PALE YELLOW TOBACCOS AND THEIR HYBRIDS WITH FLUE-CURED TOBACCO[1]

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Chlorophyll-deficient Tobacco Introductions (T.I.s), carrying the factor(s) for "Pale Yellow," were crossed with flue-cured tobacco varieties. Hybrids and parents were tested for agronomic and smoke flavor characteristics, and chemical constituents. T.I. parents were below the flue-cured parents and hybrids in yield, acre value, price per pound, and percentage sugar but higher in percentage total alkaloids. F_1 hybrids were intermediate between the parents for most characteristics. The greatest evidence of heterosis occurred in total alkaloids and sugar. The intermediacy of the hybrids in most cases except chlorophyll content indicates that backcrossing to flue-cured germ plasm should result in tobaccos possessing the simply inherited pale yellow character, together with the other characteristics of the recurrent flue-cured parent.

Leaf color plays an important part in tobacco *(Nicotiana tabacum* L.) production. Color of the unharvested leaf is used as a criterion to indicate "ripeness" and suitability for harvest. Color is used as an indicator in curing and is one of the criteria used in judging the value of the cured leaf.

There are certain tobaccos which have heritable chlorophyll deficiencies (1, 5, 7, 8, 9, 10). One chlorophyll-deficient type forms the basis for production of burley tobaccos (3, 6). Another chlorophyll-deficient type described as "Pale Yellow" could also play a part in commercial production although its usage has not been fully explored. Pale yellow is apparently determined by at least one gene which is dominant to green. Chaplin (2) found that pale yellow plants contain 50 percent as much chlorophyll as the flue-cured variety 'Hicks'. He harvested hybrids between pale yellow and green flue-cured varieties in two harvests in an effort to see if the reduced chlorophyll content would permit reducing the number of harvests. Under conventional harvesting the cured leaf of hybrids that had been harvested conventionally were slightly lower in price per pound and sugar but higher in total alkaloids and alpha amino nitrogen. However, under a one or two harvest system the sugar, total alkaloids, and alpha amino nitrogen of the hybrids were more similar to the flue-cured parents.

The study reported herein was performed to evaluate eight tobacco introductions (T. I.s) which carry the pale yellow character, and three flue-cured varieties together with their hybrids. From this evaluation the most promising T.I. line and flue-cured variety will be identified for further breeding designed to incorporate the pale yellow character into a flue-cured background genotype.

MATERIALS AND METHODS

The flue-cured varieties 'NC 95', 'NC 2326' and 'Coker 316' together with eight tobacco introductions (T.I.s) were selected for this study. The latter include; T.I. 14 from Uruguay, T.I. 544 from Ecuador, T.I.s 1067, 1088, 1304 and 1372 from Argentina, and T.I. 1143 and 1419 from Brazil. The homology among the T.I.s for pale yellow has not been determined.

Each T.I. was crossed with each flue-cured variety resulting in 24 F1 hybrids. The hybrids together with the 11 parents were grown in a randomized complete block design with three replications at Whiteville, Oxford and Reidsville, North Carolina in 1969. Production practices were those commonly used in the flue-cured area, and harvesting and curing was essentially that common to flue-cured production. All F1s were pale yellow in appearance and because of this they may have been harvested somewhat faster and in fewer primings than the flue-cured parents.

Acre yield, acre value, price per pound, percentage total alkaloids, and percentage reducing sugars were determined. Estimates of heterosis were obtained by computing the deviation of the hybrid from the mid-parent. Observations on the cured leaf were made at two locations and in addition cured leaf from certain entries were made into cigarettes and smoked by taste panels at each of six tobacco manufacturers.[3] Percentage total alkaloids was determined by the Griffith (4) procedure and sugars were determined on a Technicon Autoanalyzer by the ferric-cyanide reduction method.

RESULTS

The component "entries by locations" from the analysis of variance was statistically significant at the 1% probability level for price per pound, percentage total alkaloids and percentage sugar. Usually this interaction necessitates the presentation of data by locations, but since the magnitude of the interaction is small in relation to other components of variance, and since the data indicates consistency in ranking, means across locations are presented.

Flue-cured and T.I. parents are compared in **Table 1.** Yields, acre values, price per pound and percentage sugars were almost without exception higher for flue-cured varieties than T.I. lines. This was also true of the overall flue-cured and T.I. means. The T.I. lines tended to be higher than flue-cured varieties in percentage total alkaloids. Considering all characters, T.I. 1372 more closely resembled the flue-cured varieties than any of the other T.I.s. Among the flue-cured varieties, NC 2326 was the highest for all characters ex-

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[3] *Participating tobacco companies were American Tobacco Co., Brown & Williamson Tobacco Corp., Imperial Tobacco Co., Liggett & Myers, Inc., Philip Morris, and R. J. Reynolds Tobacco Co.*

Table 1. Agronomic characteristics and chemical constituents of parents.

