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INHERITANCE AND GENETIC ANALYSIS OF YIELD IN TOBACCO VARIETIES AND THEIR DIALLEL F1, F2 AND BC1 PROGENIES

Ana Korubin – Aleksoska

University"St.Kliment Ohridski"-Bitola, Scientific Tobacco Institute-Prilep, Republic of Macedonia, e-mail: anakorubin@yahoo.com

ABSTRACT

Investigations were made on the mode of inheritance of green and dry mass yields per stalk and genetic analysis was of six parental tobacco genotypes (P-23, MB-3, SM-1, YV 125/3, FL-5 and O-87), with fifteen diallel crosses of each generation: F1, F2, BC1(P1) and BC1(P2). The trial was set up in 2008-2009 on the Experimental field of Scientific Tobacco Institute - Prilep in randomized block system with four replications, using standard agrotechnical practices during the vegetation period.

The aim of investigations was to study the genetics of inheritance of green and dry mass, using genetic components of variance to determine the types of genes as carriers of the characters and to assess the impact of the environment on their manifestation.

The yield is the most important agronomic character inherited mostly by partial dominance. Positive heterosis was observed in the hybrid MB-3 x YV 125/3 and negative heterosis in FL-5 x O-87. Genetic analysis of the four investigated generations revealed that additive genes were dominant in creation of yield. Results presented in this paper will give good directions in tobacco selection.

Key words: Tobacco (*Nicotiana tabacum L.*), mode of inheritance, heterosis, genetic analysis, components of genetic variance

НАСЛЕДУВАЊЕ И ГЕНЕТСКА АНАЛИЗА НА ПРИНОСОТ КАЈ ТУТУНСКИ СОРТИ И НИВНОТО ДИЈАЛЕЛНО F1, F2 И BC1 ПОТОМСТВО

Трудот содржи проучувања за начинот на наследување на приносот на зелена маса и приносот на сува маса по страк, како и нивната генетска анализа, кај шест родителски генотипови тутун (P-23, MB-3, SM-1, YV 125/3, FL-5 и O-87) и нивните 15 F1, и по исто толку F2, BC1(P1) и BC1(P2) дијалелни крстоски. Опитот беше поставен во 2008 и 2009 година на опитното поле од Научниот институт за тутун - Прилеп по случаен блок - систем во четири повторувања, а за време на вегетативниот период беа применети стандардни агротехнички мерки.

Целта на истражувањата беше да се проучи генетиката на наследување на приносот на зелена и сува маса, преку одредување на генетските компоненти на варијансата да се определи видот на гените - носители на својствата и да се оцени влијанието на надворешната средина врз нивното манифестирање.

Приносот како најважно агрономско својство се наследува првенствено парцијално доминантно. Кај крстоската MB-3 x YV 125/3 има појава на позитивен хетерозис, а кај FL-5 x O-87 негативен. Генетската анализа на четирите проучувани генерации покажува дека предност имаат адитивни гени во неговото креирање. Резултатите прикажани во трудот ќе дадат сигурни насоки во селекцијата на тутунот.

Клучни зборови: тутун (*Nicotiana tabacum L.*), начин на наследување, хетерозис, генетска анализа, компоненти на генетска варијанса.

INTRODUCTION

Properties of the living organisms are created by genomes. In their genetic system they are inheritable and have a limited changeability. Each individual is phenotypic manifestation of properties, influenced by its own genotype and environmental factors. In agronomy, selection is based on phenotypic and genotypic investigations, in order to increase the yield and to improve the quality. Tobacco is agricultural crop which gives pleasure to the consumers and they can hardly resist it, in spite of its bad influence on humans health. For this reason, the aim of breeding, accompanied by various chemical, medicinal and technological investigations, is to reduce the risk of disease and death.

The aim of this paper is to study the mode of inheritance of the characters green and dry mass yields per stalk and to make their genetic analysis using biometric methods, which will improve the knowledge on successive generations and give further directions in selection of tobacco.

MATERIAL AND METHODS

Investigations included six tobacco genotypes, of which four oriental (Prilep P-23, Basma MB-3, Samsun SM-1, Yaka YV 125/3) and two semi-oriental (Floria FL-5, Otlia O-87).

