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Original scientific paper

YIELD AND QUALITY PROPERTIES OF SOME ORIENTAL TOBACCO (*Nicotiana tabacum* L.) HYBRIDS*

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Turkey is an important tobacco producing country and leading the world in oriental tobacco production. In the present study, effect of heterosis on yield and quality of oriental tobacco was investigated, and development of oriental tobacco hybrids with high yield and quality properties for Black Sea region of Turkey was targeted. Seven oriental tobacco genotypes with considerable acreages in Turkey (Xanthi-2A, Nail, Gümüşhacıköy, Taşova, Katerini, Canik, Erbaa) and 21 hybrids produced by half-diallel crosses among them were compared. Field trials were conducted in Erbaa and Bafra locations in 2012 and 2013 growing periods. Cured leaf yields, reducing sugar and nicotine contents of leaves and expertise quality were studied. Xanthi-2A × Katerini (1.70 t ha^{-1} cured leaf yield and 75% quality grade index) and Nail × Katerini (1.64 t ha^{-1} cured leaf yield and 75% quality grade index) hybrids showed good yield and quality properties in Erbaa conditions, while Nail × Katerini (1.88 t ha^{-1} cured leaf yield and 75% quality grade index) and Katerini × Erbaa (1.65 t ha^{-1} cured leaf yield and 78% quality grade index) had good yield and quality properties in Bafra conditions. It has been concluded that hybrid cultivars that can meet the demands of tobacco sector could be developed from some currently grown oriental tobacco cultivars in Turkey. Based on average of locations, an average of 16.20% and 6.85% heterosis were found as the average of all hybrids for cured leaf yield and expertise quality. Yield effects due to heterosis could be increased in future by adopting growing techniques adjusted for hybrids.

Keywords: Diallel crossing, quality grade index, nicotine content, oriental tobacco, reducing sugar

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INTRODUCTION

Tobaccos grown in the world could be categorized into two groups: yield and quality types. Virginia and Burley type tobaccos have high yields while oriental tobaccos have high qualities. Quality type oriental tobaccos are mostly used in cigarette blends as regulator. Therefore, breeding efforts in oriental tobaccos need to concentrate on physical quality properties such as aroma, leaf size and leaf color and chemical quality properties such as reducing sugar and nicotine contents. In addition, yields of new cultivars should satisfy farmers. Breeding of oriental tobacco should aim to improve both yield and quality together, or in other words, should aim to increase yields without decreasing the quality.

Hybrid breeding relies on the principle of producing superior F_1 plants compared to their respective parents. Hybrid cultivars can have high performance in good growing conditions as well as in relatively poor ones (PHILOUZE, 1976). Therefore, replacing classical pure line tobacco cultivars with hybrids could improve both yield and quality in diverse environments. YI *et al*. (2005) reported that hybrids between different burley cultivars were 2.9% superior to their parents. Another study on burley tobaccos revealed that yields of hybrids were 9.8% higher than parents (MATZINGER *et al*., 1971). In flue-cured tobaccos, hybrid cultivars were found to have 1.16% higher yields than pure line cultivars (MATZINGER *et al*., 1962). In oriental tobaccos, hybrid cultivars had 2.8-4.7% higher cured leaf yields compared to their parents (GIXHARI *et al*., 2010b). Studying nine oriental tobacco cultivars and their hybrids, MARANI *et al*. (1966) determined that average cured leaf yields of hybrids were higher than their parents.

Agronomic studied indicate mixed associations between cured leaf yield and quality properties (SIFOLA *et al*., 2003; KARAIVAZOGLOU *et al*., 2006) in tobaccos. Hybrid breeding studies in Virginia and burley type tobaccos show a negative association between cured leaf yield and quality traits (MATZINGER *et al*., 1971; ALEKSOSKI *et al*., 2011). On the other hand, simultaneous yield and quality improvements have been reported in hybrid oriental tobacco (YI *et al*., 2005; GIXHARI *et al*., 2010), which might indicate that hybrid breeding could be method of choice for oriental tobaccos.

Decreasing oriental tobacco production in Turkey and in the world in recent years has led to problems to meet the needs of tobacco industry. As a traditional oriental tobacco producer, Turkey has an important role to increase the production. When the yields of oriental tobacco are insufficient because of too much attention to quality, farmers easily give up this crop also as a result of difficulties in growing and processing the crop during curing operations. Although there are a number of oriental tobacco cultivars in Turkey, there is a need to develop new cultivars that could satisfy both farmers and industry. Aims of the present study were to develop superior hybrid cultivars from oriental tobacco cultivars or lines produced in traditional oriental tobacco production areas of Erbaa and Bafra in Black Sea region of Turkey and to determine heterosis effect in oriental tobacco.

MATERIALS AND METHODS

Plant materials

Seven oriental tobacco lines or cultivars grown in Black Sea region of Turkey (Xanthi-2A, Nail, Gümüşhacıköy, Taşova, Katerini, Canik, Erbaa) and 21 hybrids produced by half-diallel crosses (without reciprocal crosses) among them were used (Table 1). F_1 hybrid seeds

were produced using plants grown in greenhouse in 2011 based on method described by WERNSMAN *et al.* (1980).

Table 1. Half diallel crossing of parents

♀ / ♂	Nail	Gümüşhacıköy	Taşova	Katerini	Canik	Erbaa
Xanthi-2A	X	X	X	X	X	X
Nail		X	X	X	X	X
Gümüşhacıköy			X	X	X	X
Taşova				X	X	X
Katerini					X	X
Canik						X

Meteorological conditions

Field trials were carried out in Erbaa county of Tokat province (latitude 40˚60′ N, longitude 36º62′ E, elevation 580 m) and Bafra county of Samsun province (latitude 41˚03′ N, longitude 35º04′ E, elevation 162 m) in 2012 and 2013. Climatic data for tobacco growing period in long term (1975-2011) and experimental years were given in Table 2.

