OIL CROPS: SESAME AND SUNFLOWER SUBNETWORKS

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PROCEEDINGS OF THE JOINT SECOND WORKSHOP HELD IN CAIRO, EGYPT, 9–12 SEPTEMBER 1989

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IDRC-MR271e
November 1990

OIL CROPS:
SESAME AND SUNFLOWER SUBNETWORKS

Proceedings of the Joint Second Workshop held in Cairo, Egypt, 9–12 September 1989

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Organized by
Agricultural Research Centre, MOA, Giza, Egypt
and
International Development Research Centre, Canada

Sponsors
Food and Agriculture Organization, Industrial Crops and European Office, Rome
International Bureau of Plant Genetic Resources, Rome
International Development Research Centre, Canada

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FOREWORD

In September 1989, the Sunflower and Sesame subnetworks held their bi-annual meetings in Cairo, Egypt. The meetings were well attended and papers, presented in these proceedings, provide a very informative overview of some of the cropping systems, management practices, production constraints and research highlights for both crops in several countries.

Chronic edible oil deficit is a major problem facing many developing countries in Africa and Asia where most countries are forced to import large quantities to satisfy the requirements of their growing populations. With the present rates of population increase and the improvement of nutrition standards it is likely that the consumption of edible oil will rise over the years, increasingly drawing on scarce foreign exchange for the importation of this vital food staple. For this reason, several countries have opted to increase self-sufficiency in edible oil.

Production deficits are due to a number of factors, among which neglect in oilcrops research, in both developed and developing countries has been a major one. This is particularly true for minor crops such as sesame. In the context of the IDRC oilcrops network, initiated in 1981, the interchange of information and the sharing of results between scientists have proved to be very useful and beneficial for the generation of scientific knowledge and the stimulation of research in this important area. It is hoped that conclusions and recommendations of this meeting will stimulate further research and development in the future.

A second important reason for limited national production has been the exceptionally low levels of world prices for oils and fats in the 1980's and the comparative advantage of importation over production for developing countries. The description of a case study using a system's approach to analysis the Vegetable Oil/Protein System of Kenya has stirred much interest during the Cairo meetings and it is hoped that similar work can be carried out in other countries in the future.

The Cairo meetings will also unfortunately be remembered as the one which has witnessed the diagnosis of the fatal disease of late Dr. Hiruy Belayneh, Chairman of the Brassica Subnetwork. We will all regret his absence.

On behalf of IDRC and of all participants, I would like to thank the Government of Egypt for its hospitality, the organizers for the excellent arrangements and all those who contributed to the success of these meetings by their presentations and discussions.

Eglal Rached,
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USE OF WILD SPECIES IN SUNFLOWER BREEDING

Dragan Skoric

The domesticated sunflower has narrow genetic variability, especially regarding important agronomic characters. High-oil varietal populations and hybrids are distinguished for the narrowness of their genetic variability. The situation is similar with local populations only, in addition, they have inferior agronomic characters.

The large number of wild *Helianthus* species and pronounced variability within them offer opportunities of increasing genetic variability of the domesticated sunflower by interspecific hybridization. The validity of this assumption is confirmed by the fact that there exists a large number of natural interspecific hybrids among wild sunflowers.

The inclusion of wild sunflower species in sunflower breeding programs is not a simple but complex and long process. Differences in chromosome number (tetraploid and hexaploid species) and incompatibility render interspecific hybridization difficult, if possible at all. Fortunately, these obstacles have recently been made surmountable by the development of embryo culture and other techniques of tissue culture.

Interspecific hybridization is further burdened by insufficient knowledge of the genomic character of *Helianthus* genus. Consequently, we may lose characters in the course of hybridization. Furthermore, we introduce both desirable and undesirable characters into the domesticated form in the process of hybridization, especially the linked characters. It is therefore a must to gain more knowledge about the characters of the genus *Helianthus* in order to be able to set clear cut targets of interspecific hybridization which would ultimately ensure success in sunflower breeding.

The studies conducted so far on wild sunflowers, have not provided sufficient information from the aspect of breeding, especially for certain important characters, e.g., resistance to diseases and pests. The job on the collecting of wild sunflower species from natural populations has not been completed yet. That work should be maximally accelerated because, the rapidly spreading urbanization threatens the existing natural populations of wild sunflowers with extinction.

The use of wild sunflower species in breeding programs has been insufficient and yet it invariably produced very good results, especially in breeding for resistance to certain diseases (*Plasmopara helianthi* and *Puccinia helianthi).* It should be mentioned at this point that the domesticated sunflower is poorest in disease resistance. Wild sunflowers were also invaluable as sources of cytoplasmically male sterile (cms) and restorer (Rf) genes which practically enabled the use of heterosis in the development of sunflower hybrids.

The future uses of wild sunflowers in breeding should be directed towards the discovery of sources of resistance to the major diseases and insects, which are the dominant limiting factors of sunflower production. The work on the discovery of new sources of cms and Rf genes should be continued.

Furthermore, wild sunflowers are irreplaceable in the programs of breeding for resistance to drought and high soil salinity. It may be expected that the future breeding programs for oil and protein contents and seed quality will largely depend on certain wild sunflower species. The increase of heterosis for yield components is possible only if based on wild sunflowers.

To successfully use wild sunflowers in breeding programs, breeders should be thoroughly acquainted with all their characters, problems related to interspecific hybridization and breeding techniques.

Basic Characters of Wild Sunflower Species

Helianthus, a genus of the family *compositae (Asteraceae)* has a disjunct distribution, some 50 or so species being found in Canada, the United States, and northern Mexico, and the remaining 17 species limited to the Andes from southern Colombia to Peru (20).

Helianthus species fall into four sections and a number of series based on genetic and morphological characteristics. Section Fructicosi contains 17 South American perennial species that are only distantly related with North American sunflowers. The South American species have been transferred to genus *Helianthopsis* (53), and will not be considered further here.

The North American species of *Helianthus* occupied a variety of habitats (66). Several could be classed as desert species and a few somewhat paludose at least in the early stages of growth. Most species are found in fully open habitats and a few will be grown in rather dense shade, Table 1. A number of species can be classed as weeds. *Helianthus annuus* which has the most extensive distribution of any species apparently grows only in areas distributed by man. Many of the other species both annual and perennials, have distributions that have probably been enlarged by man. At least one from the densely pubescent race of *H. nuttallii* subsp. *parishii*, has become extinct as the result of man's activities and others may have suffered a restriction in range. Several species are intentionally cultivated by man, either for ornamental purposes or for food as *H. annuus* and *H. tuberosus* (21).

Helianthus genus is a polyploid complex consisting of diploids, tetraploids and hexaploids, all with the basic chromosome number of $x=17$ (55).

North American *Helianthus* species fall into three sections and a number of series based on genetic and morphological characteristics.

- I. Section Annui
- II. Section Ciliares
  - A. Series Ciliares
  - B. Series Pumili
- III. Section Divaricati
  - A. Series Angustifolii
  - B. Series Atrorubentes
  - C. Series Divaricati
  - D. Series Gigantei
  - E. Series Microcephali

I. Section Annui

Section Annui contains 14 or 15 species, nearly all of which are annual species occurring in the western half of the United States (21). Species of this section are nearly always annual, or rarely, taprooted perennials. Except for *H. agrestis H.=(Viguiera) ludens* and *H.=(Viguiera) similis*, all species are closely related and may intercross to produce hybrids with reduced fertility (51).

In most species the majority of the leaves are alternate, commonly ovate, and with few exceptions long petiolate. Disks of this section are mostly flat. The disk flowers are mostly reddish or purplish, but some species have yellow disk flowers.

Table 1. Collection and habitat information for helianthus species (Thompson et al., 1981).

