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EFFECT OF PET1 AND ANN5 CYTOPLASMS ON SOME QUANTITATIVE TRAITS IN SUNFLOWER LINES AND HYBRIDS

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SUMMARY

Studied in this paper was the effect of PET1 and ANN5 cytoplasms on plant height, hectoliter mass, seed kernel content, and seed husk content of four inbred sunflower lines as well as of the crosses of the lines' sterile forms with three restorers. In the crosses, heterosis relative to the parental mean (H_1) and heterosis relative to the better parent (H_2) were calculated. PET1 cytoplasm affected plant height in lines L-1, L-10, and L-14, hectoliter mass in all of the lines, and on seed husk content in lines L-11 and L-10. ANN5 cytoplasm, for its part, influenced plant height in lines L-10, L-14, and L-19 and on hectoliter mass in lines L-1, L-10, and L-14. PET1 cytoplasm caused no significant increase in the seed kernel content of the lines, and ANN5 cytoplasm did not significantly increase the lines' kernel and husk contents, either. The said cytoplasms' effects on the expression of the quantitative traits under study were not equally significant in all of the crosses. The incorporation of PET1 cytoplasm proved the most useful in the L-10P x RHA-1 cross, where it caused highly significant increases of plant height, hectoliter mass, and seed kernel content as well as a decrease of seed husk content. ANN5 cytoplasm, on the other hand, was most effective in the cross L-14A x RHA-2, in which it produced a highly significant increase in hectoliter mass, a significant increase in seed kernel content, and a highly significant decrease of seed husk content as well as a certain decline in plant height.

Key words: sunflower, cytoplasm, plant height, hectoliter mass, kernel content, seed husk content, inbred lines

INTRODUCTION

A desire to obtain as high seed and oil yields per unit area as possible has led to the development of hybrids in sunflower (*Helianthus annuus* L.). Although sunflower is considered second on the list of crops in which hybrids predominate in commercial production (maize being the first), it was only after a suitable source of male sterility was discovered that the development of first commercial hybrid became possible. The most suitable type of male sterility for practical utilization of

heterosis in sunflower is cytoplasmic male sterility, discovered by Leclercq (1969) in a wild *H.petiolaris* (PET1). This male-sterile cytoplasm can be found in all commercially grown sunflower hybrids. Since its discovery, more than 50 more male-sterile cytoplasms have been found in many wild sunflower populations.

Using backcrossing, male-sterile cytoplasm is incorporated into inbred lines once their general and specific combining abilities have been tested. As the number of newly discovered male-sterile cytoplasms increased, researchers became increasingly interested in determining whether the introduction of such cytoplasms into inbred lines had an effect on plant and seed traits in the lines as well as hybrids derived from them.

Stojanova and Petrova (1980) reported finding no effect of male–sterile PET1 cytoplasm (Leclercq, 1969) on the biological and economic traits of sunflower and based on that concluded that this cytoplasm could be successfully used in the production of hybrid seed. Several years later, however, Petrov *et al.* (1985) reported that inbred lines into which PET1 cytoplasm had been incorporated were more susceptible to broomrape (*Orobanche cumana* Wallr.) than the B-line maintainers.

Heaton *et al.* (1992) found that in some lines and hybrids PET1 cytoplasm decreased the level of total saturated fatty acids by as much as 50%. Sterile forms of some of the genotypes from the above study produced seed whose oil had 1% less stearic and 3% less palmitic acid. The oleic acid content of the sterile forms was higher than that of the maintainers. Effects of PET1 cytoplasm were recorded in hybrids from all locations.

Studying the effects of different male-sterile cytoplasms on sunflower's quantitative traits, Petrov (1992) reported that PET2 cytoplasm (Whelan, 1980) had no negative effect on the crop's biological and economic properties and that it could therefore be used for developing sunflower hybrids. The same author also found that male-sterile cytoplasms ANN1 (Serieys, 1991) and ANT1 (Vranceanu *et al.*, 1986) affected plant height, seed yield per plant and head diameter and concluded that their use in hybrid development was therefore subject to certain limitations.

Investigating the interdependences among four genotypes, two male-sterile cytoplasms (PET1 and ANN5, Marinković and Miller, 1992) and some quantitative traits (head diameter, seed yield per plant, 1000-seed mass, seed oil content), Marinković *et al.* (1996) found that all four inbred lines had different values of the studies traits depending on the male-sterile cytoplasm that had been incorporated into them.

