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Correlation and path analysis studies on F_2 populations of FCV tobacco (*Nicotiana tabacum* L.)

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Abstract
Tobacco ('*Nicotiana tabaccum*') is an industrial plant because of its cured leaves which are used in cigarette and cigar making. Due to the economic significance of cured leaves, the correlated response of cured leaves with other traits is of vital importance in tobacco breeding programs. In the present research, correlation and path analysis is used to determine the interrelationships among cured leaf yield and 8 related traits comprising days to flowering, plant height, number of leaves per plant, leaf length, leaf width, leaf area per plant, fresh leaf yield and top grade equivalent. Correlation coefficient analysis revealed that cured leaf yield was positively and significantly correlated with most of the studied traits in both F2 populations. The characters such as days to flower and plant height had weak association in both F_2 populations. Path analysis revealed that direct contribution of leaf area per plant, top grade equivalent in F_2 population of cross TB-70 x TB-102 and fresh leaf yield, top grade equivalent in F_2 population of cross TB-100 x TB-102 were of higher magnitude on cured leaf yield. However, indirect positive contribution of leaf area per plant, fresh leaf yield and top grade equivalent were appreciable to enhance the yield.

Keywords: FCV tobacco**,** correlation, path analysis; direct effect, indirect effect, cured leaf yield

1. Introduction

Tobacco (*Nicotiana tabaccum* L.) is an industrial plant and polyploid in nature. India is the only country where many different types of tobacco, *viz.*, flue-cured Virginia (FCV), burley, natu, cigar filler, cigar wrapper, cheroot, hookah, bidi and chewing are grown under different agro-climatic conditions. Among them FCV and burley are exportable tobacco types and are mainly used in cigarette manufacturing. The most important aim of tobacco breeding programs is improving cured leaf yield of the plant which is a complex trait associated with many interrelated components. Cured leaf yield in tobacco is a quantitative trait largely influenced by the environment and hence has a low heritability (Xiao *et al.*, 2007) [15]. Therefore, the response to direct selection for dry leaf yield may be unpredictable unless there is good control of environmental variation. Commonly, plant breeders prefer to select for yield related traits that indirectly increase yield. According to the literature, indirect selection by yield related traits such as plant height, leaf area index, number of leaves, leaf length and flowering date can increase tobacco dry leaf yield (Legg and Collins, 1975) [12]. White *et al*. (1979) [3, 14] used simple correlation analysis based on agronomic, physical and chemical characteristics to show the interrelationships among flue-cured tobacco genotypes and indicated that all agronomic traits present positive correlations with dry leaf yield. Honarnejad and Shoai-Deylami (2004) [11] found high significant correlations between dry leaf yield and agronomic traits except for plant height and leaf number in a F_2 population of tobacco. Wenping *et al.*, (2009) [13] reported that the most strongly correlated traits with dry leaf yield are leaf number and leaf length. Since increasing numbers of independent variables can compound apparent interdependence, therefore, correlations may be insufficient to explain the associations in a way to enable breeders to decide on a direct or indirect selection strategy.

2. Materials and Methods

Present investigation was carried out at the College of Agriculture, University of Agricultural and Horticultural Sciences, Navile, Shivamogga during *Kharif* season of 2016. The materials for the study consisted of two F_2 poppolations (TB-70 x TB-102 and TB-100 x TB-102) of FCV tobacco. The experiment was conducted in randomized block design (RBD) with three replications. The entries were planted in rows of 6m length with spacing of 90 x 60 cm and the recommended agronomic practices were followed during the crop growth period. In each F_2 population, seventy five plants were selected at random for recording the observations on eight different quantitative characters. Statistical analysis for calculation of correlation was worked out as per Al-Jibouri *et al* (1958) [10] and path coefficient of various characters was calculated according to Deway and Lu (1959) [9].

3. Results and Discussion

A complex association exists among different leaf characters and character themselves do not exist in isolation. These characters are often correlated with each other, either due to pliotrophy is due to genetic linkage (Harland, 1939) [8]. For rational approach towards the improvement of yield, selection will be more rewarding when it is based on the components of yield. Association of yield comport with yield thus assume special important as the basis of indirect selection. In the present investigation yield related traits were investigated and their relations with yield as well as among themselves was examined using phenotypic correlation analysis (Table 1 & 2) and correlation among the characters other than the economically important character (cured leaf yield) was summarized in table 3 and 4 for both F_2 populations TB-70 x TB-102 and TB-100 x TB-102, respectively. Path coefficient analysis permitting a critical examination of direct and indirect contribution of component characters towards leaf yield was analyzed using the phenotypic correlation coefficients and their results are presented in Table 5 and 6.

