Tobacco Research 46(1) : 11-18, 2020

GENETIC STUDIES ON YIELD AND QUALITY PARAMETERS IN BIDI TOBACCO (*NICOTIANA TABACUM* L.)

P.PULLI BAI[1], S. JAFFAR BASHA[1], K.SARALA[2] AND C.CHANDRASEKHARA RAO[2]

[1]Regional Agricultural Research Station, Acharya N.G.Ranga Agricultural University,Nandyal-51850, A.P.
[2] ICAR - Central tobacco research institute, Rajahmundry-533105, A.P.

(Recieved on 06th Jan, 2020 and accepted on 27th Mar, 2020)

The genetic studies on the yield, quality and their attributes are very much limited in bidi tobacco. Hence, in a study carried out at Regional Agricultural Research Station Nandyal, Kurnool district in Andhra Pradesh during 2017-18 and 2018-19, general combining ability (GCA) and specific combining ability (SCA) estimates were made using line x tester design. Five lines and five testers were used to generate 25 F_1 hybrids in all possible cross combinations. All the hybrids along with parents were grown in randomized block design with three replications and observations recorded on cured leaf yield per plant, days to flowering, number of leaves per plant, plant height, leaf length, leaf width, days to maturity, nicotine content and reducing sugar content. Analysis of the data through line x tester analysis indicated that the variance estimates due to general combining ability (GCA) were observed to be highly significant for most of the traits indicating most of the characters are governed by additive gene action. The estimates of variances due to specific combining ability (SCA) differed significantly for all the characters indicating the importance of non-additive gene action for the inheritance of these traits. The estimates of GCA effects shown that the parents, ABD132, NyBD56, ABD146 and NBD290 were good general combiners for cured leaf yield and its related attributes. The estimates of SCA effects indicated that cross combinations of NBD289 X GT4, NBD289 X GT7 and ABD132 X NBD290 were significant and positive for cured leaf yield. These crosses showing significant SCA effect can be used to exploit transgressive segregants.

INTRODUCTION

Tobacco is one of the important high value commercial crops in India and is valued for its potential to generate farm income and employment to farmers and farm labours and revenue to the government. There are different types of tobaccos viz., flue cured virginia, hookah, cigar, lanka, bidi *etc*. Bidi tobacco is grown in Asian countries like India and Pakistan. In India, it is grown in mainly in the states of Andhra Pradesh, Gujarat and Karnataka. The quality and prices of bidi tobacco is assessed based on the spangle score, nicotine content, chloride content, reducing sugars and the ratio between reducing sugar to nicotine.

Varietal improvement is a key area for increasing the yields of bidi tobacco grown in various areas. However, the genetic enhancement work done in bidi tobacco was very limited in Andhra Pradesh. To enhance the present yield levels of bidi tobacco grown in AP, systemic varietal improvement through hybridization and exploitation of generated variability through recombination breeding is essential. Estimation of combining ability based on line x tester analysis is a powerful tool to select good combiners and thus selecting the appropriate parental lines for hybridization programme. The line x tester analysis approach as proposed by Kempthorne, (1957) provides systemic approach for identification of superior parents and crosses for success of plant breeding programmes. For identifying the parents and cross combinations for increasing the yields of bidi tobacco, an investigation on the gene action and combining ability effects was made at Regional Agricultural Research Station, Nandyal and presented in the current paper.

MATERIALS AND METHODS

The present investigation on combining ability analysis in bidi tobacco (*Nicotiana tabacum* L.) was undertaken at Regional Agricultural Research Station, Nandyal for two consecutive years 2017-

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

18 and 2018-19. Twenty five hybrids, developed by crossing five lines with five testers, along with parents and one check A119 (Table 1)were evaluated in a randomized block design with three replications. Observations were recorded on cured leaf yield per plant, days to flowering, number of leaves per plant, plant height, leaf length, leaf width, days to maturity, nicotine content and reducing sugar content. With the data obtained for parents and hybrid on various parameters, line x tester analysis was made (Kempthrone, 1957) to estimate the gene action and identify general and specific combiners.

