POSSIBILITIES OF INCREASING THE GENETIC VARIABILITY OF SUNFLOWER DUE TO SEED QUALITY COMPOSITION

W. SCHUSTER and I. KÜBLER

Institut für Pflanzenbau und Pflanzenzüchtung
Justus-Liebig-Universität Giessen, F. Rep. of Germany

INTRODUCTION

Sunflower oil contains no long-chain fatty acids with more than 18 C-atoms and linolenic acid only in little proportion (Cummins et al., 1967; Ermakov, 1977; Kinman, 1972; Marquard et al., 1977; Sietz, 1969). For use as edible oils or fats high percentage of linoleic acid is demanded. In this case sunflower is surpassed by safflower *(Carthamus tinctorius)* and *Guizotia abyssinica* (Knowles, 1972). Linoleic acid content of 75—80% (total fatty acids = 100) would be a possibility to produce cheeper diet fats in great amount.

A near environmentally and genetically influenced negative correlation between linoleic and oleic acid exists (Barker and Hilditch, 1950; Beringer and Saxena, 1968; Canvin, 1965; Kinman, 1972; Marquard, 1980; Marquard et al., 1977; Schuster et al., 1972). Oleic acid is of interest for different uses in foodstuff industry, too. Therefore two different types of sunflower with different fatty acid composition — one type with high linoleic acid content for production of diet fats and another type with high oleic acid content for production of edible oil to substitute expensive olive-oil (Fick, 1982; Kinman, 1972), could be selected.

In sunflower breeding only little attention has been paid to protein content of seeds because sunflower residues of oil production cannot be indefinitely used as feeding stuff. Quality improvement can be achieved by breeding for thin hull and high protein and oil content and by increasing the variability of quality characteristics. Therefore on one hand investigations on variability of open-pollinated variety VNIIMK 8931 were carried out (half-seed-method) and on the other hand the variability of the above mentioned quality characteristics was enlarged by artificial induction of mutations. Results are reported in this paper.

MATERIALS AND METHODS

Among a great number of selfings from the open-pollinated variety VNIIMK 8931 ten single seeds per selfing were selected in the second inbred generation and were investigated for oil and protein content, hull percentage and fatty acid composition. Remaining "half-seed" was planted in 1980, selfings were produced again and ten seeds of each selfing investigated for the above metioned characteristics, too.

Parallel to these investigations seeds of variety VNIIMK 8931 were treated mutagenically and tested by 2 "half-seed"—method in M_2 and M_3. The mutagenic treatment was conducted by seed radiation with x-rays. The dose of x-rays was 20 and 30 KR. On the other hand seeds were treated 20 hours in 1% EMS-solution.

The investigations of quality were conducted as follows: The seeds were dried in an exsiccator before weighting them. The oil content was determined by an NMR-Analyzer. Further on the hull was removed from the achenes and weighted. The analyses of protein content and fatty acid composition were made on a portion of the seed while the remainder containing the embryo was saved for growing into a plant in case of positive analysis results. The protein content was determined by means of a pyrolyse-gas-chromatograph. The fatty acids were also determined by a gas-chromatographic analysis after triglycerids had been converted to methylesters.

RESULTS

The variability of different quality characteristics in I_2 and I_3 from VNIIMK 8931 is shown in Table 1 by means of minimum and maximum values as well as mean values. The differences between the two inbred generations are small in relation to the mean values

Table 1

Variation in composition of single sunflower seeds from VNIIMK 8931 in I_2 and I_3
Mean values ($\bar{x}$), variation range (Min—Max) and s% values of 350 single seeds

Components	I_2				I_3			
	Min.	$\bar{x}$	Max.	s%	Min.	$\bar{x}$	Max.	s%
Oil content in seed%	13.3	31.0	43.2	20.7	8.7	33.5	46.2	17.6
Oil content in kernel %	33.4	45.5	68.1	12.1	28.6	44.7	69.3	12.1
Protein content in seed %	4.8	18.1	31.8	23.5	5.1	22.1	36.4	21.8
Protein content in kernel %	8.7	27.5	39.9	23.4	9.3	29.5	48.9	16.8
Hull proportion %	10.1	32.4	57.6	30.3	11.1	25.4	77.6	43.1
Oleic acid in % of TFA	7.7	17.0	37.2	27.3	8.3	20.5	35.8	30.3
Linoleic acid in % of TFA	50.5	72.0	80.7	8.9	42.3	72.6	85.0	9.6

and variation range of individual values. A small decrease of oil content in kernel can be established and is accompanied by an increase of protein content in kernel. Hull percentage (25.4%) is lower in I_3 than in I_2. Values for oleic and linoleic acid are similar in the two generations as well as variation range of extreme values which are situated between 7 and 38% for oleic acid and between 40 and 85% for linoleic acid.

In order to analyse the results shown in the first table, oil and protein content of seed, hull percentage as well as oleic and linoleic acid content of the investigated seeds are presented graphically by means of the sum of frequencies.

Figure 1 shows the oil content of seeds. In I_2 two thirds of the investigated seeds are divided in classes 25 to 40% while in I_3 class 35 to 40% shows an absolute frequency of 169 seeds and is twice as high as the class 30 to 35% oil which may be attributed to selection of positive types.