Table 2. Climatic data for Erbaa and Bafra locations during tobacco growth period

Months	Years	Average temperature (°C)		Average Moisture (%)		Total precipitation (mm)	
		Erbaa	Bafra	Erbaa	Bafra	Erbaa	Bafra
May	1975-2011	18.5	15.4	53.8	78.6	73.5	46.3
	2012	17.6	17.4	62.6	89.0	114.7	28.6
	2013	19.4	18.5	53.1	84.1	32.3	28.8
June	1975-2011	21.1	20.1	49.8	74.2	36.2	44.9
	2012	21.4	22.4	56.5	79.7	36.3	69.8
	2013	20.8	21.5	52.4	81.1	36.1	43.6
July	1975-2011	22.7	22.8	49.1	72.5	16.2	29.8
	2012	23.6	24.2	54.6	81.5	30.7	116.8
	2013	21.9	23.3	51.0	81.4	1.6	48.0
August	1975-2011	23.1	22.7	47.4	73.9	1.0	44.4
	2012	23.4	23.2	51.8	82.8	1.5	209.8
	2013	22.8	23.8	49.3	87.8	0.4	66.8
September	1975-2011	20.1	19.2	54.1	76.3	8.7	58.5
	2012	20.3	20.5	50.9	85.8	5.1	78.2
	2013	19.8	18.9	47.8	82.8	12.3	37.2

Turkish state meteorological service

Monthly temperature averages in experimental years were similar to long term averages. Erbaa location had higher precipitation in 2012 compared to long-term precipitation in growing season. Precipitation was almost three times the long-term average in the month of July. However, the same location had lower amount of precipitation in 2013. Total amounts of precipitation in both location were higher in the first experimental year, the difference being

clearly evident in Bafra location (Table 2). Average moisture was slightly higher in most months of tobacco growing season in experimental years compared to long-term averages.

Results of soil analysis carried out in experimental areas were given in Table 3. Soil of Erbaa location was slightly alkaline, moderate in $CaCO_3$, rich in organic matter, insufficient for phosphorus, sufficient for potassium in 2012, and slightly acidic, insufficient for $CaCO_3$, insufficient in organic matter, sufficient for potassium but had excess phosphorus in 2013. Soil of Bafra location was strongly alkaline, moderate in organic matter, strongly insufficient for phosphorus, sufficient for potassium but had excess amount of $CaCO_3$ in 2012, and strongly alkaline, insufficient for $CaCO_3$, sufficient in organic matter, sufficient in potassium but had excess amount of phosphorus in 2013 (KARAMAN *et al*., 2004).

Table 3. Soil properties of experimental fields in Erbaa and Bafra locations

	Erbaa		Bafra	
	2012	2013	2012	2013
Texture	Sandy clayed loam	Clay	Clay	Clay
pH	7.87 – Slightly alkaline	6.98 – Slightly acidic	8.05 – Strongly alkaline	8.34 – Strongly alkaline
EC dS/m	0.23 - non-salt	1.10 – low salt	0.57 – low salt	0.48 – non-salt
% $CaCO_3$	10.66 – Moderate	3.71 – Insufficient	20.87 – Excess	4.60 – Insufficient
Organic matter (%)	4.41 – High	1.82 – Insufficient	2.03 – Moderate	3.80 – Sufficient
P_2O_5 kg da^{-1}	3.55 – Insufficient	9.38 – High	2.38 – Strongly insufficient	17.50 – Excess
K_2O kg da^{-1}	42.98 – Sufficient	49.14 – Sufficient	50.24 – Sufficient	47.19 – Sufficient

Methods

Field trials were conducted in farmers' fields to better represent tobacco growing areas under rainfed conditions. Plots consisted of four rows of 4 m with 45 cm row spacing. Fertilizations were made at the rates of 60 kg ha^{-1} N, 40 kg ha^{-1} phosphorus (P_2O_5) and 60 kg ha^{-1} potassium (K_2O) using 15-15-15 composed fertilizer, ammonium sulfate and potassium nitrate (KINAY, 2010). All fertilizers were applied to plots before planting and mixed into soil (ÇAMAŞ *et al*., 2011). Seedlings were grown in seedling trays under controlled greenhouse conditions. Plantation was made to field when seedlings had 4-6 leaves and were 12-15 cm tall. Maintenance procedures were applied such as hoeing, stripping off the lower leaves, soil pulling up around the base of plants and pest and disease control. Leaves were primining three times when they reached harvest maturity. Harvested green leaves were stringed and cured by hanging inside a greenhouse. After curing, strings containing tobacco leaves were packed (KURT and YILMAZ, 2018). Leaves were weighed, moisture contents were determined and cured leaf yields were calculated based on 17% moisture content. Organoleptic observations were made on cured leaves based on procedure defined by Turkish Standards Institute (TSI, 2006). Organoleptic evaluations (quality grade index) were made by consensus of three tobacco experts. Reducing sugar and nicotine contents of leaves were determined in Chemical Analysis Laboratory of Field Crops Department at Tokat Gaziosmanpasa University using spectrophotometric method (KINAY, 2010).

Statistical analysis

Experimental design was randomized complete blocks with three replications. Statistical analyses were made using SPSS software (Version 20, IBM Software, Chicago, Illinois). Differences among treatments were compared using Duncan's multiple range test (WANG *et al.*, 2013). In order to compare the differences between hybrids and their respective parents, one-degree of freedom test was carried out.

