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Genetic analysis for seed yield and important characters in tobacco (*Nicotiana tabacum* L.)

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Abstract
Tobacco is a principal 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 the characters in different crosses except number of leaves per plant in Cross II, plant height in Cross II and capsule weight in Cross IV. The estimates of gene effects in Cross I reflected the involvement of additive gene effect in the expression of plant height, seed weight per capsule and test weight; whereas additive as well as non-additive gene effects were involved in the expression of days to flowering, number of capsules per plant, capsule weight, khakhri yield per plant and seed oil yield per plant. Whereas only non-additive gene effect was evident for number of leaves per plant, days to capsule maturity, seed yield per plant and seed oil percent.

Keywords: 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 4.17 lakh hectares and third in terms of production with 681 million kg of Tobacco. In Gujarat, tobacco occupies about 1.77 lakh hectares area with 253 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 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 off springs 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., A 145, L 108-15-3, Sanand local, ABD 74, GT 4, Jaylakshmi and Dediapada their F_1, F_2 and back crosses (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 along with 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 flowering, number of leaves per plant, plant height, number of branches per plant, days to capsule maturity, number of capsules, capsule weight, seed weight per capsule, test weight, seed yield per plant, khakhri yield per plant, 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].

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 flowering, only additive or dominance and epistatic (additive x additive and dominance x dominance) 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 of the models. The decreasing alleles were prepended with both additive and dominance gene effects. For the characters, plant height (cm) only additive gene effect was important, seed weight per capsule and test weight; dominance and epistatic (additive x additive and dominance x dominance) for days to capsule maturity; additive, dominance and epistatic (additive x additive, additive x dominance and dominance x dominance) for number of capsules per plant; additive, dominance and epistatic (additive x additive, additive x dominance and dominance x dominance) for inheritance of capsule weight; dominance, additive x additive and additive x dominance for inheritance of seed yield per plant; Additive, dominance and epistatic (additive x additive, additive x dominance and dominance x dominance) for khakhri yield per plant; additive x dominance and dominance x dominance for seed oil percent; additive, dominance, additive x additive and additive x dominance gene effects in see oil yield per plant were found to be significant and important for inheritance. However the magnitude of non-additive gene effect for the expression of most of the character revealed preponderance non-additive genetic control of most of the characters.

Number of leaves per plant is a main attribute of khakhri yield. The presence of additive geneaction for this trait in cross IV 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) [10].

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' tests were significant which suggested inadequacy of additive dominance model. Significance of 'χ^2' value of joint scaling test confirmed presence of digenic interactions and linkages. From the above results, it is concluded that dominance x dominance; dominance and different epistatic and additive x additive and dominance x dominance played major role for inheritance of the trait in various crosses. 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 2).

For days to capsules maturity, in crosses I, II, III 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 'C' and 'D' individual scaling test as well as 'χ^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 2).

The number of capsules per plant is the main attribute of the seed yield per plant. The existence of non additivity along with additive effect in cross I, II, III and IV suggested that cyclic method of breeding could be adopted to increase the desirable genes.

The capsule weight is main components of seed yield per plant. The significance of simple scaling test in crosses I, II and III, presence of additive and non additive as well as epistatic gene effects suggested that cyclic method of breeding for increasing desirable genes.

For seed weight per capsule 'χ^2' value of joint scaling test were significant for all four crosses and existence of additive; dominance and epistatic; additive, dominance and epistatic and dominance and various epistatic gene effects suggested that improvement of characters by cyclic methods.

For the characters, test weight (mg) the additive dominance model was adequate only 'C' individual scaling tests as well as 'χ^2' value of joint scaling test were significant in cross I suggested the presence of digenic interactions in addition to principle gene effects. The estimates of gene effects for test weight revealed that ony additive gene effect was significant.

