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STUDY OF INHERITANCE OF PROGRESSIVE SUNFLOWER PLANT TRAITS IN RELATION TO STAND DENSITY

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SUMMARY

In the previous studies we concentrated attention to "head inclination" as one of the progressive sunflower plant traits. This trait has been found to be conditioned by a large number of major genes. Hybridological analysis has revealed 12 genes forming four three-member groups; each of the gene triads regulates the head inclination by 15° and within the gene triad complete dominance exist.

The aim of this study is investigation of other progressive traits such as petiole length, leaf position and reaction of these traits to stand structure, i.e., increased stand density.

Key words: Progressive trait, petiole lenght, leaf position, stand density, gene effect

MATERIAL AND METHOD

a) Short petioles

To obtain the phenotypic expression of short petioles in the cultivated sunflower, application of interspecific hybridization is neccessary.

Mutations with short and thick petioles can rarely occur in the species *H.annuus*, however, in most cases expression of deformation is involved that can hardly be used for the construction of a productive plant type. Naturally formed short leaf petioles can be obtained from crosses between *H.annuus* and perennial wild sunflower species with short petioles (e.g., *H.maximiliani*, *H.hirsutus*, *H.rigidus* and other) or those completely without petioles (*H.mollis*). Inheritance of short petioles when interspecific hybridization is applied has not been systematically studied till now. We have revealed certain trends after having evaluated the results of the trait measurements in parental forms and the F_1 hybrid generation.

Average values of the length were enumerated for nine lines of the cultivated sunflower and of the following wild sunflower species and their hybrids:

1. *H.annuus*, wild population A
2. *H.annuus*, wild population B
3. *H.argophyllus*, population A
4. *H.argophyllus*, population B
5. *H.praecox ssp.hirtus*
6. *H.praecox ssp.runyoni;*

the above mentioned species are annual, the following species are perennial:

7. *H.maximiliani*

8. *H.hirsutus*
9. *H.rigidus*

b) Erectoid leaf position and lack of leaves in the upper part of the plant

Parameters of leaf occurrence in two lines with a specific habit and lines with the normal habit were compared to obtain some data on the plant forms with progresive traits. Specific habit represents erectoid leaf position in one case and lack of leaves below the head (so-called "long neck") in the second case. Characteristics of these variants are summarized in Tables 1–3.

Table 1

Line with habit	Plant height			Leaf number		
	total cm	with leaf cm	part %	total	per 100 cm of the stem length	not shed
Standard	86.0	73.5	85.5	23.0	26.7	18.5
Erectoid	104.0	99.2	95.4	28.8	27.7	19.9
Long neck	83.0	65.9	79.4	24.8	29.9	18.5

Table 2

	Internode			Leaf area (in cm^2)	
	number	length total	(cm) not shead parts	leaf	plant
Standard	21.0	3.50	3.37	239.0	4422
Erectoid	25.7	3.86	4.37	222.0	4418
Long neck	21.2	3.11	3.14	318.3	5888

Table 3

	Leaf cylinder			Leaf cylinder density	Leaf area at the unified volume of the leaf cylinder 0,25 m^3
	height	width	volume (cm^3)		
Standard	59.0	75.9	0.2674	1.65	4134
Erectoid	82.6	62.6	0.2543	1.74	4343
Long neck	55.0	65.3	0.1841	3.20	7996

RESULTS AND DISCUSSION

The results in Tables 4 and 5 show that incomplete dominance of long petioles in F_1 manifests in the crosses with annual species that have leaf petioles at least 4 cm long. The shorter the petioles in the wild species, the relatively more distinct is the dominance of the cultivated species in the petiole elongation.

Whereas the average level of partial dominance reaches 16%, after crossing with *H.annuus* A population (petiole length 4,5 cm), the average level of partial dominance reaches up to 50%.

Hybridization between cultured lines and perennial wild species with the petiole length between 1–2,5 cm leads in the F_1 generation mostly to the expression of incomplete dominance of the short petiole. The level of partial dominance of short petioles achieved the value of shortened length by 2/3–3/4 compared with the intermediate expression.