15 diallel crosses for F1 were made, from which the following year seed material for F2 generation was obtained. Backcrossings were made with one of the parents for BC1 (P1) and with the second parent for BC1 (P2), after which a diallel for F1 was crossed again. The trial was carried out in 2008 and 2009 in the field of Scientific Tobacco Institute - Prilep in randomized block design with four replications. During the vegetation period, adequate cultural practices were applied on tobacco.

Green mass yield was weighed after each harvest and after the last harvest, for estimation of green mass yield per stalk, the total tobacco weights obtained from each plot were added and then divided with the number of tobacco stalks. The same method was used to estimate the dry mass leaf per stalk, by weighing tobacco after its manipulation and applying the formulae for corrected yield.

Mode of inheritance was determined by the test-significance of mean values of F1, F2, BC1(P1) and BC1(P2) progenies and parental average, according to Borojevic (1).

Components of genetic variance were determined by the methods of Jinks (4), Hayman (2,3) and Mather & Jinks (5, 6).

The following parameters were analysed:

D - Component of variance resulting from additive gene action

H1 - Component of variance resulting from dominant gene action

H2 - Component of variance resulting from dominant gene action, corrected in relation to their distribution,

H1 = H2 when u = v

(u - dominant alleles, v - recessive alleles)

F - Interaction between additive and dominant effects,

F = 0 when u = v

F = positive value, with higher number of dominant alleles

F = negative value, with higher number of recessive alleles

E - Noninherited environmental variance, obtained by the analysis of variance with randomized block design

$\sqrt{\frac{H1}{D}}$ - Average degree of dominance

- The value lower than 1 ($\sqrt{\frac{H1}{D}} < 1$) denotes partial dominance

- The value equal to 1 ($\sqrt{\frac{H1}{D}} = 1$) denotes complete dominance

- The value higher than 1 ($\sqrt{\frac{H1}{D}} > 1$) denotes overdominance

$\frac{H2}{4H1} = u \cdot v$ - frequency of dominant - u and recessive - v genes.

During tobacco vegetation in field (May-Sept 2008), mean monthly air temperature was 19.91^{0}C and the total amount of precipitations (in 39 rainy days) was 235.44 mm. In the same period in 2009, mean monthly air temperature was 19.89^{0}C and the total amount of precipitations (in 42 rainy days) was 240.6 mm.

RESULTS AND DISCUSSIONS

Selected parental genotypes significantly differ in relation to green and dry mass yields per stalk. Of all 15 combinations in 2008 and 2009, only between MB-3 and SM-1 did not show significant difference for the two characters. According to the statistical data analysis, there are no significant differences among replications, which indicates that the trial was properly set up and accurately processed.

The highest yield was recorded in the semi-oriental variety O-87, and the lowest in the oriental aromatic varieties MB-3 and SM-1 (Table 1).

Table 1. Green and dry mass yields in parental genotypes in 2008 and 2009

Parental genotypes	Green mass yield per stalk(g)		Dry mass yield per stalk (g)	
	2008	2009	2008	2009
	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
1. P1 (Prilep P-23)	156.00	158.00	24.00	25.22
2. P2 (Basma MB-3)	78.00	79.35	12.00	12.18
3. P3 (Samsun SM-1)	81.25	85.46	12.50	13.39
4. P4 (Yaka YV 125/3)	139.75	141.82	21.50	22.15
5. P5 (Floria FL - 5)	279.50	280.82	43.00	44.30
6. P6 (Otlia O-87)	318.50	320.94	49.00	49.55
LSD 0,05	11.36	11.69	1.09	1.33
0,01	17.81	18.32	1.70	2.09

In F1 progeny of 2008, green mass yield was inherited by partial dominance, intermediate dominance and positive or negative dominance. Positive heterosis was observed in MB-3 x YV 125/3, and negative in FL-5 x O-87. The mode of inheritance of this character in 2009 was intermediate and partially dominant, and heterosis appearance was observed in the same crosses as in the previous year.