RESULTS AND DISCUSSION

Significant differences were found among genotypes for cured leaf yields in all four environments (Table 4). Due to heterogeneity of error variances from environments, a combined analysis was not performed. Based on one-degree freedom statistical analysis, hybrids had significantly higher cured leaf yields than parents in all locations (Table 4). In Erbaa location, parents had cured leaf yields of 1.181-1.557 t ha^{-1} (average 1.312 t) in 2012 and 1.182-1.749 t ha^{-1} (average 1.546 t) in 2013 while hybrids had leaf yields of 1.216-1.732 t ha^{-1} (average 1.432 t) in 2012 and 1.441-2.078 t ha^{-1} (average 1.732 t) in 2013. In Erbaa location, average cured leaf yields of hybrids were 9.15 and 10.74% higher than average leaf yields of parents in 2012 and 2013, respectively. Cv. Xanthi-2A is the commonly grown cultivar in Erbaa location and only one genotype (Nail) gave significantly higher cured leaf yield than cv. Xanthi-2A in 2012 and two genotypes (cvs. Nail and Katerini) in 2012, while four hybrids (Canik × Erbaa, Gümüşhacıköy × Canik, Taşova × Erbaa and Xanthi-2A × Katerini) had significantly higher yields than cv. Xanthi-2A in 2012 and 11 hybrids (Nail × Canik, Canik × Erbaa, Katerini × Erbaa and eight others) in 2013. Superior cured leaf yields of hybrids were more pronounced in Bafra location. Parents had cured leaf yields varying from 0.758 to 1.962 t ha^{-1} (average 1.288 t) in 2012 and from 0.946 to 1.364 t ha^{-1} (average 1.573 t) in 2013 whereas cured leaf yields of hybrids varied from 0.967 to 2.439 t ha^{-1} (average 1.166 t) in 2012 and from 1.143 to 1.818 t ha^{-1} (average 1.383 t) in 2013. In Bafra location, average cured leaf yields of hybrids were 22.13 and 18.60% higher than average leaf yields of parents in 2012 and 2013, respectively. Nail is the commonly grown cultivar in Bafra location and only one genotype (cv. Canik) gave significantly higher cured leaf yield than Nail in 2012 and no genotype had better yield than Nail in 2013, while five hybrids had significantly higher yields than Nail in 2012 (Canik × Erbaa, Nail x Katerini, Nail × Canik, Katerini × Canik and Nail × Erbaa) and two hybrids (Taşova × Katerini and Katerini × Canik) in 2013. One-degree of freedom analysis showed that hybrids of only one parent was superior to that parent (cv. Gümüşhacıköy) in Erbaa 2012 location while two (cvs. Xanthi-2A and Gümüşhacıköy) in Erbaa 2013, four (cv. Xanthi-2A, Nail, Erbaa and Gümüşhacıköy) in Bafra 2012 and four (cvs. Gümüşhacıköy, Taşova, Katerini and Canik) in Bafra 2013 (Table 5).

Reducing sugar content of cured tobacco leaves directly affects the quality of oriental tobacco and higher amount of reducing sugars means higher quality. Reducing sugar contents in Erbaa location (11.6% in 2012 and 11.8% in 2013) were clearly higher than those in Bafra location (4.08 and 6.75% in 2012 and 2013, respectively) (Table 6). Most of the hybrids had higher reducing sugar contents than Xanthi-2A cultivar in Erbaa in 2012 and 2013. In Bafra location, however, commonly grown Nail genotype had higher reducing sugar content than hybrids in both years. Average of parents did not differ from average of hybrids in any location

(Table 6). However, there were significant differences among genotypes and between some hybrids and their parents. Nail and Katerini generally had higher reducing sugar contents across the environments. However, hybrids of these two genotypes had significantly lower reducing sugar content in three out of four environments. On the other hand, hybrids of Xanthi-2A, genotype with the lowest reducing sugar content, had significantly higher levels in three out of four environments (Table 7). Hybrids of Gümüşhacıköy and Erbaa had significantly higher sugar content in one environment and significantly lower in one environment.

Table 4. Cured leaf yields of tobacco parents and hybrids (t ha^{-1}) grown in Erbaa and Bafra locations

No	Parent or hybrid	Erbaa				Bafra				Average of genotype
		2012*		2013*		2012*		2013*		
1	Xanthi-2A	1.273	d-g	1.391	gh	0.845	kl	1.245	c-g	1.189
2	Nail	1.557	a-e	1.749	b-e	1.485	e-h	1.265	c-g	1.514
3	Gümüşhacıköy	1.181	g	1.182	h	0.758	l	0.946	g	1.017
4	Taşova	1.225	fg	1.447	fgh	1.311	f-j	1.031	fg	1.254
5	Katerini	1.314	b-g	1.704	b-f	1.446	e-ı	1.201	c-g	1.416
6	Canik	1.355	b-g	1.686	b-g	1.962	bc	1.112	efg	1.529
7	Erbaa	1.282	d-g	1.666	b-g	1.210	g-k	1.364	c-f	1.381
8	Xanthi-2A × Nail	1.377	b-g	1.733	b-f	1.594	c-g	1.206	c-g	1.478
9	Xanthi-2A × Gümüşhacıköy	1.216	fg	1.549	e-g	1.412	e-ı	1.356	c-f	1.384
10	Xanthi-2A × Taşova	1.237	e-g	1.441	f-h	0.967	jkl	1.316	c-f	1.240
11	Xanthi-2A × Katerini	1.627	abc	1.779	b-e	1.287	f-j	1.538	abc	1.558
12	Xanthi-2A × Canik	1.389	b-g	1.691	b-f	1.331	f-j	1.271	c-g	1.421
13	Xanthi-2A × Erbaa	1.269	d-g	1.598	d-g	1.451	e-ı	1.516	abc	1.459
14	Nail × Gümüşhacıköy	1.598	a-d	1.556	e-g	1.688	c-f	1.143	efg	1.497
15	Nail × Taşova	1.258	efg	1.904	abc	1.544	d-g	1.260	c-g	1.492
16	Nail × Katerini	1.485	a-g	1.793	a-e	2.255	ab	1.498	a-d	1.758
17	Nail × Canik	1.404	a-g	2.078	a	1.976	bc	1.503	a-d	1.741
18	Nail × Erbaa	1.446	a-g	1.894	a-d	1.916	bcd	1.445	b-e	1.676
19	Gümüşhacıköy × Taşova	1.288	d-g	1.586	e-g	1.486	e-h	1.306	c-f	1.417
20	Gümüşhacıköy × Katerini	1.510	a-g	1.646	b-g	1.582	c-g	1.165	d-g	1.476
21	Gümüşhacıköy × Canik	1.643	ab	1.898	abc	1.381	e-ı	1.244	c-g	1.542
22	Gümüşhacıköy × Erbaa	1.448	a-g	1.821	a-e	1.248	g-k	1.371	c-f	1.472
23	Taşova × Katerini	1.299	c-g	1.621	c-g	1.129	h-l	1.818	a	1.467
24	Taşova × Canik	1.284	d-g	1.597	d-g	1.074	ı-l	1.258	c-g	1.304
25	Taşova × Erbaa	1.634	ab	1.546	efg	1.539	d-g	1.131	efg	1.463
26	Katerini × Canik	1.514	a-f	1.782	a-e	1.974	bc	1.745	ab	1.754
27	Katerini × Erbaa	1.413	a-g	1.932	ab	1.764	cde	1.536	abc	1.662
28	Canik × Erbaa	1.732	a	1.941	ab	2.439	a	1.422	b-e	1.884
Average of location		1.402		1.686		1.502		1.329		1.480
CV (%)		12.4		10.7		14.6		14.8		