Regarding protein content in seed, presented in Figure 2, it is shown that variation of values increases from I_2 to I_3, too. In mean classes from 15 to 25% protein in seed, a higher amount of values is given in I_3 than in I_2 and a higher absolute frequency of protein content over 30% appears while in I_2 lower classes show higher frequencies.

The graphic presentation of seed hull percentage (Fig. 3) depicts completely different figures for both investigated inbred generations. The distribution of absolute frequencies in individual classes corresponds with the nor-

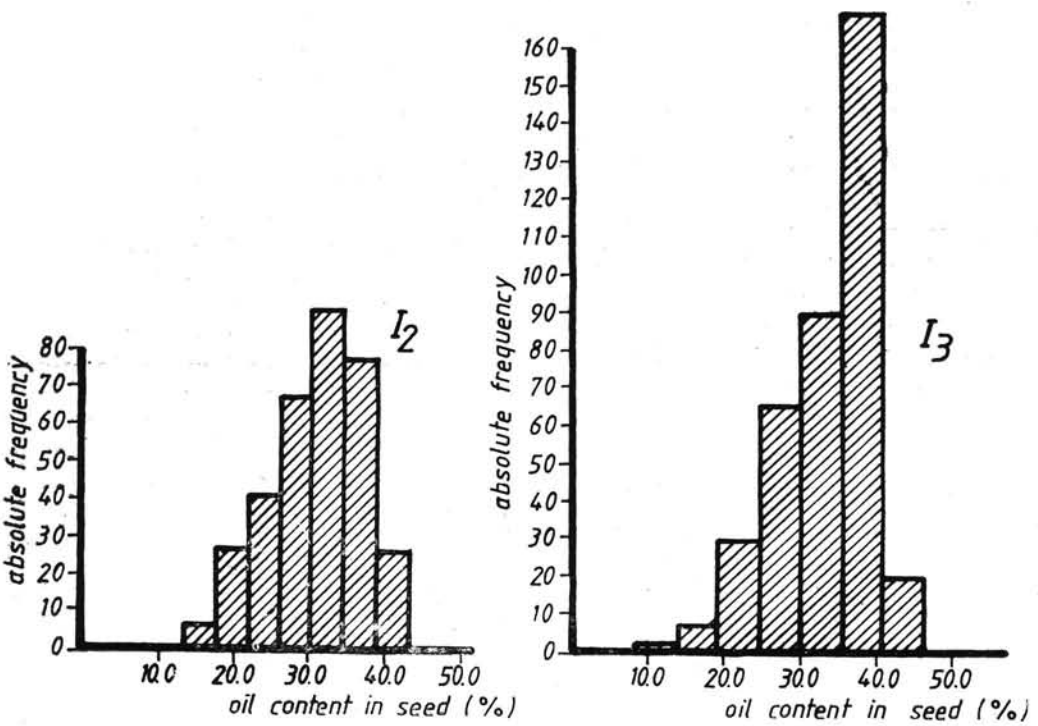

Fig. 1 — Frequency distribution of 350 investigated seeds within I_2 and I_3 from VNIIMK 8931, for seed oil content

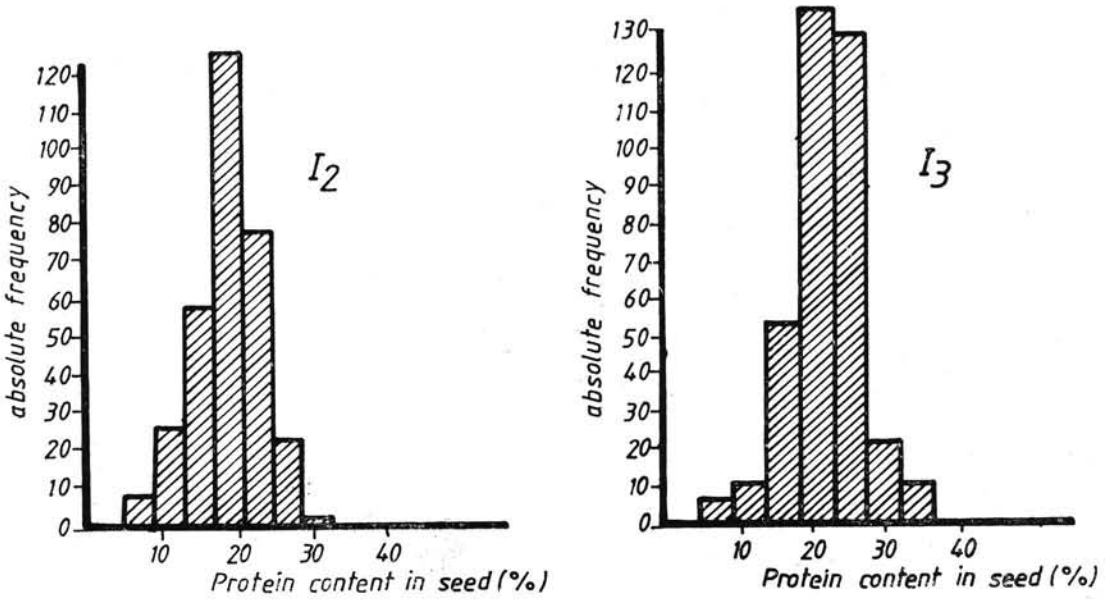

Fig. 2 — Frequency distribution of 350 investigated seeds within I_2 and I_3 from VNIIMK 8931, for seed protein content