All modes were present in inheritance of the character dry mass yield, with advantage of the partial dominance. Positive heterosis was observed in MB-3 x YV 125/3 and negative heterotic effect in FL-5 x O-87 both in 2008 and 2009 (Table 2, Fig. 1).

Table 2. The mode of inheritance of green and dry mass yields in diallel F1 progeny in 2008 and 2009

F1 generation	Green mass yield per stalk (g)				Dry mass yield per stalk (g)			
	2008		2009		2008		2009	
	$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$	
1. P1 x P2	120.05	i	120.95	i	18.35	i	19.05	i
2. P1 x P3	113.98	i	116.55	i	17.55	i	18.23	i
3. P1 x P4	140.15	-d	140.58	pd	21.32	-d	21.84	-d
4. P1 x P5	199.57	pd	182.80	i	30.55	pd	30.15	pd
5. P1 x P6	169.10	-d	172.05	pd	25.75	-d	26.57	-d
6. P2 x P3	81.55	+d	83.44	i	12.50	+d	12.28	-d
7. P2 x P4	160.23	+h	161.92	+h	23.45	+h	24.31	+h
8. P2 x P5	122.30	pd	122.48	pd	18.60	pd	18.99	pd
9. P2 x P6	123.86	pd	128.15	pd	19.15	pd	19.89	pd
10. P3 x P4	102.05	pd	106.50	i	15.55	pd	16.05	pd
11. P3 x P5	156.29	i	145.45	i	23.9	pd	24.27	pd
12. P3 x P6	149.39	pd	149.33	i	22.75	pd	22.85	pd
13. P4 x P5	220.95	i	222.82	i	34.00	i	33.78	i
14. P4 x P6	155.62	-d	153.78	pd	23.65	-d	24.16	-d
15. P5 x P6	173.75	-h	174.29	-h	26.6	-h	27.18	-h

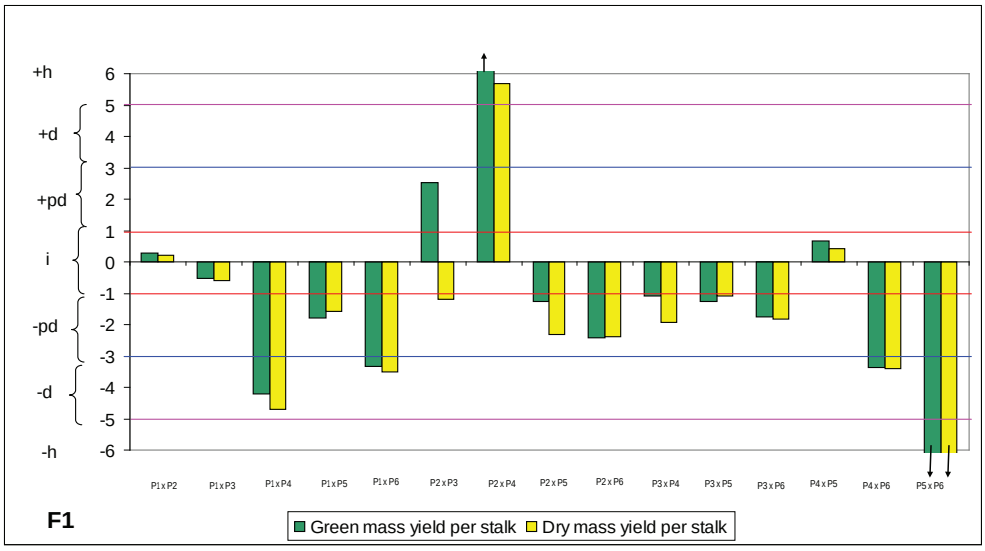

Figure 1 . Graphic presentation of the mode of inheritance of green and dry mass yield per stalk in the diallel F1 progeny

The inheritance of green mass yield in F2 progeny in 2008 and 2009 was intermediate and partially dominant. Negative heterosis was observed in FL-5 x O-87.

Dry mass yield in F2 generation is inherited in the same way as the green mass yield. Intermediate inheritance and partial dominance denote shortening of the selection process and fast fixation and stabilization of the investigated characters (Table 3, Fig. 2).