*p<0.05

Nicotine content of cured leaves is another quality criterion in tobacco. Higher nicotine content in oriental type tobaccos, also called quality type, results in lower quality. Erbaa location

had similar average nicotine contents in 2012 and 2013 (1.64 and 1.65%, respectively) while Bafra location resulted in somewhat lower nicotine content in 2012 (1.24%) and higher in 2013 (2.00%) (Table 8). There were significant differences among genotypes in all environments, but hybrids did not differ from parents based on one-degree freedom analysis (Table 9). Nicotine content of Xanthi-2A in Erbaa where it is the mainly grown cultivar was in the highest group in both years. Similarly, nicotine content of Nail genotype in Bafra was among genotypes with the highest nicotine content. These findings indicate that genotypes grown in these areas are not suitable for their nicotine content. Cv. Gümüşhacıköy on the other hand had clearly low nicotine contents in all four environments compared to other parents as well as hybrids. When hybrids and their parents were compared using one-degree of freedom analysis, it was observed that hybrids of Xanthi-2A and Katerini, cultivars with the highest nicotine contents, had significantly lower nicotine contents in four and three environments, respectively. On the other hand, nicotine contents of hybrids of Gümüşhacıköy and Canik, cultivars with the lowest nicotine contents, had significantly higher nicotine content in three out of four environments.

Table 5. Results of one-degree freedom analysis for cured leaf yields (t ha^{-1}) of tobacco parents and hybrids grown in Erbaa and Bafra locations

Parent or hybrid	Erbaa 2012	Erbaa 2013	Bafra 2012	Bafra 2013	Average	Difference (%)
Xanthi-2A	1.273 ^{NS}	1.390*	0.846**	1.246 ^{NS}	1.189	19.7
Xanthi-2A hybrids	1.353	1.632	1.341	1.368	1.424	
Nail	1.557^{NS}	1.749 ^{NS}	1.485*	1.266 ^{NS}	1.514	6.1
Nail hybrids	1.428	1.827	1.829	1.343	1.607	
Gümüşhacıköy	1.182*	1.182**	0.758**	0.947*	1.017	44.0
Gümüşhacıköy hybrids	1.451	1.676	1.467	1.264	1.465	
Taşova	1.225 ^{NS}	1.448 ^{NS}	1.311 ^{NS}	1.031*	1.254	11.4
Taşova hybrids	1.334	1.616	1.290	1.348	1.397	
Katerini	1.314 ^{NS}	1.705 ^{NS}	1.447 ^{NS}	1.200*	1.417	13.8
Taşova hybrids	1.475	1.759	1.666	1.550	1.613	
Canik	1.356 ^{NS}	1.686 ^{NS}	1.963 ^{NS}	1.112*	1.529	5.1
Canik hybrids	1.495	1.831	1.696	1.408	1.608	
Erbaa	1.282 ^{NS}	1.667 ^{NS}	1.210**	1.365 ^{NS}	1.381	16.1
Erbaa hybrids	1.491	1.789	1.727	1.404	1.603	
Average of parents	1.312^{b}	1.546^{b}	1.288^{b}	1.166^{b}	1.329	
Average of hybrids	1.432^{a}	1.732^{a}	1.573^{a}	1.383^{a}	1.531	

NS: Non Significant, *p<0.05, **p<0.01

Quality grade index is an organoleptic quality index determined by tobacco experts to be used purchasing price of oriental tobacco in Turkey. It is determined by integrity, color, texture and smell of tobacco leaves and is expressed as percentage. Since the prices for different grades with expertise quality scores higher 60% do not differ greatly, quality grade index larger than 60% is considered satisfactory.

Table 6. Reducing sugar contents (%) in cured leaves of tobacco parents and hybrids grown in Erbaa and Bafra locations