Helianthus Species 1	Subspecies 2	Number of Collections 3	Where collected 4	General habitat 5	Estimated annual rainfall (cm) 6
niveus	niveu	1	Mexico	Sand dunes	<12
	tephrodes	1	CA	Sand dunes	<12
	canescns	6	TX, NM, AZ	Sand	12-50
debilis	debilis	15	FL	Sandy coast	125
	vestitus	1	FL	Sandy	125
	tardiflorus	1	FL	Sandy coast	125-140
	silvestris	3	TX	Sand	75-115
	cucumeriflolius	2	TX, CA	Sand	64-90
praecox	praecox	2	TX	Sand	120
	runyonii	5	TX	Coastal prairies	50-100
	hirtus	4	TX	Sand	50
petiolaris	petiolaris	50	Central U.S.	Sand	38-127
	fallax	15	South west U.S.	Sand	25-80
neglectus		9	TX	Sand	25-50
annuus		483	U.S. Mexico	variable	25-100
argophyllus		18	TX	Sand	50-100
bolanderi		1	CL	Valleys	25-150
exilis		5	CL	Rock outcrop areas	50
deserticola		1	UT	Sand	12-25
anomalus		1	UT	Sand	25-50
paradoxus		1	TX	Wet places	25
agrestis		1	FL	Wet places	125
gracilentus		2	CA	Dry stopes	25-50
pumilus		1	CO	Rocky soils	25-65
cusickii		2	OR,CA	Dry hills	20-75
arizonensis		1	AZ	Light soils	25-50
lociniatus		1	NM	Stopes	25-60
ciliaris		5	TX, NM	Variable	50-75
mollis		19	TX, OK, KS,AL,MT	Variable	90-140
occidentalis	occidentalis	4	TX,MT,AR	Dry sandy areas	65-140
	plantagineus	2	TX	Variable	100-125
divaricatus		3	TX,OK, MT	Dry areas	75-140
hirsutus		4	TX,OK	Dry open areas	63-140
decapetalus		4	TX,IN,IL	Shaded woodlands	60-140
x multiflorus[a]		1	IN	Cultivated only	Much
eggertii		11	TN	Barrens	127
strumosus		7	OK,NC,AL,TN	Variable	65-140
tuberosus		11	TX,IA,IL,OK,SC.AL	Variable	50-140
rigudus	rigidus	7	TX,OK,NC,IC,CO	Prairies	63-100
	subrhomboideus	1	CO	Dry prairies	38-90
x laefilorus[a]		6	TX,NE,KS,NC	prairies	75-115
giganteus		1	MN	Wet areas	50-140
grosseserratus		16	TX,KS,NE,IN,OK	Prairies	50-127
nuttallii	nuttallii	5	CO,UT	Wet areas	12-76
	rydbergii	1	ND	Sand	50
	parishii			Swampy areas	25
maximiliani		30	TX,NM,KS,NE,AL,AR	Prairies	25-127
salicifolius		5	TX,KS	Alkaline soils	76-115
californicus		2	CA	Wet areas	25-127
resinosus		1	MS	Variable	127-178
schweinitzii		2	NC	Sand	115

Table 1 contd.

1	2	3	4	5	6
microcephalis		2	SC	Variable	76-180
glaucophyllus		1	NC	Semishade	115-152
laevigatus		1	VA	Shale-barrens	90-127
smithii		1	NC	DRy areas	127-200
longifolius		1	AL	Variable	127-150
angustifolius		10	TX,AL,GA	Wet areas	90-175
simulans		1	FL	Variable	140-150
floridanus		2	FL	SAnd	127
silphioides		2	OK,FL	Variable	114-140
atrorubens		6	MS,GA,SC,NC	Variable	114-127
heterophyllus		1	MS	Wet sand	127-152
radula		3	FL	Wet sand	127-152
carnosus		2	FL	Wet sand	127
imbaburensis		1	Equador	?	0

[a] Hybrids common enough to be recognized.

Annual species of this section usually occupy open habitats.

Section Annui contains:

1. *H. annuus* L., common annual sunflower (n=17),
2. *H. agrestis* Pollard, rural sunflower (n=17),
3. *H. anomalus* Blake, anomalous sunflower (n=17),
4. *H. argophyllus* Torrey and Gray, silver-leaf sunflower (n=17),
5. *H. bolanderi* Gray, Bolanders sunflower (n=17),
6. *H. debilis* Nuttall, weak sunflower (n=17),
   - *H. debilis* Nuttal subsp. *cucumarifolius* (T. and G.) Heiser, cucumber-leaf sunflower (n=17),
   - *H. debilis* Nuttall subsp. *debilis* Nuttall, beach sunflower (n=17),
   - *H. debilis* Nuttall subsp. *tradiflorus* Heiser, slow-flowering sunflower (n=17),
   - *H. debilis* Nuttall subsp. *vestitus* (Wutson) Heiser clothed sunflower (n=17),
   - *H. debilis* Nuttall subsp. *silvestris* Heiser, forest sunflower (n=17),
7. *H. deserticola* Heiser, desert-inhabiting sunflower (n=17),
8. *H. exilis* Gray. Thin (serpentine) sunflower (n=17),
9. *H. (=Viguiera)* ludens Shinners, playing sunflower (n=17),
10. *H. neglectus* Heiser, Neglected sunflower (n=17),
11. *H. niveus* (Benth.) brandegee, snowy sunflower (n=17),
    - *H. niveus* (Benth.) Brandegee, subsp. *canescens* Heiser, gray sunflower (n=17),
    - *H. niveus* (Benth.) Brandegee, subsp. *niveus* (Benth.) Brandegee, snowy Sunflower (n=17),
    - *H. niveus* (Benth.) Brandegee, subsp. *tephrodes* (Gray) Heiser, ash-Colored sunflower (n=17),
12. *H. paradoxus* Heiser, paradoxical sunflower (n=17),
13. *H. petiolaris* Nuttall, petioled (prairie) sunflower (n=17),
    - *H. petiolaris* Nuttall, subsp. *fallax* Heiser, deceptive sunflower (n=17),
    - *H. petiolaris* Nuttall, subsp. *petiolaris* Nuttall, petioled sunflower (n=17),
14. H. praecox Engleman and Gray, premature sunflower (n=17),
    - *H. praecox* Engleman and Gray subsp. *hirtus* Heiser, premature rough sunflower n=17),
    - *H. praecox* Engleman and Gray subsp. Praecox Engleman and

Gray, (n=17),
- *H.praecox* Engleman and Gray subsp. *runyonii* Heiser, javelin sunflower (n=17),
15. *H.* *(=Viguiera)* *similis* (Brandegee) Blake, similar sunflower.

II. Section Ciliares

These are Western North American perennials of low stature. Plants lack rhizomes and develop from tap roots or long lateral roots. Leaves are mostly or all opposite (21,51).

A. Series Ciliares

This series is composed of 3 species of western perennials. Plants develop from long, abundant lateral roots. Leaves are usually bluish or grayish nearly hairless, and either lack or have very short petioles (51).

1. *H.* *arizonensis* R.Jackson, Arizona sunflower (n=17),
2. *H.* *ciliaris* DC, Hair-lik sunflower (n=34),
3. *H. laciniatus* Gray, Jagged-edge sunflower (n=17),

B. Series Pumili

Series Pumili is composed of 3 western perennials, taprotted sunflower species. New plants grow from buds at base of old stem. Leaves usually have rough or stiff hairs (21, 51).

1. *H. cusickii* Gray, Parsnip-root sunflower (n=17),
2. *H.* *gracilentus* Gray, Slender sunflower (n=17),
3. *H.* *pumilus* Nuttall, Dwarfish sunflower (n=17),

III. Section Divaricati

Species are perennials (except *H. porteri*), primarily from eastern and central United States and Canada. New plants grow from rhizomes, tubers or crown buds. Leaves are mostly lance-to egg-shaped. Disk corollas with yellow lobes except for seven species (21, 51).

A. Series Augustifolii

Species of this series have resemble fibers or thick roots or well developed rhizomes. Stems are hairy and have mostly alternate, linear to lance-shaped leaves with rolled-under margins. Disks are small to medium-sized, with yellow or purple-lobed corollas. Bracts are narrow. Seeds are from 2-3 mm long. Species are found primarily in south eastern states (52).

1. *H. angustifolius* L., Narrow-leaf sunflower (n=17),
2. H. floridanus Gray ex Chapman, Florida sunflower (n=17),
3. H. similans Watson, Lmitative sunflower, (n=17).

B. Series Atrorubentes

Species of this series have fibrous or cordlike roots that usually lack rhizomes. Basal rosette leaves are well-developed, while stem leaves may be few and small disk lobes are almost always purple. Seeds are from 3 to 5 mm long and are often black. Species occur mostly in south eastern states, and all are perennial (51).