Table 3. The mode of inheritance of green and dry mass yields in diallel F2 progeny in 2008 and 2009

F2 generation	Green mass yield per stalk (g)				Dry mass yield per stalk (g)			
	2008		2009		2008		2009	
	$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$	
1. P1 x P2	118.15	i	120.06	pd	18.175	i	18.55	i
2. P1 x P3	116.35	i	119.23	i	17.9	i	18.50	i
3. P1 x P4	143.22	pd	145.08	pd	22.035	pd	22.50	-d
4. P1 x P5	208.16	i	206.57	i	32.025	i	32.72	i
5. P1 x P6	202.31	pd	205.90	pd	31.125	pd	31.63	pd
6. P2 x P3	80.45	pd	82.78	i	12.375	pd	12.65	i
7. P2 x P4	130.65	pd	136.21	+d	20.1	pd	20.30	pd
8. P2 x P5	149.82	pd	151.38	pd	23.05	pd	23.42	pd
9. P2 x P6	161.36	pd	163.98	pd	24.825	pd	25.15	pd
10. P3 x P4	105.88	i	109.79	i	16.275	i	16.80	i
11. P3 x P5	167.82	i	164.50	i	25.825	i	26.37	i
12. P3 x P6	173.87	i	176.47	i	26.75	i	27.00	i
13. P4 x P5	215.31	i	216.87	i	33.125	i	33.84	i
14. P4 x P6	191.42	pd	192.46	pd	29.45	pd	29.95	pd
15. P5 x P6	235.95	-h	237.90	-h	36.3	-h	37.27	-h

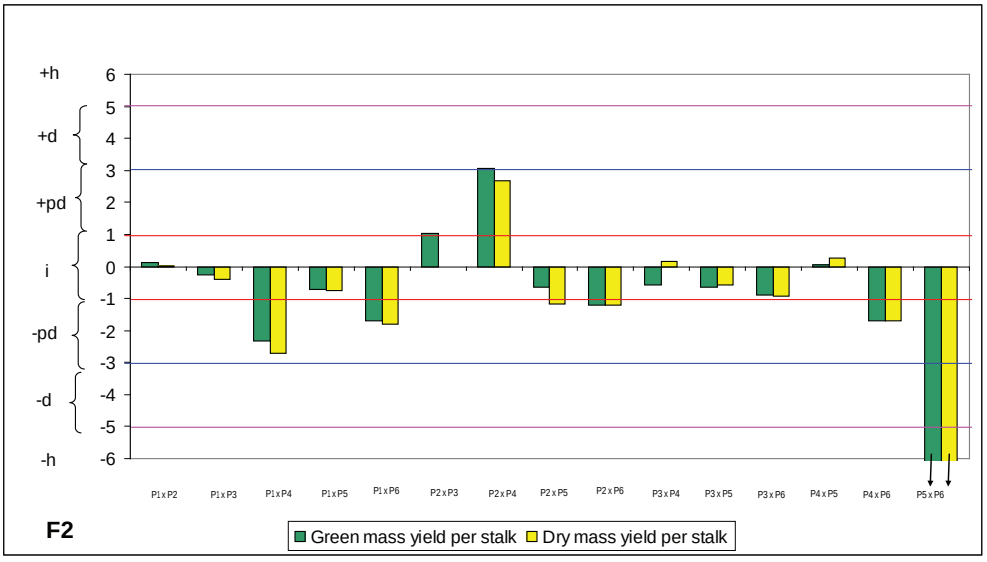

Figure 2 . Graphic presentation of the mode of inheritance of green and dry mass yield per stalk in the diallel F2 progeny

The most frequent mode of inheritance of green mass yield per stalk in the backcross BC1 (P1) generation in 2008 and 2009 was partial dominance. In several combinations both intermediate and negatively dominant inheritance were present. In FL-5 x O-87 the appearance of negative heterosis was observed.

Dry mass yield in this generation is inherited identically as the green mass yield (Table 4, Fig. 3).

