

GENETIC CONTROL OF OLEIC AND LINOLEIC ACID CONTENTS IN SUNFLOWER

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SUMMARY

The object of study were 8 divergent sunflower inbred lines and 15 F₁ hybrids, which were analyzed for mode of inheritance, gene effects, combining ability and components of genetic variance for oleic and linoleic acid content. Mode of inheritance was estimated on the basis of a test of significance of mean values of F₁ hybrids in relation to the parents' mean (Borojević, 1965). Combining ability was determined by the method line × tester (Singh and Choudhary, 1976). The inheritance of oleic and linoleic acid contents varied in the F₁ generation. Dominance, partial dominance, intermediacy and heterosis were found. The inbred lines HA-22 and RHA-N-K exhibited highly significant positive GCA values for the content of oleic acid, the lines HA-74 and RHA-C-B for the content of linoleic acid. The inbred lines HA-22 and RHA-C-B exhibited highly significant negative GCA values for the content of oleic acid, the line RHA-N-K for the content of linoleic acid. All F₁ hybrids exhibited non-significant specific combining ability (SCA) for the two characteristics.

Prevalence of additive gene action was observed in the control of inheritance of oleic acid content. The non-additive component, *i.e.*, dominance and epistasis, prevailed in the control of inheritance of linoleic acid content.

Key words: sunflower, oleic and linoleic acids, inheritance, GCA, SCA, gene effect

INTRODUCTION

In consequence to an increased interest in "healthy food" shown in recent years, quality of oil of various oilcrops (palm tree, olive tree, rapeseed, sunflower, soybean, *etc.*) has been investigated. Quality of sunflower oil is judged on the basis of the ratio oleic/linoleic acid. The most frequent fatty acid composition in sunflower oil is: 55-65% of linoleic acid, 20-30% of oleic acid, and the remainder including other fatty acids, primarily palmitic and stearic. It has been determined that there exists a negative correlation between the contents of oleic and linoleic acid, that their contents are genetically controlled, and that these contents are heavily influenced by environmental factors, especially by temperature at the stage of flowering. A study of Canvin (1965) showed that some genotypes produced over 80% of lino-

leic acid at 10°C and only 25% at 26.5°C. There are numerous references on variability of higher fatty acids in different sunflower genotypes and on the effect of environmental factors on that important parameter. Conversely, there are scant data on genetic control of the content of higher fatty acids. Inheritance of high oleic acid content has been studied most extensively. These studies were reviewed by Fick and Miller (1997). Testing sunflower inbreds possessing high to normal contents of linoleic acid under various temperature conditions, Simpson *et al.* (1989) found that the content of linoleic acid is controlled by a partially recessive gene.

Mode of inheritance of higher fatty acids in the F₁ generation of sunflower was studied by Škorić *et al.* (1978), in crosses between cultivated sunflower and annual wild species by Fernandez-Martinez and Knowles (1987) and in high-oleic populations of sunflower by Baldini *et al.* (1991).

Most authors agreed that the genetic study of characteristics associated with oil quality is complicated because of strong influences of environmental factors.

Studying genetic variability of the contents of oleic and linoleic acids in sunflower inbred lines and F₁ hybrids that had high values of most agronomic characteristics, Joksimović *et al.* (2001) found that the tested material was suitable for selection for conventional oil composition (65% linoleic acid, 22% oleic acid). Based on the analysis of components of genetic variance, the authors concluded that, on one side, the contents of oleic and linoleic acids depended on the genotype but, on the other, they were largely influenced by environmental factors.

The objectives of this study were to examine a set of sunflower genotypes for mode of inheritance, combining ability and gene effects controlling the contents of oleic and linoleic acids.

MATERIAL AND METHOD

The object of study were 8 divergent sunflower inbred lines and 15 F₁ hybrids developed at Institute of Field and Vegetable Crops in Novi Sad. Experiments were conducted for two years. Fatty acids content was determined by gas chromatography in average seed samples collected from 40 plants. Modes of inheritance of oleic and linoleic acids were determined by comparing the values of the F₁ generation against the parents' average (Borojević, 1965). The analysis of combining ability conducted by the linija × tester method (Singh and Choudhary, 1976) provided information on the effects of general and specific combining abilities for the examined characteristics, as well as information on the components of genetic variance.

RESULTS AND DISCUSSION

Mode of inheritance of oleic and linoleic acids

The hybrid combinations which exhibited significant differences from the mean values of the parents and the average value of the parents were analyzed for modes of inheritance of oleic and linoleic acids. Dominance was exhibited in the largest

number of combinations (6), followed by partial dominance (1), intermediacy (1) and negative heterosis (1) (Table 1).