RESULTS AND DISCUSSION

Analysis of variance for combining ability: The variance due to hybrids showed significant differences for all the characters except days to maturity (Table 2). The mean squares due to females and mean squares due to males were generally highly significant for all the characters except days to maturity. The estimates of

Table 1: Parental characteristics used in the study

Sr. No.	Parents	Characteristics
1	ABD132	High yielder, taller plant, good leaf thickness, less smoke toxicants, resistance to lodging.
2	ABD163	High yielder good spangling
3	NyBD56	High yielding, long and thick leaf nature with important leaf attributes.
4	NBD289	High yielder, taller plant good quality
5	ABD146	Medium plant height, high yielder.
6	GT4	Drought tolerant, better smoking quality, compact plant habit with profuse spangling.
7	Nandyala pogaku 1	Light green Colour, High yielder.
8	GT5	TMV resistant, High yielder.
9	GT7	Drought tolerant, high leaf potential, high yielder.
10	NBD290	High yielder, taller plant good quality.
11	A119 (Check)	Tolerant to leaf burn disease, High nicotin content, drought tolerant

Table 2: Analysis of variance for different yield attributing and quality traits in bidi tobacco

Sources of variation	d.f.	Cured leaf yield per plant(g)	Days to flowering	No.of leaves/ plant	Plant height (cm)	Leaf length (cm)	Leaf Width (cm)	Days to maturity	Nicotine Content (%)	Reducing sugar content (%)
Replications	2	9.45	19.65	0.24	4.26	39.79	8.03	10.05	0.030	0.003
Genotypes	35	2149.31**	125.13*	3.34**	153.69**	32.37**	40.15**	22.76*	0.35**	0.58**
Parents	9	2425.42**	407.14**	8.74**	141.86**	41.95**	54.02**	52.15*	0.23**	0.85**
Lines	4	2350.53**	901.02**	11.13**	60.65**	84.32**	85.70**	32.23	0.16**	0.22**
Testers	4	2320.71**	48.41	4.64**	41.79**	34.92	67.21*	59.90**	0.27**	1.06**
Lines *vs* Testers	1	5182.82**	225.28**	8.64**	855.18**	18.44	74.89**	101.78**	0.32**	1.98**
Hybrids	24	1960.59**	30.45**	1.58**	116.74**	24.36**	29.18**	9.92	0.38**	0.43**
Parents vs Hybrids	1	515.48**	45.47*	0.40	362.31**	147.92**	217.97**	80.56*	0.002**	0.72**
Check vs Hybrids	1	10542.12**	1.80	0.14	795.83**	37.68*	6.43	3.81	0.75	1.52**
Error	70	30.31	7.99	0.57	10.87	7.78	6.61	12.94	0.018	0.013

*, ** Significant at 5% and 1% levels, respectively.

component due to various sources revealed that variances due to females ($ó^2f$) were highly significant for cured leaf yield per plant, days to flowering, number of leaves per plant, leaf width, nicotine and reducing sugar content (Table 3). Estimates of variance component due to males ($ó^2m$) were found to be highly significant for all the traits except days to maturity. A comparison of the variance components due to lines and testers indicated that females exhibited higher magnitude of variability for number of leaves per plant, days to maturity, nicotine and reducing sugar content. The $ó^2sca/ó^2gca$ ratio was found above the unity for all characters, indicating the predominant role of non-additive gene action for the inheritance of these traits.

Table 3: Estimates of general and specific combining ability for different characters in bidi tobacco

Sources of variation	d.f.	Cured leaf yield per plant(g)	Days to flowering	No.of leaves/ plant	Plant height (cm)	Leaf length (cm)	Leaf Width (cm)	Days to maturity	Nicotine Content (%)	Reducing sugar content (%)
$ó^2F$	-	-1.04**	-0.26**	0.05**	-2.37	0.15	0.96**	0.26	-0.02**	0.07**
$ó^2$ M	-	11.52**	1.35**	-0.02*	22.43**	1.40**	3.35**	-0.02	-0.04**	-0.01**
$ó^2$ gca	-	5.9**	0.62**	0.004**	10.51**	0.62**	2.19**	0.15	0.023**	0.03**
$ó^2$sca	-	565.85**	7.80**	0.44**	18.11**	3.73**	3.55**	-0.81*	0.17**	0.06**
$ó^2$ sca / $ó^2$ gca	-	115.49	16.22	79	1.63	5.08	1.69	-6.01	5.6	1.71

*, ** Significant at 5% and 1% levels, respectively.