The significant estimates of 'A', 'B' and 'C' individual scaling tests as well as 'χ^2' value of joint scaling test in cross III 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 crosses II and III 'A', 'B', 'C' and 'D' 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', 'C' and 'D' individual scaling tests as well as 'χ^2 value of joint scaling test in cross II and III suggested presence of non allelic interactions along with major gene effects (Table 3). 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 'χ^2 values of joint scaling test. The interallelic interactions were balanced out because of differential directions of the epistasis estimates, hence interallelic interactions were under estimated (Table 3). The data in the present investigation revealed that additive and non additive gene effects governed the inheritance of thistrait in cross II and III. Hence, cyclic method of breeding would be the most appropriate method for increasing seed oil yield per plant in this population.

The khakhri 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', 'C' and 'D' individual scaling tests as well as 'χ^2value of joint scaling test in cross I suggested presence of digenic interactions and higher order interactions with or without linkages (Table 3).

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

Crosses	Gene effect													X^2 at 3 d.f.
	Scaling Test				Six parameters model						Three parameters models			
	A	B	C	D	M	$\hat{d}$	$\hat{h}$	$\hat{i}$	$\hat{j}$	$\hat{l}$	m	$\hat{d}$	$\hat{h}$	
Days to flowering														
I	-0.25	-1.20	-11.8**	-5.20**	61.22**	-2.15**	6.02**	10.40**	0.47	8.95*	-	-	-	37.55**
II	-3.80*	-5.70**	-4.75*	2.37*	61.93**	-5.75**	-9.40**	-4.75*	0.95	14.25**	-	-	-	142.7**
III	7.80**	-1.55	11.90**	2.82	72.22**	1.82	-6.14	-5.64	4.67**	-0.60	-	-	-	34.07**
IV	-6.55**	3.20	-13.80**	-5.22**	58.08**	12.60**	-8.92*	10.45**	-4.87**	-7.1	-	-	-	496.1**
Number of leaves per plant														
I	-3.35**	2.20**	3.45**	2.30**	15.71**	-1.27	-8.29**	-4.59**	-2.77**	5.74**	-	-	-	113.11**
II	0.45	0.01	-0.85	-0.65	-	-	-	-	-	-	18.36**	-3.10**	-2.20*	2.73
III	-1.75**	-1.45	-3.65**	-0.17	19.36**	-1.69	1.60	0.35	-0.19	0.94	-	-	-	17.13**
IV	-5.40**	1.80**	-8.10**	-2.25**	13.15**	2.84**	0.85	4.50**	-3.60**	-0.90	-	-	-	330.98**
Plant height (cm)														
I	4.80	2.65	14.0*	3.27	109.1**	5.87*	12.75	6.55	1.07	0.89		-	-	5.99
II	0.70	-1.35	2.95	1.80	-	-	-	-	-	-	109.3**	-34.93**	-12.94**	0.27
III	5.55	-9.25	34.95**	19.32**	116.51**	-16.95**	-41.89**	-38.64**	7.40	42.35	-	-	-	18.36**
IV	-39.9**	-6.15	-66.40**	-10.15**	78.88**	39.02**	-0.77	20.30*	-16.90**	25.80	-	-	-	100.2**
Number of branches per plant														
I	0.55	-1.00*	0.05	0.25	6.72**	-0.25	-0.82	-0.50	0.77	0.95	-	-	-	8.82*
II	-2.30**	-0.60	-1.60	0.65	7.42**	-2.65*	-1.95*	-1.30	-0.85	4.19**	-	-	-	25.17**
III	-1.10**	-1.60**	1.65*	2.17**	7.95**	-1.07	-3.52**	-4.34**	0.24	7.04**	-	-	-	32.41**
IV	-2.75**	-0.60	-0.25	1.55**	6.31**	0.22	-1.84	-3.09**	-1.07	6.44**	-	-	-	19.59**

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

Table 2: Estimates of scaling tests and gene effects for days to capsule maturity, number of capsules, capsule weight, seed weight per capsule in four crosses of tobacco.