The objective of this paper was to determine if PET1 and ANN5 cytoplasms influence plant height, hectoliter mass, and husk and kernel contents in several sunflower inbreds and their hybrid combinations with three different restorers.

MATERIALS AND METHODS

The male sterile PET1 and ANN5 cytoplasms were incorporated into four selected inbred lines using backcrosses. Once the introduced cytoplasms had been stabilized, crosses were made between the maintainers (B-lines) and male sterile lines (4+4) with three restorers. When making the crosses between the maintainers and restorers, the stamens of the maintainer plants used as the female parent were removed by hand in the early morning hours in order to prevent potential self-pollination.

Materials which comprised of four male-fertile lines and their sterile forms, three restorers, and 36 hybrid combinations were sown in a trial with three replications according to a randomized block design. The trial was established at the Rimski Šančevi Experiment Field of the Institute of Field and Vegetable Crops in Novi Sad. The materials were sown in four rows with 12 plants per row in each replicate. The row-to-row and plant-to-plant spacings were 70 and 25 cm, respectively.

Plant height (cm) was measured in the field and the hectoliter mass (kg hl^{-1}), kernel content (%), and husk percentage in the laboratory.

The size of samples used for trait analyses was 60 plants per treatment (inbred lines and F_1 hybrids), i.e., 20 plants per replicate. All analyses except those for hectoliter mass were performed at the plant level. Mean values for each treatment within the replicates were calculated.

The size of samples used for the analysis of husk and kernel percentages was 2 x 5 g per plant. The seeds were dehulled by hand and the husk and kernel contents were expressed as percentage. In order to be able to apply the analysis of variance, data were transformed using the arcsin percentage.

Heterosis relative to the parental means was calculated according to the formula $HF_1=F_1/[P_1+P_2] \times 100$ and heterosis relative to the better parent according to the formula $HF=F_1/BP \times 100$.

RESULTS AND DISCUSSION

The male-sterile cytoplasm did not have the same effect on all traits and all four inbreds used in the study (Table 1). In the case of plant height, highly significant values relative to the maintainer (B-analogue) were recorded in the sterile forms of lines L-10 and L-14. Further, the results showed that both the L-10 sterile form with PET1 cytoplasm and L-14 sterile form with ANN5 cytoplasm had highly significant values in relation to the other lines. Also, the L-1 sterile form with PET1 cytoplasm and L-19 sterile form with ANN5 cytoplasm had highly significant values for this trait relative to the B-analogue and the other sterile form. It should be noted that no decrease of plant height was recorded in the sterile forms of inbred lines used in the trial.

Table 1: Mean values of the traits in inbred lines and their sterile forms

Genotype		Trait			
		Plant height (cm)	Hectoliter mass (cm)	Kernel content (%)	Husk content (%)
L-1	M*	105.70	33.97	74.23	25.77
L-1	P	119.28**	37.63**	77.63^{NS}	22.37*
L-1	A	107.47^{NS}	38.57**	77.30^{NS}	22.70^{NS}
LSD 0.05		4.88	1.14	3.22	3.22
LSD 0.01		8.11	1.89	5.34	5.34
L-10	M	94.35	31.27	74.83	25.17
L-10	P	137.83**	35.07*	78.13^{NS}	21.87**
L-10	A	100.59**	36.00**	77.07^{NS}	22.93**
LSD 0.05		3.69	2.80	1.78	1.78
LSD 0.01		6.13	4.65	2.95	2.95
L-14	M	132.45	30.93	72.50	27.50
L-14	P	141.28**	33.97*	74.00^{NS}	26.00^{NS}
L-14	A	190.55**	42.50**	70.80^{NS}	29.20^{NS}
LSD 0.05		7.66	2.28	3.22	2.58
LSD 0.01		12.72	3.78	5.34	4.28
L-19	M	137.12	32.72	78.67	21.33
L-19	P	109.10^{NS}	38.27**	77.93^{NS}	22.07^{NS}
L-19	A	148.04**	31.40^{NS}	74.17^{NS}	25.83^{NS}
LSD 0.05		5.38	2.03	6.30	5.49
LSD 0.01		8.94	3.36	10.46	9.12

* M-maintainer; P=PET-1 source; A=ANN-5 source

Positive effects of PET1 cytoplasm on sunflower plant height have been reported by Spirova *et al.* (1984). Velkov and Stojanova (1974) observed no depressive influence of PET1 cytoplasm on plant height during the cytoplasm incorporation into inbred lines. Similar findings are reported by Petrov (1980) as well. Studying the effects of 10 different male-sterile cytoplasms on sunflower traits, Serieys (1992) noticed that although plant height increased systematically in all cytoplasms involved, (which included PET1), the increases were significant only in the sterile forms of PEF1, ANN1, ANN2, PET2, and ANL2 cytoplasms. Petrov (1990) found positive effects of ANN1 as well as ANT1 cytoplasm on plant height. However, he found no positive influence of PET2 cytoplasm on this trait. Spirova (1991) reported a negative influence of genetic male sterility on plant height.