Table 4. Mode of inheritance of green and dry mass yields in diallel BC1(P1) progeny in 2008 and 2009

BC1(P1) generation	Green mass yield per stalk (g)				Dry mass yield per stalk (g)			
	2008		2009		2008		2009	
	$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$	
1. P1 x P2	137.64	pd	139.72	pd	21.22	pd	21.78	pd
2. P1 x P3	135.10	pd	137.37	pd	20.84	pd	21.38	pd
3. P1 x P4	147.29	i	149.13	i	22.45	i	23.35	i
4. P1 x P5	177.29	pd	175.86	pd	27.22	pd	27.90	pd
5. P1 x P6	161.70	-d	165.15	-d	24.81	-d	25.50	-d
6. P2 x P3	79.62	i	81.25	pd	12.15	pd	12.51	pd
7. P2 x P4	115.25	i	120.59	pd	17.88	i	17.82	i
8. P2 x P5	99.45	-d	101.01	-d	15.41	-d	15.39	-d
9. P2 x P6	101.24	-d	103.58	-d	15.95	-d	15.70	-d
10. P3 x P4	91.16	pd	95.70	pd	14.05	pd	14.97	pd
11. P3 x P5	118.30	pd	115.65	pd	17.87	pd	18.05	pd
12. P3 x P6	114.56	pd	117.60	pd	17.92	pd	18.19	pd
13. P4 x P5	180.37	pd	182.12	pd	27.94	pd	28.24	pd
14. P4 x P6	146.75	-d	147.68	-d	22.92	-d	23.05	-d
15. P5 x P6	226.20	-h	227.87	-h	34.70	-h	35.55	-h

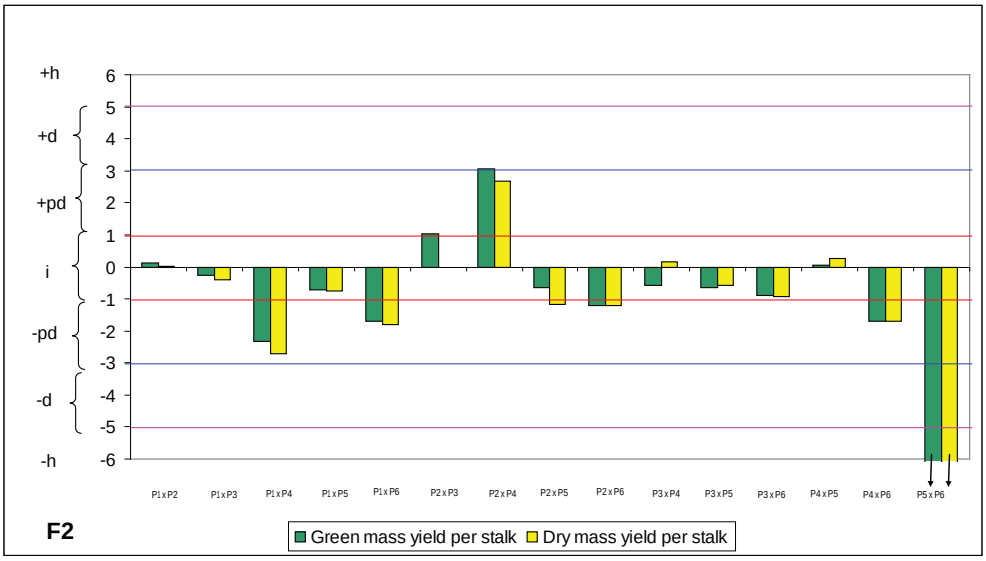

Figure 3 . Graphic presentation of the mode of inheritance of green and dry mass yield per stalk in the diallel BC1(P1) progeny

In BC1 (P2) generation, green mass yield in both investigating yeras was inherited mostly with partial dominance. In a number of combinations intermediary and dominant inheritance was present. In MB-3 x YV 125/3 in 2008 the character was inherited from the higher-yielding parent (YV 125/3), and in 2009 this combination had positive heterotic effect. The hybrid FL-5 x O-87 showed negative heterosis.

Dry mass yield in this generation was inherited mostly with partial dominance. Results from both investigating years were identical, except for the hybrid MB-3 x SM-1, which had positive heterotic effect in 2008 and in 2009 intermediate inheritance was present. This is a result of the insignificant difference for this character between the two parental genotypes, so that small differences appear as a consequence of the poor effect of non- genetic factors (Table 5, Fig. 4).