Crosses	Gene effect													X^2 at 3 d.f.
	Scaling Test				Six parameters model						Three parameters models			
	A	B	C	D	M	$\hat{d}$	$\hat{h}$	$\hat{i}$	$\hat{j}$	$\hat{l}$	m	$\hat{d}$	$\hat{h}$	
Days to capsules maturity														
I	-0.30	-1.75	-20.5**	-9.25**	108.80**	0.65	19.02**	18.49**	0.72	-16.44**	-	-	-	24.20**
II	2.10	-5.45**	4.80	4.07**	111.65**	-10.52**	1.84	-8.15**	3.77**	11.50*	-	-	-	30.66**
III	4.00**	-9.95*	-6.70	-0.37	118.21**	2.09*	-2.02	0.74	6.97**	5.20	-	-	-	14.28**
IV	5.15**	1.55	5.65	-0.52	91.52**	24.72**	-15.07**	1.05	1.79	-7.75	-	-	-	9.30*
Number of capsules per plant														
I	-183.3**	-48.25	21.79	126.6**	498.6**	-82.7**	-321.3**	-253.3**	-67.52**	484.8**	-	-	-	36.07**
II	-173.0**	105.3*	224.35*	146.02**	579.3**	-228.2**	-130.5	-292.0**	-139.2**	359.7**	-	-	-	53.65**
III	-219.7**	-291.2**	-194.9**	158.0**	573.08**	-13.82	-98.47	-316.0**	35.75	827.0**	-	-	-	84.02**
IV	195.60**	-87.15**	133.24**	12.40	268.1**	133.7**	115.6**	-24.79	141.3**	-83.65	-	-	-	131.6**
Capsule weight (mg)														
I	-17.80	-56.00**	5.50	39.65**	339.50**	-40.60**	-60.45**	-79.29**	19.09*	153.10**	-	-	-	23.00**
II	50.70**	-108.0**	57.05*	57.20**	308.0**	55.1**	-88.47**	-114.4**	79.37**	171.7**	-	-	-	257.6**
III	-77.40**	10.65	-103.9**	-18.6*	302.38**	-21.22**	62.04**	37.19**	-44.02**	29.55	-	-	-	54.07**
IV	-9.05	5.85	42.40	22.80	-	-	-	-	-	-	313.6**	60.91**	-1.61	4.02
Seed weight per capsule (mg)														
I	12.20*	26.15**	67.45*	14.55	199.5**	-51.32**	-22.65	-29.10	-6.97	-9.25	-	-	-	17.82**
II	-5.55	-32.15**	20.25	28.97**	165.2**	17.77	-30.82**	-57.94**	13.30**	95.64**	-	-	-	65.50**
III	-11.05	8.50	-50.10**	-23.77**	158.5**	-9.57**	17.25**	47.55**	-9.77*	-45.00**	-	-	-	43.49**
IV	2.15	65.10**	96.15**	14.45*	173.1**	0.42	-84.10**	-28.89*	-31.47**	-38.34	-	-	-	80.53**

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

Table 3: Estimates of scaling tests and gene effects for test weight, seed yield per plant, *khakhri* yield per plant, seed oil percent and seed oil yield per plan in four crosses of tobacco.