The influence of cytoplasms under study on hectoliter mass was similar to that on plant height. The effect of PET1 cytoplasm on this trait was highly significant in lines L-1 and L-19 and significant in L-10 and L-14. ANN5 cytoplasm had a highly significant effect on hectoliter mass in all of the lines except L-19, where hectoliter mass was similar to that of the B-analogue. Both the sterile form of L-14 with ANN5 cytoplasm and the sterile form of L-19 with PET1 cytoplasm had highly significant hectoliter mass values relative to the respective B-analogue and to the other sterile

form. In the other two inbreds there was no significant difference between the two sterile forms.

According to Djakov (1966), selection for increased oil yield can be performed by evaluating the selection materials for kernel yield, since there is a strong positive correlation between these two traits (r=+0.99). The kernel content of the inbred lines in our study ranged from 72.50% in L-14 to 78.68% in L-19. In most of the lines, PET1 and ANN5 cytoplasms had no significant effect, either positive or negative, on the expression of the trait in question in relation to the B-analogue. The effect of PET1 cytoplasm on the trait's expression was highly significant in line L-10 and significant in line L-1, while ANN5 cytoplasm had significant influence only on L-10. A highly significant difference between the sterile analogues was observed only in line L-14. Its sterile form with PET1 cytoplasm had a considerably higher value than the one with ANN5 cytoplasm.

Results similar to these were also reported by Velkov and Stojanova (1974) and Petrov (1980). These authors found no significant difference between inbred lines and their male-sterile forms based on PET1 cytoplasm.

Given that sunflower husks have little value for the processing industry, the husk percentage should be reduced as much as possible through breeding. Having said that, as Roath *et al.* (1985) have pointed out, it must also be borne in mind that excessive reduction of seed husk percentage can lead to problems regarding the development of the protective carbon layer and the dehulling process in factories. In contrast to the previous three traits, therefore, the desirable cytoplasm effect in this case is a decrease or at the very least the maintenance of the husk content at the level of the B-analogue.

The use of cytoplasm affected in different ways the expression of seed husk content in the lines. In some of them (L-1 and L-10) there was a significant decrease and in others a negligible increase of the seed husk content of the sterile analogues. In line L-10, both cytoplasms brought about a highly significant decline of seed oil content, whereas in line L-1 only PET1 cytoplasm caused this content to decrease significantly relative to the B-analogue.

Taking into account all of the above, it becomes apparent that L-10 is the most interesting line of the four. In L-10, both male-sterile cytoplasms led to either significant or highly significant increase of plant height, hectoliter mass, and kernel content and a decrease of seed husk content. Line L-1 has also proven interesting, whereas the other two are of no interest to breeders, at least as far as the two cytoplasms and the traits studied are concerned.

Our analysis of the hybrid combinations of inbred lines and their sterile forms with restorers revealed that the cytoplasms had different effects on the expression of the traits depending on the genotype into which they were incorporated (Table 2). PET1 cytoplasm significantly increased plant height in the crosses between L-1 and RHA-3 restorer relative to the crosses between the B-analogues and RHA-3. This cytoplasm also increased hectoliter mass in the crosses of L-10 with RHA-1 and RHA-3 restorers and seed kernel content in the crosses between L-1 and RHA-3, L-10 and RHA-2, and L-14 and RHA-2. In the rest of the crosses, the values were similar to those from the crosses between the B-analogues and the restorers. The high-

Table 2: Mean values of the traits in the B-analogues and sterile forms of the inbred lines and restorers

