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PHENOTYPE VARIABILITY AND INHERITANCE OF PLANT HEIGHT AND BRANCHING IN F_1 GENERATION OF SUNFLOWER

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SUMMARY

Highly variable populations of wild sunflower species were crossed with CMS cultivated lines. Variability was determined by measuring plant height and evaluating the type of branching. Mode of inheritance was tested by comparing the 27 hybrid populations against parents. Differences among parents in the observed traits were significant. All modes of inheritance for plant height were present in the F_1 generation. Heterosis was most frequent, followed in decreasing order by partial dominance, dominance and intermediacy. More than one mode of inheritance for plant height occurred because of the large variability in wild species and poligenic inheritance of the characteristic. All F_1 populations were fully branched, with or without the central head. The wild type of branching was found in F_1 because the wild parent dominated in genetic control of that trait over the cultivated one.

Key words: **sunflower, wild species, interspecies hybridization, variability, plant height, inheritance, branching**

INTRODUCTION

There are seven annual and 22 perennial species of wild sunflowers in the collection of Novi Sad Oilcrops Department. They are used because of high variability that has been confirmed by the cluster analysis of morphological characters (Schiling and Heiser, 1981), which also showed phylogenetic relationships inside the *Helianthus* genus. Plant height and branching are important characters in sunflower production because they can have large influence on seed yield. The use of wild species in sunflower breeding increases the variability of those traits and often results in branched F_1 plants. The goal of this study was to define the variability of

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the tested traits and the mode of inheritance for plant height. That was done through hybridization of cultivated inbred lines with populations of wild sunflower.

MATERIALS AND METHODS

Seven annual and sixteen perennial populations have been used for hybridization. Pollen from wild species has been applied to the inflorescences of cultivated cytoplasmatic male sterile sunflower.

All F_1 and parent populations were measured for plant height and the obtained data were used for calculating mean values, standard deviations and variation coefficients. The mode of inheritance was determined by testing the significance of differences between mean values of F_1 generations and parent populations (Borojević, 1965).

The type of branching was evaluated by using the sunflower descriptors (IBPGR, 1985). There are five types of branching described:

0 -no branching,

1 -basally branched,

2 -top branched,

3 -fully branched with a central head and

4 -(wild type) fully branched without a central head (Figure 1).

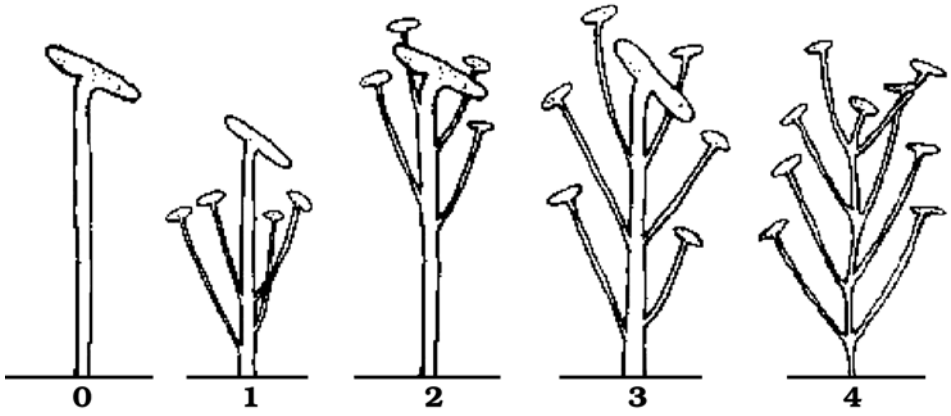

Figure 1: Types of branching

RESULTS

All modes of inheritance for plant height were registered. The most frequent was heterosis (11/27) followed by partial dominance (6/27) and dominance (5/27). Intermediate mode of inheritance and dominance of cultivated sunflower was noted in two hybrid combinations each (Table 1).

Ten populations of *H. annuus* were crossed with cultivated lines. In four out of eleven F_1 hybrid combinations dominance of wild parent was noted. Positive heterosis was equally frequent. No significant differences between parents or between parents and the F_1 generation were found in the hybrid combination HA26A × ANN2188.