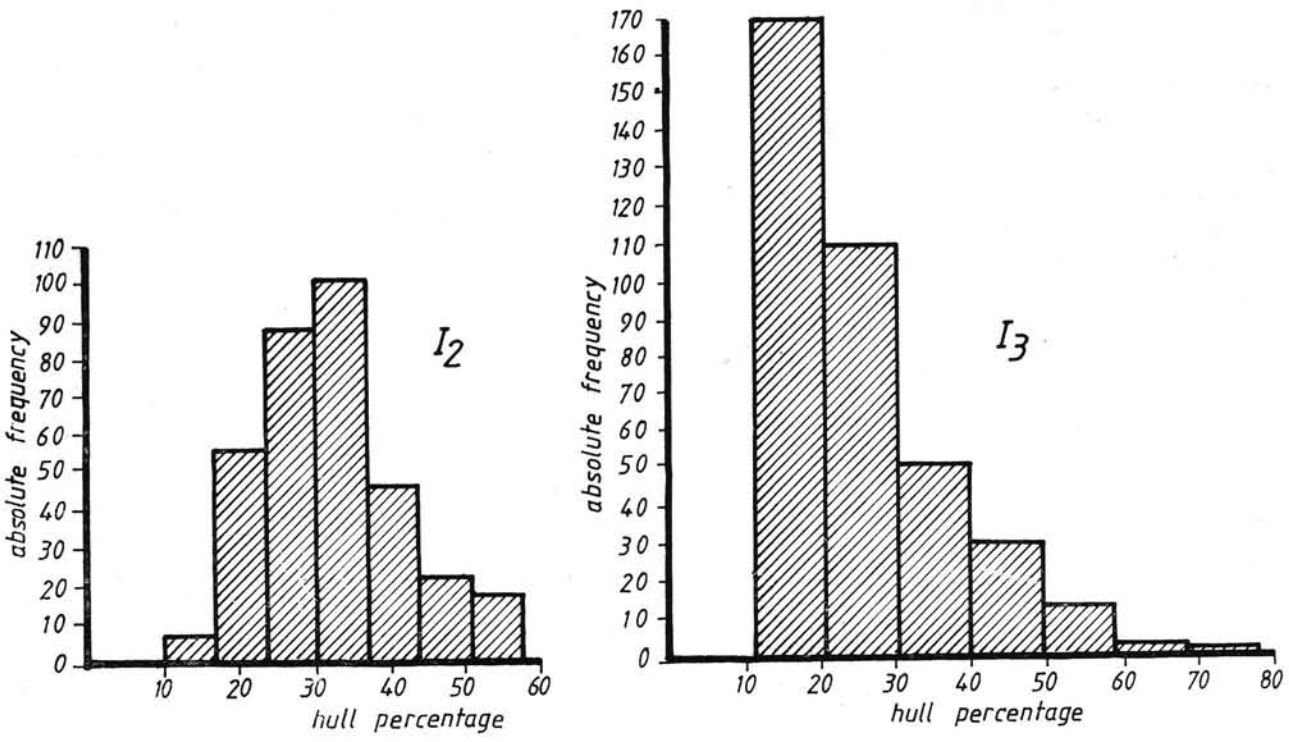

Fig. 3 — Frequency distribution of 350 investigated seeds within I_2 and I_3 from VNIIMK 8931, for hull percentage

mal curve in I_2. The most of values are situated between 25 and 35% and a small part only between 10 and 20% hull proportion. In comparison to that absolute frequency of the class 10 to 20% increases in I_3, half of the investigated achenes have a hull percentage of 10 to 20%.

The two next pictures show oleic and linoleic acid content in % of the total fatty acids. In relation to the oleic acid (Fig. 4) great differences between I_2 and I_3, don't appear, most seeds having the oleic acid content between 10 and 20% while few seeds only over 25% oleic acid. Corresponding to the negative correlation between oleic and linoleic acid, high absolute frequencies of classes 67 to 80% occur in linoleic acid content presented in Figure 5. The sum of frequencies corresponds