No	Parent or hybrid	Erbaa				Bafra				Average of genotype
		2012*		2013*		2012*		2013*		
1	Xanthi-2A	11.8	f-j	8.4	jk	1.66	g	7.80	b-e	7.42
2	Nail	15.4	bc	11.8	ghı	5.77	b	9.64	a	10.65
3	Gümüşhacıköy	11.8	g-j	11.8	f-ı	5.61	bc	5.41	fgh	8.66
4	Taşova	9.5	l	11.7	f-ı	4.99	c	5.17	fgh	7.84
5	Katerini	11.2	hıj	12.7	d-g	7.30	a	7.60	b-e	9.70
6	Canik	10.5	jkl	12.9	b-g	0.89	h	5.95	d-g	7.56
7	Erbaa	11.0	ıjk	13.6	b-f	2.34	ef	5.71	fgh	8.16
8	Xanthi-2A × Nail	16.2	ab	13.8	b-e	1.81	g	7.81	bcd	9.91
9	Xanthi-2A × Gümüşhacıköy	13.1	efg	16.0	a	2.43	ef	8.68	ab	10.05
10	Xanthi-2A × Taşova	11.9	g-j	7.6	k	3.10	de	8.49	abc	7.77
11	Xanthi-2A × Katerini	14.2	cde	13.7	b-f	3.03	de	8.16	bc	9.77
12	Xanthi-2A × Canik	12.4	f-ı	9.9	ıj	3.24	de	5.90	efg	7.86
13	Xanthi-2A × Erbaa	13.0	e-h	12.1	d-g	2.63	de	5.83	efg	8.39
14	Nail × Gümüşhacıköy	11.4	hıj	12.4	d-g	1.31	g	7.37	b-e	8.12
15	Nail ×Taşova	12.1	f-j	14.7	abc	3.36	d	7.33	b-e	9.37
16	Nail × Katerini	10.7	jkl	8.4	jk	3.48	de	6.47	c-f	7.26
17	Nail × Canik	12.8	e-h	12.7	c-g	3.11	de	4.64	gh	8.31
18	Nail × Erbaa	16.2	ab	13.4	b-f	3.67	d	7.23	c-f	10.13
19	Gümüşhacıköy × Taşova	11.7	hıj	13.9	bcd	3.31	de	5.93	d-g	8.71
20	Gümüşhacıköy × Katerini	11.8	g-j	11.3	ghı	2.48	ef	6.60	c-f	8.05
21	Gümüşhacıköy × Canik	12.3	f-j	14.6	ab	2.67	ef	3.57	h	8.29
22	Gümüşhacıköy × Erbaa	11.8	g-j	10.4	hı	2.51	ef	3.88	h	7.15
23	Taşova × Katerini	9.8	kl	11.9	e-h	3.64	d	6.80	c-f	8.04
24	Taşova × Canik	17.1	a	10.1	ıj	3.27	d	4.69	gh	8.79
25	Taşova × Erbaa	15.0	bcd	12.4	d-g	2.55	ef	9.03	ab	9.75
26	Katerini × Canik	10.8	jkl	10.6	hı	1.96	fg	4.53	gh	6.97
27	Katerini × Erbaa	12.2	f-ı	12.4	d-g	1.70	g	4.47	gh	7.69
28	Canik × Erbaa	13.6	def	12.2	d-g	1.49	g	6.87	c-f	8.54
Average of location		12.6		12.1		3.05		6.48		8.56
CV (%)		2.62		5.76		1.67		3.75		

*p<0.05

Three of the four environments had similar average quality scores around 70%, while average quality score of Erbaa location in 2012 was somewhat lower (64%). Quality grade index of Katerini was high in all for environments, being significantly higher than other parents in Erbaa 2013 and Bafra 2013 environments (Table 10). Quality grade index of Xanthi-2A was highest in 2012 and second highest in 2013 in Erbaa conditions. Quality grade index of Nail genotype was among the top group in 2012 and 2013 in Bafra conditions. These findings mean that these cultivars had satisfactory quality levels in the environments where they are the most commonly grown oriental tobacco genotype. Average quality grade index of hybrids were 5-9% higher than that of parents in three out of four environment, and 3% lower in Erbaa 2012 environment. However, differences were not significant. Four or five out of seven parents (57-71%) had satisfactory expertise scores of over 60% in all four environments while 17-19 hybrids out of 21 (81-90%) had satisfactory quality grade index in three environments and all of the

hybrids had satisfactory quality grade index in one environment (BAFRA, 2013). A comparison of parents and their hybrids using one degree of freedom analysis revealed that quality scores were significantly improved in all four environments in Canik hybrids and in three out of four environments in Gümüşhacıköy hybrids compared to their common parent (Table 11). These were the cultivars with the lowest quality grade index. On the other hand, quality grade index of Katerini hybrids, the cultivar with the highest overall quality grade index across four environments were decreased significantly in all four environments.

Table 7. Results of one-degree freedom analysis for reducing sugar (%) in leaves of tobacco parents and hybrids grown in Erbaa and Bafra locations

Parent or hybrid	Erbaa 2012	Erbaa 2013	Bafra 2012	Bafra 2013	Average	Difference (%)
Xanthi/2A	11.8**	8.4**	1.66**	7.80 NS	7.40	20.95
Xanthi/2A hybrids	13.5	12.2	2.70	7.48	8.95	
Nail	15.4**	11.8 NS	5.77**	9.64**	10.63	-17.18
Nail hybrids	13.2	12.5	2.79	6.81	8.80	
Gümüşhacıköy	11.8 NS	11.8*	5.61**	5.41 NS	8.65	-3.18
Gümüşhacıköy hybrids	12.0	13.1	2.45	6.01	8.38	
Taşova	9.5**	11.7 NS	4.99**	5.17**	7.80	11.86
Taşova hybrids	12.9	11.8	3.20	7.04	8.73	
Katerini	11.2 NS	12.6*	7.29**	7.60**	9.65	-17.62
Katerini hybrids	11.6	11.4	2.71	6.17	7.95	
Canik	10.5**	12.8*	0.89**	5.95 NS	7.50	8.00
Canik hybrids	13.2	11.6	2.62	5.03	8.10	
Erbaa	11.0**	13.5*	2.34 NS	5.71 NS	8.13	5.85
Erbaa hybrids	13.7	12.1	2.43	6.22	8.60	
Average of parents	11.6	11.8	4.08	6.75	8.56	
Average of hybrids	12.9	12.1	2.70	6.39	8.52	

NS: Non Significant, *p<0.05, **p<0.01

Cured leaf yield and quality traits should be simultaneously taken into account in breeding of oriental tobaccos. There are many factors affecting cured leaf yield and quality of tobaccos (SHOAI *et al*., 1996; BUTORAC, 2000; BUTORAC *et al*., 2004; GIXHARI e*t al*., 2010a). Genotype used is at the forefront of these factors.