Populations of tetraploid perennial *H. divaricatus* had the same mean height as the cultivated line they were crossed with (90 cm). The mean height in the F_1 generation was 140 and 150 cm. Positive heterotic effects were found in both hybrid combinations (Figure 2). Intermediate mode of inheritance was found in two hybrid combinations, PHBC1 214A × ARG1805 and HA26A × LAE1618.

Table 1: Hybrid combinations, basic statistics and modes of inheritance

Hybrid combination	Plant height (X ± Sx cm)			SD (F1)	CV (F1)	I.*
	Cultivated line	F_1	Wild population			
HA26A × ANN2129	90 ±1.11	90 ± 1.70	100 ± 1.70	7.21	2.5	d^c
HA26A × ANN2141	90 ±1.11	100 ± 2.46	100 ± 2.46	8.82	2.8	d^w
HA26A × ANN2155	90 ±1.11	119 ± 2.16	120 ± 2.16	6.46	1.9	d^w
HA26A × ANN2157	90 ±1.11	110 ± 0.83	100 ± 0.83	6.78	1.9	h
HA26A × ANN2159	90 ±1.11	120 ± 2.24	95 ± 2.24	6.62	1.8	h
HA26A × ANN2180	90 ±1.11	150 ± 1.96	170 ± 1.96	8.80	1.9	pd^w
HA26A × ANN2188	90 ±1.11	85 ± 1.97	90 ± 1.97	5.46	2.0	-
PHBC1 190A × ANN2159	75 ±2.36	73 ± 2.24	95 ± 2.24	25.52	11.1	d^c
PHBC1 210A × ANN2165	55 ±1.69	130 ± 1.91	120 ± 1.91	9.85	2.4	d^w
PHBC1 188A × ANN1963	95 ±1.63	119 ± 1.45	50 ± 1.45	19.73	5.2	h
PHBC1 213A × ANN2165	60 ±1.39	150 ± 1.91	120 ± 1.91	7.87	1.7	h
PHBC1 203A × ARG1812	75 ±2.36	150 ± 1.25	180 ± 1.25	8.87	1.9	pd^w
PHBC1 202A × ARG1812	70 ±1.70	160 ± 3.04	180 ± 1.25	9.61	1.9	pd^w
PHBC1 214A × ARG1805	70 ±1.70	170 ± 1.83	250 ± 1.83	10.96	2.0	i
PHBC1 212A × DEB1810	60 ±1.39	120 ± 1.89	120 ± 1.89	11.08	1.7	d^w
PHBC1 193A × PET1910	120±2.0	170 ± 2.29	180 ± 2.29	8.04	1.5	pd^w
HA26A × PET1383	90 ±1.11	120 ± 1.69	130 ± 1.69	8.83	2.3	pd^w
HA26A × PET2122	90 ±1.11	110 ± 1.83	90 ± 1.83	8.93	2.6	h
HA26A × NEG1181	90 ±1.11	150 ± 1.38	120 ± 1.38	8.87	1.9	h
HA26A × TUB6	90 ±1.11	125 ± 3.06	110 ± 3.06	13.70	4.0	d^w
HA26A × TUB20	90 ±1.11	115 ± 2.24	95 ± 2.24	7.82	2.1	h
HA26A × TUB1698	90 ±1.11	170 ± 2.11	110 ± 2.11	16.41	3.5	h
HA26A × DIV2056	90 ±1.11	150 ± 1.48	85 ± 1.48	9.37	2.1	h
HA26A × DIV2085	90 ±1.11	140 ± 1.49	95 ± 1.49	8.50	1.9	h
HA26A × STR1927	90 ±1.11	105 ± 2.08	115 ± 2.08	9.49	2.2	pd^w
HA26A × STR1623	90 ±1.11	140 ± 2.83	90 ± 2.83	9.02	1.9	h
HA26A × LAE1618	90 ±1.11	110 ± 2.36	150 ± 2.36	6.86	2.2	i
	LSD 5% =6.81		LSD 1%=8.96			

*Inheritance modes: i-intermediate, h-heterosis, pd^c-partial dominance of cultivated sunflower, d^w-dominance of wild sunflower, d^c-dominance of cultivated sunflower

Figure 2: Wild population DIV2085 and F_1 hybrid with cultivated sunflower

Figure 3: Wild population PET1383 and F_1 hybrid with cultivated sunflower

Cultivated lines were not branched except for the populations PHBC1 202A and PHBC1 203A, in which plants with basal branching were found. Six out of seven hybrid combinations with *H. annuus*, in which non-branched plants were crossed with the wild branching type, resulted in fully branched plants with central heads.