Association of cured leaf yield was highly significant and positive with leaf area per plant (0.9526), fresh leaf yield (0.9445), top grade equivalent (0.9066), leaf length (0.2398) and leaf breadth (0.1404) in F2 population of cross TB-70 x TB-102.Whereas in F2 population of the cross TB-100 x TB-102, plant height exhibited low positive but significant correlation (0.0.1371)) with cured leaf yield. Characters like leaf area per plant (0.6929), fresh leaf yield (0.0.9515), top grade equivalent (0.9168), leaf length (0.2829) and leaf breadth (0.1975) had significant positive correlation with the cured leaf yield. On the contrary, he association of days to maturity with cured leaf yield was low and negative (-0.1619) in desirable direction.

Days to flowering exhibited non-significant positive correlation with cured leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102. Whereas it exhibited negative significant correlation with cured leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-100 × TB-102, except high indirect effect via fresh leaf yield. So selection for this trait may increase the cured leaf yield, thus leading to the conclusion that, selection has to be for early flowering genotypes to achieve improvement in cured leaf yield. The correlation between plant height and cured leaf yield was not significant at phenotypic level. At phenotypic level neither the direct effect nor the indirect effects were of considerable magnitude in the cross TB-70 x TB-102. Whereas, in cross TB-100 x TB-102 cured leaf yield showed positive significant correlation with plant height (Patel *et al.,* 1981) [1] and its direct and indirect effects were of negligible magnitude irrespective of their direction. Thereby suggesting that tall plants are likely to outyield the dwarf plants.

Number of leaves per plant exhibited non-significant positive correlation with cured leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102 and TB-100 x TB-102. In the cross TB-100 × TB-102, number of leaves per plant had considerable positive indirect effect via fresh leaf yield similar results reported by Hamid *et al*., 1975 [2], White *et al*., 1979 [3, 14], Kim and Hwang, 1981. So selection for this trait may not increase the cured leaf yield. Leaf length showed highly significant and positive correlation with cured leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102 and TB-100 x TB-102, except high indirect effect *via* leaf area and fresh leaf yield in the cross TB-70 × TB-102 and TB-100 x TB-102, respectively. But most of the direct and indirect effects were positive revealing that selection for leaf length increases the cured leaf yield in both the crosses. Thus the inference was that selection for high leaf length, leaf area and fresh leaf yield leads to high cured leaf yield.

Leaf breadth showed highly significant and positive correlation with cured leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102 and TB-100 x TB-102, except high indirect effect *via* leaf area and fresh leaf yield in the cross TB-70 × TB-102 and TB-100 x TB-102, respectively. Thus the inference was that selection for high leaf breadth, leaf area and fresh leaf yield leads to high cured leaf yield. At phenotypic level, correlations of leaf area with cured leaf yield were significant in both the crosses. Leaf area had high positive direct effect and considerably high positive indirect effect through top grade equivalent and negative indirect effect through fresh leaf yield, the other effects being negligible. Thus inference was that selection for high leaf area leads to high cured leaf yield in the cross TB-70 x TB-102. Whereas in cross TB-100 x TB-102, correlations of leaf area with cured leaf yield was positive and significant. However, it had substantial positive direct effect and also majority of its indirect effects with substantial magnitudes were positive. These observations revealed that selection for high leaf area is likely to result in increased cured leaf yield.Fresh leaf yield exhibited highly significant and positive correlation with cured leaf yield and it had considerably high positive direct and considerably high positive indirect effects through top grade equivalent and leaf area, respectively in both the crosses TB-70 × TB-102 and TB-100 × TB-102, the other effects being negligible, these results were on par with Chaubey *et al*., 1990 [5] and Lakshmish and Shivanna, 1999 [6]. Thus selection for this trait can increase the cured leaf yield. Top grade equivalent exhibited highly significant and positive correlation with green leaf yield and its direct were positive and indirect effects were of negligible magnitude irrespective of their direction in both the crosses, except the high indirect effect *via* leaf area and moderate indirect effect *via* fresh leaf yield in cross TB-70 x TB-102 and TB-100 x TB-102, respectively. Further, the number of positive indirect effects with substantial magnitudes was greater than the number of negative indirect effects with substantial magnitude (Lakshmish and Shivanna, 1999, sampurna, 2016) [6, 7]. These observations led to the conclusion that increasing cured leaf yield without sacrificing top grade equivalent is possible.

