Study on inheritance of agronomically important traits of sunflower

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Abstract

Research on agronomically important traits of sunflower is in long term carried out in the framework of the international programme FAO - Subnetwork for applied genetics - Sunflower. In addition to the development of methods for the evaluation and in connection with the preceding study on agronomic traits like head inclination, head shape, types of ramification, self-fertility, much attention has been paid in the last years to the inheritance of the position of leaves and of the leafless stem below the head. The whole research continues in studying traits that can affect directly or indirectly the yield or avoid losses. Studies of agronomic traits are based on the importance of the development of new sunflower breeding material. A higher attention was paid to the study of agronomic traits in relation to the structure of the stand, i.e. to the possibility to increase the number of individuals per area unit.

Research on sunflower genetics and its results can be considered as very valuable and useful for the future development of sunflower breeding and crop management on the European international level.

Introduction

Since several years research on agronomically important traits of sunflower was carried out in the Subnetwork for applied genetics FAO, in the Research Institute of Crop Production, Department of Genetics and Plant Breeding in Prague-Ruzyně, with the aim to reveal inheritance of the traits and thus contribute to the development of excellent sunflower hybrids.

Following traits are primarily considered in the study :

- head inclination
- self-fertility
- leafless stem below the head
- erectoid position of leaves
- head insertion on the stem
- thickness of the head receptacle
- short petioles
- head shape

Some quantitative traits were also studied rather from the point of view of the trait variability under various geographic conditions than of inheritance study. These are for instance :

- yield components : yield per plant
  huskiness
  achene weight
  number of achenes per plant
- plant height
- earliness (vegetation period)
- number of leaves
- leaf area

or also other traits of physiological character, as for instance :

- empty center of the head
- stem breaking
- difference in the loss of water during ripening
- persistence of green leaves till ripening
- drying of receptacle at the maturity and similar

Traits that can affect increase of sunflower yield potential must eliminate conditions suitable for disease development e.g. in denser stands and similar.

Material and Methods

During the study several experiments corresponding with the number of the studied traits were successively established. Trials were established without replication at one location (Praha-Ruzyně).

Diallel crosses between the lines showing a distinct degree of the trait on homozygous level (after repeated inbreeding for more years and non-segregation in the following generations). In the case of the first two traits when inheritance of the distinct mutant expression - erectoid position of leaves and leafless stem below the head is considered, crosses of two alternative expressions of the trait, i.e. mutant and standard, always reciprocally, were carried out. In two other traits with well distinct extreme expression of the traits three lines were crossed. As for the head shape, concave, convex and straight shaped (standard) form of the head were classified. In the petiole length, short, long and medium (standard) trait expression were distinguished. As for the head position five lines with distinctly different angles between head and stem were crossed. Half-diallel crosses for analysis of inhe-

ritance of this trait were used (without reciprocal combinations).

Results were evaluated by analysis for evaluation of traits determined by a low number of major genes (1-12) using non-parametric tests of good coincidence.

Results and Discussion

A trait advantageous for the increase of the number of individuals per area unit is "erectoid type" of sunflower plants. A plant showing this phenotype has petioles inserted under a more acute angle. The plant perimeter is slightly decreased so that the plant has "poplar" shape. Number and size of single plants may remain unchanged. With regards to a higher mutual shading of leaves the total active photosynthetic plant area is decreased. This may not considerably affect the yield because the normal leaf area in sunflower has a larger dimension than necessary for the obtained achene yield.

Narrowing the plant which favours the possibility of a higher stand density can be also obtained by shortening the petiole. Petioleless leaves inserted to the stem are the extreme case. This expression of the complete petiolelessness does not occur within the frame of the variability of cultivated species of Helianthus annuus but can be transformed from some wild species of sunflower.

Mutations with shorter and thicker petioles can rarely occur in the species of H. annuus, however, in most cases it is a deformation that is difficult to be used for the construction of productive plant types. Naturally formed shorter leaf petiole can be obtained after crossing H. annuus with perennial wild species of sunflower with short petioles (e.g. H. maximiliani, H. hirsutus, H. rigidus and other) or completely without petioles (H. mollis). Inheritance of shortened petioles has not been studied systematically. We have revealed certain trends after having evaluated results of measuring this trait in parental forms and in F_1 hybrid generation. Crosses between the cultivated sunflower and perennial petioleless species H. mollis gave plants with completely petioleless leaves in F_1 generation. These results offer some suppositions for the development of cultivated sunflower genotypes with highly shortened petioles. Obstacle in their experimental use are difficulties in obtaining higher hybrid generations or generations of back-crosses particularly in combinations with perennial species.

Shortening or even complete reduction of petioles considerably limits the materialization of sunflower leaf phototropism. Photo-

tropic leaves display by about 10% higher utilization of the sunshine than stationery leaves. However, the effectiveness of sunflower leaf area is usually higher than corresponds to the head sink area and capacity of the veins leading products of photosynthesis to the head. Smaller plants with shortened and erect petioles offer presumption for the desired increase of the stand density to 85 000 individuals. New form must preserve the present level of physiologic plant traits, i.e. fully utilized area of the head at the diameter 18 cm at the minimum, capacity and effectiveness of the root system and also undiminished capacity of vein tissues. Only the total active leaf area may be decreased, preserving its effectiveness per area unit that is sufficient to achieve the desired yield of achenes per plant (i.e. 75 grammes).

Besides the traits enabling increase of the stand density, the new type of the plant must have traits limiting head diseases in more dense stands.