Crosses carried out between the cultivated sunflower and perennial petioleless species *H.mollis* offered plants with completely petioleless leaves in the F_1 generation. These results offer a possibility of obtaining cultural genotypes with very short petioles. Obstacle in their experimental use is the difficulty in obtaining advanced hybrid generations or generations of back–crosses in combinations with perennial species.

Table 4

Average petiole length in cm (line)	H.a.A 21.6	H.A.B 17.3	H.arg.A 11.9	H.arg.B 7.4	H.p.h. 4.5	H.p.r. 4.1
19.0	22.1a25.2	18.6	–	16.6	–	13.7
15.6	–	19.3	–	14.1	13.3	–
12.6	18.4	–	–	–	–	–
11.8	–	–	–	–	14.0	–
11.2	–	–	14.3	13.9	–	–
10.5	–	21.5	–	–	–	–
10.5	19.9	–	–	–	–	–
10.5	–	–	–	–	–	13.9
8.9	–	–	–	13.2	–	–

Table 5

Average petiole length in cm (line)	*H.maximiliani* 2.2	*H.hirsutus* 1.5	*H.rigidus* 1.1
19.0	–	3.8	2.7a2.4
15.6	2.3	–	1.6
10.5	–	–	6.3

In the next part of the study, length, number of unshed leaves at harvest time, difference between the leaf number and internode number, leaf area in relation to the space with leaves (leaf cylinder) and similar were studied.

On the whole an erectoid line shows a narrower and longer leaf space of the plant, maintaining its average volume as compared with the standard. The accompanying phenomena are a higher number of partially diminished leaves, longer internodes and a higher density of leaf area in the volume occupied by the plant. Except internode elongation and height of the plant space with leaves, other habit expressions can be considered as equal with the standard or better than it. Lines without leaves below the head have a shorter and narrower dimension and hence a diminished volume of the plant leaf space. The leaf number corresponds to the standard, however, the leaf area is much larger. Internodes are slightly shortened in this form, in lower insertions leaves in opposite position on the stem occur more frequently. Plant leaf area is substantially larger.

A line without leaves below the head was also compared with a standard line for the differences in the formation of leaf area at various parts of the plant at two growth stages.

According to the character (size and shape) of the leaves we have divided the plant into four vertical parts (near ground, low, middle and upper plant parts). The near ground part includes only first pair of true leaves. The low part has smaller leaves at the basal part of the plant and the upper part smaller leaves in the upper plant part. The middle part is characterized by large leaves between the low and upper plant part.

Partitioning into these four parts is also connected with the importance of individual leaf groups for the formation of sunflower yield. Leaves of the middle plant part affect the formation of the level of both basic yield components, i.e., achene number and achene weight, to a large extent. We evaluated the leaf number and leaf area of single plant parts at the stage of bud development and achene ripening.

Varietal population is characterized by a higher leaf proportion in the upper plant part and lower in the middle part. This is in agreement with the known fact that populations, unlike lines and hybrids, usually have a relatively longer vegetative phase of development, i.e., they continue for a certain period the formation and growth of vegetative parts (stem and leaves) after flowering, when the plants of lines and hybrids have already stopped their vegetative growth. A line without leaves below the head has a substantially lower proprotion of leaves in the upper plant part and increased proportion of leaves in the lower plant part in comparison with the standard line. The proportion of leaves in the middle part is approximately equal.