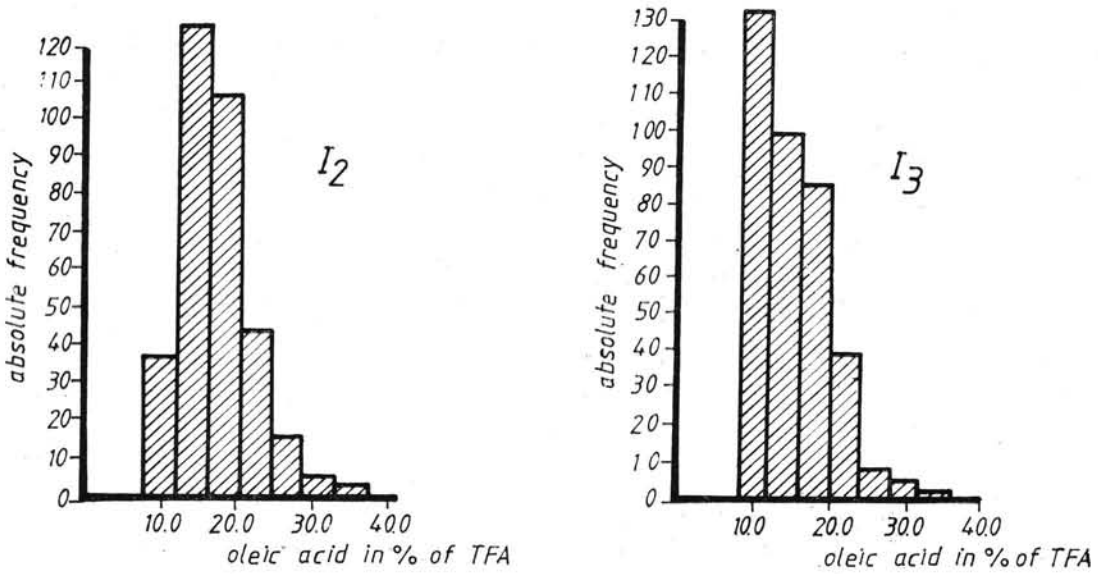

Fig. 4 — Frequency distribution of 350 investigated seeds within I_2 and I_3 from VNIIMK 8931, for oleic acid content

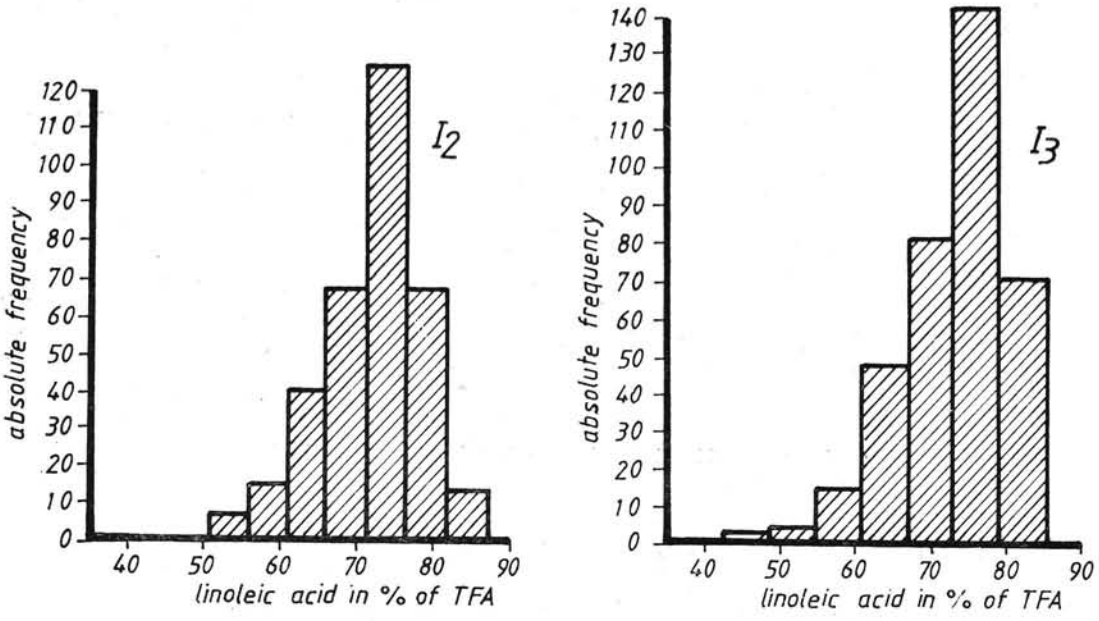

Fig. 5 — Frequency distribution of 350 investigated seeds within I_2 and I_3 from VNIIMK 8931, for linoleic acid content

to the normal curve in both inbred generations, but the class over 80% linoleic acid clearly increases in I_3.

To study the genetic variability of fatty acids in the investigated material, 3 selfings with different fatty acid composition in I_2 and I_3 were selected. For each of both inbred generations, selfings with high linoleic acid content (Sf 1963/79, Sf 1363/80) and with high oleic acid content (Sf 1929/79, Sf 1511/80) were found. The corresponding fatty acids were accordingly low. Selfings Sf 1982/79 and Sf 1195/80 had mean oleic and linoleic acid content. Thus different genotypes could be found by means of selfing within the population of VNIIMK 8931.