Genotype	Crosses with restorer RHA-1				Crosses with restorer RHA-2				Crosses with restorer RHA-3			
	Plant height (cm)	Hectoliter mass (kg/hl)	Husk content (%)	Kernel content (%)	Plant height (cm)	Hectoliter mass (kg/hl)	Husk content (%)	Kernel content (%)	Plant height (cm)	Hectoliter mass (kg/hl)	Husk content (%)	Kernel content (%)
L-1 M	169.02	40.07	30.27	69.73	191.27	42.03	23.00	77.00	197.95	40.23	27.77	72.23
L-1 P	178.68**	40.97	29.17	70.83	192.16	42.07	25.88	74.12	195.55	41.80	23.43	77.23**
L-10 M	135.99	36.93	33.93	66.07	185.51	40.97	25.77	74.23	149.26	34.80	25.80	74.20
L-10 P	171.66**	38.77**	29.63	70.33**	208.74**	41.90	25.40	74.60	188.33**	38.00**	25.97	74.03
L-14 M	187.00	39.60	32.67	67.33	211.89	40.23	28.07	71.93	207.14	39.43	26.67	73.33
L-14 P	191.45	39.50	31.50	68.50	191.66	40.13	25.17**	74.83	194.46	38.80	26.33	73.67
L-19 M	169.93	40.83	29.87	70.13	192.39	41.60	26.10	73.90	188.59	39.53	23.10	76.90
L-19 P	172.85	41.50	31.00	69.00	205.88**	41.57	26.60	73.40	201.80**	39.97	25.00	75.00
L-1A	185.32**	41.83**	30.43	69.57	197.01*	43.47*	23.27	76.73	202.24	41.37	24.27	75.73**
L-10A	176.10**	41.07**	32.67	67.33	213.91*	43.47**	26.53	73.47	205.77**	39.50**	24.90	75.10
L-14A	193.78**	41.57**	32.60	67.40	204.05	42.33**	25.67	74.33*	210.58	42.50**	24.88	75.12
L-19A	181.61**	42.73**	30.70	69.30	206.25*	41.97	23.27	76.73*	216.54**	40.97	25.33	74.67
LSD 0.05	4.15	0.97	2.63	2.63	5.08	1.27	2.30	2.30	12.17	1.95	2.28	2.51
LSD 0.01	5.64	1.32	3.58	3.58	6.91	1.72	3.13	3.13	16.55	2.51	3.10	3.41

est decreases of trait values caused by PET1 cytoplasm were recorded in the case of seed husk content in the crosses between L-10 and L-14 and the RHA-1 and RHA-2 restorers.

These data also show that the introduction of PET1 cytoplasm into line L-10 was most effective. The sterile form of L-14 is also interesting, since PET1 cytoplasm in combination with RHA-2 restorer brought about a significant increase of kernel content, a decrease of seed husk percentage, a certain decrease in plant height, and the maintenance of hectoliter mass at the level found in the crosses between the B-analogue and the RHA-2.

In the crosses between the sterile forms of the inbred lines with ANN5 cytoplasm and all three restorers, there was a considerably higher number of combinations with either significant or highly significant values of the studied traits compared with the values from the crosses between the B-analogues and restorers. In all crosses between the sterile analogues and RHA-1 restorer, for instance, highly significant values for plant height and hectoliter mass were found. In the crosses between these sterile forms and RHA-2 and RHA-3, significant or highly significant values were found in three and two combinations, respectively.

No significant increases in seed kernel and husk contents were recorded in the crosses between the inbreds' sterile forms and RHA-1. However, the use of RHA-2 and RHA-3 in the crosses resulted in significantly increased kernel content in one and two combinations, respectively. It should be noted that in the latter two combinations we observed a significant positive increase of kernel content and a significant or highly significant decrease of seed husk content.

Based on the above, it can be concluded that the incorporation of ANN5 cytoplasm was most justified in the case of line L-14. The crossing of the sterile form of this line with RHA-2 brought about a highly significant increase in hectoliter mass, a significant increase of kernel content, a highly significant decrease of seed husk percentage, and a non-significant decline in plant height. The introduction of this germplasm into line RHA-19 would also be justified, since this line and RHA-2 produced an interesting combination as well.

The F_1 generation heterosis for the traits concerned was determined in two ways: 1) relative to the parental means (H_1); and 2) relative to the better parent (H_2). Relative to the parental mean, heterosis for plant height was found in the crosses between all three forms of the inbred lines and RHA-1 restorer (Table 3). In relation to the better parent, heterosis was not found only in the cross between the B-analogue of line L-10 and the said restorer. The highest degree of heterosis relative to the parental mean was recorded in the cross of the sterile form of L-1 with ANN5 cytoplasm and RHA-1 and the highest heterosis level relative to the better parent in the cross between the sterile form of L-14 with PET1 cytoplasm and RHA-1 restorer.