Table 4: Study of general combining ability (GCA) effects of the parents for nine characters in bidi tobacco

S. No.	Parents	Cured leaf yield per plant(g)	Days to flowering	No.of leaves/ plant	Plant height (cm)	Leaf length (cm)	Leaf Width (cm)	Days to maturity	Nicotine Content (%)	Reducing sugar content (%)
Lines (Female parents)										
1	ABD132	34.65**	-4.10**	1.18**	19.44**	-0.75	1.13	-0.14	0.14**	0.08**
2	ABD163	-7.54**	-4.97**	0.95**	-11.05**	3.36**	1.17**	-0.69**	-0.12**	-0.05**
3	NyBD56	33.05**	3.77**	1.91**	8.85**	-2..36**	0.30	-2.14	0.02	-0.03
4	NBD289	-22.16**	-5.04**	-1.68**	-0.44	-1.96**	-1.65**	-1.04**	0.14**	0.06**
5	ABD146	29.98**	-5.46**	-2.09**	-20.95**	1.42	0.48	-1.38	-0.03	0.46
	S.E. (gi)	2.68	0.59	0.30	1.29	0.48	0.51	0.06	0.03	0.02
	CD @ 5%	9.25	2.04	0.68	4.51	2.05	1.32	2.09	0.11	0.04
Testers (Male parents)										
6	GT4	-2.52	-9.80**	-1.84**	9.33**	0.80	-1.12**	-1.27	-0.07**	-0.28**
7	Nandyala Pogaku-1	-24.69**	-2.23**	1.59**	-10.22**	-0.92	1.14**	-1.69	0.12**	-0.03
8	GT5	-9.94**	0.70	1.65*	9.55**	2.63**	0.30	-0.19*	-0.43**	-0.26**
9	GT7	-42.36**	-3.33**	-1.56**	-2.67	-3.06**	-1.45**	-0.58**	-0.07	0.01
10	NBD290	29.41**	1.60	0.42	9.23**	0.50	0.48	-4.62	0.04	0.06**
	S.E. (g_i)	3.79	0.84	0.27	1.81	0.72	0.51	0.86	0.03	0.03
	CD @ 5%	11.68	2.56	0.85	5.65	2.63	1.52	2.54	0.13	0.07

*, ** Significant at 5% and 1% probability levels, respectively

Gene action and combining ability effects: The variance due to GCA and SCA were found highly significant for cured leaf yield, plant height, days to flowering, number of leaves per plant, leaf length, leaf width, days to maturity, nicotine content and reducing sugar content were governed by both additive and non-additive gene action (Table 3.). The SCA variance was higher in magnitude than gca variance for days to flowering, number of leaves per plant, leaf length, leaf width, days to maturity, nicotine content and reducing sugar content indicating that the characters were governed by non-additive gene effect for the expression of the above traits in accordance with Jung *et al*, (1982),

Table 5: Estimates of Specific combining ability (SCA) effects of hybrids for various yield and quality traits in bidi tobacco

