimates of scaling tests and gene effects for number of branches per plant, sand leaves yield per plant and number of capsules per plant in four crosses of tobacco.

Cross	Gene effects													
	Scaling tests				Six parameter model						Three parameter model			X^2 (3)
	A	B	C	D	m	d	h	i	j	l	m	d	h	
NUMBER OF BRANCHES PER PLANT														
I	-2.20	-2.35*	-3.15*	-3.0	8.14**	0.48	1.35	0.60	1.08	1.95				8.81**
					7.95**	-0.60**	-0.60	0.60	2.15	1.95				
II	0.80	0.30	-4.70**	-2.90**	7.26**	1.53**	7.32**	5.80**	0.25	-6.90**				24.64**
					1.87	1.28**	14.23**	5.80**	0.50	-6.90**				
III	-1.80*	1.65	0.45	0.30	9.51**	1.63**	0.80	-0.60	-1.73**	0.75				6.99
					9.30**	0.10	0.10	-0.60	3.45**	0.75				
IV	0.80	-1.40	0.35	0.47							7.41	0.83	-0.26	4.51
SAND LEAVES YIELD PER PLANT (g)														
I	-42.80**	-29.45**	-80.35**	-4.05	97.22**	22.00**	24.47	8.10	-6.68	64.15*				67.38**
					101.03**	28.68*	-39.68	8.10	-13.35	64.15				
II	9.90	6.50	-39.50**	-27.95**	73.68**	11.43*	74.37**	55.89**	-1.70	-72.29**				17.39**
					18.43	9.73**	146.68**	55.90**	3.40	-72.30**				
III	-27.60**	-30.50**	-43.00**	7.10	104.41**	-14.58	3.42	-14.20	1.45	72.30*				22.11**
					120.77**	-16.03**	-68.88	-14.20	2.90	72.30*				
IV	-26.25**	-13.85	-24.35	7.88	97.06**	10.00	-22.25	-15.75	-6.20	55.85*				13.95**
					122.15**	16.20**	-78.10	-15.75	-12.40	55.85*				
NUMBER OF CAPSULES PER PLANT														
I	-74.20*	-130.45**	210.70**	-3.03	252.73**	96.93**	46.95	6.05	28.12	198.60**				46.64**
					278.90**	68.80**	-151.65	6.05	56.25	198.60				
II	-46.90*	-14.20	-131.15**	-35.03	194.80**	27.97	86.07	70.04	-59.33	8.94				19.55**
					149.53**	-11.63**	95.03	70.05	-32.70	8.95				
III	-94.90**	23.75	-91.95*	-10.40	231.83**	-88.35**	44.38	20.80	-59.33	50.35				25.50**
					222.22**	-29.03**	-5.97	20.80	-118.65**	50.35				
IV	94.35**	-30.95	5.10	-29.15	216.41**	87.52**	36.22	58.30	62.64**	-121.70				9.33**
					167.88**	24.88**	157.93	58.30	125.30**	-121.70				

N.B.: *, ** significant at 5% and 1% level of significance, respectively.

The sand leaves (lower most leaves of the tobacco plant which remains in contact with water and consists of decreased concentration of nicotine) yield per plant (g) showed significant negative estimates with various individual scaling tests which might be due to inadequacy of the scale used for recording observations or due to the differential fertility and /or viability of the members of segregations. Significance of 'A', 'B' and 'C' individual scaling tests as well as X^2 value of joint scaling

test in cross I suggested presence of digenic interactions and higher order interactions with or without linkages (Table 2).

Table 3: Estimates of scaling tests and gene effects for days to capsules maturity, test weight and seed yield per plant in four crosses of tobacco