1. *H.* *atrorubens* *L.*, Dark-head sunflower, (n=17),
2. *H.* *carnosus* Small, Fleshy sunflower (n=17),
3. *H.* *heterophyllus* Nuttall, Different-Leaf sunflower, (n=17),
4. *H.* *radula* (Purch) Torrey and Gray, Scraper sunflower, (n=17),

C. Series Divaricati

Series Divaricati has roots fibrous to coarse, with tubers mostly lacking. Rhizomes usually long and slender, sometimes becoming terminally enlarged. Leaves are usually lance-shaped to ovate, 3-veined, and mostly opposite. Stem leaves well developed except in *H.*

occidentialis and sometimes in *H. rigidus*. Disk flowers are variable in size and have yellow lobes, except in *H. rigidus*. Achenes are from 3-6 mm long (21, 51).

1. *H. decapetalus* L. Ten-Petals sunflower, (n=17 or n=34),
2. *H. multiflorus* L. Many-flowers sunflower (All plants are sterile triploids),
3. *H. divaricatus* L., Divergent sunflower (n=17),
4. *H. eggertii* Small, Eggert's sunflower (n=51),
5. *H. hirsutus* Rafinesque, Rough sunflower (n=34),
6. *H. mollis* Lambert, Soft sunflower, (n=17),
7. *H. occidentalis* Riddel, Western sunflower, (n=17),
   - *H. occidentalis* Riddell, subsp. *occidentalis* Riddell, Western sunflower, (n=17),
   - *H. occidentalis* Riddell, subsp. *plantagineus* (T. and G.) Heiser, branching Western sunflower (unknown),
8. *H. rigidus* (Cass.) Desf., Stiff Sunflower (n=51),
   - *H. rigidus* (Cass.) Desf., Subsp. *rigidus* (Cass.) Desf., Stiff sunflower (n=51),
   - *H. rigidus* (Cass.) Desf., subsp. subrhomboideus (Rydb.) Heiser, Nearly 4-sided sunflower, (n=51),
9. *H. xlactiflorus* Pers., Cheerful sunflower (n=51?),
10. *H. strumosus* L., Swollen sunflower (n=34, N=51),
11. *H. tuberosus* L., Tuberosus sunflower (Jerusalem Artichoke), (n=51).

D. Series Gigantei

The tallest sunflowers occur among species of this series. Roots usually become enlarged, often tuber-like, and produce short, stout rhizomes less than 15 cm long. Stem leaves are well developed. Leaves are mostly alternate, usually lanceolate and single-veined. Disk small to large. Lobes of disk-corolla are yellow, except in *H. salicifolius*. Seeds are 4-5 mm long. All species of series Gigantei are perennial (21,51).

1. *H. clifornicus* DC., California sunflower, (n=51),
2. *H. giganteus* L., Gigant sunflower (n=17),
3. *H. grosseserratus* Martens, Thick-tooth sunflower, (n=17),
4. H. maximiliani Schrader, Maximilian sunflower, (n=17),
5. *H. nuttallii* Torrey and Gray, Nuttall's sunflower, (n=17),
   - *H. nuttallii* Torrey and Gray, subsp. *nuttallii* Torrey and Gray, Nuttall's sunflower (n=17),
   - *H. nuttallii* Torey and Gray, subsp. *parishii* (Gray) Heiser, Parish's sunflower, (n=17),
   - *H. nuttallii* Torrey and Gray, subsp. rydbergii (Britton) Long, Rydberg's sunflower (n=17),
6. *H. resinosus* Small, Resinosus sunflower (n=51),
7. *H. salicifolius* Dietr., Willow-leaf sunflower (n=17),
8. *H. schweinitzii* Torrey and Gray, Schweinitz's sunflower, (n=51).

E. Series Microcephali

This series contains 5 perennial and 1 annual species of sunflower. Roots fibrous to coarse, not tuberous. Rhizomes lacking, poorly developed or short and thick.
Stems are usually glabrous, but sometimes they may be covered with a whitish bloom. Stem leaves are well developed except in *H. longifolius*, becoming alternate above. Disks are small. Lobes of disk corolla yellow. Seeds are 2-4 mm long (21, 51).

1. *H. glaucophyllus* Smith, White leaf sunflower, (n=17),
2. *H. laevigatus* Torrey and Gray, Smooth sunflower, (n=34),
3. *H. longifolius* Purch, Long-Leaf sunflower, (n=17),
4. *H. microcephalus* Toprrey and Gray, Small-headed sunflower, (n=17),
5. *H. porteri* (A. Gray) Heiser, Porter's sunflower. (n=17),

6. *H. smithii* Heiser, Smith's sunflower, (n=17).

Seed Germination of *Helianthus* Species

The seeds of cultivated species usually germinate more readily and more evenly than those of the most nearly related wild type(21). The germination of seeds of the cultivated strains of *H. annuus* approaching 100%, and generally all of them germinate readily. Under the same conditions, seeds of wild *Helianthus* species usually do not germinate or rarely do as much as 20%. To secure better gemrination, various methods have been attempted. Successful method for annual species was to plant the seeds in pots which are then set outside for 3-4 weeks where they are exposed to varying temperatures, including alternate freezing and thawing. Germination was still very irregular. This method has not proved very successful for the desert annuals *(H. anomalus and H. deserticola)*. For them, various other methods including wetting and drying, washing in several changes of water and soaking for several days have been tried, but germination has seldom reached 10%. Germination of perennials shows considerable variability. *H. grosseserratus* and some other give rather high percentages after a three weeks cold treatment, but most of the other species give very low percentages of germination (21).

Pollination Biology

With the exception of *H. agrestis*, one strain of *H. argophyllus* and certain cultivated strains of *H. annuus*, all species are self-incompatible with obligate cross-pollination (21). The method for determining self-incompatibility was not discussed. From observations in the field and in the experimental garden it is obvious that bees, including the honey bee, are the principal pollinators. Butterflies visit *Helianthus* only occasionally.

Hybridization and Cross-Compatibility Relationships

Interspecific hybridization between the cultivated sunflower *(H. annuus)* and other *Helianthus* species has been of considerable interest because of the potential for utilizing the immense diversity in the genus. The great diversity of the interspecific hybrid progenies with regard to morphological, genetical, physiological, biological, immunobiological reactions, as well as of other properties, represent a most valuable source of germplasm to be used in the individual crop breeding (14).

Among the annuals, only *H. annuus* is known to hybridize to a great extent with other species. The reason is that, most of the other species are allopathic with each other. All of the artificial hybrids between annual species show reduction in fertility, probably resulting from the structural differences in chromosomes so that one might consider that structural rearrangement of chromosomes has played an important role in the speciation. The reduced fertility is seen both in pollen stainability and seed set, with the latter generally running lower than that of the pollen stainability. Pollen stainability is probably the more direct indication of the degree of structural differences in the chromosomes of the two parents. Pollen production directly follows meiosis (21).

Sterility is not the only barrier to gene exchange in the annuals, since many species have their peak of blooming at different seasons and also show ecological differences (21, 14). These two barriers are also prominent among many of the perennials, but strong sterility barriers are poorly developed in the perennials.

Obviously, in the annuals good seed set would be a necessity, whereas in most perennials there would be less selective value of good seed set since the rhizomes provide an efficient means of survival and increase.

Relationships of *Helianthus* species based on crossing results were reported (55), Fig. 1.

Many of the species in the genus, particularly the perennial species, have never been successfully hybridized with the cultivated sunflower. Abortion of the hybrid embryos during early developmental stages has been one of the important barriers preventing interspecific hybridization.

Cultivated *H. annuus* has been successfully hybridized with 12 annual species and more with 7 subspecies (14,21,51,66). The 10 perennial species have been hybridized with *H. annuus*, Table 2.