Table 6 (A – long–neck line, B – standard line)

	Number of leaves				Average size of leaves				Leaf area			
	pieces		%		cm^2		%		cm^2		%	
	A	B	A	B	A	B	A	B	A	B	A	B
First true leaves	2.0	2.0	12.1	23.5	18.2	24.7	23.4	36.0	36.4	49.4	2.8	8.5
Lower leaves	8.8	4.5	53.0	53.0	92.2	112.0	118.7	163.2	811.4	504.0	62.9	86.4
Middle leaves	5.8	2.0	34.9	23.5	76.2	15.0	98.2	21.7	442.0	30.0	34.3	5.1
Total	16.6	8.5	100	100	77.7	68.6	100	100	1289.8	583.4	100	100

Table 6 presents the values of leaf number and leaf area of both variants at the stage of bud formation. The data show a substantially faster formation of the leaf area in the line lacking leaves below the head. In addition to a substantially larger number of leaves formed by that line at the bud stage it is much more advanced in the leaf formation in the middle part. Both variants have an equal proportion of lower part leaves (53%) that are decisive for plant growth at that stage. The standard line has more developed lower leaves (larger and by the size nearer to the final stage). The line without leaves below the head is characterized by a higher number of medium–sized leaves in the lower, as well as the middle plant part. The line without leaves below the head has a higher total leaf area in the lower and particularly middle plant part. The lower part shows only 63% of the whole leaf area in this variant, whereas in the standard line it presents more than 85% of the whole leaf area. At harvest time, the relations change to some degree, as shown in Table 7.

Table 7

	Number of leaves				Average size of leaves				Leaf area			
	pieces		%		cm^2		%		cm^2		%	
	A	B	A	B	A	B	A	B	A	B	A	B
First true leaves	4.5	2.0	24.3	10.8	165	139	51.9	58.2	742	278	12.6	6.3
Lower leaves	12.0	12.0	64.9	64.9	394	282	123.9	118.0	4728	3384	80.3	76.5
Middle leaves	2.0	4.5	10.8	24.3	209	169	65.7	70.7	418	760	7.1	17.2
Total	18.5	18.5	100	100	318	239	100	100	5888	4422	100	100

In the plant form with the erectoid leaf position, some aspects of trait inheritance were evaluated. According to Bulgarian authors this trait is inherited as a monogenic incompletely dominant trait. In the F_2 generation segregation occurs in the approximate ratio 1:2:1, where the most frequent phenotype represents the intermediate trait expression.

In our trials we found segregation into two categories, i.e., the standard and erectoid phenotype (the intermediate category was included into the standard one) in the ratio 35:7, that fits the theoretical ratio 3:1 with the probability of 22% error of I.kind at the value $X^2_{(1)}$ 1.556. Also the fused ratio 3:1, i.e., 298:102, fits fully the theoretical ratio with 80% probability.

Further on, the angle between leaves and the stem and petiole length in the parental lines and the crosses between the erectoid and standard form were studied. The erectoid line had the angle of leaf insertion 22° on average, the two standard lines used for crossing 36° and 39°. The hybrids of the F_1 generation had the angles of leaf insertion 29° and 32°, i.e., approximately intermediate (mean value of the parents 29° and 30.5°).

Petiole length in the erectoid form was 10.3 cm on average, in standard lines 13.7 and 12.7. The hybrids of the F_1 generation had average petiole lengths of 15.3 and 15.0 cm. Hybrid vigour for this trait showed about 15% as compared with the standard parents and almost 30% as compared with the average of the parents.

The result in Table 8 indicate that with a higher stand density the erectoid line increases its height less than the variety. In spite of this fact both variants respond by a larger growth in more dense stands, albeit not very high (7 cm in the line, 17 cm in the variety).

Achene yield per plant increases markedly with a more dense stand in the erectoid line markedly (by 28%), while in the varieties it slightly decreases (by 10%) in comparison with the stand densities of 40 000 and 80 000 individuals.

With a higher stand density the achene yield per area unit increases in both variants, however, substantially more in the erectoid line than in the variety. Due to this, the difference between the production in the dense stand of the line and variety decreases in the yield per hectare (13.6 q in favour of the cultivar at 40 000 individuals and 11.0 q at 80 000 individuals).

Yield results per hectare will be likely biased by the real number of individuals at the experimental plot that were only 120, 90 and 60 plants and the calculated yield per hectare in dense stands will be evidently overestimated.