Cross	Gene effects													
	Scaling tests				Six parameter model						Three parameter model			X^2 (3)
	A	B	C	D	m	d	h	I	j	l	m	d	h	
DAYS TO CAPSULES MATURITY														
I	-0.90	-19.00**	-2.80	8.55**	177.31**	16.58**	-19.72**	-17.10**	9.05**	37.00**				214.93**
					196.42**	7.52**	-56.72**	-17.10	18.10	37.00**				
II	6.25**	1.10	29.75**	11.20**	172.25**	2.95*	-22.22**	-22.39**	2.57	15.05*				81.0**
					187.13**	0.38	-37.27**	22.40**	5.15	15.05*				
III	28.95**	-19.30**	50.80**	20.58**	182.65**	14.18	52.85**	41.15	24.13	31.50**				1202.00**
					216.95**	-9.95**	-84.35**	-41.15**	48.25**	31.50**				
IV	-0.80	-8.65**	17.95**	13.70**	168.30**	1.70*	-25.73**	-27.40**	3.92**	36.85**				96.19**
					190.38**	-2.22**	-62.57**	-27.40**	7.85**	36.85**				
TEST WEIGHT (mg)														
I	31.35**	27.95**	77.45**	9.08	88.30**	6.88*	-37.53**	-18.15	1.69	41.15**				262.26**
					96.77**	5.18**	3.62	-18.15*	3.40	-41.15**				
II	42.75**	16.00**	48.20**	-5.27	104.4**	-3.88	24.65*	10.55	13.37**	-69.29**				77.71**
					74.75**	-17.25**	93.94**	10.55	26.75*	-69.30**				
III	-22.15**	-27.95**	-40.85**	4.63	106.26**	5.15	16.80*	16.80	-9.25	59.35**				119.19**
					112.70**	2.25**	-42.55*	-9.25	5.80	59.35**				
IV	27.00**	-17.40**	43.70**	17.05**	103.74**	7.82*	-74.52**	-34.10**	22.20**	24.50				59.40**
					147.13**	-14.38**	-99.03**	-34.10**	44.40**	24.50				
SEED YIELD PER PLANT (g)														
I	-18.20**	-20.80**	-47.65**	-4.32	43.68**	70.25**	23.08*	8.65	1.30	30.35**				121.72**
					39.73**	-5.72**	-7.28	8.65	2.60	30.35				
II	-10.30**	-12.55**	-27.40**	-2.27	39.56**	-2.30	7.72	4.55	1.23	18.30				53.31**
					40.28**	-3.43**	-10.58	4.55	2.25	18.30				
III	-15.95**	-13.85*	-34.15**	-2.17	44.95**	-5.03	5.07	4.35	-1.05	25.45*				57.88**
					48.78**	-3.97**	-20.44	4.35	-2.01	25.45*				
IV	-10.05*	-16.35**	-32.85**	-3.22	40.71*	7.55**	2.99	6.45	3.15	19.95				48.07**
					44.20**	4.40**	-16.95	6.45	6.30	19.95				

N.B.: *, ** significant at 5% and 1% level of significance, respectively.

The importance of additive effect alongwith non additive effect suggested that *interse* crossing of desired segregants keeping adequate size of population would be of great advantage to develop lines with higher sand leaves yield. The number of capsules showed adequate scaling as it is measured numerically therefore, differential fertility and viability of members of various segregating generations could have resulted in negative and significant- estimates of different scaling tests. Significance of 'A', 'B' and 'C' individual scaling tests as well as X^2 value f joint scaling test in cross I suggested possibility of involvement of digenic interactions (Table 2.). The number of capsules per plant is the main attribute of the seed yield per plant. The existence of non additivity alongwith additive effect in cross I, III and IV suggested that cyclic method of breeding could be adopted to increase the desirable genes. For days to capsules maturity, in cross I, II and IV the estimates of various simple scaling tests were significant and negative, which might be due to different fertility and viability segregants of the respective cross. Additive dominance model in cross I was inadequate as 'B' and 'D' individual scaling test as well as X^2 value of joint scaling test were significant. Since both additive and non additive gene effects were involved in this trait, biparental mating approach or reciprocal recurrent selection would be appropriate recurrent selection would be appropriate in utilizing both the types of gene effect (Table 3). For the characters, test weight (mg) the additive dominance model was adequate 'A', 'B' and 'C' individual scaling tests as well as X^2 value of joint scaling test were significant in cross I. The magnitude of various gene effects revealed preponderance of non additive gene effect and negative genes largely influenced positive genes. Duplicate epistasis was evidenced through positive and negative estimates of different gene effects. The significant estimates of 'A', 'B' and 'C' individual scaling tests as well as X^2 value of joint scaling test in cross II suggested presence of interallelic interactions in addition to principle gene effects (Table 3). Test weight is an important direct attribute of seed yield and oil yield. The presence of additive and non additive gene action suggested cyclic method of breeding could be adopted to increase the desirable genes. For seed yield per plant, in all the crosses 'A', 'B' and 'C' individual scaling tests were significant with negative estimates, the probable reasons for that could be variation for fertility and viability among the members of F_2 generations. Significant estimates of 'A', 'B' and 'C' individual scaling tests as well as X^2 value of joint scaling test in cross I suggested presence of non allelic interactions alongwith major gene effects (Table 4). For seed yield attribute, direction of different simple scaling test suggested differential fertility and viability of member of segregating generations. Significance of various simple scaling tests suggested inadequacy of additive dominance model, which was strongly supported by significance of X^2 values of joint scaling test. The significance of 'B' and 'D' individual scaling tests and X^2 value of joint scaling test for seed oil percent indicated inadequacy of additive dominance model and there by involvement of digenic interactions and linkages in cross I. The significant and negative value of 'B' scaling test suggested variation for fertility and viability of members of F_2 generation. The interallelic interactions were balanced out because of differential directions of the epistasis estimates, hence interallelic interactions were under estimated (Table 4). The data in the present investigation revealed that additive and non additive gene effects governed the inheritance of this trait in cross I and IV. Hence, cyclic method of breeding would be the most appropriate method for increasing seed oil yield per plant in this population.

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