<u>Sunflower Interspecific Hybridization Using Embryo Culture</u>

The wild *Helianthus* species are potential sources of germplasm for improving the cultivated sunflower (*Helianthus annuus* L.), but many have never been artificially hybridized with the cultivated sunflower, particularly the perennials. Abortion of the hybrid embryos during early developmental stages is an important barrier. The classic solution to this problem is the use of embryo culture, excising the embryo before it has aborted and placing it on nutrient media to grow "in-vitro"

into a seedling capable of supporting itself. Using embryo culture techniques hybrids have obtained between the domestic sunflower as the pollen parent and *H. angustifolius*, *H. argophyllus*, *H. exilis*, *H. gracilentis*, *H. hirsutus*, *H. maximiliani*, *H. niveus* ssp. *tephrodes*, *H. petiolaris* ssp. *fallax*, *H. strumosus*, *H. bolanderi*, *H. giganteus*, and *H. grosseserratus* *(5,6)*.

Embryo culture system using two modifications of Gamborg's B5 medium to produce interspecific *Helianthus* hybrids was developed (6,7). Embryos were successfully excised and cultured 3 to 7 days after pollination. Embryos initial ly developed on a solid medium containing inorganic components, vitamins, amino acids, and 12% sucrose. For embryo germination and seedling growth the cultured embryos were transferred to a liquid medium containing only the inorganic components and 1% sucrose.

Table 2. *Helianthus* species successfully hybridized with cultural annuus.

Helianthus Species	Subspecies	Habit
niveus	canescens	a*
debilis	debilis	a
	vestitus	a
	tardiflorus	a
	silvestris	a
praecox	praecox	a
	runyonii	a
	hirtus	a
petiolaris	petiolaris	a
	falax	a
neglectus		a
annuus		a
argophyllus		a
bolanderi		a
exilis		a
deserticola		a
anomalus		a
paradoxus		a
divaricatus		p
hirsutus		p
decapetalus		p
strumosus		p
tuberosus		p
giganteus		p
maximiliani		p
angustifolius		p
grosseserratus		p
rigidus		p

* a= annual, p = perennial

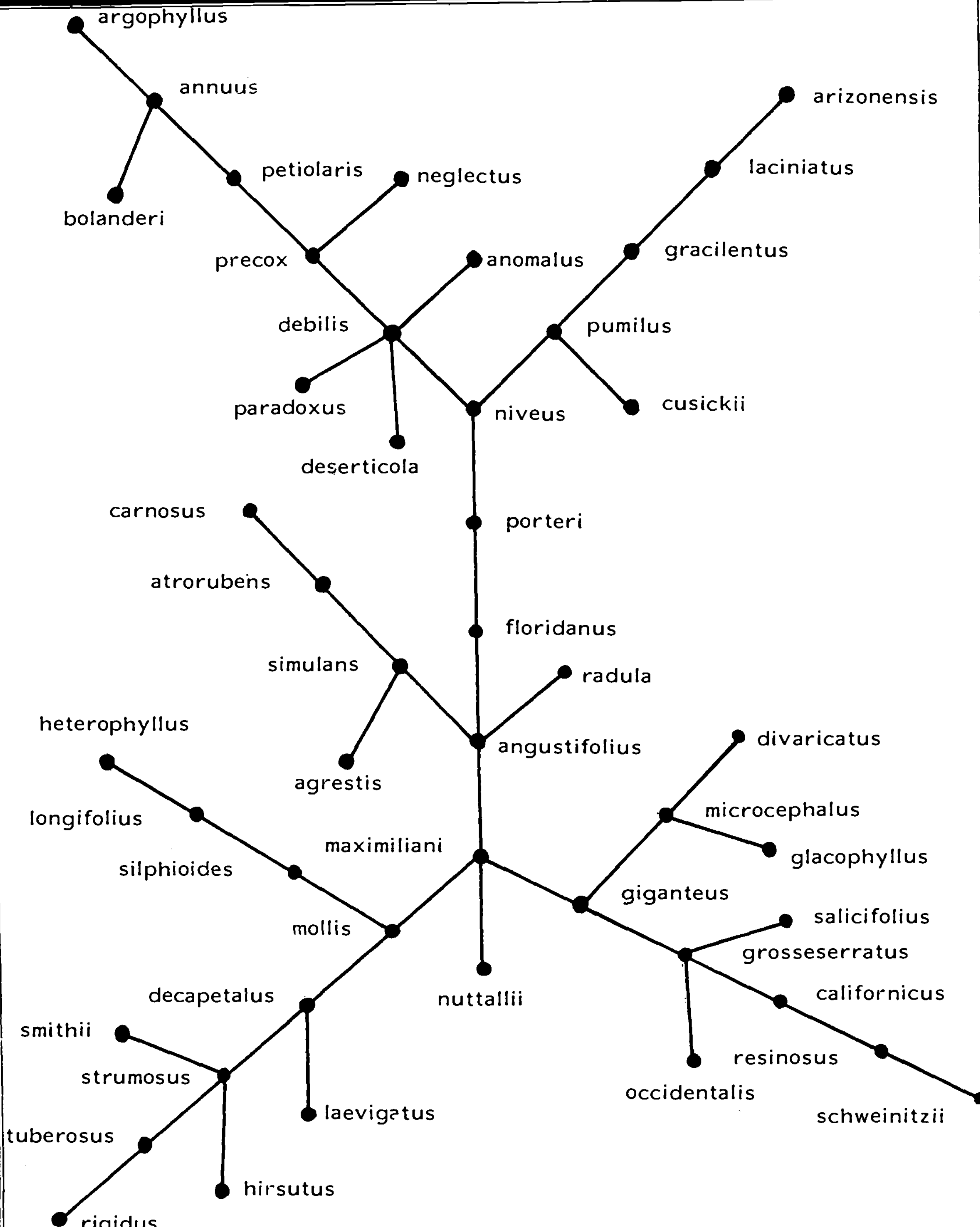

Figure 1: PRIM NETWORK SHOWING RELATIONSHIPS OF HELIANTHUS SPECIES BASED ON CROSSING RESULTS (55).

Experiments have been done using tissue culture techniques on sunflower (18), Table 3. Formation of callus seems feasible, and plants have been regenerated from stem callus.

Vegetative propagation of shoots provides a means of rapid increase of desired genotypes. Developing seeds have been cultured "in-vitro" and embryo culture has greatly facilitated interspecific hybridization.

Table 3. Summary of progress in the tissue culture of *Helainthus annuus* L. (18).

Author	Source tissue	Response
White and Braun, 1931	Secondary grown gall	Isolated bacteria free gall Callus
Hildebrant et al., 1945	- do -	Effect of temp., pH, and sugar
Hildebrant et al., 1974	- do -	Effect of growth hormones
de Roop, 1947	- do - Stem	Root from stem callus
Rogers et al, 1974	Stem	Root from stem callus
Sadhu, 1974	Stem	Plants from stem callus
Chandler and Beard, 1978	Embryo	Culture to plants
Georgieva et al., 1980	Stem	Plants from stem callus
Binding et al., 1981	Apex, leaf	Protoplasts, callus, roots from apex
Silver et al., 1981	Seed	Pest-pollination seed culture
Trifi et al., 1981	Apex, leaf node	Rapid vegetative propagation

The Chromosome Doubling in Sunflower

Wild *Helianthus* species have contributed valuable genes to the improvement of the cultivated sunflower (*H. annuus)*. The large genetic variability preserved in them should continue to play an important role in the future improvement of this crop. Utilization of some of these species is very difficult because of their low crossability with the cultivated sunflower and the high degree of F_1 sterility when hybrids are obtained.

All the interspecific hybrids that have been produced have lower fertility than their parents. The problem apparently revolves around differences in chromosome structure between the various species. This condition disrupts the orderly pairing and segregation of chromosomes during the cell division process. The cultivated sunflower is very different in chromosome structure from most other species. It has been explained (7) why fertility is so low in those hybrids produced by crossing the cultivated sunflower with most of the wild species. Sterility is one obstacle to interspecific hybridization which is not easy to overcome (7). One possible answer lies in artificially doubling the number of chromosomes in the hybrid, which would give each chromosome an exact copy to pair-with so that meiosis can occur in an orderly fashion.

Techniques for doubling chromosomes in sunflower were developed (27). These techniques for doubling chromosomes can be beneficial in two ways. First, doubling the chromosomes of one or both parents have improved interspecific crossability. Second, chromosome doubling of the hybrids is effective in improving the fertility in hybrids where sterility is associated with meiotic abnormalities (inter-specific sunflower hybrids). The most effective technique is: young seedlings at two true- leaf stage were inverted, and their apical meristems were submerged in a colchicine solution of either 0.25% or 0.15% concentration at PH=5.4 with 2% DMSO for five hours. Treated seedlings were then washed and planted in pots in the greenhouse and later transplanted into the field.