Parents	Yield† lbs/acre	Acre Value $/acre	Price per lb. $	Total Alkaloids %	Sugar %
T.I. Lines					
T.I. 14	2257 c	1481 d	.65 d	3.25 bcd	6.9 d
T.I. 544	1889 de	1204 e	.63 de	3.50 b	4.7 e
T.I. 1067	1437 f	881 f	.61 ef	2.99 cdef	3.9 e
T.I. 1088	1457 f	893 f	.61 ef	3.45 b	4.5 e
T.I. 1143	1895 de	1174 e	.62 ef	2.84 efg	3.7 e
T.I. 1304	2015 d	1226 e	.61 f	2.59 gh	4.9 e
T.I. 1372	2243 c	1570 cd	.70 c	3.55 b	10.2 c
T.I. 1419	1799 e	1129 e	.63 e	3.90 a	7.4 d
Mean of T.I. Parents	1874	1195	.63	3.26**	5.8
Flue-Cured Varieties					
NC 2326	2680 a	1956 a	.73 a	2.75 fgh	18.8 a
C 316	2550 ab	1838 ab	.72 ab	2.24 i	16.1 b
NC 95	2418 bc	1699 bc	.70 bc	2.94 def	17.6 a
Mean of F.C. Parents	2549**	1831**	.72**	2.64	17.5**
All Parents	2058	1368	.66	3.09	9.0

†*Means with the same letter do not differ at the 5% level of probability based on Duncan's multiple range test.*

***Significant at the .01 probability level in specific comparisons between T.I. parental lines and flue-cured parental varieties.*

Table 2. Agronomic characteristics and chemical constituents of T.I. hybrid families.

Hybrid Family	Yield† lbs/acre	Acre Value $/acre	Price per lb. $	Total Alkaloids %	Sugar %
T.I. Hybrid Family					
T.I. 14	2648 a	1880 a	.71 b	3.19 ab	12.3 b
T.I. 544	2440 b	1686 c	.69 c	3.31 a	11.0 c
T.I. 1067	2082 d	1406 e	.68 d	3.19 ab	9.6 d
T.I. 1088	2118 d	1433 e	.68 d	3.00 bc	9.3 d
T.I. 1143	2261 c	1534 d	.68 d	3.18 ab	7.5 e
T.I. 1304	2260 c	1530 d	.68 d	2.87 c	9.1 d
T.I. 1372	2457 b	1798 b	.73 a	3.23 a	13.8 a
T.I. 1419	2276 c	1534 d	.67 d	3.37 a	12.1 b
All Hybrids	2318	1600	.69	3.17	10.6

†*Means with the same letter do not differ at the 5% level of probability based on Duncan's multiple range test.*

Table 3. Agronomic characteristics and chemical constituents of flue-cured hybrid families.

Hybrid Family	Yield† lbs/acre	Acre Value $/acre	Price per lb. $	Total Alkaloids %	Sugar %
F. C. Hybrid Family					
NC 2326	2343 a	1646 a	.70 a	3.35 a	11.0 a
C 316	2321 a	1565 b	.67 c	2.92 c	9.9 b
NC 95	2289 a	1590 b	.69 b	3.23 b	10.8 a
All Hybrids	2318	1600	.69	3.17	10.6

†*Means with the same letter do not differ at the 5% level of probability based on specific comparisons—F test.*

Table 4. Percent heterosis of F_1 hybrids.

Hybrid	Yield	Percent Heterosis† Acre Value	Price per lb.	Total Alkaloids	Sugar
14 x NC 95	14**	21**	6**	4	— 2
544 x NC 95	8*	10**	3	2	4
1067 x NC 95	8	9*	3	10	—15
1088 x NC 95	7	10*	4*	— 3	—18*
1143 x NC 95	3	5	3	10	—31**
1304 x NC 95	2	6	5**	7	—13
1372 x NC 95	5	11**	6**	3	1
1419 x NC 95	7*	6	— .3	— .3	6
14 x NC 2326	7*	12**	4**	15*	3
544 x NC 2326	6	8*	3	13*	— 5
1067 x NC 2326	.2	— 1	2	14*	—15*
1088 x NC 2326	2	2	3	1	—11
1143 x NC 2326	3	5	2	24**	—27**
1304 x NC 2326	— 1	— 1	2	17**	—28**
1372 x NC 2326	12	6	6**	2	3
1419 x NC 2326	5	5	1	8	—13*
14 x C 316	10**	9**	— 1	6	— 1
554 x C 316	16**	16**	.4	8	— 3
1067 x C 316	6	3	— .2	16*	— 2
1088 x C 316	9*	4	— 2	— 4	—19*
1143 x C 316	— 1	— 3	— 1	14	—31**
1304 x C 316	— 4	— 5	.3	3	—14
1372 x C 316	3	1	— 1	8	— 6
1419 x C 316	2	.4	— .5	1	— 2

†$\frac{F_1 - midparent}{midparent} \times 100 = \%$ *heterosis*

*,**Significant difference between F_1 and midparent at .05 and .01 probability level respectively. t test.

cept for percentage total alkaloids.