Cured leaf yields of hybrids (1.531 t/ha) were about 15% higher than those of pure lines (1.329 t/ha) in all locations. Cured leaf increases of 1.2-28.9% were reported for tobacco in general (MATZINGER *et al*., 1971; GUDOY *et al*., 1988; YI *et al*., 2005) and 2.8-16.2% for oriental tobaccos (GIXHARI *et al*., 2010a; GIXHARI *et al*., 2010b) due to heterosis. Calculated heterosis values of different hybrids for cured leaf yield in the present study (5-44%) were higher than those reported in literature. An examination of heterosis values based on parents revealed higher heterosis levels for parents with low cured leaf yields, which was also indicated by a significant negative association of r= -0.892 between average heterosis value of parents and their average cured leaf yields. Although the parents used in the present study are genotypes used for production in the oriental tobacco growing regions of Turkey, they are not genotypes subjected to intense breeding. In fact, of the genotypes used, Nail and Erbaa are not registered varieties; they are pure lines commonly grown by farmers for oriental tobacco production.

Table 8. Nicotine contents (%) in cured leaves of tobacco parents and hybrids grown in Erbaa and Bafra locations

No	Parent or hybrid	Erbaa				Bafra				Average of genotype
		2012*		2013*		2012*		2013*		
1	Xanthi-2A	2.21	a	2.36	a	1.60	a	2.53	b	2.18
2	Nail	1.45	bc	1.71	c	1.14	a	2.48	b	1.70
3	Gümüşhacıköy	0.80	e	0.71	e	0.76	b	0.58	f	0.71
4	Taşova	2.37	a	1.68	c	1.36	a	2.31	b	1.93
5	Katerini	2.27	a	2.52	a	1.18	a	2.75	ab	2.18
6	Canik	1.71	bc	1.23	c	0.77	b	1.55	cd	1.32
7	Erbaa	1.58	bc	0.88	e	1.86	a	1.25	cd	1.39
8	Xanthi-2A × Nail	1.48	bc	2.45	a	1.45	a	2.51	b	1.97
9	Xanthi-2A × Gümüşhacıköy	1.33	bc	1.42	c	0.89	b	1.73	cd	1.34
10	Xanthi-2A × Taşova	2.36	a	1.24	c	1.43	a	1.89	c	1.73
11	Xanthi-2A × Katerini	1.93	b	2.54	a	1.35	a	2.98	a	2.20
12	Xanthi-2A × Canik	1.89	bc	1.74	c	1.16	a	2.26	b	1.76
13	Xanthi-2A × Erbaa	2.28	a	2.13	a	1.75	a	2.71	b	2.22
14	Nail × Gümüşhacıköy	1.44	bc	0.72	e	1.08	a	1.05	ef	1.07
15	Nail × Taşova	1.77	bc	1.63	c	0.99	b	2.63	b	1.76
16	Nail × Katerini	1.64	bc	2.37	a	1.32	a	2.38	b	1.93
17	Nail × Canik	1.39	bc	1.59	c	0.81	b	1.73	cd	1.38
18	Nail × Erbaa	1.57	bc	0.95	d	1.38	a	1.54	cd	1.36
19	Gümüşhacıköy × Taşova	1.27	bc	1.19	c	1.30	a	1.19	de	1.24
20	Gümüşhacıköy × Katerini	1.05	cd	2.52	a	0.67	b	1.67	cd	1.48
21	Gümüşhacıköy × Canik	0.95	de	0.65	e	0.70	b	1.06	de	0.84
22	Gümüşhacıköy × Erbaa	0.98	cd	0.64	e	0.72	b	0.90	ef	0.81
23	Taşova × Katerini	2.18	a	1.85	c	1.61	a	2.78	ab	2.11
24	Taşova × Canik	1.82	bc	1.28	c	1.31	a	2.61	b	1.76
25	Taşova × Erbaa	1.33	bc	2.31	a	1.64	a	2.39	b	1.92
26	Katerini × Canik	1.56	bc	2.35	a	1.35	a	2.50	b	1.94
27	Katerini × Erbaa	1.73	bc	1.93	b	1.74	a	2.44	b	1.96
28	Canik × Erbaa	1.60	bc	1.59	c	1.36	a	1.61	cd	1.54
Average of location		1.64		1.65		1.24		2.00		1.63
CV (%)		0.50		0.96		0.35		0.81		

*$p<0.05$

Similar to our results, PICKETT (1993) reported for wheat, another self-pollinating crop like tobacco, that hybrids developed from highly bred parents had less heterosis than older, lower yielding parents of wheat. It is possible that negative effects of deleterious alleles of some genes on performance and quality of tobacco crop in one of low-bred parents were compensated by non-deleterious alleles from other parent of the hybrid in heterozygous condition.

Table 9. Results of one-degree freedom analysis for nicotine content (%) in leaves of tobacco parents and hybrids grown in Erbaa and Bafra locations

Parent or hybrid	Erbaa 2012	Erbaa 2013	Bafra 2012	Bafra 2013	Average	Difference (%)
Xanthi/2A	2.21**	2.36**	1.60**	2.53*	2.18	-13.79
Xanthi/2A hybrids	1.88	1.92	1.34	2.35	1.88	
Nail	1.45 NS	1.71 NS	1.14 NS	2.48**	1.70	-7.35
Nail hybrids	1.55	1.62	1.17	1.97	1.58	
Gümüşhacıköy	0.80**	0.71**	0.76 NS	0.58**	0.73	58.62
Gümüşhacıköy hybrids	1.17	1.19	0.90	1.27	1.15	
Taşova	2.37**	1.68 NS	1.36 NS	2.31 NS	1.95	-8.97
Taşova hybrids	1.79	1.58	1.38	2.25	1.78	
Katerini	2.27**	2.52**	1.18*	2.75**	2.20	-11.36
Katerini hybrids	1.68	2.26	1.34	2.46	1.95	
Canik	1.70 NS	1.23**	0.77**	1.55**	1.33	13.21
Canik hybrids	1.54	1.53	1.12	1.96	1.50	
Erbaa	1.58 NS	0.88**	1.86**	1.25**	1.43	14.04
Erbaa hybrids	1.58	1.59	1.43	1.93	1.63	
Average of parents	1.77	1.58	1.24	1.92	1.63	
Average of hybrids	1.60	1.67	1.24	2.03	1.64	