Size of pollen is then best criterion for discriminating doubled from undoubled plants since pollen grains from tetraploid heads are substantially larger than from the diploids. Meiotic chromosome examinations on side buds from doubled branches have positively confirmed chromosome doubling.

Using Wild *Helianthus* Species in Breeding for Resistance to Diseases and Pests

Diseases are limiting factors of production in the majority of sunflower-growing countries. Different diseases are dominant in different regions on account of various agro-ecological conditions. The cultivated sunflower has a narrow genetic base and it is deficient in resistance genes. So far, sources of resistance have been sought and found in wild sunflowers. Certain wild species have contributed genes of resistance to *Plasmopara helianthi*, *Puccinia helianthi*, *Verticillium albo-atrum*, and *Verticillium dahliae*. There is yet a large number of diseases for which resistance sources remain to be found. Among those, the most important ones are *Sclerotinia sclerotiorum*, *Phomopsis-Diaporthe helianthi*, *Macrophomina phaseoli*, *Phomopa sp.*, *Alternaria helianthi*, *Botrytis cinerea*, *Rhizopus spp.*, etc. The diversity of *Helianthus* offers possibilities of discovering resistance sources to all diseases.

To accomplish that, breeders should include all available wild species in their programs of sunflower breeding for resistance to pathogenic fungi. This is the only solution to the problem of sunflower diseases since the cultivated sunflower lacks genetic sources of disease resistance. It has been noticed that pathogenic populations undergo genetic change developing new races. It means that the use of wild sunflower in breeding for disease resistance should be considered as continual process. An illustration of this is the occurrence of new races of *Plasmopara helianthi* and *Puccinia helianthi* and successful use of wild sunflowers in discovering new Pl and R genes.

Wild sunflowers are effectively used in breeding for resistance to *Orobanche cumana* which frequently develops new races.

Although insects impose serious problems in sunflower production in North and South America and Africa, the use of wild sunflower in breeding for insects resistance has been insufficient. Best results have been achieved in breeding for resistance to sunflower moth (*Homeosoma nebullella*). In recent years only American breeders have intensified the use of wild sunflower in breeding for resistance to several insect species.

Breeding for Disease Resistance

In the previous paragraphs we mentioned pathogens which have successfully been fought against by means of breeding based on wild sunflowers. In this chapter, we shall review several sunflower pathogens, the extent of wild sunflower use in breeding for resistance to them, and further prospectives in breeding opened up by wild sunflowers.

Plasmopara helianthi: A great break thorough in the breeding for resistance was the discovery of Pl genes which bring genetic resistance to downy mildew. The line AD-66 was the first source of Pl_1 genes. The line was derived from Canadian material (Advent) which had been developed on the basis of wild sunflowers(69). The sources of Pl_2 gene were also wild sunflowers (81), as well as the sources of Pl_3 and Pl_4 genes (71,74).

A possibility of developing new varietal populations on the basis of *H. tuberosus*, which are resistant to downy mildew (Pl_2 and Pl_5 ?) was found (42). The new varieties (Yubilejnaya 50, Progress and October), developed by interspecific hybridization, enlarged the genetic variability of the domesticated sunflower.

A new race of downy mildew discovered in the U.S. in 1980 was found to be widespread (11). Selected lines with known genes for world in-breeding resistant cultivars were all susceptible to the new race. Three sources of resistance were identified among more than 400 diverse sources of germplasm. These sources originated from the Soviet cultivar Progress, an NS hybrid from Romania and a cross of an ornamental sunflower possessing red ray flowers and ligulate disk flowers (12).

Progress and NS hybrids, which are downy mildew resistant have been derived from *H. tuberosus*.

Puccinia helianthi: Rust is the most extensively studied sunflower disease. Breeding for resistance has been successful in spite of the changes in the pathogen's population. Sunflower resistance to the discovered four races of rust is controlled by four independent dominant genes (R_1, R_2, R_3 and R_4. It was reported that all lines having resistance to rust have been derived form wild sunflowers (28,39). A large number of wild species possesses genes of resistance to rust (41). These species are diploid, tetraploid, or hexaploid. Although several genetic sources of resistance to rust are available, the disease inflicts considerable damages in North and South America, Africa, and Australia because of genetic changes in the pathogen population and the appearance of new races.

Phomopsis (Diaporthe) helianthi: Stem canker is a new sunflower disease which displays a tendency of rapid spreading in a large number of sunflower-growing countries, threatening to jeopardize the sunflower production as a whole. Only few years ago, the pathogen has been outside the scope of interest and work of sunflower breeders. It perhaps explains why the entire assortment of presently grown sunflower varieties and hybrids lack sources of resistance to stem canker. It was reported that the cultivated sunflower does not possess resistance to stem canker (63).

Sources of resistance to the pathogen should be searched for in wild sunflowers. A study of Cuk, which is still in due course, showed that stem canker was not found in the following wild species: *H. tuberosus*, *H. resinosus*, *H. decapetalus*, *H. divaricatus*, *H. eggertii*, *H. giganteus*, *H. grosseserratus*, *H. hirsutus*, *H. mollis*, *H. salicifolius*, *H. nuttallii*, *H. radula*, etc.

There are some indications that sources of resistance to stem canker may be expected to be found in *H. tuberosus*.

Alternaria helianthi: Studies conducted so far have indicated the lack of genetic sources of resistance to this pathogen in the cultivated sunflower. Resistance should thus be searched for in wild sunflowers. A total of 21 annual and 37 perennial *Helianthus* species and subspecies and a closely related annual taxon *Tithonia rotundifolia* have been tested for resistance to *A. helianthi* in the greenhouse (32). All the annual species were susceptible. The perennial *Helianthus spp.* were susceptible except for *H. hirsutus Ref.*, H. rigidus subsp. *Subrhomboideus* Heiser, and *H. tuberosus* L. which were moderately resistant. This resistance is transferable to the cultivated

sunflower (*H. annuus)* by backcrossing of inbred lines with the resistant perenial species. C u k arrived at similar results which have not been published yet.

The testing of wild sunflowers, especially perennial ones, for genetic sources of resistance to *A. helianthi* should be accelerated, making use of the largest possible genetic variability within each wild species. Besides determining sources of resistance to *A. helianthi*, it is also necessary to design the most suitable methods of incorporating resistance genes in the cultivated sunflower since the resistance genes appear to be present in wild hexaploids.

Sclerotinia sclerotiorum: Sclerotinia stem-and head-rot is one of the most widespread and destructive diseases of vegetable and field crops. It has a very wide host range including Brassicas, legumes, and many vegetable and weed species.

The currently grown sunflower varieties and hybrids are not genetically resistant to *S. sclerotiorum*. Nevertheless, a number of reports has appeared in recent years indicating the existance of differences in the degree of susceptibility among the varieties and hybrids.

The variety Yubilejnaya 60 should be resistant to *S. sclerotiorum* (42). However, the variety performs otherwise when grown in field. The same authors reported the following wild species as suitable materials for breeding for resistance to *Sclerotinia* stem- and head-rot: *H. tomentosus, H. lactiflorus, H. scaberimus, H. divaricatus, H. tuberosus, H. macrophyllus* and *H. rigidus.*

Dr. C.A. Thomas (USDA-ARS, Beltsville, MD) informed the author of these pages in personal contact to have found a source of resistance to *S. sclerotiorum* (basla stem infection) in *H. tuberosus,* controlled by three dominant genes.

It is evident that, of all sunflower diseases Sclerotinia rot will be the most difficult to find genetic sources of resistance.

Verticillium wilt: The first source of genetic resistance developed to *Verticillium albo-atrum,* discovered in the line CM-144, came from an interspecific hybrid (37). The existance of sources of resistance to *Verticillium dahliae* in *H. tomentosus* was reported (42).