Crosses	Gene effect													X^2 at 3 d.f.
	Scaling Test				Six parameters model						Three parameters models			
	A	B	C	D	m	$\hat{d}$	$\hat{h}$	$\hat{i}$	$\hat{j}$	$\hat{l}$	m	$\hat{d}$	$\hat{h}$	
Test weight (mg)														
I	-4.45	-3.70	-14.05**	-2.95	91.28**	-2.87*	5.39	5.89	0.37	2.25	-	-	-	13.42**
II	25.95**	0.65	19.90**	-2.70	94.61**	17.47**	6.42	5.39	13.30**	-30.69**	-	-	-	129.31**
III	-29.55**	-9.20**	-43.45**	-2.35	85.82**	-9.30**	-14.97**	4.70	-10.17**	34.04**	-	-	-	231.37**
IV	-6.55**	7.15**	-14.50**	-7.55**	77.38**	-1.72	0.27	15.10**	-6.84**	-15.70**	-	-	-	43.84**
Seed yield per plant (g)														
I	7.15*	-1.60	-6.60	-6.07*	70.20**	-0.87	24.05**	12.10*	4.37*	-17.70	-	-	-	9.92*
II	11.35**	18.95**	42.45**	6.08*	69.31**	-18.22**	-5.50	-11.60*	-3.7	-19.25*	-	-	-	132.85**
III	-14.95**	6.70**	-16.45**	-4.10*	72.82**	-12.72**	17.75*	8.65	-11.12*	0.19	-	-	-	37.02**
IV	23.15**	24.70**	53.15**	2.65	42.11**	4.47**	0.47	-5.29	-0.74	-42.40**	-	-	-	360.39**
***Khakhri* yield per plant (g)**														
I	-21.75**	-8.30	12.95*	21.50**	92.18**	-8.42*	-35.90**	-43.00**	-6.72**	73.05**	-	-	-	122.96**
II	5.50	-53.40**	-23.60**	12.45**	90.75**	-14.60**	-15.80*	-24.90**	29.45**	72.80**	-	-	-	138.56**
III	10.90**	-16.05**	-42.85**	-18.85**	96.23**	-8.27**	21.90**	37.70**	13.47**	-32.55**	-	-	-	85.40**
IV	8.75**	-13.70**	-67.55**	-31.30**	43.86*	47.12**	51.30**	62.60**	11.22**	-57.64**	-	-	-	346.73**
Seed oil percent														
I	-2.13**	-2.21**	-4.95**	-0.30	30.85**	0.48	-0.55	0.60	4.39**	3.74*	-	-	-	55.32**
II	2.38**	1.61*	5.52**	0.76	30.59**	-1.02	0.23	-1.52	0.38	-2.48	-	-	-	29.53**
III	-0.77	-2.25**	3.92**	3.47**	31.24**	1.04	-6.42**	-6.95**	0.74	9.98**	-	-	-	30.51**
IV	1.54**	-1.95	5.21**	2.81**	29.96**	-1.69**	-2.47	-5.63**	1.74**	6.04*	-	-	-	40.70**
Seed oil yield per plant (g)														
I	0.76	-1.96	-5.32**	-2.06*	21.66**	22.52**	7.27**	4.28*	1.42*	-3.20	-	-	-	12.45**
II	4.18**	6.87**	15.71**	2.23*	21.20**	-6.20**	-1.74	-4.35*	-1.30	-6.99*	-	-	-	151.80**
III	-5.56**	-0.11	-2.41	1.56	22.73**	-2.95**	0.64*	-2.51	-2.69**	7.61*	-	-	-	23.81**
IV	-6.85**	6.74**	17.86**	1.88**	12.62**	57.24**	-1.23	-3.97	5.17**	-9.62**	-	-	-	344.91**

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

Conclusion

The system of breeding that can be employed for improvement of character depends upon the type of gene action involved in its expression. The type and magnitude of gene effects differed for different characters in the same cross and for the same character in different crosses, which necessitates specific handling of individual cross in segregating generations. The characters, number of capsules per plant and seed yield per plant in most of the crosses were controlled by additive gene effect and hence the most appropriate method of breeding for improving these traits would be pedigree method of selection. In contrast to this, majority of the characters were controlled by non-additive gene effect or additive and non-additive gene effects in different crosses hence, those could be successfully improved by heterosis breeding or *inter se* matting followed by cyclic method of breeding i.e. recurrent selection.

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Ethical approval: This article does only for research purposes and also do not use any other live things. This article does not contain any studies with human participants or animals performed by any of the authors.

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