Table 5. Mode of inheritance of green and dry mass yields in diallel BC1(P2) progeny in 2008 and 2009

BC1(P2) generation	Green mass yield per stalk (g)				Dry mass yield per stalk (g)			
	2008		2009		2008		2009	
	$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$	
1. P1 x P2	98.65	pd	100.40	pd	15.41	pd	15.30	pd
2. P1 x P3	97.66	pd	101.17	pd	15.25	pd	15.50	pd
3. P1 x P4	139.16	-d	141.04	-d	21.28	-d	21.99	-d
4. P1 x P5	239.07	pd	237.27	pd	36.81	pd	37.50	pd
5. P1 x P6	242.94	i	246.65	i	37.59	i	37.85	i
6. P2 x P3	81.25	+d	84.30	pd	12.69	+h	12.91	i
7. P2 x P4	146.14	+d	151.83	+h	22.53	+d	22.70	+d
8. P2 x P5	200.20	i	201.75	i	31.78	pd	31.28	i
9. P2 x P6	221.50	i	224.35	i	34.00	i	34.17	i
10. P3 x P4	120.41	pd	123.88	pd	18.50	pd	19.05	pd
11. P3 x P5	217.42	pd	213.35	pd	33.15	pd	34.30	pd
12. P3 x P6	233.22	pd	235.34	pd	36.57	pd	36.22	pd
13. P4 x P5	250.25	pd	251.62	pd	38.70	pd	39.46	pd
14. P4 x P6	236.11	i	237.24	i	36.33	i	36.59	i
15. P5 x P6	245.70	-h	247.95	-h	37.50	-h	38.20	-h

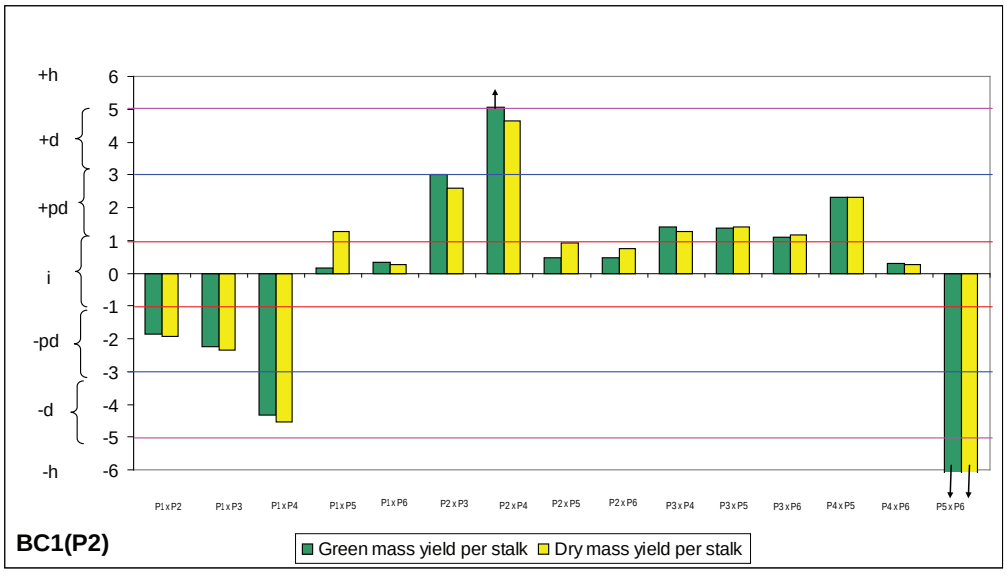

Figure 4 . Graphic presentation of the mode of inheritance of green and dry mass yield per stalk in the diallel BC1(P2) progeny

According to the presented data, mean values of the characters investigated in 2008 were similar to those in 2009, and the laws of inheritance were also identical. High similarities were also observed in meteorological data about mean monthly air temperatures and total amount of precipitations during the vegetation period (May-September).