Table 2 shows the genetic variability of different quality components in M_2 and M_3 of VNIIMK 8931 after the mutagenic treatment with x-rays (dose 30 KR). Comparing the mean values of the corresponding components an increase of values from M_2 and M_3 could be found with the exception of protein content in kernel and oleic content. Hull percentage decreases from M_2 to M_3 too, but this is a positive effect. Variation range between minimum and maximum values of all components is larger in M_2 than in M_3 and this can be attribu-

Table 2

Variation in composition of single sunflower seeds from VNIIMK 8931 in M_2 and M_3, after radiation with x-rays (30 KR)

Mean values ($\bar{x}$), variation range (Min—Max) and s% values of 30 single seeds

Components	M_2				M_3			
	Min.	$\bar{x}$	Max.	s%	Min.	$\bar{x}$	Max.	s%
Oil content in seed %	13.6	20.9	33.3	22.8	22.0	29.3	39.9	11.6
Oil content in kernel %	28.2	37.9	46.0	13.3	38.4	47.6	65.3	10.9
Protein content in seed %	10.5	16.9	24.7	18.1	10.5	18.1	23.6	13.0
Protein content in kernel %	17.7	30.8	37.0	15.2	23.7	29.7	36.2	11.5
Hull proportion %	17.4	44.5	56.9	26.1	28.4	37.5	49.4	13.8
Oleic acid in % of TFA	7.7	20.4	33.8	34.2	13.3	18.7	25.7	16.1
Linoleic acid in % of TFA	51.7	68.4	80.9	10.7	61.5	69.9	75.7	5.4

ted to the continued selfing and increasing homogeneity of the material in connection with selection for positive characteristics.

To show the genetic variability of the material, Figures 6—10 depict diagrams of oil and protein content, hull percentage and oleic and linoleic acid content.

The accumulation of oil content values, presented in Figure 6, shows a fluctuation of values to higher oil content from M_2 to M_3. Variation range of values is larger in M_2 than in M_3. The highest oil content in seed, 35.4%, appears in M_3.

The variation of differences for protein content (Figure 7) between M_2 and M_3 are not so distinct like those for oil content. Variation range as well as the highest frequency of values corresponds in M_2 and M_3 and indicates that variability of protein content is smaller.

Hull percentage in Figure 8 is generally high which can be attributed to growth interruptions after mutagenic treatment. Range of values in M_2 is wider than in M_3 where values variate between 30 and 50%. Extreme values of 17% respectively 58% hull proportion, as appear in M_2, don't exist in M_3 because of higher homogeneity of the material.

The variability of oleic and linoleic acid values is larger in M_2 than in M_3, too (Figures 9 and 10). Mean value of oleic acid content decreases from 20.4% in M_2 to 18.7% in M_3. The most of the other values range around this mean, while in M_2 a wide range of values from 7—34% oleic acid occurs. Linoleic acid content shows the same tendency. One can find wide variation of values in M_2 from 50—80% linoleic acid and a narrow range around the mean values in M_3 which is unimportantly higher than in M_2 where a greater number of values over 70% linoleic acid appears.

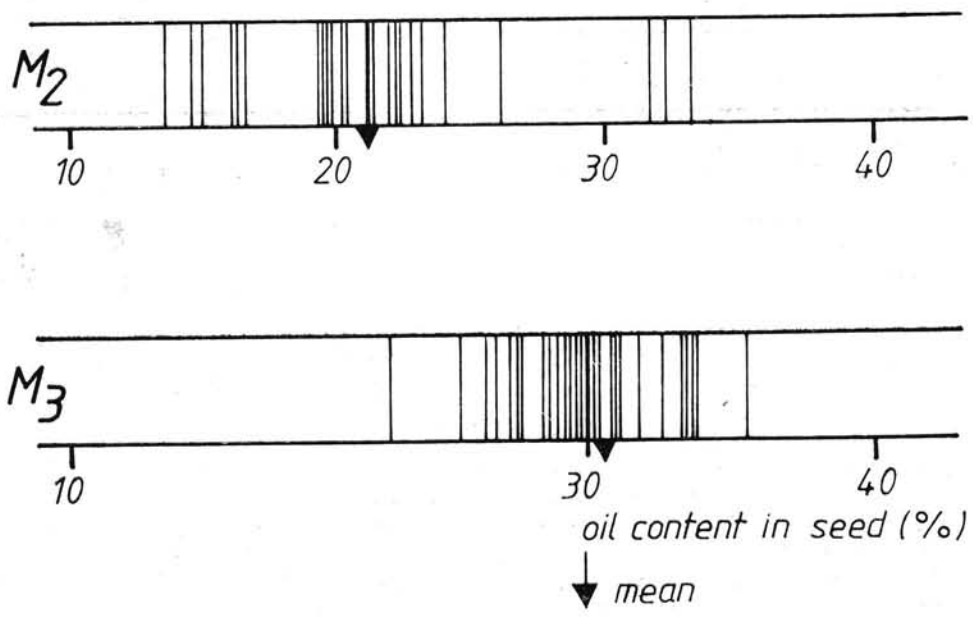

Fig. 6 — Variability of oil content in 30 investigated seeds in M_2 and M_3 from VNIIMK 8931, after irradiation with X-rays (30 KR)