However, it is obvious that the erectoid line responds to the increase of stand density more favourably than the production variety. It can be expected that the hybrid with the erectoid habit will have a higher yield and height than the line. Therefore, the initial difference compared with the production variety will be more favourable and, on the contrary, the response to the increase of stand density less distinct than in the less robust and less productive line.

At the stand density of 80 000 individuals the erectoid hybrid will obviously offer a more distinct yield increase in comparison with the stand density of 40 000 individuals than the production variety and a less distinct yield increase than the erectoid line.

Relative values are given in Table 8.

Table 8

Erectoid line	number of individuals per ha (in thous.)		
	40	60	80
plant height	100%	100.8%	105.6%
yield per plant	100%	119.4%	128.4%
yield per hectare	100%	179.1%	256.9%
Varietal population			
plant height	100%	102.0%	109.0%
yield per plant	100%	95.3%	90.3%
yield per hectare	100%	143.0%	180.6%
Difference between the erectoid line and varietal population (in % of the variety)			
plant height	33.5%	34.3%	35.6%
achene yield	43.4%	29.1%	19.5%

CONCLUSION

Studies of progressive sunflower traits in relations to genetic, ecological and technological factors show that the higher productivity of the stand is connected with the increase of the number of individuals per area. However, plants that tolerate the higher density have to possess progressive traits.

Among the morphological traits, the following are particulary important: low height, erectoid habit, short leaf petioles, suitable head inclination, lack of leaves on the stem below the head.

The optimum stand density for the present hybrids and growing conditions of the ČSFR was determined in semi–large trials at 68 000 plants. The stand of plants possessing progressive traits will be suitable for the density of 85 000 individuals and more.

Of the progressive morphological traits the result of wide crosses in the F_1 generation was evaluated for the short petiole. Crosses with annual wild specied usually display incomplete dominance of long petioles of the cultivated sunflower. Crosses with perennial species induce incomplete dominance of short petioles of the wild species.

Erectoid habit is characterized by a narrower and longer leaf space of the plant while preserving its average volume. Plants without leaves on the stem below the head have a shorter and narrower size and a diminished volume of the leaf space.

In comparison with the standard habit, the plant without leaves on the upper part of the stem has an equal proportion of leaves in the middle part, but a higher number of unshed lower leaves; hence, it also has a higher total leaf area concentrated in a smaller space.

The erectoid habit has recessive inheritance with prevailing occurrence of intermediate plants in various degrees. By increasing the stand density to 80 000 individuals the yield of plant with erectoid habit increases by 28%.

From the point of view of sunflower breeding all progressive traits can be relatively well handled.

For the future it will be necessary to combine the studied characters into one genotype, complete them with progressive physiological traits, evaluate their yield level and possibility of their utilization in the development of hybrids.

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ESTUDIO DE LA HERENCIA DE CARACTERES FAVORABLES DE GIRASOL EN RELACION A LA DENSIDAD

RESUMEN

En estudios previos se concentró una atención mas alta en las inclinacion del capitulo dentro de caracteres de girasol favorables para mas alta densidad. Este caracter fué encontrado al estar condicionado por un número más alto de genes mayores. El análisis de hibridos reveló 12 genes formando grupos de tres miembros. Cada una de las triadas de genes regula la inolalinación del capitulo de 15^0 y que existe dominacia dentro de la triada de genes. El propósito de este estudio es la investigación de otrcaracteres favorables como longitud del peciolo, posición de la hoja y reacción de estos caracteres en relación de más alta densidad.

RESUME

Dans des études précédentes, nous avons concentré notre travail sur l'iniclinaison du capitule, parmi les caractères du tournesol liés au développement architectural. Ce caractère a été trouvé conditionné par un grand nombre de gènes majeurs. Un analyse en croisement a révélé 12 gènes formant 4 groupes de trois membres: chaque triade génique regule l'inclinaison du capitule de 15^0 et à l'intérieur de la triade il y a dominance complète.

Le but de cette étude est la recherche d'autres caractères liés au développement architectural teis que la longueur du pétiole, la position des femilles, et la réaction de ces caractéres en liaison avec la tenue de tige et le peuplement.