Table 1: Mean values and mode of inheritance for oleic acid content

Lines		Testers		
		RHA-178 (T-6) 22.44±0.41	RHA-C-B (T-7) 19.70±0.25	RHA-N-K (T-8) 23.68±0.75
CMS-V-8931-3-4 21.70±0.69	(L-1)	21.65±0.41	20.14±0.61	22.82±0.66
CMS-V-8931-5-4 20.33±0.78	(L-2)	22.72±0.36 d	20.70±0.52	24.10±0.48 d
HA-22 25.35±0.55	(L-3)	23.32±0.38 d	22.00±0.59 i	26.52±0.52 pd
HA-74 19.93±0.69	(L-4)	20.52±0.36 d	20.81±0.77	23.06±0.57 d
HA-BCPL 23.85±0.73	(L-5)	20.81±0.30 -h	20.28±0.66 d	23.73±0.66

Linoleic acid content was inherited partially dominantly in 5 hybrid combinations, dominantly in 3, intermediately in one, and superdominantly in one combination (Table 2).

Table 2: Mean values and mode of inheritance for linoleic acid content

Lines		Testers		
		RHA-178 (T-6) 65.43±0.32	RHA-C-B (T-7) 67.89±0.24	RHA-N-K (T-8) 62.09±0.65
CMS-V-8931-3-4 65.32±0.68	(L-1)	65.68±0.48	67.83±0.47 pd	64.37±0.68 pd
CMS-V-8931-5-4 66.70±0.85	(L-2)	64.52±0.40 pd	67.35±0.40	62.95±0.42 d
HA-22 62.76±0.63	(L-3)	65.12±0.37 pd	66.78±0.55 d	61.46±0.52
HA-74 67.86±0.66	(L-4)	67.45±0.39 pd	67.49±0.72	64.65±0.50 i
HA-BCPL 62.68±0.80	(L-5)	66.66±0.26 h	67.42±0.58 d	62.57±0.43

The results on the inheritance of higher fatty acids obtained in this study support those obtained by Škorić *et al.* (1978) who studied mode of inheritance for oleic and linoleic acids in diallel crosses of 4 inbred lines (RHA-18, RHA-56, HA-9 and HA-17) which had been derived from various sunflower populations.

Studying mode of inheritance for oleic and linoleic acids in crosses between cultivated and wild sunflowers, Fernandez-Martinez and Knowles (1977) found that the genes for high linoleic acid content were dominant in respect to the genes for high oleic acid content. A similar relationship was established in our study. In a large number of cases, hybrid combinations with partial dominance of dominance of better parent for linoleic acid also had partial dominance or dominance of poorer parent for oleic acid. For example, the hybrid combination HA-BCPL × RHA-178

had negative heterosis for oleic acid and positive heterosis for linoleic acid. All these results indicate the existence of negative correlation between oleic and linoleic acid contents (Fick and Miller, 1997).

Table 3: Effect of combining ability for oleic acid content in inbred lines and F₁ hybrids

Lines		Testers		
		RHA-178 (T-6) -0.358	RHA-C-B (T-7) -1.461**	RHA-N-K (T-8) 1.818**
CMS-V-8931-3-4 -0.692	(L-1)	0.47	0.06	-0.53
CMS-V-8931-5-4 -0.246	(L-2)	0.61	-0.42	-0.19
HA-22 1.720**	(L-3)	-0.27	-0.48	0.75
HA-74 -0.653	(L-4)	-0.37	0.70	-0.33
HA-BCPL -0.620	(L-5)	-0.44	0.14	0.31
		Lines	Testers	F ₁ hybrids
LSD	5%	0.659	0.511	1.142
	1%	0.877	0.681	1.521

Combining abilities and components of genetic variance

Highly significant positive GCA effect for oleic acid content was registered in the inbred HA-22 (female line) and the tester RHA-N-K (Table 3). Highly significant negative GCA effect for oleic acid content was registered in the tester RHA-C-B. GCA effect for linoleic acid content was highly significant and positive in HA-74 and RHA-C-B and highly significant and negative in HA-22 and RHA-N-K (Table 4).

Table 4: Effect of combining ability for linoleic acid content in inbred lines and F₁ hybrids

Lines		Testers		
		RHA-178 (T-6) 0.387	RHA-C-B (T-7) 1.875**	RHA-N-K (T-8) -2.262**
CMS-V-8931-3-4 0.461	(L-1)	-0.67	0.00	0.67
CMS-V-8931-5-4 -0.561	(L-2)	-0.80	0.53	0.27
HA-22 -1.045**	(L-3)	0.28	0.45	-0.73
HA-74 1.031**	(L-4)	0.53	-0.91	0.38
HA-BCPL 0.113	(L-5)	0.66	-0.06	-0.59
		Lines	Testers	F ₁ hybrids
LSD	5%	0.663	0.513	1.148
	1%	0.882	0.684	1.529

The SCA values calculated for the F_1 hybrids were not significant either for oleic or linoleic acid (Tables 3 and 4).

The obtained results indicate that the female line HA-22 and the tester RHA-N-K are good general combiners for high oleic and low linoleic acid content, the tester RHA-C-B is a good general combiner for high linoleic and low oleic acid, while the line HA-74 is a good general combiner for high linoleic acid.