Hybrids/Traits	Cured leaf yield per plant(g)	Days to flowering	No.of leaves/ plant	Plant height (cm)	Leaf length (cm)	Leaf Width (cm)	Days to maturity	Nicotine Content (%)	Reducing sugar content (%)
ABD 132X GT4	-9.89**	2.99**	-0.46	-0.18	0.25	0.69	0.85	0.18**	0.04
ABD132 X Nandyala pogaku1	-10.65**	-5.60**	0.33	4.70**	-4.22**	-2.33	-0.65	-0.25**	0.45**
ABD132 X GT5	2.59	0.76	-0.16	4.11**	-2.45*	-3.46	1.17	-0.08	-0.36**
ABD132 X GT7	-6.43*	0.66	0.16	-7.34**	3.23**	3.43**	-1.56	0.45**	-0.05
ABD132 X NBD290	30.56**	-0.33	0.04	-1.31	2.20	1.57	0.24	-0.34**	-0.12**
ABD 163X GT4	15.05**	1.75	1.07**	-0.15	1.12	3.50**	-0.89	-0.01	0.19**
ABD163 X Nandyala pogaku1	-2.74	0.83	0.03	-11.19**	-0.67	-1.14	0.37	0.02	-0.22**
ABD163 X GT5	3.32	-0.70	-0.32	1.34	0.34	1.76	0.51	-0.41**	-0.06
ABD163 X GT7	2.45	1.32	-0.66**	4.29**	-0.25	-2.36	-1.89	0.25**	-0.11**
ABD163 X NBD290	-17.65**	-3.20**	-0.12	5.72**	-0.55	-1.75	1.91	0.30**	0.20**
NyBD56X GT4	-20.19**	-2.82**	-0.04	0.66	-2.82*	-2.75	-0.83	0.49**	0.08
NyBD56 X Nandyala pogaku1	21.55**	5.26**	0.99**	0.76	1.43	2.38	1.11	0.59**	-0.61**
NyBD56 X GT5	-3.82*	1.66	-0.62**	-1.65	1.17	1.31	-2.09	-0.31**	0.03
NyBD56 X GT7	-9.48**	-2.98**	-0.44*	1.37	-0.82	-1.20	1.17	-0.42**	0.18**
NyBD56 X NBD290	13.74**	-1.10	0.11	-1.13	1.05	0.27	0.65	-0.25**	0.24**
NBD289X GT4	47.93**	2.79**	-0.01	-1.47	4.53**	0.65	3.34	-0.35**	-0.22**
NBD289 X Nandyala pogaku1	-22.62**	-1.20	-1.45**	1.07	-1.52	-1.02	0.31	-0.31**	-0.12**
NBD289 X GT5	-13.83**	-3.13**	1.14**	-1.97	0.49	1.71	-0.23	0.88**	0.28**
NBD289 X GT7	31.84**	-1.90	0.72**	0.61	-1.83	-1.84	1.37	-0.31**	0.14**
NBD289 X NBD290	-36.44**	3.44**	-0.40	1.77	-1.67	0.50	-3.83	0.10*	-0.09*
ABD146XGT4	-30.69**	-5.64**	-0.65**	1.08	-3.07**	-2.18	-1.43	-0.17**	-0.07
ABD146XNandyala pogaku1	23.52**	-0.38	0.11	4.71**	3.98**	2.12	-1.16	-0.09*	0.41**
ABD146XGT5	16.35**	1.42	-0.04	-1.83	0.45	-1.32	0.64	-0.04	0.13**
ABD146XGT7	-17.86**	2.91**	0.22	1.09	-0.33	1.97	0.91	0.07	-0.16**
ABD146XNBD290	18.51**	1.19	0.36	-5.05**	-1.03	-0.59	1.04	0.23**	-0.20**
S.E. (Sij)	2.50	1.04	0.22	1.38	1.13	1.01	1.34	0.06	0.04

*, ** Significant at 5% and 1% levels, respectively

Kher *et al*, (2001), Makwana, (2006), Patel, (1998), Patel *et al*, (2006), Pawar, (2010) and Vankar, (2007).

The estimates of GCA effect was highly significant and positive for cured leaf yield, number of leaves per plant, plant height, leaf length**,** leaf width, nicotine and reducing sugar per cent (Table 4.). Female parents viz., ABD 132, NyBD56, ABD146, ABD163 and NBD289 and male parents viz., NBD 290, GT5, Nandyala pogaku 1 and GT4 observed to be the good general combiners. (Table 4.) Among female parents, ABD146 and among male parents, GT4 and Nandyala pogaku 1 exhibited highly significant negative GCA effect for days to flowering. Female parents, ABD163 and NBD289, and male parents, GT-5 and GT-7 showed significantly negative GCA for days to maturity. Mostly similar results were reported for bidi tobacco by Bhatt *et al.* (2004), Patel (1998) and Rangaswamy *et al.* (2002).

Estimates of SCA effects were highly significant and positive for cured leaf yield, plant height, leaf length, leaf width, nicotine content and reducing sugar content among hybrids NBD289 X GT4, NBD289 X GT7, ABD132 X NBD290, ABD163 X NBD290, ABD146 X Nandyala pogaku 1 , ABD132 X Nandyala pogaku 1, ABD132 X GT7, ABD163 X GT4 , NBD289 X GT5 and NyBD56 X Nandyala pogaku1 (Table 5.) . Significant and negative SCA effect for days to flowering were found in ABD146 X GT4, ABD132 X Nandyala pogaku 1 and ABD163 X NBD290. NBD289 X NBD290 showed highest negative but non-significant SCA effect for days to maturity. Similar such results were obtained by Makwana (2006) and Patel (1997).