Both populations of annual species *H. argophyllus* that were crossed with cultivated lines had the wild type of branching. All types of branching were found in the hybrid combination PHBC1 202A × ARG1812. The most frequent were fully branched plants, with or without the central head. Most of the plants in the other two hybrid combinations were fully branched with the central head (Table 2).

Table 2: *Types of branching in* F_1 *hybrid combinations with annual species*

Hybrid combination	Type of branching		
	Cultivated line	F_1	Wild population
HA26A × ANN2129 ts11	0	1^6, 3^4 *	4
HA26A × ANN2141 ts13	0	3^8, 4^2	4
HA26A × ANN2155 ts10	0	1^5, 0^3, 3^2	3
HA26A × ANN2157 ts8	0	1^4, 3^4, 2^1, 0^1	3^7, 4^3
HA26A × ANN2159 ts6	0	3^7, 4^2, 1^1	4^8, 3^2
HA26A × ANN2180 ts25	0	3^7, 4^3	3
HA26A × ANN2188 ts7	0	3^9, 4^1	4
PHBC1 190A × ANN2159 ts1	0	3^4, 1^3, 4^2, 0^1	4^8, 3^2
PHBC1 210A × ANN2165 ts3	0	3	4
PHBC1 188A × ANN1963 ts20	0	3^5, 1^3, 4^2	4
PHBC1 213A × ANN2165 ts22	0	3	4
PHBC1 203A × ARG1812 ts4	0, 1^1	3^6, 1^3, 4^1	4
PHBC1 202A × ARG1812 ts21	0^5, 1^5	4^4, 3^3, 1^1, 0^1, 2^1	4
PHBC1 214A × ARG1805 ts18	0	3^8, 2^1, 1^1	4
PHBC1 212A × DEB1810	0	4^6, 3^4	4
PHBC1 193A × PET1910	0	4	4
HA26A × PET1383	0	3^7, 4^3	4
HA26A × PET2122	0	4	4
HA26A × NEG1181 ts12	0	4^8, 3^2	4

*1^6, 3^4 six plants with basal branches and four fully branched with central inflorescence.

Table 3: Types of branching in F_1 hybrid combinations with perennial species

Hybrid combinations	Type of branching		
	Cultivated line	F_1	Wild population
HA26A × TUB6	0	3^8, 4^2	2
HA26A × TUB20	0	3^9, 4^1	2^8, 0^2
HA26A × TUB1698	0	3^9, 4^1	2^7, 0^3
HA26A × DIV2056	0	3^9, 4^1	2^8, 1^2
HA26A × DIV2085	0	3^9, 4^1	2^9, 1^1
HA26A × STR1623	0	3^9, 4^1	2^8, 0^2
HA26A × STR1927	0	3	2
HA26A × LAE1618	0	4^6, 3^3, 1^1	2

Three populations of the annual species *H. petiolaris* were crossed with the lines of cultivated sunflower. Wild populations were fully branched without the central head. All plants in the hybrid combination HA26A × PET1383 were fully branched. There were seven plants with the central head and three without it (Figure 3.). Plants from the other two F_1 hybrid combinations had the wild type of branching.

Three populations of the perennial hexaploid species *H. tuberosus* were crossed with cultivated lines of sunflower. All three were top branched. Non-branched plants were found in populations TUB20 and TUB1698. A similar type of branching was found in all other populations of perennial species used. It is likely that plants had such type of branching because of population density and plant competition. In the F_1 generation, most of the plants were completely branched with central heads (Table 3.).

DISCUSSION

Plant height shows continuous variability in accordance with the normal distribution of frequencies. Such variability is due to a large number of genes that control that trait. More than one mode of inheritance occurred because of large variability in the wild species and quantitative inheritance of that trait (Marinković, 1982). Because of that, determination of the mode of inheritance was influenced by genetic differences between parents as well as by interactions with the environment.