For hectoliter mass relative to the parental mean, heterosis was found in all crosses between the three forms of the inbreds and RHA-1 restorer. In relation to the better parent, heterosis was not found only in the crosses of the line L-10 B-analogues and the sterile form of L-14 with ANN5 cytoplasm and RHA-1. The highest

Table 3: Mean value (x) of lines and hybrids with restorer RHA-1 and effects of heterosis (%) in relation to the parental mean (H_1) and to the better parent (H_2)

Genotype	Trait											
	Plant height (cm)			Hectoliter mass (kg/hl)			Kernel content (%)			Husk content (%)		
	X	H_1	H_2	X	H_1	H_2	X	H_1	H_2	X	H_1	H_2
L-1 M	105.70			33.97			74.23			25.77		
L-10 M	94.35			31.27			74.83			25.17		
L-14 M	132.45			30.93			72.50			27.50		
L-19 M	137.12			32.72			78.67			21.33		
L-1 P	119.28			37.63			77.63			22.37		
L-10 P	137.83			35.07			78.13			21.87		
L-14 P	141.28			33.97			74.00			26.00		
L-19 P	109.10			38.27			77.93			22.07		
L-1 A	107.47			38.57			77.30			22.70		
L-10 A	100.59			36.00			77.07			22.93		
L-14 A	190.55			42.50			70.80			29.20		
L-19 A	148.04			31.40			74.17			25.83		
RHA-1	141.73			37.67			57.67			42.33		
L-1 M x RHA-1	169.02	36.61	19.25	40.07	13.84	6.37	69.73	5.73	-	30.27	-	-
L-10 M x RHA-1	135.99	15.21	-	36.93	7.14	-	66.07	-	-	33.93	-	-
L-14 M x RHA-1	187.00	36.41	31.94	39.60	15.45	5.31	67.33	3.44	-	32.67	-	-
L-19 M x RHA-1	169.93	21.88	19.90	40.83	15.99	8.39	70.13	2.89	-	29.87	-	-
L-1 P x RHA-1	178.68	36.92	26.07	40.97	8.82	8.76	70.83	4.64	-	29.17	-	-
L-10 P x RHA-1	171.66	22.81	21.12	38.77	6.60	2.92	70.33	3.58	-	29.63	-	-
L-14 P x RHA-1	191.45	35.30	35.08	39.50	10.27	4.86	68.50	4.04	-	31.50	-	-
L-19 P x RHA-1	172.85	37.78	21.96	41.50	9.30	8.44	69.00	1.74	-	31.00	-	-
L-1 A x RHA-1	185.32	48.73	30.76	41.83	9.73	8.45	69.57	3.08	-	30.43	-	-
L-10 A x RHA-1	176.10	45.34	24.25	41.07	11.48	9.02	67.33	-	-	32.67	-	-
L-14 A x RHA-1	193.78	16.64	1.70	41.37	3.19	-	67.40	4.91	-	32.60	-	-
L-19 A x RHA-1	181.61	11.55	9.17	42.73	23.75	9.83	69.30	6.29	-	30.70	-	-

heritability values relative to the parental mean and the better parent were found in the crosses between the sterile form of L-19 and ANN5 cytoplasm with RHA-1.

In the case of seed kernel content, only heterosis in relation to the parental mean was observed in 10 of the 12 crosses. The heterosis values were very low, ranging from 1.74 to 6.29.

No heterosis for seed husk content was recorded in any of the crosses either relative to the parental mean or to the better parent. The seed husk content values of all crosses were close to the values of the parent with the smaller value for this trait.

In the crosses with RHA-1, not a single combination was found in which the value of any of the traits under study was smaller than in the parent with the lower value, i.e., there was no negative heterosis.

In the crosses of the inbred lines and the sterile forms with RHA-2 restorer, heterosis for plant height was found in all combinations and both relative to the parental mean and relative to the better parent (Table 4). The highest heterosis values relative to the parental mean and the better parent were recorded in the cross between the sterile form of line L-10 and ANN5 cytoplasm with RHA-2.

For hectoliter mass, only heterosis relative to the parental means was observed in all crosses, while heterosis in relation to the better parent was found only in two combinations, both involving the sterile forms of L-1 and L-10 with ANN5 cytoplasm. The highest heterosis value relative to the better parent was recorded in the cross L-14A x RHA-2. High values were also found in L-1P x RHA-2, L-19P x RHA-2, and L-1A x RHA-2.