Selection of the parents based on their combining ability is a pre-requisite for hybridization in all crop improvement programmes. General combining effects of parents (Table 6) indicated that none of the parents was found good general combiner for all the characters studied. Five parents *viz;* ABD132, NyBD56, ABD146, GT5 and NBD290 possessed significant gca effects for cured leaf yield. In addition to that ABD132 was also a good combiner for number of leaves per plant, plant height, nicotine and reducing sugar content. While the parent, GT5 was a good general combiner for number of leaves per plant, plant height and leaf length. The parent, NyBD56 also appeared as good general combiner for number of leaves per plant but average combiner for plant height leaf length and days to maturity and poor combiner for remaining characters. ABD163 was a poor combiner for cured leaf yield, days to maturity, nicotine content but was a good general combiner for leaf length, leaf width. The parent, NBD289 was a good general combiner for cured leaf yield and No. of leaves per plant but a poor

Table 6: Classification of parents with respect to general combining ability effects for various characters in bidi tobacco

Characters	Parents									
	ABD132	ABD163	NyBD56	NBD289	ABD146	GT4	Nandyala pogaku1	GT5	GT7	NBD290
Cured leaf yield per plant(g)	G	P	G	P	G	A	P	G	P	G
Days to flowering	A	A	P	A	G	G	G	P	P	A
No.of leaves /plant	G	A	G	A	P	A	G	G	A	P
Plant height (cm)	G	A	A	A	A	G	P	G	P	A
Leaf length (cm)	A	G	A	A	P	P	A	G	A	A
Leaf width (cm)	A	G	P	A	A	A	G	A	A	P
Days to maturity	A	P	A	A	A	A	A	A	A	A
Nicotine content (%)	G	P	P	G	P	A	G	A	P	A
Reducing sugar content(%)	G	A	P	G	P	A	P	A	A	G

G = good combiner, A = average combiner and P = poor combiner

combiner for days to flowering, leaf width, nicotine and reducing sugar content.

The parent, GT4 was a good general combiner for days to flowering, plant height but poor combiner for leaf length. Though, Nandyala pogaku1 was a poor combiner for cured leaf yield, plant height and reducing sugar content, it was a good general combiner for days to flowering, no. of leaves per plant, leaf width and nicotine content. While the parent, GT7 found to be a poor combiner for cured leaf yield, days to maturity, plant height and nicotine content. The results revealed that most of the characters had relatively high degree of significance between lines performance and gca effects.

Specific combining ability effects (Table 5) indicated that top three hybrids NBD289 X GT4 (poor x average), NBD289 X GT7 (poor x poor) and ABD132 X NBD290 (good x good) were recorded higher cured leaf yield and also possessed highly significant sca effect and can further be utilized to get desirable segregants for improvement.

In self-pollinated crops, SCA effects are not much important as they are mostly related with non-additive gene effects which cannot be fixed in a pure line. However, if a cross-combination exhibited high sca effects as well as per se performance having at least one parent as good general combiner for a particular trait, it is expected that such cross-combinations would

Table 7: Top three parents and Hybrids for combining ability estimates and parents with respect to general and specific combining ability effects for various characters

Traits	Combining ability effects		
	General Combining Ability		Specific Combining Ability
	Females	Males	
Cured leaf yield (g/pl.)	ABD146	NBD290	NBD289 X GT4
	NyBD56	GT5	NBD289 X GT7
	ABD132	-	ABD132 X NBD290
Days to flowering	ABD146	GT4	ABD146XGT4
	-	Nandyala pogaku 1	ABD132XNandyala pogaku1
	-	-	ABD163XNBD290
No.of leaves per plant	ABD132	GT5	NBD289XGT5
	NyBD56	Nandyala pogaku 1	ABD163XGT4
	-	-	NyBD56X Nandyala pogaku1
Plant height(cm)	ABD132	GT5	ABD163XNBD290
	-	GT4	ABD146X Nandyala pogaku1
	-	-	ABD132X Nandyala pogaku1
Leaf length(cm)	ABD163	Nandyala pogaku 1	NBD289XGT4
	-	-	ABD146X Nandyala pogaku1
	-	-	ABD132XGT7
Leaf width(cm)	ABD163	Nandyala pogaku 1	ABD163XGT4
	-	-	ABD132XGT7
	-	-	NyBD56X Nandyala pogaku1
Days to maturity	ABD146	NBD290	NBD289XNBD290
	NyBD56	Nandyala pogaku 1	-
	NBD289	-	-
Nicotine content (%)	NBD289	GT7	NBD289XGT5
	ABD132	NBD290	NyBD56X Nandyala pogaku1
	-	-	ABD132XGT7
Reducing sugar content	ABD132	NBD290	ABD132X Nandyala pogaku1
(%)	NBD289	-	ABD146X Nandyala pogaku1
	-	-	NBD289XGT5

throw desirable transgressive segregants in later generations. Significant sca effects of those combinations involving good x good combiners showed the major role of additive type of gene effects, which is fixable. However, two good general combiners may not necessarily throw good segregants. Similarly, the superior crosses involving both the poor x poor general combiners, very little gain is expected from such crosses because high sca effects may dissipate with the progress towards homozygosity.