Hybrid families were formed by each T.I. and each flue-cured variety. (e.g., T.I. 14 family is the result of T.I. 14 by each of the three flue-cured varieties and NC 2326 family is the result of NC 2326 by each of the eight T.I. lines.) The performances of the these families are shown in **Tables 2 and 3.** The T.I. 14 family had the highest acre yield and acre value, while the T.I. 1372 family had the highest price per pound and percentage sugar. The T.I. 1419 family was the highest in percentage total alkaloids. T.I.s 1067 and 1088 produced families with low yield, acre value, and percentage sugar. T.I. 1143 family had the lowest sugar content.

Performances of the flue-cured families are shown in **Table 3.** Considering all characters, NC 2326 produced the highest family averages and in most instances Coker 316 produced the lowest.

The obvious differences between the T.I. and flue-cured parents would lead one to expect hybrids to differ from either parent. The general absence of dominant gene action in tobacco would cause one to expect the hybrid to fall somewhere near the midparent. The percentage heterosis for each hybrid is given in **Table 4.** A slight amount of positive heterosis was shown in most cases for yield, acre value, and price per pound. Some values were as high or higher than 10% but these were exceptions. The hybrids T.I. 1143 x NC 2326 and T.I. 1304 x NC 2326 showed highly significant amounts of heterosis for total alkaloids. It is interesting that the parents involved in these examples were not greatly different from each other in alkaloid content. T.I. 1143 and T.I. 1304 were also involved in hybrids that were considerably below the midparent in sugar content. The T.I. with the highest sugar content as a parent, T.I. 1372, showed rather low amounts of heterosis in its hybrids.

The means of each hybrid family together with the T.I. parent are shown in **Table 5.** The hybrid means exceeded the T.I. parent in every case except one for yield, acre value, price per pound, and sugar. In total alkaloids the T.I. parent exceeded the hybrid mean for T.I.s 1088, 1372, and 1419, whereas the hybrid exceeded the T.I. for T.I.s 1067, 1143, and 1304.

Observations were made on the cured leaf of each entry at two locations. The hybrid T.I. 1372 x NC 2326 produced the best-appearing cured leaf of the hybrids, and it also compared favorably with NC 2326. Cured leaf samples of T.I. 1372, NC 2326, NC 95, T.I. 1372 x NC 2326, and T.I. 1372 x NC 95 were made into cigarettes and smoked by panelists of six tobacco companies. Each panel was asked to compare each entry with NC 95. Because of differences in the manner in which each panel conducted its evaluation and differences also in reporting, the actual results will not be presented. The consensus was that T.I. 1372 was considered to be inferior and that the hybrids were better than T.I. 1372 but somewhat below the flue-cured varieties. The better hybrid was 1372 x NC 2326.

DISCUSSION

For the characters measured in this study the T.I.s were below the flue-cured varieties, with the exception of total alkaloids. Total alkaloids are at a desirable level in flue-cured varieties NC 2326 and NC 95, so that a further increase by the T.I.s does not constitute a practical advantage. This would lead one to the conclusion that the use of these T.I.s *per se* in tobacco production would not be practical.

Hybridization with flue-cured germ plasm tended to moderate the effect of the T.I. germ plasm and at

the same time produce a pale yellow tobacco. The F1s were much improved over the T.I. parents, and some hybrids, (such as T.I. 1372 x NC 2326) compared well with the flue-cured parents. Of all T.I.s, 1372 and 14 seem to offer the most promise as far as hybridization is concerned. Of the flue-cured varieties tested NC 2326 is perhaps the best for this purpose. Hybridization results indicate that continued backcrossing to flue-cured varieties with appropriate selection of pale-yellow phenotypes would result in still further progress toward flue-cured characteristics. This should be a relatively easy breeding program to follow because of the dominant pale yellow character.

Although estimates of heterosis indicate heterotic effects in some instances and quite commonly for the characters total alkaloid and sugar, the hybrids were not equal to the better parent across all characters. The hybrids offering the most promise were T.I. 1372 x NC 2326 and T.I. 1372 x NC 95.

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Table 5. Agronomic characteristics and chemical constituents of hybrid family means and T.I. parents.

T.I.	Yield lbs/acre		Value $/ acre		Price per lb. $/lb.		Total Alkaloids %		Sugar %	
	Hybrid Family	T.I. Parent	Hybrid Family	T.I. Parent	Hybrid Family	T.I. Parent	Hybrid Family	T.I. Parent	Hybrid Family	T.I. Parent
14	2648**	2257	1880**	1481	.71**	.65	3.19	3.25	12.3**	6.9
544	2440**	1889	1686**	1204	.69**	.63	3.31	3.50	11.0**	4.7
1067	2082**	1437	1406**	881	.68**	.61	3.19**	2.99	9.6	3.9
1088	2118**	1457	1433**	893	.68**	.61	3.00	3.45**	9.3**	4.5
1143	2261**	1895	1534**	1174	.68**	.62	3.18**	2.84	7.5**	3.7
1304	2260**	2015	1530**	1226	.68**	.61	2.87*	2.59	9.1**	4.9
1372	2457*	2243	1798**	1570	.73**	.70	3.23	3.55*	13.8**	10.2
1419	2276**	1799	1534**	1129	.67**	.63	3.37	3.90**	12.1**	7.4

*,**Significant at the .05 and .01 level, respectively—F test.