Heterosis values for seed kernel content show that heterosis relative to the parental mean and heterosis relative to the better parent manifested themselves in 6 and 3 of the 12 combinations, respectively. Although heterosis was found only in few combinations and the values were low, these findings are of great significance for further work on developing higher-yielding sunflower hybrids.

In the case of seed husk content, the situation was different. Whereas hectoliter mass and seed kernel content require hybrid combinations with high positive heterosis, with seed husk content it is more desirable that the combinations have negative heterosis. In our crosses between the inbreds' sterile forms and RHA-2, negative heterosis was found in 6 of 8 combinations, with L-1A x RHA-2 having the lowest value. ANN5 cytoplasm had a greater effect on the husk content decrease in the crosses involving L-1 and L-19 crosses and PET1 cytoplasm in the crosses of L-14 and L-19 with RHA-2.

Similar to this, in all crosses between the three forms of the inbred lines and RHA-3 restorer we found heterosis for plant height in relation to the parental mean as well as the better parent (Table 5). The highest value of heterosis relative to the parental mean was found in L-10A x RHA-3, the highest value relative to the better parent in L-19A x RHA-3. In combinations involving the B-analogues of L-1 and L-14 we found higher heterosis values than in combinations that involved these lines' sterile analogues.

As for hectoliter mass, heterosis relative to the parental mean was found in 9 and that relative to the better parent in only 2 of the 12 crosses. The highest values

Table 4: Mean value (x) of lines and hybrids with restorer RHA-2 and effect of heterosis (%) in relation to the parental mean (H_1) and to the better parent (H_2)

Genotype	Trait											
	Plant height (cm)			Hectoliter mass (kg/hl)			Kernel content (%)			Husk content (%)		
	X	H_1	H_2	X	H_1	H_2	X	H_1	H_2	X	H_1	H_2
L-1 M	105.70			33.97			74.23			25.77		
L-10 M	94.35			31.27			74.83			25.17		
L-14 M	132.45			30.93			72.50			27.50		
L-19 M	137.12			32.72			78.67			21.33		
L-1 P	119.28			37.63			77.63			22.37		
L-10 P	137.83			35.07			78.13			21.87		
L-14 P	141.28			33.97			74.00			26.00		
L-19 P	109.10			38.27			77.93			22.07		
L-1 A	107.47			38.57			77.30			22.70		
L-10 A	100.59			36.00			77.07			22.93		
L-14 A	190.55			42.50			70.80			29.20		
L-19 A	148.04			31.40			74.17			25.83		
RHA-2	168.83			42.80			73.17			26.83		
L-1 M x RHA-2	191.27	39.35	13.29	42.03	38.39	-	77.00	4.45	3.73	23.00	-	-
L-10 M x RHA-2	185.51	40.98	9.88	40.97	37.04	-	74.23	0.03	-	25.77	-	-
L-14 M x RHA-2	211.89	40.66	25.50	40.23	36.87	-	71.93	-	-	28.07	3.31	2.07
L-19 M x RHA-2	192.39	25.76	13.95	41.60	37.76	-	73.90	-	-	26.10	8.38	-
L-1 P x RHA-2	192.16	33.39	13.82	42.07	40.22	-	74.12	-	-	25.88	7.56	-
L-10 P x RHA-2	208.74	36.14	23.64	41.90	38.94	-	74.60	-	-	25.40	4.31	-
L-14 P x RHA-2	191.66	23.60	13.52	40.13	38.39	-	75.17	2.16	1.58	24.83	-	-
L-19 P x RHA-2	205.88	48.15	21.94	41.57	40.54	-	73.40	-	-	26.60	8.79	-
L-1 A x RHA-2	197.01	42.61	16.69	43.47	40.69	1.56	76.73	1.98	-	23.27	-	-
L-10 A x RHA-2	213.91	58.79	26.70	43.47	39.40	1.56	73.47	-	-	26.53	6.63	-
L-14 A x RHA-2	204.05	13.56	7.08	42.33	42.69	-	74.33	3.25	1.58	25.67	-	-
L-19 A x RHA-2	206.25	30.18	22.16	41.97	37.10	-	76.73	4.15	-	23.27	-	-

Table 5: Mean value (x) of lines and hybrids with restorer RHA-3 and effect of heterosis (%) in relation to the parental mean (H_1) and to the better parent (H_2)