Considering the GCA effects of parents involved for the expression of sca effects 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 and poor x poor, in which the 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 the presence of intra allelic gene interactions. The sca effects of certain crosses in the undesirable direction could be due to the failure of desirable alleles of the parent to co-operate. As a result, a cross from good general combiner parents may exhibit poor sca effects. The results revealed that there was some degree of sca effects (Table 7) of hybrids as well as gca effects of parents play a role in manifestation of heterosis for most of the traits (Bhatt, 1999 and Patel, 2005).

Based on the general combining effects of parents, they are classified as good, average and poor combiner for different characters studied. Significant and desirable estimates of variances due to sca for all the characters indicates the importance of non-additive gene action for the inheritance of these traits. As variance due to both GCA and SCA were found significant for most of the character appeared to be under the influence of both additive and non-additive gene actions. The estimates of gca effects suggested that the parents, ABD132, NyBD56, ABD146 and NBD290 were good general combiners for cured leaf yield and its related attributes. The estimates of sca effects indicated that the crosses NBD289 X GT4, NBD289 X GT7 and ABD132 X NBD290 were the most promising for cured leaf yield and some of its related traits.

ACKNOWLEDGEMENT

The authors are grateful to All India Network Project on Tobacco (AINPT), ICAR-CTRI, Rajahmundry and Regional Agricultural Research Station, Nandyal, ANGRAU, Andhra Pradesh for providing the facilities for smooth conduct of the experiment.

REFERENCES

Bhatt, M.M. 1999. Heterosis and combining ability in bidi tobacco (*N. tabacum L.*) over environments. **Ph.D. thesis submitted to Gujarat Agricultural University**, Sardarkrushinagar.

Bhatt, M.M., H.C. Pathak and J.S. Patel. 2004. Combining ability analysis for yield and its components in bidi tobacco (*N. tabacum L.*). **Tob. Res**. 30(2): 129-134.

Jung, S.H., J.K. Hwang and S.H. Son. 1982. Analyses of inheritance of quantitative characters in a diallel cross of oriental tobacco varieties (*N. tabacum L.*). **J. Kor. Soc.Tob. Sci**. 4(1):7-13.

Kempthorne, O. 1957. An introduction to genetical statistics. **The Iowa State University Press**, Ames, Iowa. pp. 545.

Kher, H.R., H.C. Pathak, M.G. Makwana and J.N. Patel. 2001. Combining ability studies for yield and yield components in bidi tobacco (*N. tabacum L.*) over diverse cytoplasms. **Tob. Res.**. 27(2): 134-139.

Makwana, M.G. 2006. Generation mean analysis over environments in tobacco (*N. tabacum L.*). **Ph.D. thesis submitted to Anand Agricultural University**, Anand.

Patel, A.D., P.A. Patel and J.S. Patel. 2006. Line x Tester study for yield and yield components in Bidi Tobacco (*Nicotiana tabacum L.*) .**Tob.Res**.32 (2):39-44.

Patel, G.P. 1997. Genetic variations in improved population of tobacco (*Nicotiana tabacum L.*)

.**M.Sc. (Agri.) thesis submitted to Gujarat Agricultural University**, Sardarkrushinagar.

Patel, J.N. 2005. Genetic analysis of important quantitative characters and seed oil yield in tobacco (*Nicotiana tabacum L.*). **Ph.D. thesis submitted to Anand Agricultural University**, Anand.

Patel, P.A. 1998. Heterosis and combining ability studies in tobacco (*Nicotiana tabacum L.*). **M.Sc. (Agri.) thesis submitted to Gujarat Agricultural University**, Sardarkrushinagar.

Pawar, S.A. 2010. Line x Tester studies on morphological and seed oil yield traits in tobacco (*Nicotiana tabacum L.*). **M.Sc. (Plant breeding and Genetics) thesis submitted to Anand Agricultural University**, Anand.

Rangaswamy, B.R., S. Ramesh, M. Rudraradhya and N.Vasuki 2002. Genetic and combining ability analysis of quantitative traits in FCV tobacco. **Tob. Res**. 28:5-9.

Vankar,H.D. 2007. Heterosis and combining ability studies in bidi tobacco (*Nicotiana tabacum L.*). **Crop. Sci**. 10:437-440.