NS: Non Significant, *p<0.05, **p<0.01

Table 10. Quality grade index (%) of tobacco parents and hybrids grown in Erbaa and Bafra locations

No	Parent or hybrid	Erbaa				Bafra				Average of genotype
		2012*		2013*		2012*		2013*		
1	Xanthi-2A	80	a	75	d	80	a	70	c	76.3
2	Nail	70	abc	65	f	75	c	70	c	70.0
3	Gümüşhacıköy	55	de	55	h	55	g	50	e	53.8
4	Taşova	60	cde	75	d	55	g	70	c	65.0
5	Katerini	75	ab	90	a	75	c	80	b	80.0
6	Canik	50	ef	55	h	50	h	45	f	50.0
7	Erbaa	70	abc	60	g	75	c	70	c	68.8
8	Xanthi-2A × Nail	65	bcd	80	c	70	d	70	c	71.3
9	Xanthi-2A × Gümüşhacıköy	70	abc	65	f	75	b	70	c	70.0
10	Xanthi-2A × Taşova	80	a	80	c	80	a	80	b	80.0
11	Xanthi-2A × Katerini	60	cde	90	a	70	d	80	b	75.0
12	Xanthi-2A × Canik	60	cde	80	c	70	d	70	c	70.0
13	Xanthi-2A × Erbaa	75	ab	90	a	80	a	70	c	78.8
14	Nail × Gümüşhacıköy	70	abc	55	h	75	c	65	d	66.3
15	Nail × Taşova	65	bcd	90	a	70	d	85	a	77.5
16	Nail × Katerini	60	cde	90	a	70	d	80	b	75.0
17	Nail × Canik	40	f	65	f	65	e	80	b	62.5
18	Nail × Erbaa	60	cde	70	e	70	d	70	c	67.5
19	Gümüşhacıköy × Taşova	65	bcd	65	f	75	c	70	c	68.8
20	Gümüşhacıköy × Katerini	60	cde	60	g	70	d	80	b	67.5
21	Gümüşhacıköy × Canik	55	de	60	g	75	c	70	c	65.0
22	Gümüşhacıköy × Erbaa	40	f	40	ı	60	f	70	c	52.5
23	Taşova × Katerini	70	abc	70	e	75	c	85	a	75.0
24	Taşova × Canik	70	abc	75	d	75	c	65	d	71.3
25	Taşova × Erbaa	75	ab	85	b	75	c	70	c	76.3
26	Katerini × Canik	50	ef	75	d	70	d	70	c	66.3
27	Katerini × Erbaa	70	abc	75	d	75	c	80	b	75.0
28	Canik × Erbaa	65	bcd	70	e	60	f	65	d	65.0
Average of location		64		72		70		71		69.3
CV (%)		5.75		4.56		5.60		6.02		

Table 11. Results of one-degree freedom analysis for quality grade index (%) in leaves of tobacco parents and hybrids grown in Erbaa and Bafra locations

Parent or hybrid	Erbaa 2012	Erbaa 2013	Bafra 2012	Bafra 2013	Average	Difference (%)
Xanthi-2A	63.6**	60.1**	63.6**	56.8**	61.03	-1.84
Xanthi-2A hybrids	56.0	64.7	59.8	59.1	59.90	
Nail	56.8**	53.8**	60.1**	56.8**	56.88	0.70
Nail hybrids	50.9	61.0	56.9	60.3	57.28	
Gümüşhacıköy	47.9 NS	47.9*	47.9**	45.0**	47.18	14.31
Gümüşhacıköy hybrids	50.9	49.2	58.2	57.4	53.93	
Taşova	47.9 NS	60.1**	47.9**	56.8**	53.18	10.16
Taşova hybrids	50.9	62.3	60.1	61.0	58.58	
Katerini	60.1**	71.9**	60.1**	63.6NS	63.93	-8.21
Katerini hybrids	51.8	61.9	57.9	63.1	58.68	
Canik	45.0*	47.9**	45.0**	42.1**	45.00	22.00
Canik hybrids	48.9	57.4	56.4	56.9	54.90	
Erbaa	56.8 NS	50.8**	60.1**	56.8**	56.13	0.94
Erbaa hybrids	53.5	58.7	57.0	57.4	56.65	
Average of parents	66	68	66	65	66.3	
Average of hybrids	63	73	72	74	70.5	