The results for GCA and SCA effects confirm the irreversible relationship between the contents of oleic and linoleic acid observed by numerous authors. Highly significant GCA values and absence of significant SCA value indicate the additive gene actions that control oleic and linoleic acid contents. The calculated ratio GCA/SCA (1.384) confirms the additive gene action for oleic acid, while the ratio for linoleic acid smaller than unity (0.853) indicates the prevalence of non-additive component of genetic variance (dominance and epistasis) in the total genetic variance (Table 5).

Table 5: Components of genetic variance for oleic and linoleic acid contents

		V_A	V_D	V_A / V_D	GCA	SCA	GCA/SCA
Oleic acid	F = 0	1.167	0.843	0.722	0.292	0.211	1.384
	F = 1	0.584	0.211	0.361			
Linoleic acid	F = 0	1.467	1.720	1.172	0.367	0.430	0.853
	F = 1	0.734	0.430	0.586			

Contrary to the results obtained in this study, the studies of Škorić *et al.* (1978) and Baldini *et al.* (1991) indicated that the non-additive component of genetic variance, dominance and epistasis, was more important than the additive component for the inheritance of the contents of oleic and linoleic acids.

CONCLUSION

Dominance or partial dominance, intermediacy and superdominance were expressed most frequently in the inheritance of oleic and linoleic acid contents in sunflower.

The effect of GCA was significant for both characteristics in two female lines (HA-22 and HA-74) and in two restorers (RHA-C-B and RHA-N-K).

The effect of SCA was not significant in the F_1 hybrids for either of the two characteristics under study.

Additive gene action is more important for the content of oleic acid than non-additive gene action. Conversely, non-additive gene action, *i.e.*, dominance and epistasis, are more important for the inheritance of linoleic acid.

The results obtained on mode of inheritance, GCA and SCA effects and the values of genetic variance will help to use the studied inbred lines more effectively in breeding programs.

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CONTROL GENÉTICO DEL CONTENIDO DE ACEITE OLEICO Y LINÓLICO EN GIRASOL

EXTRACTO

El material experimental constaba de 8 líneas consanguíneas divergentes y 15 híbridos F₁. Fue analizado el modo de heredar, el efecto de genes, las habilidades de combinación y las componentes de la variancia genética para el contenido del ácido oleico y linólico. El modo de heredar es determinado sobre la base de la prueba de significación de los valores medios de los híbridos F₁ en relación con el promedio parental (Borojević, 1965). Las habilidades de combinación han sido determinadas por el método línea × tester (Singh y Choudhary, 1976). El modo de heredar el contenido del ácido oleico y linólico fue diferente en la generación F₁. Fueron encontrados los casos de dominancia, dominancia parcial, intermediaridad y heterosis. El efecto positivo altamente significativo de las habilidades de combinación comunes (HCC) tuvieron las líneas consanguíneas HA-22 y RHA-N-K para el contenido del ácido oleico, y las líneas consanguíneas HA-74 y RHA-C-B para el contenido del ácido linólico. Los valores negativos altamente significantes de OKS, tuvieron las líneas consanguíneas HA-22 y RHA-C-B para el contenido del ácido oleico, y la línea consanguínea RHA-N-K para el contenido del ácido linólico. El efecto de las habilidades de combinación especiales (HCE) no era significativo para las dos propiedades investigadas en los híbridos F₁. En la herencia del contenido del ácido oleico, fue significativa la componente aditiva de la variancia genética, mientras que para la herencia del contenido del ácido linólico, más significativo era la no aditiva (dominación y epistasia).

CONTRÔLE GÉNÉTIQUE DES CONTENUS D'ACIDE OLÉIQUE ET LINOLEIQUE CHEZ LE TOURNESOL

RÉSUMÉ

Le matériel soumis à l'expérience était fait de 8 lignées autogames divergentes et de 15 hybrides F_1 . L'analyse portait sur le mode d'hérédité, l'action des gènes, l'aptitude combinatoire et les composantes de variance génétique pour le contenu d'acide oléique et linoléique. Le mode d'hérédité a été évalué par un test de signification des valeurs moyennes des hybrides F_1 en rapport avec la moyenne des parents (Borojević, 1965). L'aptitude combinatoire a été déterminée par la méthode lignée \times contrôle (Singh et Choudhary, 1976). L'hérédité des contenus d'acide oléique et linoléique variaient dans la génération F_1 . On a constaté dominance, dominance partielle, intermédierité et hétérosis. Les lignées autogames HA-22 et RHA-N-K manifestaient des valeurs GCA positives très significatives pour le contenu d'acide oléique, les lignées HA-74 et RHA-C-B pour le contenu d'acide linoléique. Les lignées autogames HA-22 et RHA-C-B manifestaient des valeurs GCA négatives très significatives pour le contenu d'acide oléique, la lignée RHA-N-K pour le contenu d'acide linoléique. Tous les hybrides F_1 manifestaient une aptitude combinatoire spécifique (SCA) non significative pour les deux caractéristiques.

La prédominance de l'action du gène additif a été observée par le contrôle de l'hérédité du contenu d'acide oléique. La composante non additive, i.e., dominance et épistasie, a prévalu dans le contrôle de l'hérédité du contenu d'acide linoléique.