Genotype	Trait											
	Plant height (cm)			Hectoliter mass (kg/hl)			Kernel content (%)			Husk content (%)		
	X	H_1	H_2	X	H_1	H_2	X	H_1	H_2	X	H_1	H_2
L-1 M	105.70			33.97			74.23			25.77		
L-10 M	94.35			31.27			74.83			25.17		
L-14 M	132.45			30.93			72.50			27.50		
L-19 M	137.12			32.72			78.67			21.33		
L-1 P	119.28			37.63			77.63			22.37		
L-10 P	137.83			35.07			78.13			21.87		
L-14 P	141.28			33.97			74.00			26.00		
L-19 P	109.10			38.27			77.93			22.07		
L-1 A	107.47			38.57			77.30			22.70		
L-10 A	100.59			36.00			77.07			22.93		
L-14 A	190.55			42.50			70.80			29.20		
L-19 A	148.04			31.40			74.17			25.83		
RHA-3	175.07			41.07			68.80			31.20		
L-1 M x RHA-3	197.95	47.35	13.07	40.23	7.22	-	72.53	1.41	-	25.47	-	-
L-10 M x RHA-3	149.26	10.80	14.74	34.80	-	-	74.20	3.31	-	25.80	-	-
L-14 M x RHA-3	207.14	34.70	18.32	39.43	9.53	-	73.33	3.79	1.14	26.67	-	-
L-19 M x RHA-3	188.59	20.81	7.72	39.53	7.13	-	76.90	4.28	-	23.10	-	-
L-1 P x RHA-3	195.55	32.86	11.70	41.80	6.12	1.78	77.23	5.48	-	23.43	-	-
L-10 P x RHA-3	188.33	20.04	7.57	38.00	-	-	74.03	0.76	-	25.97	-	-
L-14 P x RHA-3	194.46	22.94	11.08	38.80	3.41	-	73.67	3.18	-	26.33	-	-
L-19 P x RHA-3	201.80	42.02	15.27	36.97	-	-	75.00	2.22	-	25.00	-	-
L-1 A x RHA-3	202.24	43.16	15.52	41.37	3.89	0.73	75.73	3.67	-	24.27	-	-
L-10 A x RHA-3	205.77	49.29	17.54	39.50	2.49	-	75.10	2.96	-	24.90	-	-
L-14 A x RHA-3	210.58	15.19	10.51	42.50	1.70	-	75.12	7.62	6.10	24.88	-	-
L-19 A x RHA-3	216.54	34.03	23.69	40.07	10.57	-	74.67	4.46	0.67	25.33	-	-

of heterosis in relation to the parental mean and the better parent were recorded in L-19A x RHA-3 and L-1P x RHA-3, respectively. Negative heterosis was found in the cross L-19P x RHA-3. The calculated heterosis values show that heterosis was mostly higher in the crosses that included the B-analogues of the inbred lines. ANN5 cytoplasm brought induced heterosis relative to the parental mean in all the crosses with RHA-3, while PET1 cytoplasm did so in only two inbreds.

For seed kernel content, heterosis relative to the parental mean was found in all crosses and that relative to better parent in only three. The highest heterosis values relative to both the parental mean and the better parent were found in the cross involving the sterile form of L-14 with ANN5 cytoplasm. In the crosses that included the sterile forms of L-10, L-14, and L-19 based on ANN5 cytoplasm we found higher values of heterosis relative to parental mean than in the crosses involving the sterile forms of these lines based on PET1 cytoplasm. However, the cross with the sterile form of L-1 based on PET1 cytoplasm had a higher heterosis value than that involving the line's sterile form based on ANN5 cytoplasm. Heterosis relative to the better parent was not found in any of the cross involving the PET1-based sterile forms.

For the most part, the seed husk content stayed within the parental value range. In only four crosses (two of them involved the B-analogues of L-14 and L-19 and two the ANN5-based sterile forms of L-14 and L-19) the mean values for this trait were lower than in the worse parent, i.e., negative heterosis occurred. In L-14A x RHA-3 we found a higher value of negative heterosis than in L-19A x RHA-3. No negative heterosis was observed in the crosses that included the inbreds' sterile forms based on PET1.

All the seed husk content means from the crosses were lower than the parental means. The decreases ranged from 8.48 to 12.03% in the crosses involving the B-analogues, from 2.15 to 12.58% in those involving the lines' sterile forms based on PET1 cytoplasm, and from 7.98 to 17.62% in the crosses that included the lines' sterile forms based on cytoplasm. The lowest value relative to the parental mean was found in L-14A x RHA-3.