Table 1: Phenotypic correlation coefficients for leaf yield and physiological in F_2 generation of FCV tobacco cross TB-70 xTB102

	DF	PH	NLP	LL	LB	LA	FLY	TGE
DF	1.000	-0.1314	-0.064	0.209**	0.142*	0.0713	0.0669	0.0548
PH		1.000	0.0661	0.0251	0.0035	0.0436	0.0397	0.0428
NLP			1.000	-0.1059	-0.0900	0.0322	0.0319	0.0338
LL				1.000	0.8690**	0.2745**	0.2701**	0.2274**
LB					1.000	0.1679*	0.1603*	0.0979
LA						1.000	0.9951**	0.8681**
FLY							1.0000	0.8634**
TGE								1.000
CLY	0.0565	0.0396	0.0293	0.2398**	0.1404*	0.9526**	0.9445**	0.9066**

DF- Days to flowering
PH-Plant height (cm)
NLP-number of leaves per plant
LL-Leaf length (cm)
LB- Leaf breadth (cm)
LA-Leaf area per plant (cm^2)
FLY-Fresh leaf yield (kg/ha)
TGE- Top grade equivalent (kg/ha)

Table 2: Phenotypic correlation coefficients for leaf yield and physiological traits in F_2 generation of FCV tobacco cross TB-100 xTB-102

	DF	PH	NLP	LL	LB	LA	FLY	TGE
DF	1.000	0.0731	-0.0004	-0.1539*	-0.0409	-0.1389*	-0.1796**	-0.1191
PH		1.000	0.0427	0.0497	-0.0261	0.0751	0.1206	0.1366*
NLP			1.000	0.0595	0.0655	0.0442	0.1084	0.1019
LL				1.000	0.4925**	0.2446**	0.2963**	0.2887**
LB					1.000	0.1952**	0.2212**	0.1962**
LA						1.000	0.7013**	0.6423**
FLY							1.0000	0.8742**
TGE								1.000
CLY	-0.1619*	0.1371*	0.072	0.2829**	0.1975**	0.6929**	0.9515**	0.9168**

DF- Days to flowering
PH-Plant height (cm)
NLP-number of leaves per plant
LL-Leaf length (cm)
LB- Leaf breadth (cm)
LA-Leaf area per plant (cm^2)
FLY-Fresh leaf yield (kg/ha)
TGE- Top grade equivalent (kg/ha)

Table 3: Summary of correlations among the characters with other than the economically important characters in F_2 population of TB -70 X TB -102

Character	Nature of correlation	Significant at phenotypic level
Days to flowering	Positive Negative	Leaf length (0.2990) and leaf breadth (0.1420)
Leaf length (cm)	Positive Negative	Days to flowering(0.209), leaf breadth (0.8690), leaf area per plant (0.2745), fresh leaf yield (0.2701), top grade equivalent (0.2274) and chlorides (0.2647)
Leaf breadth (cm)	Positive Negative	Leaf area per plant (0.1679), fresh leaf yield (0.1603), leaf breadth (0.8690) and leaf length (0.2120)
Leaf area per plant (cm^2)	Positive Negative	Fresh leaf yield (0.9951), top grade equivalent (0.8681), specific leaf weight (0.1363), leaf length (0.2745) and leaf breadth (0.1679)
Fresh leaf yield (Kg/ha)	Positive Negative	Top grade equivalent (0.8634), leaf length (0.2701), leaf breadth (0.1603) and leaf area per plant (0.9951)
Top grade equivalent (Kg/ha)	Positive Negative	Specific leaf weight (0.1574), leaf length (0.2274), leaf area per plant (0.8681) and fresh leaf yield (0.8634).

Table 4: Summary of correlations among the characters with other than the economically important characters in F_2 population of TB -100 X TB -102

Character	Nature of correlation	Significant at phenotypic level
Days to flowering	Positive Negative	Internodal length (0.2186) Chlorophyll content (-0.1432), specific leaf weight (-0.2231), leaf length (-0.1539), leaf area per plant (-1389) and fresh leaf yield (-0.1796)
Plant height (cm)	Positive Negative	Top grade equivalent (0.1366)Specific leaf weight (-0.2060)
Number of leaves per plant	Positive Negative	Reducing sugars/nicotine (L) (0.1525)
Leaf length (cm)	Positive Negative	Leaf breadth (0.4925), leaf area per plant (0.2446), fresh leaf yield (0.2963), top grade equivalent (0.2887) and stem girth (0.2124) Days to flowering (-0.1539)
Leaf breadth (cm)	Positive Negative	Stem girth (0.1684), number of leaves per plant (0.4925), leaf area per plant (0.1952), fresh leaf yield (0.2212) and top grade equivalent (0.1962) Internodal length (-0.1518)
Leaf area per plant (cm^2)	Positive Negative	Stem girth (0.2117), leaf length (0.2446), leaf breadth (0.1952), fresh leaf yield (0.7013) and top grade equivalent (0.6423) Days to flowering (-0.1389)
Fresh leaf yield (Kg/ha)	Positive Negative	Leaf length (0.2963), leaf breadth (0.2212), leaf area per plant (0.7013) and top grade equivalent (0.8742) Days to flowering (-0.1796)
Top grade equivalent (Kg/ha)	Positive Negative	Plant height (0.1366), leaf length (0.2887), leaf breadth (0.1962), leaf area per plant (0.6423) and fresh leaf yield (0.8742)