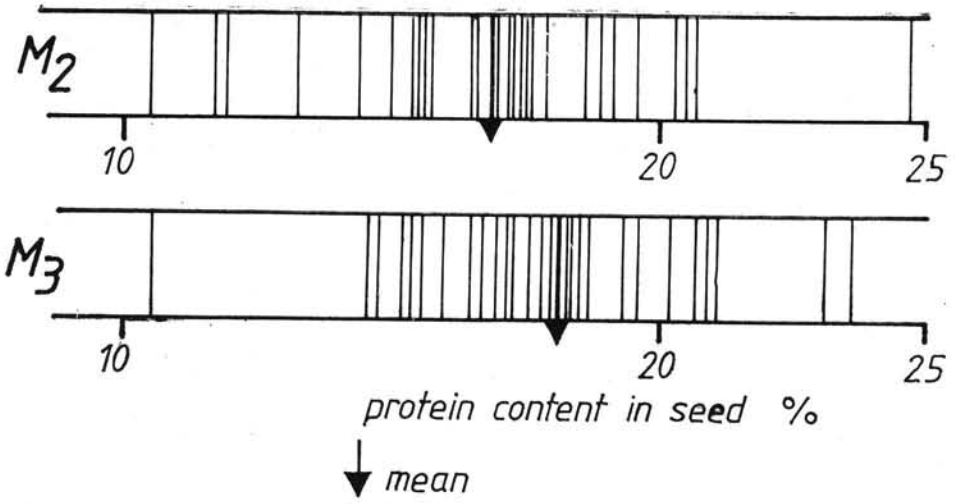

Fig. 7 — Variability of protein content of 30 investigated seeds in M_2 and M_3 from VNIIMK 8931, after irradiation with X-rays (30 KR)

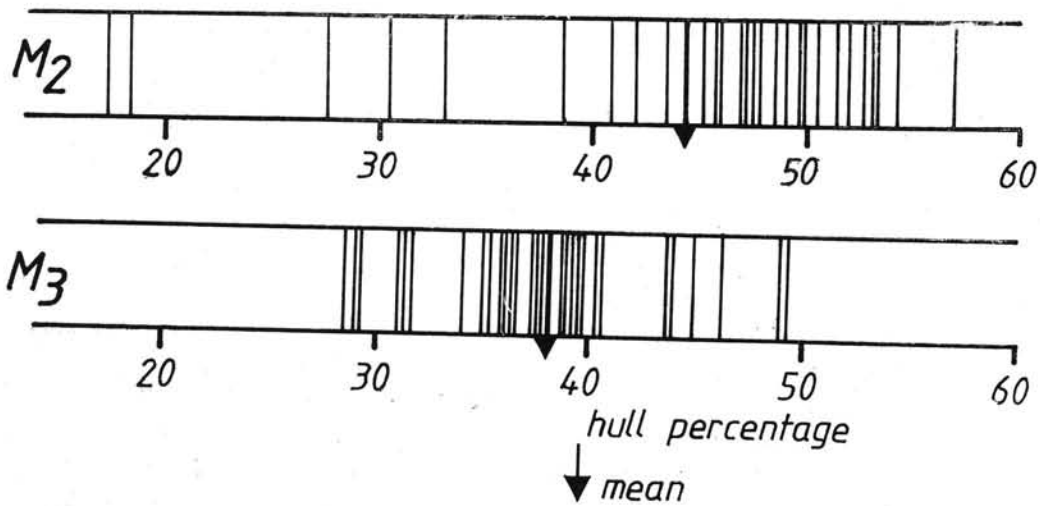

Fig. 8 — Variability of hull percentage of 30 investigated seeds in M_2 and M_3 from VNIIMK 8931, after irradiation with X-rays (30 KR)

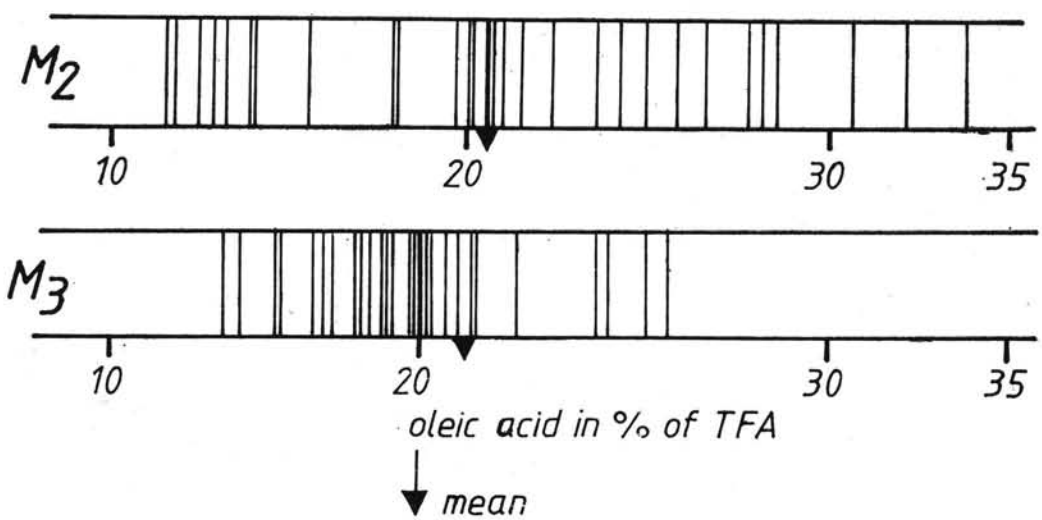

Fig. 9 — Variability of oleic acid content of 30 investigated seeds in M_2 and M_3 from VNIIMK 8931, after irradiation with X-rays (30 KR)