CONCLUSION

Based on our results and the findings of other researchers, it can be concluded that the male-sterile cytoplasm effect does exist and that it influences the expression of quantitative traits in inbred lines as well as in hybrid combinations. In some genotypes the cytoplasm effect affected quantitative traits in positive direction, while in others the effects were negative. There were, however, some genotypes in which no effects on the expression of the trait concerned were observed. Therefore, breeding programs should include a larger number of male-sterile cytoplasms in order to determine whether and in what way some of them influence the expression of quantitative traits in lines and hybrids with different restorers. The discovery of appropriate male-sterile cytoplasms for particular lines or hybrid combinations would lead to a more economical sunflower production.

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EFECTO DE CITOPLASMAS PET1 Y ANN5 SOBRE CIERTAS CARACTERISTICAS CUANTITATIVAS DE LINEAS Y HIBRIDOS DE GIRASOL

RESUMEN

En el trabajo ha sido estudiado el efecto de los citoplasmas PET1 y ANN5 sobre la altura de planta, el peso en hectolitro, el contenido de hueso y contenido de cáscara en cuatro lineas inbred de girasol y los cruces de formas estériles de esas cuatro lineas con tres lineas-restauradores. Para los cruces fueron calculadas la heterosis con relación a los valores medios de padre (H_1) y la heterosis con relación al padre mejor (H_2). El citoplasma PET1 hacia efecto sobre la altura de planta en las lineas L-1, L-10, y L-14, sobre el peso en hectolitro de todas lineas y el contenido de cáscara en las lineas L-11 y L-10. El citoplasma ANN5 hacia efecto sobre la altura de planta en las lineas L-10, L-14, y L-19 y sobre el peso en hectolitro en las lineas L-1, L-10, y L-14. El citoplasma PET1 no causó el aumento considerable de los contenidos de hueso y cáscara. La influencia de los citoplasmas indicados sobre la expresión de caracteristicas cuantitativas no fué igual en todos cruces. El citoplasma PET1 se mostró como el más útil en el cruce de L-10P x RHA-1, donde causó el aumento considerable de la altura de planta, del peso en hectolitro y del contenido de hueso, asi como la reducción del contenido de cáscara. Por otro lado, el citoplasma ANN5 fué las más eficaz en el cruce de L-14A x RHA-2, donde causó el aumento muy considerable del peso en hectolitro, el aumento considerable del contenido de hueso, la reducción muy considerable del contenido de cáscara y cierta reducción de la altura de planta.

EFFET DES CYTOPLASMES PET1 ET ANN5 SUR CERTAINES CARACTÉRISTIQUES QUANTITATIVES DES LIGNES ET DES HYBRIDES DE TOURNESOL

RÉSUMÉ

Cet article analyse l'effet des cytoplasmes PET1 et ANN5 sur la hauteur de la plante, la masse hectolitre, le contenu du noyau et celui de l'écale dans quatre lignes inbred de tournesol ainsi que dans les croisements de formes stériles de ces quatre lignes avec trois restorers. Dans les croisements, on a calculé l'hétéroside en rapport à la valeur moyenne du parent (H_1) et l'hétéroside en rapport avec le meilleur parent (H_2). Le cytoplasme PET1 a eu un effet sur la hauteur de la plante dans les lignes L-1, L-10 et l-14, sur la masse hectolitre dans toutes les lignes et sur le contenu de l'écale dans les lignes L-11 et L-10. Le cytoplasme ANN5 a eu un effet sur la hauteur de la plante dans les lignes L-10, L-14 et L-19 et sur la masse hectolitre dans les lignes L-1, L-10 et L-14. Le cytoplasme PET1 n'a pas provoqué d'augmentation significative dans le contenu du noyau des lignes observées et le cytoplasme ANN5 n'a pas non plus provoqué d'augmentation dans le contenu du noyau et de l'écale. L'effet des cytoplasmes observés sur l'expression des caractéristiques quantitatives n'était pas également réparti dans tous les croisements. Le cytoplasme PET1 s'est montré le plus utile dans le croisement L-10P X RHA-1, où il a provoqué une augmentation significative de la hauteur de la plante, de la masse hectolitre et du contenu du noyau ainsi qu'une diminution du contenu de l'écale. D'un autre côté, le cytoplasme ANN5 a été le plus efficace dans le croisement L-14A X RHA-2, où il a provoqué une augmentation hautement significative de la masse hectolitre, une augmentation significative du contenu du noyau, une diminution hautement significative du contenu de l'écale et une certaine diminution de la hauteur de la plante.