Phoma sp.: It was reported that the resistance to *Phoma sp.* appears to exist in the following wild sunflowers: *H. gigantheus, H. argialis, H. tomentosus, H. tuberosus, H. macrophyllus, H. rigidus,* and *H. subcanescens,* (41,42), Table 4. The newly developed variety, Yubilejnaya-60 was reported to be resistant to *Phoma sp* (42). According to unpublished data of Skoric, only certain genotypes within the variety Yubilejnaya-60 display resistance to *Phoma sp.*

Resistance to Phoma sp. in wild sunflower has been insufficiently studied. Studies carried out presently in several countries should give a more complete picture on the resistance of wild sunflowers to *Phoma sp.* and on the possibilities of wild sunflowers use in the development of resistant varieties and hybrids.

Rhizopus head-rot: It is one of the most important sunflower diseases, especially in arid regions. The pathogens of *Rhizopus* head-rot are *R. arrhizus* Fischer, *R. oryzae* Went. and *R. stolonifer* Vuill. *Rhizopus arrhizus* is more prevalent and virulent than *R. oryzae* or *R. stolonifer.*

The cultivated sunflower genotypes do not possess genetic resistance to *Rhizopus* head-rot. Resistance of wild *Helianthus* species to *Rhizopus* spp. has not been sufficiently studied. It was found that four of 32 tested wild species and subspecies were resistant when inoculated separately with *R. arrhizus* and *R. oryzae (H. divaricatus, H. hirsutus, H. laetiflorus,* and *H. resinosus) (80).* Studies of wild sunflower resistance to Rhizopus head-rot should be continued in order to find sources of resistance to this group of pathogens.

Erysiphe cichoracearum: Although the disease caused by this pathogen, powdery mildew does not bring economic damages to sunflower at present, it is nevertheless desirable to work on the determination of resistance genes in wild sunflowers and their introduction in the cultivated sunflower.

Three annual species or subspecies (*H. bolanderi, H. debilis subs. silvestris, H. praecox subsp. praecox)* and 14 perennial species of sunflower were resistant to *E. cichoracearum* which causes powdery mildew of sunflower in file and greenhouse tests (56). *H. grosses-serratus* and *H. maximiliani* collected from some location were resistant but from other locations were susceptible to *E. cichoracearum.*

Obviously, there exist several sources of resistance in annual and perennial wild species. In breeding for resistance to powdery mildew, however, preference should be given to the annual species because they are more easily crossed with the cultivated sunflower.

We have limited knowledge of the genetic base of resistance to powdery mildew in wild sunflowers. We know that we deal with dominant genes but we do not know their number.

Orobanche cumana: The genetic sources of resistance to *O. cumana* were derived mostly from wild sun flowers.

Table 4. Phytopathological estimates of wild *Helianthus* species (41).

Species	2n	*Plasmopara helianthi* (%)	*Puccinia helianthi* (%)	*Phoma* sp. (%)	*Orobarche cumana* (%)	Armour layer (%)
H. debilis Nutt.	34	100	100	90	100	100
H. lenticularis Doug.	34	100	100	70	100	100
H. arhophyllus T.et C.	34	100	100	90	100	100
H. petiolaris Nutt.	34	100	100	20	100	100
H. mollis Lam.	34	0	0	30	0	100
H. giganteus	34	16.60	0		0	100
H. grosseserratus Mart.	34	35.70	10		0.45	100
H. maximiliani Schard	34	0	0	50	0.5	100
H. nuttalli T.E G.	34	0	0	10	0.4	100
H. trachelioflorus Miller	34	0	0	100	100	
H. californicus D.C.	34	0	0	400	100	
H. multiflorus Hook.	34	0	0	30	0	100
H. arhialis D.C.	34	14.20	0		0	100
H. divaricatus	34	11	0	10	0	100
H. tomentosus Mich.	68	15.50	0		1.9	100
H. leatiflorus Pers.	68	25	0	10	1.3	100
H. scaberimus Elt.	68	22	0	20	0	100
H. tuberosus L.	102	0	0	0	0	100
H. macrophyllus Wild	102	0	0	0	0.56	100
H. rigidus (Coss) Desv.	102	0	0	0	0	100
H. subcanescens Gray	102	0	0	0	0	100

Several varieties were developed (42) on the basis of *H. tuberosus* which were resistant to the new population of broomrape, Yubilejnaja-60 being the most prominent among those varieties. Five different genes which bring resistance to the popualtion of *O. cumana* which are presnet in Romania were determined (68). Some of the genes originated from interspecific hybrids.

Breeding for Insect Resistance

Several hundreds of insect species are associated with sunflower. Only a few insect species are economically important as pest to the cultivated sunflower (61). Although host resistance has played a major role in the management of diseases in sunflower (83), there has been little emphasis on resistance as a management tactic for insect pests. *Homeosoma* species are serious pests of cultivated sunflower in four continents. *Homeosoma nebulella* (Hubner) attacks sunflower in Europe and Asia. Sunflower in South America is damaged by *H. heinrichi (Pastrana)*. In Mexico, the U.S. and Canada, *H. electellum* (Hulst) is a major pest nearly everywhere the crop is grown.

Resistance of sunflower varieties to the European sunflower moth (*H. nebulella)* was obtained 40-45 years ago in the USSR by interspecific hybridization of *H. annuus* cultivars with *H. tuberosus var. purpurellus*, Cockerell. The resistance mechanism giving protection against *H. nebulella* is a phytomelanin (armor) layer in the wall of the achenes. This resistance is controlled by a single dominant gene.

The North American sunflower moth, *H. electellum* appears to be more virulent toward cultivated sunflower than *H. nebulella*, and American sunflower breeders have largely discounted the importance of the phytomelanin layer as an effective resistance mechanism.

It was shown (51) that 20% of the larvae *(H. electellum)* were recovered after 5 days on *H. arizonensis*, *H. ciliaris*, *H. decapetalus*, *H. grosseserratus*, *H. maximiliani*, *H. microcephalus*, *H. pumilus*, *H. resinosus*, *H. rigidus x laetiflorus*, *H. silphioides* and *H. smithii* than on hybrid 896. Also, larval growth was more significantly reduced on *H. arezonensis*, *H. ciliaris*, *H. decapetalus*, *H. grosseserratus*, *H. maximiliani*, *H. pumilus*, *H. resinosus*, *H. rigidus x laetiforus*, *H. silphioides* and *H. smithii* than on hybrid 896. Floral injury was significantly lower on *H. arizonensis*, *H. ciliaris*, *H. decapetalus*, *H. divaricatus*, *H. grosseserratus*, *H. maximiliani*, *H. mollis*, *H. nuttallii*, *H. occidentalis* subsp. *Plantagineus*, *H. pumilus*, *H. rigidus x laetiflorus*, *H. silphioides*, *H. smithii* and *H. strumosus* than on hybrid 896.

Two annual and 10 perennial *Helianthus* species were significantly more resistant to the aphid *Masonaphis masoni* (Knowlton), (47,50). These were the other species or the hybrid 896-control (43,46). After 1 month, mortality of *M. masoni* was 100% on *H. carnosus* Small, *H. exilis* Gray, *H. floridanus* Gray ex Champan, and *H. radula* Torrey and Gray.

Adults of the carrot beetle (*Bothynus gibbosus*, Dr. Gear) did significantly more damage to roots of hybrid 896 than to roots of *H. tuberosus*, *H. maximiliani*, *H. niveus*, *H. x laetiflorus*, *H. salicifolius*, *H. mollis*, *H. grosseserratus*, *H. argophyllus* or *H. ciliaris* (47).

Wild sunflowers may successfully be used for the determination of sources of resistance to pests, Tables 5 and 6 (44,45,47). The results indicate some wild species to be resistant to *Zygogramma exclamations*, *Bothynus gibbosus*, *Masonaphis masoni* and *Empoasca abrupta*. *H. tuberosus*

Table 5. Relative resistance of *Helianthus* species, Section *Divaricati* to four species of insects in laboratory feeding tests (45).