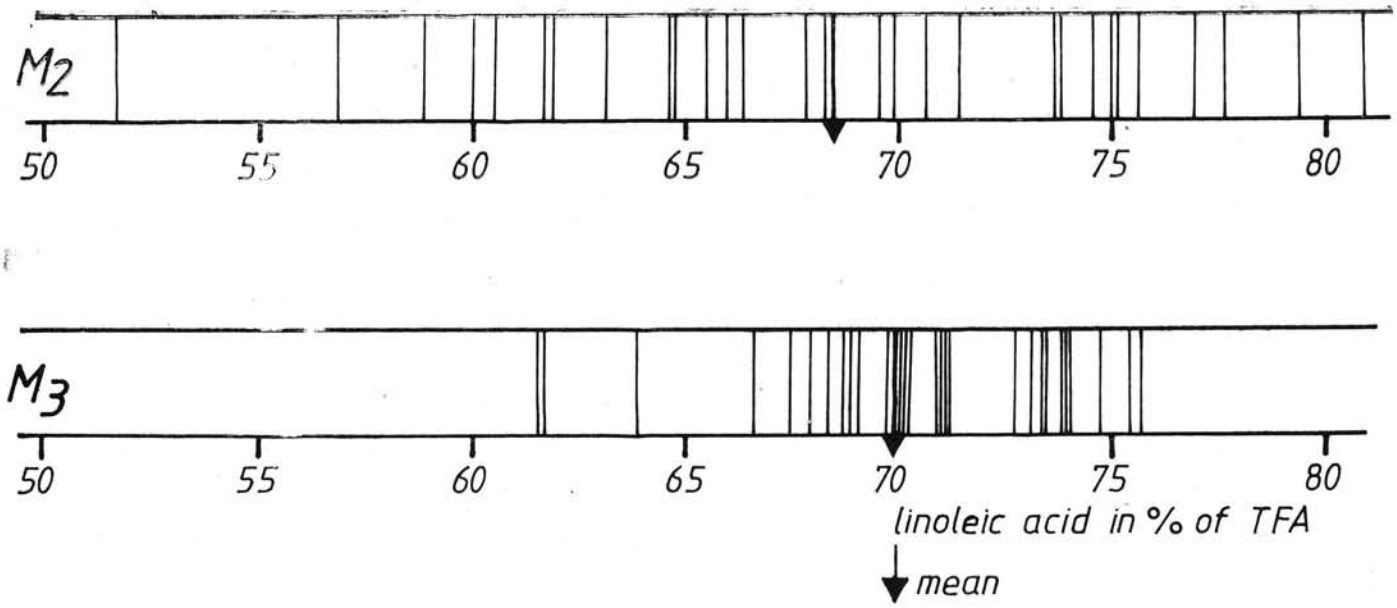

Fig. 10 — Variability of linoleic acid content of 30 investigated seeds in M_2 and M_3 from VNIIMK 8931, after irradiation with X-rays (30 KR)

Table 3 shows the effects of different mutagenic treatments on quality of sunflower seeds. One variant without treatment (control) stands in opposite to a 20-hour-treatment with 1% — EMS-solution and a radiation treatment with a dose of 20 KR. Mean values of oil content are higher after both treatments in comparison to the control, the other values don't show differences. Variation range increases after mutagenic treatment except that of hull percentage, which is narrower after the treatment. Radiation treatment has higher influence on variability of protein content and EMS-treatment enlarges the variability of oleic acid compared to control.

CONCLUSIONS

The reported results show that the variability of an open-pollinated variety like VNIIMK 8931 can be used by continued selfing and single seed selection and valuable genotypes can be found with regard to the improvement of sunflower seed quality and in order to use them in hybrids breeding.

Mutagenic treatment enlarges the variability of different important quality characteristics. Positive genotypes regarding fatty acid composition appear especially after EMS-treatment, while radiation seems to be suitable for a selection for low hull percentage and high protein content.

Table 3

Variation in composition of single sunflower seeds from VNIIMK 8931 in M_2 after mutagenic treatment in comparison to the untreated control

Mean values ($\bar{x}$), variation range (Min—Max) and s% values of 60 and respectively 30 single seeds

Components	VNIIMK 8931 (control)				VNIIMK 8931 (EMS-M_2)				VNIIMK 8931 (x-rays-M_2)			
	Min.	$\bar{x}$	Max.	s%	Min.	$\bar{x}$	Max. *	s%	Min.	$\bar{x}$	Max **	s%
Oil content in seed %	19.2	29.9	39.2	15.4	23.1	34.1	40.9	13.4	22.0	35.5	41.2	15.6
Oil content in kernel %	37.6	45.8	53.7	6.7	35.0	47.5	55.0	8.7	35.5	48.2	57.0	10.9
Protein content in seed %	10.2	19.4	25.3	22.1	13.0	20.5	31.4	17.9	14.8	21.3	45.5	25.9
Protein content in kernel %	14.4	29.5	37.9	14.7	19.7	29.1	41.1	19.3	24.9	28.9	59.6	22.3
Hull proportion %	16.1	34.2	61.1	31.3	17.0	28.5	51.4	26.0	14.1	26.4	39.8	29.6
Oleic acid in % of TFA	11.3	16.5	37.8	26.5	10.9	20.1	40.2	30.8	11.1	22.9	35.7	29.8
Linoleic acid in % of TFA	36.4	69.8	79.9	11.4	47.1	69.0	80.7	10.7	50.8	68.1	77.5	9.6