Traits of the head are primarily involved. It is necessary to obtain the optimal position (degree of head inclination), as thin receptacle as possible and the ability to dry fast during achene ripening.

A suitable type is also a straight, narrow insertion of the stem into the middle part of the receptacle and flat shaped form of the head without curvatures on the inner or outer side.

An advantageous trait for limiting head diseases is leafless stem below the head. Longer distance between the leaves and the head extends the length of veins between the closest source of assimilates and achenes, but the leaves located in the upper part of the stem of sunflower are usually less developed and their contribution to the achene yield is limited. The most important leaves located in the middle of the plant are no more far away from the head in this type of sunflower with "long neck" than usual for the standard type.

The mentioned traits increase the sunflower yield potential or enable its maximum materialization. Yield potential of a single plant can be increased by limiting the so called empty "middle" by achieving a regular filling of the head with normal achenes. This is primarily connected with harmonization of physiological traits of the plant, namely effectiveness of the root system and the photosynthetic apparatus on the one side and the capacity of veins particularly in that part of the stem where it joins the head on

the other side. Optimal density of the stem varies according to the location, species, soil, type of the hybrid or also level of nutrition and management.

With the aim to obtain some data on plant types with progressive traits, parameters of leaf area were compared in two lines of a specific type and a line of a standard type. The specific type represents erectoid position of leaves in one case and leafless stem below the head ("long neck") in the second case. Characteristics of these variants are given in tables 1-3.

Table 1

Line type	Plant height			Number of leaves		
	total cm	with leaves cm	%	total	per 100 cm stem length	remaining on plant
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

Line type	Internodes			Leaf area in cm^2	
	number	length (cm) total	part with remaining leaves	of leaf	of 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

Line type	Leaf cylinder			Density of leaf cylinder	Leaf area at unified volume of leaf cylinder 0.25 m^3
	height	width	volume (m^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

When the effect of crosses on petiole length was evaluated, average values of the length of nine lines of cultivated sunflower in the following species of wild sunflower and their hybrids were calculated :

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. runyonii

Species given above are annual, following are perennial

7. H. maximiliani
8. H. hirsutus
9. H. rigidus

Table 4

Average petiole length in cm (line)	H.a./A	H.a./B	H.arg./A	H.arg./B	H.pr.hir.	H.pr.runyonii
	21.6	17.3	11.9	7.4	4.5	4.1
19.0	22.1 and 25.2	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	H. hirsutus	H. rigidus
	2.2	1.5	1.1
19.0	-	3.8	2.7 a 2.4
15.6	2.3	-	1.6
10.5	-	-	6.3

Conclusions

Study of progressive sunflower traits in relation to genetic, ecological and crop management factors indicates that the enhancement of stand productivity requires a perfect knowledge of progressive traits.

Following morphological traits are of primarily importance : smaller height, erectoid type, suitable head inclination, leafless stem below the head.

In shortened petioles, crosses with annual wild species that have leaf petiole at least 4cm long, incomplete dominance of long petioles manifests in F_1 generation. The shorter petiole has the wild species the more distinct is the dominance of the cultivated species in extension of the petiole.

Whereas the average level of partial dominance achieves 16 % after crossing lines with a population of H. annuus A (petiole length 21.6 cm) the average level of partial dominance reaches up to 50 %.

Hybridization between cultivated lines and perennial wild species with petioles 1 - 2.5 cm long usually shows incomplete dominance of shortened petioles in F_1 generation. The level of partial dominance of short petioles achieves the value of length shortening by 2/3 - 3/4 compared with intermediary expression.

Erectoid type is characterized by a narrower and longer plant space with leaves at maintaining its average volume. Plants with leafless stem below the head are shorter and narrower and the volume of the space with leaves is reduced.

Compared with the standard type the plant lacking leaves in the upper part of the stem has the same proportion of the middle leaves but more remaining lower leaves; it also has a larger total leaf area concentrated into a smaller space.

Erectoid type has recessive inheritance with prevailing occurrence of intermediary plants in various degrees. With the stand density increase (to 80 000 individuals) the yield per plant of erectoid type increases by 28 %.

From the point of view of plant breeding it is possible to manipulate the above mentioned progressive traits relatively well.

For the future it will be necessary to combine them into one genotype, complete with progressive physiological traits, evaluate their yielding level and possible use in the development of hybrids.

LITERATURE

KOVÁČIK, A., 1984.: The cytogenetics of sunflower and its role in improvement.
Agric. Ital. fasc. 3/4, p.p. 37 - 82

KOVÁČIK, A.; ŠKALOUD, V., 1986: Rendement en huile du Tournesol comme modele graphique des valeurs d'un caractere complexe.

KOVÁČIK, A.; ŠKALOUD, V., 1980: Collection of sunflower marker genes available for genetic studies.
FAO "Helia" Infor. bull. of the F.A.O. Nr. 3, December 1980

KOVÁČIK, A.; ŠKALOUD, V., 1988: Determination of the Optimum Density of a Sunflower Stand.
Rostl. výroba., 34 (6) : 607-612

KOVÁČIK, A.; VLČKOVÁ, V., 1988: Comparative Study of Embryogenesis in Sunflower (Helianthus annuus L.).
Genet. a šlecht., 24 (4) : 271-280.

KOVÁČIK, A.; ŠKALOUD, V., 1990: The yield results of pilot trials with sunflower hybrids.
Rostl. Výr., 36, (3) : 263-269

KOVÁČIK, A.; ŠKALOUD, V., 1990: Results of Inheritance Evaluation of Agronomically Important traits in Sunflower FAO "Helia" No 13, Vol. 13, October 1990