Table 5: Estimates of Direct and indirect effect of yield components on cured leaf yield at phenotypic level in F2 population of FCV tobacco TB-70x TB-102

	DF	PH	NLP	LL	LB	LA	FLY	TGE
DF	-0.0061	0.0008	0.0004	-0.0013	-0.0009	-0.0004	-0.0004	-0.0003
PH	0.0006	-0.0047	-0.0003	-0.0001	0.0000	-0.0002	-0.0002	-0.0002
NLP	0.0002	-0.0002	-0.0037	0.0004	0.0003	-0.0001	-0.0001	-0.0001
LL	-0.0128	-0.0015	0.0065	-0.0610	-0.0530	-0.0167	-0.0165	-0.0139
LB	-0.0066	0.0002	-0.0042	0.0405	0.0466	0.0078	0.0075	0.0046
LA	-0.0689	0.0421	0.0311	0.2651	0.1622	0.9660	0.9612	0.8386
FLY	-0.0187	-0.0111	-0.0089	-0.0756	-0.0449	-0.2786	-0.2800	-0.2418
TGE	0.0175	0.0137	0.0108	0.0726	0.0313	0.2772	-0.2757	0.3193
r values	0.0565	0.0396	0.0293	0.2398**	0.1404*	0.9526**	0.9445**	0.9066**

DF- Days to flowering
LB- Leaf breadth (cm)
PH-Plant height (cm)
LA-Leaf area per plant (cm^2)
NLP-number of leaves per plant
FLY-Fresh leaf yield (kg/ha)
LL-Leaf length (cm)
TGE- Top grade equivalent (kg/ha)

Table 6: Estimates of Direct and indirect effect of yield components on cured leaf yield at phenotypic level in F2 population of FCV tobacco TB-100x TB-102

	DF	PH	NLP	LL	LB	LA	FLY	TGE
DF	-0.0043	-0.0003	0.0000	0.0007	0.0002	0.0006	0.0008	0.0005
PH	0.0009	0.0130	0.0006	0.0006	-0.0003	0.0010	0.0016	0.0018
NLP	0.0000	-0.0012	-0.0285	-0.0017	-0.0019	-0.0013	-0.0031	-0.0029
LL	0.0013	-0.0004	-0.0005	-0.0087	-0.0043	-0.0021	-0.0026	-0.0025
LB	0.0003	0.0002	-0.0005	-0.0038	-0.0076	-0.0015	-0.0017	-0.0015
LA	-0.0045	0.00024	0.0014	0.0079	0.0063	0.0324	0.0227	0.0208
FLY	-0.1136	0.0763	0.0686	0.1874	0.1400	0.4437	0.6327	0.5530
TGE	-0.0412	0.0472	0.0352	0.0998	0.0678	0.2221	0.3023	0.3458
r values	-0.1619	0.1371*	0.072	0.2829**	0.1975**	0.6929**	0.9515**	0.9168**

DF- Days to flowering
LB- Leaf breadth (cm)
PH-Plant height (cm)
LA-Leaf area per plant (cm^2)
NLP-number of leaves per plant
FLY-Fresh leaf yield (kg/ha)
LL-Leaf length (cm)
TGE- Top grade equivalent (kg/ha)

4. Conclusion

Cured leaf yield had positive significant correlation with leaf length, leaf breadth, leaf area per plant, fresh leaf yield and top grade equivalent in both F_2 populations. Hence, these characters can be considered as one of the traits where selection can operate to get high cured leaf yielding lines in further generations in both the crosses of F_2 population. In path analysis leaf area per plant and top grade equivalent in F_2 population of the cross TB-70 x TB-102 and fresh leaf yield and top grade equivalent in F_2 population of the cross TB-100 x TB-102 were exhibited high direct effect on cured leaf yield so selection based on these traits can directly improve the cured leaf yield.

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