* = seeds treated 20 h with 1% EMS-solution
* = seeds treated 20 h with 1% EMS — solution

LITERATURE

Barker C., Hilditch T. P., 1950, *The influence of environment upon the composition of sunflower seed oil. I.: Individual varieties of sunflowers grown in different parts of Africa,* J. Sci. Food Agric. 1, 118.

Beringer H., Saxena N. P., 1968, *Einfluss der Temperatur auf den Tocopherolgehalt von Samenfetten,* Z. Pflanzenernähr., Düng., Bodenkunde 120, 71.

Canvin D. T., 1965, *The effect of temperature on the oil content and fatty acid composition of the oils from several oil seed crops,* Canad. J. Bot. 43, 63.

Cummins D. G., Marion J. E., Craig-Miles J. P., Buens R. E., 1967, *Oil content, fatty acid composition and other agronomic characteristics of sunflower introductions,* J. Amer. Oil Chemists' Soc. 44, 581.

Ermakov A. I., 1977, *Prospects for improving oil composition and content in sunflower cotton and linseed,* Trudy po Prikladnoi Botanike, Genetike i Selektsii 59, 137.

Fick G. N., 1982, *Genetics and Breeding of Sunflower Vortrag auf der Sitzung der AOCS in Toronto,* Kanada, am 4.5.1982.

Kinman M. L., 1972, *Breeding for lipid and amino acid composition in sunflower,* J. Americ. Oil Chemists' Soc. 49.

Knowles P. F., 1972, *The plant geneticist's contribution towards changing lipid and amino acid composition of sunflower, J. americ. Oil Chemists'* Soc. 49, 27.

Marquard R. A., 1980, *Der Einfluss von Standortfaktoren un spezifischen Klimakonstellationen auf Fettgehalt, Fettsäurezusammensetzung und Tocopherolgehalt von Raps, Sonnenblumen, Soja und Lein,* Habil-Schrift Giessen.

Marquard R. A., Schuster W., Seibel K. H., 1977, *Fettsäuremuster und Tocopherolgehalt in Öl verschiedener Sonnenblumensorten aus weltweitem Anbau,* Fette, Seifen, Anstrichmittel, 79, 137.

Schuster W., Marquard R., Boye R., 1972, *Der Einfluss der Umwelt auf Fettgehalt und Fettsäuremuster verschiedener Sonnenblumensorten.* Fette, Seifen, Anstrichmittel 74, 150.

Sietz F. G., 1969, *Die Fettsäurezusammensetzung von Rüböl, Sojaöl, Sonnenblumenöl und Erdnussöl,* Fette, Seifen, Anstrichmittel 71, 446.

POSSIBILITÉS D'AUGMENTER LA VARIABILITÉ GÉNÉTIQUE DU TOURNESOL EN RELATION AVEC LA COMPOSITION QUALITATIVE DES GRAINES

Résumé

Les résultats présentés confirment la possibilité d'utiliser la variabilité existante au cadre des cultivars de tournesol à pollinisation libre — dans le cas présent le cultivar VNIIMK 8931 — par autofécondation continue et sélection individuelle des semences. De cette manière, on peut identifier les génotypes valeureux du point de vue de la qualité des semences, qui peuvent être utilisés dans l'amélioration des hybrides de tournesol.

Les traitements mutagéniques augmentent la variabilité des différentes caractéristiques qualitatives des semences. Les génotypes positifs du point de vue de la composition en acides gras apparaissent surtout après le traitement à EMS, cependant que les radiations semblent adéquates à la sélection pour le taux réduit de coques et la teneur élevée en protéines.

POSIBILIDADES DE AUMENTAR LA VARIABILIDAD GENÉTICA DEL GIRASOL EN LO QUE CONCIERNE LA COMPOSICIÓN CALITATIVA DE LAS SEMILLAS

Resúmen

Los resultados presentados confirman la posibilidad de emplear la variabilidad existente dentro de las variedades de girasol con polinización libre — en nuestro caso la variedad VNIIMK 8931 — por autofecundación continua y la selección individual de las semillas. De esta manera se pueden identificar genotipos valiosos desde el punto de vista de la calidad de las semillas, las cuales pueden ser empleados en el mejoramiento de los híbridos de girasol.

Los tratamientos mutagénicos aumentan la variabilidad de las diferentes caractrísticas calitativas de las semillas. Los genotipos positivos en lo que concierne la composición en ácidos grasos aparecen sobre todo después del tratamiento con EMS, mientras que las radiaciones parecen ser apropiados para la selección en cuanto al porcentaje reducido de pellejo y al contenido elevado en proteinas.