NS: Non Significant, *p<0.05, **p<0.01

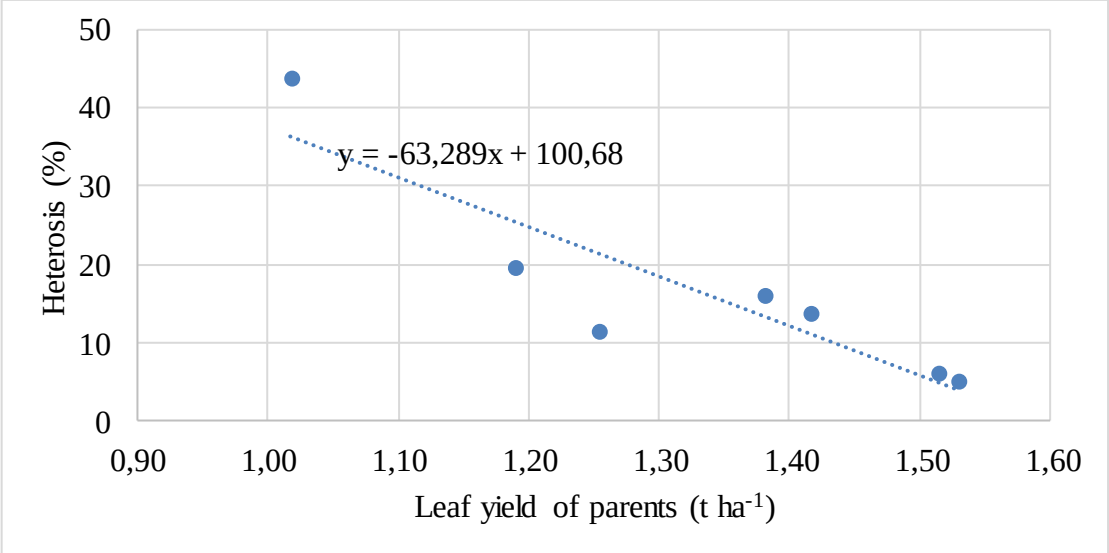

Figure 1. Relationship between leaf yield of parents and heterosis level

Leaf yield of tobacco is influenced by number of leaves, leaf width and leaf length. Leaf width trait has been reported to be more important than other traits to determine leaf yields (DYULGERSKI *et al*., 2012). It has been reported that leaf width is determined by genes which have both additive and non-additive effects (OGULVIE *et al*., 1980; NAUMVSKI, 1990; LEGG *et al*., 1970; PANDEYA *et al*., 1983; WILKINSON *et al*., 1990; GIXHARI *et al*., 2010b). Therefore, studies aiming to increase tobacco leaf yields should take leaf width trait into account.

Major chemical quality properties of tobacco are reducing sugar and nicotine contents of cured leaves. In oriental tobaccos, higher reducing sugar is associated with better quality, but higher nicotine content means lower quality. Although the sugar contents of cured leaves in the present study were within the limits acceptable for tobacco industry, leaves produced in Bafra location had somewhat lower sugar contents. Nicotine contents of the leaves, on the other hand, were lower than desired levels. However, desired level of chemical contents of tobacco leaves could be possible through manipulation of agricultural practices (LOURENCO *et al*., 2000; GONDOLA, 2002; KARAIVAZOGLOU *et al*., 2006). Hybrids of parents with low reducing sugar and nicotine contents generally had higher contents, while hybrids of parents with higher reducing sugar and nicotine contents generally had lower values. In other words, a "moderating effect" was observed in hybrids compared to parents for reducing sugar and nicotine contents. A similar effect in oriental tobaccos were also obtained by Godoy LUSSO *et al*. (2015). Observation of such an effect could indicate that it is possible to target higher leaf yields via heterosis while maintaining sufficient quality without much changes in reducing sugar and nicotine contents.

Physical quality of cured leaves, as measured by expertise quality, is another consideration that needs to be taken into account while aiming to increase cured leaf yields. Quality grade index should be 60% and over (KINAY, 2010; KURT, 2014). In general, quality grade index of hybrids were at acceptable levels. In addition, "moderating effect" observed in hybrids for protein and nicotine contents was also observed for quality grade index. This finding implies that as in chemical quality properties, it could be possible to produce higher yielding hybrids without major losses in physical quality of the leaves.

CONCLUSIONS

Results of the present study using hybrids between oriental tobacco genotypes of Turkey which were not subjected to extensive breeding revealed relatively high heterosis values for cured leaf yields. A "moderating effect" was observed in hybrids for quality traits, and hybrids of parents with low quality values generally had higher quality properties and vice versa. Although quality properties of hybrids varied based on location, hybrids generally had satisfactory chemical and physical quality levels. Conducting agronomic studies could be useful to achieve better quality traits (reducing sugar content of 8-12% and nicotine content of 2.2-2.7%) in hybrids which already promised higher leaf yields. Using new hybrid variety candidates in production could be really valuable for oriental tobacco farmers and to Turkish economy and could help close the gap of quality oriental tobacco production in the world, which has been steadily decreasing in recent years.

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PRINOS I OSOBINE PRINOSA NEKIH ORJENTALNIH HIBRIDA DUVANA (*Nicotiana tabacum* L.)

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Izvod

Turska je važna zemlja za proizvodnju duvana i vodeća u svetu u proizvodnji orijentalnog duvana. U ovoj studiji istražen je uticaj heterozisa na prinos i kvalitet orijentalnog duvana, a posebno je istražen razvoj orijentalnih hibrida duvana visokih prinosa i kvalitetnih svojstava za crnomorski region Turske. Poređeno je sedam genotipova orijentalnog duvana sa znatnim površinama u Turskoj (Ksanthi-2A, Nail, Gumushacıkoi, Tasova, Katerini, Canik, Erbaa) i 21 hibrid proizveden polu-dialelnim ukrštanjima. Poljski ogledi su postavljeni na lokacijama Erbaa i Bafra u vegetacionim sezonama 2012. i 2013. godine. Proučavani su prinosi suvih listova, smanjenje sadržaja šećera i nikotina u lišću i ekspertiza kvaliteta. Ksanthi-2A × Katerini (1.70 t ha-1 prinos listova i 75% indeks kvaliteta) i hibridi nokta × Katerini (1,64 t ha-1 prinosa listova i 75% indeksa kvaliteta) pokazali su dobra prinosna i kvalitetna svojstva u Erbai uslovima, dok su Nail × Katerini (1,88 t ha-1 sušeni prinos lišća i 75% indeks kvaliteta) i Katerini × Erbaa (1,65 t ha-1 prinos sušenog lišća i 78% indeks kvaliteta) imali dobra svojstva u prinosu i kvalitetu u Bafri uslovima. Zaključeno je da bi se hibridni kultivari koji mogu zadovoljiti zahteve duvanskog sektora mogli razviti iz nekih trenutno gajenih orijentalnih sorti duvana u Turskoj. Na osnovu proseka lokacija utvrđeno je prosečno 16,20% i 6,85% heterozisa kao prosek svih hibrida za prinos suvog lišća i kvalitet. Efekti prinosa usled heterozisa mogli bi u budućnosti biti povećani primenom novih tehnika prilagođenih hibridima.

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