Helianthus species	Cross compatible w/annuus	Insect species**			
		Zigogramma exclamation	*Bothynus gibbosus*	*Masonaphis masoni*	*Empoasca abrupta*
Angustifolii					
angustifolius	no	++	0	++	+
floridanus	no	+++	0	+++	++
simulans	no	+++	+	++	+
Atrorubentes					
atrorubens L.	no	+++	+	+++	+
carnosus	no	+++	+	+++	+
heterophyllus					
nuttall	no	+++	++	++	
radula	no	+++	+	+++	++
silphioides	no	+++		+	
Divaricati					
divaricatus L.	no	+++	++	+	
molis	no	+++	++	++	+
occidentalis					
occidentalis	no	++	++	++	
occidentalis					
plantagineus	no	+	++		
rigidus + laetiflorus	no	+++	+++		
strumosus	yes	+++			
tuberosus	yes	+++	+	+++	+
Gigantei					
californicus	no	0			
giganteus	yes	0			
grosseserratus	no	+++	++	++	+
maximiliani	yes	+++	++	+	++
nuttallii nuttallii	no	++	++	++	+
risnosus	no	+++	++		
salicifolius	no	+++	++	++	
Microcephali					
glaucophyllus	no		+		
longifolius	no	+++	+++	+	
porteri*	no	+++	++	++	
Hybrid 896 (check)	0	0	0		0

* Annual, all other species are perennial;
** +++ Plants immune to attack or caused 100% mortality to insect;
++ Plants significantly mor resistant than the hybrid check at 1% level;
+ Plants significantly more resistant than the hybrid check at 5% level;
0 Plants no more resistant than the hybrid check.

and *H. maximiliani* displayed the widest spectrum of resistance to the above pests of all wild sunflower which may be crossed with domesticated sunflower.

<u>Utilization of Wild Sunflower Species for Discovering New Sources of Cytoplasmic Male Sterility and Restorer Genes (Rf)</u>

Compared with corn, the practical utilization of heterosis in sunflower started much later because of its bisexual flowers. First CMS hybrids were developed by using interspecific hybridization. The major contribution in this field was the discovery of the first source of cytoplasmic male sterility in a cross of *H. petiolaris* and the domesticated sunflower (29). All sunflower hybrids available have been developed on the basis of this CMS source. More recently another CMS source was discovered coming from *H. lenticularis* (3). A comparative study of these two CMS sources was undertaken and confirmed that those were two separate CMS sources (31).

Having succeeded in discovering CMS sources on the basis of interspecific hybridization, attention was turned to the discovery of Rf genes in wild sunflowers. The existance of restorer genes in *H. petiolaris was reported (30).* The restorer genes in population of wild *H. annuus*, and *H. petiolaris* were found (10).

Different sources of restorer genes were discussed (70), and restorer lines derived from H. tuberosus were mentioned. H. tuberosus-based restorer lines resistant to downy mildew (pl $_2$ gene) were developed (64).

Restorer genes were found in wild *H. exilis* and *H. argophyllus (8)*, and in *H. argophyllus*, *H. rigidus* and *H. bolanderi* (54).

The work on the determination of restorer genes in wild sunflower species is in due course in a number of research centers around the world. It may be expected that restorer genes will be found in a large number of wild sunflower.

Table 6. Relative resistance of *Helianthus* species, Section *Annui*, to four species of insects in laboratory feeding tests (45).

	Insert species***			
Helianthus species*	*Zigogramma exclamation*	*Bothynus gibbosus*	*Masonaphis masoni*	*Empoasca abrupta*
agrestis Pollard	+++0	0	0	
annuus	++	0	0	0
argophyllus	++	+	-	-
bolanderi	+++0	++		
debilis debilis				
nuttall			-	
debilis silvestris	0	+	0	
deserticola Heiser		-		
exilis	+++0	+++	+	
neglectus	++	+	-	+
niveus canescens	+++++	0		
*niveus tephorodes***			++	+
paradoxus	++		-	0
petiolaris fallax Heiser		0	0	
petiolaris petiolaris	++	0	-	
praecox hirsutus	++	0	-	+
praecox praecox			-	
praecox ranyonii		+		
Hybrid 896 (check)	0	0	0	0

* All these species are cross compatible with *annuus* cultivars

** Perennial all other species and subspecies are annuals.

*** +++ Plants immune to attack or cause 100% mortality to insects;
++ Plants significantly more resistant than the hybrid check at 1% level;
+ Plants significantly more resistant than the hybrid check at 5% level;
0 Plants no more resistant than the hybrid check.

A new source of male-sterile cytoplasm in a cross of *H. giganteus* and *H. annuus* was found (77). Crosses between an inbred tester line without genes for pollen fertility restoration as the pollen parent and the existing source of male-sterile cytoplasm or four putative male-sterile backcross lines as the female parents, failed to restore pollen shed in 15 F_1 families evaluated. In similar crosses, using three pollen fertility restorer sources as the pollen parents, pollen shed was restored in male-sterile backcross lines by only one of the three pollen restorer sources, suggesting that the backcross substitution lines from *H. giganteus* are a new source of male-sterile cytoplasm which has been designated as CMS_3.

Another new source of cytoplasmic male sterility from *H. petiolaris* was obtained (80). Crosses between seven sources of pollen fertility restorer and the existing source of CMS, resulted in a high frequency of plants with normal pollen shed in all F_1 progenies. However, no normal pollen shed was evident in F_1 progenies for similar crosses between BC_5 male-steriles and three of the seven restorer sources, nor for the simple wild *H. annuus* evaluated. The foregoing suggests that the backcross substitution lines are a new source of CMS. The inheritance of restoration of pollen shed was complex and not fully elucidated. Some data suggested that two independent, complementary, dominant genes were required, but others indicated two to three independent, dominant genes.

Another source of cytoplasmic male sterility from *H. maximiliani* was obtained (76), while new sources of CMS from *H. petiolaris, H. giganteus* and *H. maximiliani,* as germplasm composite crosses CMG-1, CMG-2, and CMG-3 were registered (78).

Another new source of CMS from cross of *H. annuus* subsp. *lenticularis* and *H. annuus* L. cv. Commander was reported (22). Crosses of the male sterile plants to HA 89, known to be a maintainer of Leclercq's cytoplasmic male sterile sunflower restored pollen production. Crosses with RHA 265, known to be a restorer of Leclercq's CMS sunflower gave an F_1 male sterile plants. In addition to RHA 265, RHA 266 also serves as a maintainer of the line, designated indiana-1. Genes for pollen restoration are found in Hopi, Outlook, Perecovic, P.1. 176576, Record and Seneca, as well as in HA 89 and the original wild type. A suggestion was given for the use of CMS_1 to designate Leclercq's line and CMS_2 and CMS_3 to designate the lines developed by him; accordingly, Indiana-1 may be tentatively designated CMS_4 (77).

The determination of new CMS sources is very important, because all institutions engaged in the development of sunflower hybrids use the same source. There exists a possibility of mutual dependence between sterile cytoplasm and genes carrying susceptibility to a disease. Since all hybrids grown have the same CMS source. The pathogen's population may increase and cause devastating yield reductions. It is therefore a must to intensify the work on the determination of new CMS sources and new sources of restorer genes in wild sunflower species.

Utilization of Wild Sunflowers in Changing the Ideotype of Cultivated Sunflower

The previous chapter discussed the use of wild sunflowers in breeding for resistance to diseases and insects, which are limiting factors in sunflower production. The existing variability within the cultivated sunflower does not allow the development of ideotypes for different agro-ecological conditions. Fortunately, the variability observed in wild sunflowers opens new ways to designing different sunflower ideotypes.

The existing variability within the cultivated sunflower allows the development of inbred lines with insufficient heterotic effect for grain yield. Analyzing results of the long-term FAO trial on sunflower varieties and hybrids, it was noticed that there were no cultivars which would significantly outyield the conventional varieties, e.g., Peredovic. The problem revolves around narrow genetic variability for grain yield in the cultivated sunflower. A breakthrough can be made only by increasing genetic variability of the cultivated forms by means of wild *Helianthus* species.

One of the principal targets in sunflower breeding is a change in the architecture of the photosynthetic apparatus. It is desirable to shorten the period of attaining the maximum leaf area in parent lines and hybrids alike, to prolong leaf area duration (LAD), and to increase the efficiency of net assimilation rate (NAR). It is necessary to optimize the foliar orientation towards the sun, CO_2 uptake from the air, and aeration of the crop by altering the number and position of leaves on the stem. High genetic variability in wild sunflowers warrants the desired changes of the photosynthetic apparatus feasible. If we consider the differences in the photosynthetic apparatus of *H. mollis, H. argophyllus, H. salicifolius, H. radula, H. maximiliani*, etc., we may get an idea of the extent of genetic manipulations with leaf number, form, activity, and other characters.