The mean value differences between the parents in majority of the hybrid combinations were significant. Plant height among the wild species varied from 50 cm (ANN1963) to 250 cm (ARG1805). Within-species variability was also significant (50-170 cm, *H. annuus*). Such results confirm a large variability of the wild species (Rogers *et al.*, 1982).

All modes of inheritance for plant height were registered (heterotic, dominant, partially dominant and intermediary). Heterosis was most frequent in the F_1 hybrid populations. That is similar to the results of Ananjeva (1936), Morozov (1947), and other authors. Occurrence of heterosis shows that there were epistatic interactions between the mentioned genotypes. Plant height was under dominant or partially dominant influence of wild parent in half of the F_1 hybrid combinations. Heiser, (1951, 1955), Georgieva (1976) and other authors found such modes of inheritance in crosses between wild and cultivated sunflowers.

Dominant and recessive genes control the inheritance of branching (Miller and Fick, 1997). Two complementary dominant genes are reported to control the branching in wild species (Hocket and Knowles, 1970; Fernandez-Martinez and Knowles, 1982; Kovacik and Skaloud, 1990). Type of branching depends on the presence of different genes (Br-Br_3) and their interactions. The wild type of branching is most frequent. Recessive genes (b1-b3) can also control branching. They are often incorporated in fertility restorer lines to obtain top branching.

All F_1 interspecies hybrid populations obtained in this study were fully branched with or without the central head. The wild type of branching was frequent in the F_1 generation because the wild parents had dominant influence over that

trait. It is necessary to perform further crosses with the cultivated lines for determination of the mode of inheritance. Non-branched interspecies hybrids can be obtained through backcrossing with cultivated lines and negative selection for branching.

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VARIABILIDAD FENOTÍPICA Y HERENCIA DE ALTURA DE LA PLANTA Y DE RAMIFICACIÓN EN LA GENERACIÓN F1 DE GIRASOL

RESUMEN

Las poblaciones de alta variabilidad de las especies silvestres de girasol, fueron cruzadas con las líneas *cms* cultivadas. La variabilidad fue determinada por medición de altura de las plantas y por calificación del tipo de ramificación. El modo de herencia fue ensayado por comparación de 27 poblaciones híbridas y sus progenitores. Las diferencias entre los progenitores, en el sentido de las características consideradas, fueron significantes. Todos los modos de la herencia de altura de la planta, estaban presentes en la generación F_1. El más frecuente era el heterosis, seguido por una dominación parcial, dominación e intermediaridad. Más de un modo de la herencia de altura de la planta, se ha presentado por causa de una gran variabilidad de las especies silvestres y la herencia polígena de esta propiedad. Todas las poblaciones F_1 eran completamente ramificadas, con el capítulo central, o sin él. El tipo de ramificación silvestre fue encontrado en la generación F_1, porque el progenitor

campestre era dominante en el control genético de la propiedad, respecto al progenitor cultivado.

VARIABILITÉ PHÉNOTYPIQUE ET HÉRÉDITÉ DE LA HAUTEUR DE LA PLANTE ET DE LA RAMIFICATION DANS LA GÉNÉRATION F_1 DU TOURNESOL

RÉSUMÉ

Des populations hautement variables d'espèces de tournesol sauvage ont été croisées avec des lignées cultivées CMS. La variabilité a été déterminée par la mesure de la hauteur de la plante et l'évaluation du type de ramification. Le mode d'hérédité a été testé par une comparaison de 27 hybrides avec leurs parents. Pour les caractéristiques observées, les différences parmi les parents observés étaient significatives. Tous les modes d'hérédité de la hauteur de la plante étaient présents dans la génération F_1. L'hétérosis était le plus fréquent, suivi en ordre décroissant par la dominance partielle, la dominance et l'intermédiarité. À cause de la grande variabilité de l'espèce sauvage et de l'hérédité polygénique de la caractéristique, plus d'un mode d'hérédité pour la hauteur de la plante est apparu. Toutes les populations F_1 étaient pleinement ramifiées avec ou sans tête centrale. Le type sauvage de ramification se trouvait en F_1 parce que le parent sauvage dominait le parent sauvage pour le contrôle génétique de cette caractéristique.