Genetic analysis of green mass yield per stalk in F1, F2, BC1(P1) and BC1(P2) progenies showed high values of the additive component of genetic variance and low values of the dominant component (D > H1 and H2), which is an indication that inheritance of the character is governed both by dominant and recessive genes, with prevalence of the recessive ones. The posi-

tive value of the interaction F reveals dominance of higher-yielding parent in inheritance of this character. The low value of the environmental variability (E) indicates a low impact of the environment in inheritance of the character.

The values for H2/4H1 (genes frequency) in all generations were below 0.25, which denotes absence of symmetrical distribution of dominant and recessive alleles. The average level of dominance is lower than one, which indicates the presence of partially dominant inheritance. The results on genetic analysis of green mass yield per stalk are presented in Table 6.

Table 6. Components of genetic variance for green mass yield per stalk in diallel F1, F2, BC1(P1) and BC1(P2) generations

Components	F1	F2	BC1(P1)	BC1(P2)
D	1685.25	1673.05	1644.31	1672.28
H1	51.54	62.72	283.00	115.15
H2	39.28	55.05	191.05	92.18
F	97.66	204.38	809.55	85.37
E	8.22	11.98	22.36	12.29
H2 / 4H1	0.19	0.21	0.16	0.20
$\sqrt{H1/D}$	0.173	0.173	0.412	0.245

From genetic analysis of the character dry mass yield in F1, F2, BC1(P1) and BC1(P2) progeny it can be concluded that the additive components of genetic variance are much higher compared to those of dominant component (D > H1 and H2), according to which the inheritance is governed mostly by recessive genes. The interaction F for F1 and BC1(P2) has a negative value, indicating that the lower-yielding parent has a dominant role in inheritance of the character, whereas for F2 and BC1(P1) the interaction has a positive value, indicating the dominance of the parent with higher dry mass yield. For this character again, the environmental variance has a low value, which points out to the similar meteorological conditions in both investigation years and to identical application of suitable cultural practices during the vegetation period. The values of H2/H41 are lower than 0.25 in all generations, which indicates an absence of symmetrical distribution of dominant and recessive alleles. The average level of dominance $\sqrt{H1/D}$ is lower than one, which indicates the presence of partially dominant inheritance of this character.. The results of genetic analysis on dry mass yield per stalk are presented in Table 7.

Table7. Components of genetic variance for dry mass yield per stalk in diallel F1, F2, BC1(P1) and BC1(P2) generations

Components	F1	F2	BC1(P1)	BC1(P2)
D	39.55	39.56	39.58	39.47
H1	1.39	1.97	5.04	3.98
H2	1.31	1.82	2.15	3.46
F	-4.72	3.54	13.18	-10.62
E	0.14	0.11	0.10	0.20
H2 / 4H1	0.23	0.23	0.10	0.21
$\sqrt{H1/D}$	0.173	0.200	0.346	0.100

CONCLUSIONS

The following statements can be drawn from the results of investigation:

- Parental genotypes are homozygous, uniform and show significant differences between them.
- The inheritance of green and dry mass yields from the six parents to their diallel F1, F2, BC1(P1) and BC1(P2) progenies is mostly partially dominant and intermediate. Positive heterosis in the first hybrid generation was present in MB-3 x YV 125/3, and negative heterosis in FL-5 x O-87 for both characters and in both years of investigation.
- Genetic analysis reveals that both additive and dominant genes have an impact on creation of the investigated characters, with high dominance of additive genes (the value of the additive component of genetic variance - D is dramatically higher compared to the dominant one - H1 and H2). From the values of the estimated parameters, F denotes a presence of asymmetrical distribution of dominant and recessive alleles, H2/4H1 indicates that inheritance of the green mass yield in four generations and dry mass yield in F2 and BC1(P1) is prevailed by the higher-yielding parent and inheritance of the dry mass yield in F1 and BC1(P2) is dominated by the lower-yielding parent and $\sqrt{H1/D}$ indicates the presence of partially dominant mode of inheritance of the investigated characters.
- Investigations on heritability and genetic analysis have enormous impact on tobacco breeding, because they determine the inheritance of yield as the most important agronomic character and give useful directions for creation of new, higher-yielding varieties. The applied methods of work are also applicable for determination of quantitative characters in many other crops.

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