Sunflower crop spreads rapidly in arid regions. The cultivated sunflower does not ensure profitability of such production in all cases. There are, however, wild sunflowers which grow in extremely dry conditions and which could be used to step up drought resistance in the cultivated sunflower. Drought resistance is a complex character including resistance to soil and air drought. Breeding for drought resistance implies improvements in the efficiency of the root system, architecture of the basic plant parts, time of maturation, resistance to *Sclerotinia bataticola (M. phaseoli)*, water uptake from the soil, and utilization of taken-up nutrients.

Wild sunflower species have recently been included in a number of research programs dealing with the determination of sources of drought resistance in sunflower. The use of *H. argophyllus* in sunflower breeding for drought resistance was recommended (54). *H. argophullus* and *H. deserticola* are also used by Spanish and Romanian breeders as sources of resistance to drought.

Sunflower crop spreads also in saline soils. Wild sunflowers could again be used to increase resistance, to high PH, of the cultivated sunflower. A study conducted presently in the US has indicated *H. paradoxus* as the most resistant to increased salinity. There are several wild sunflower species that still remain to be tested for this character.

It is well-known that a system of self-incompatibility contributes to the high level of cross-pollination in open-pollinated cultivars of sunflower (*H. annuus* L.). It was reported that a sporophytic incompatibility system was present in the cultivated sunflower (19) with the conclusion that at least two multi-allelic loci governed self-incompatibility and expression was influenced by physiological factors. It was concluded that self-incompatibility in the cultivated sunflower is complex in both expression and inheritance (67).

Crosses and reciprocals were made between wild sunflower (*H. annuus* L. and the cultivated line P-21 which is self-compatible and consists of equal numbers of the genotypes *msms* and Msms (34). Results indicated that the self-incompatibility is determined sporophytically, and that at least five different "S" alleles were involved. Dominance of allels was expressed in the pollen and in dependent action in the style.

Taking into account the foregoing results and the fact that sunflower production in a number of countries shifts to stress regions, attempts should be made to reduce self-incompatibility and increase self-compatibility in future sunflower hybrids and varieties by including wild sunflowers in breeding programs.

Several authors indicated that *H. agrestis*, *H. radula* and some other wild species should be used for introducing high degree to self-compatibility in the cultivated sunflower (21).

The cultivated sunflower is an open-pollinated crop and insects, primarily bees, play an important role as pollinators. Wild sunflowers may help in increasing the nectar content and attractiveness of the cultivated sunflower. They may also be used for increasing the resistance of pollen to stress conditions. For the later purpose we may use wild sunflowers from dry regions which are well adapted to a variety of stresses.

Wild sunflower species may also play part in increasing oil and protein contents and qualities in the cultivated sunflower.

It had been reported that *H. niveus* and *H. salicifolius* are potential sources of genetic variability to increase oil content in the cultivated sunflower (65,66). Also, the wild annual species may be the best sources of genes to utilize in a breeding program to alter fatty acid composition of sunflower oil (66). Some entries of both subspecies of *H. petiolaris* appear to be valuable genetic resources to increase linoleic acid content, while lowering oleic. *H. paradoxus*, *H. argophyllus*, *H. annuus* and all subspecies of *H. praecox* appear to be good sources of genetic variability to increase the level of palmitic acid if desired.

A current study conducted in Yugoslavia indicated that *H. anomalus* has the largest achenes and the highest oil content. *H. porteri* has the highest content of linoleic acid and *H. arizonensis*, of oleic acid. A detailed analysis of wild sunflower species revealed significant differences in oil content, oil quality, and higher content of fatty acids among them (51) were found (40). High protein contents in seeds of *H. tuberosus* and *H. macrophyllus* were found (40). These two species should be used in breeding. Several authors have found differences in amino acid composition among wild sunflower species.

Utilization of Wild *Helianthus* Species in Breeding for Whole Plant Utilization of Sunflower

The diversity of wild sunflower species and genetic differences in the composition of their seeds, heads, leaves, stems, rhizomes, and tubers offer chances of improving genetic variability of the cultivated sunflower for a number of characters, turning to better use of all parts of the plant.

Interspecific hybridization allows the transfer of favorable characters for different plant parts from wild into the cultivated sunflower. In that way, sunflower plant would be so improved that the whole plant could be turned into economically profitable products. The sunflower stands chances of being not only an oil and protein crop but a versatile crop used for the production of a line of products. The following concise and incomplete review of the diversity of wild sunflowers regarding their chemical composition gives an insight in the possibilities of enriching the cultivated sunflower by means of interspecific hybridization.

Natural rubber from sunflower

Rubber production from sunflower could be an economic bonus. The residue from the plant extraction might also be a useful commodity, since residues of sunflower plants are ranked near the top for btu value. Thus, a facility for processing rubber from sunflower might also be an ideal site for energy production from biomass.

It was reported that *H. hirsutus* contains natural rubber with a molecular weight of 2.79 x 10^5 and polydispersity factor (3.1) which indicates a potential as a source of natural rubber (57), while two wild species, *H. agrestis* and *H. occidentalis* contain 1.6% rubber in their foliar parts (58). Also, *H. radula, H.californicus, H. resinosus* and *H. annuus* gave the highest rubber contents by the gravimetric method (1.45-1.93%), (60). This result indicates that there is a high potential for increasing the rubber content of cultivated sunflower on the basis of wild species.

Special carbohydrates

The sunflower may be a promising source of commercial pectin. Several wild sunflower species are promising as sources of commercial pectin.

H. tuberosus and its hybrids with *H. annuus* are used, world wide, as a source of food. The tubers are rich in starch and sugars, and are being investigated as a biomass crop for ethanol production. They also contain insulin, which is converted in the body to fructose, a sugar which is suitable for use by diabetics.

Phytochemicals

Phytochemical studies on *Helianthus* species to date have led to the isolation and characterization of acetylenes, flovonoids, sesqiterpenoids and diterpendoids. Six new sesquiterpene lactones based on the endesmanolide, transgermacradienolide and heliangolide skeletons from *H. grosseserratus* Mortens were reported (23,24). The diterpenes grandifloric, 17-hydroxy-ent-isokaur-15-enic and ciliaric acid and the flavones hispidulin and pectolinarigenin were also found in *H. grosseserratus*. They have also found four known and the new germacradien-olides and one known heliangolide from *H. pumilus*. The isolation of tifruticin, acetylfructicin, deaxytifruticin, acetyldeoxytifruticin and orizabin analogue and three heliangolides from *H. maximiliani* was also reported (23).

Chloroform extract or *H. rigidus* was found to give ciliaris acid and 16-hydroxy-11-kuren-19-oic acid of *H. salicifolius* (25). It was also reported that sesquiterpene lactones and diterpenoids were found in *H. argophyllus* (73). Three germacranolide sesquiterpene lactones, three diterpenoids, and one flavonoid were isolated and characterized from a chloroform extract of *H. argophyllus*.

Two diterpene carboxylic acids, one new kaurenoid deribative and one previously characterized labdane, (-)cis-ozic acid, as well as a known heliengolide, budlein A, and a known flavonoid hymenoxin from extract of *H. angustifolius* were found (35). The new kanrenoid-type carboxylic acid has been isolated from *H. ciliaris* and *H. salicifolius*.

Two diterpenoids were isolated from the wild sunflower species *H. occidentalis (59). H. occidentalis* is resistant to sunflower insect pests and various diterpenoid acid have shown antibiotic activity to several insect species (59). The presence of cis- and trans- ozic acid contributes perhaps to host plant resistance.

Structurally related sesquiterpene lactones from phylogenetically related taxa have been shown to exhibit antimicrobial activity against Gram-positive bacteria.

Livestock feed

In addition to phytochemicals, natural rubber and special carbohydrates, the extracted residue may be utilized as animal feed. Sunflower silage was compared with alfalfa haylage, and found that dairy steers gained as much weight when fed on sunflower silage, as with alfalfa haylage (33). A feed with a protein content of 16% is normally required for dairy cattle feed. Several samples (*H. arizonensis, H. simulans, H. grosseserratus, H. petiolaris*, and *H. neglecuts*) had greater than 16% protein. They should be included in future breeding programs.

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