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Series on Harmonisation of Regulatory Oversight in Biotechnology
No. 31

CONSENSUS DOCUMENT ON THE BIOLOGY OF Helianthus annuus L. (SUNFLOWER)

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Series on Harmonisation of Regulatory Oversight in Biotechnology

No. 31

Consensus Document on the Biology of ***Helianthus annuus*** L. (Sunflower)

Environment Directorate

Organisation for Economic Co-operation and Development

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FOREWORD

The OECD's Working[1] Group on Harmonization of Regulatory Oversight in Biotechnology decided at its first session, in June 1995, to focus its work on the development of ***consensus documents*** which are mutually acceptable among Member countries. These consensus documents contain information for use during the regulatory assessment of a particular product. In the area of plant biosafety, consensus documents are being published on the biology of certain plant species, on selected traits that may be introduced into plant species, and on biosafety issues arising from certain general types of modifications made to plants.

This consensus document addresses the biology of *Helianthus annuus* (L.) (sunflower). Included are descriptions of the taxonomy of the genus *Helianthus*; the natural habitat and the origins of the cultivated sunflower; the botanical, physiological and agronomical characteristics of the cultivated sunflower; the possibilities for intraspecific crosses; and the potential interactions with other organisms (insect pests, pathogens, and animals).

France served as the lead country in the preparation of this document. The document has been revised on a number of occasions based on the input from other member countries. It is intended for use by regulatory authorities and others who have responsibility for assessments of transgenic plants proposed for commercialisation, and by those who are actively involved with genetic improvement and intensive management of the genus.

[1] In August 1998, following a decision by OECD Council to rationalise the names of Committees and Working Groups across the OECD, the name of the "Expert Group on Harmonization of Regulatory Oversight in Biotechnology" became the "Working Group on Harmonization of Regulatory Oversight in Biotechnology."

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PREAMBLE

OECD member countries are now approving the commercialisation and marketing of agricultural and industrial products of modern biotechnology. They had previously therefore identified the need for harmonisation of regulatory approaches to the biosafety assessment of these products, in order to avoid unnecessary trade barriers.

In 1993, **Commercialisation of Agricultural Products Derived through Modern Biotechnology** was instituted as a joint project of the OECD's Environmental Policy Committee and Committee on Agriculture. The objective of this project is to assist countries in their regulatory oversight of agricultural products derived through modern biotechnology - specifically in their efforts to ensure safety, to make oversight policies more transparent and efficient, and to facilitate trade. The project is focused on the review of national policies, with respect to regulatory oversight that will affect the movement of these products into the marketplace.

The first step in this project was to carry out a survey concentrating on national policies with regard to regulatory oversight of these products. Data requirements for products produced through modern biotechnology, and mechanisms for data assessment, were also surveyed. The results were published in *Commercialisation of Agricultural Products Derived through Modern Biotechnology: Survey Results* (OECD l995a).

Subsequently, an OECD Workshop was held in June 1994 in Washington, D.C, with the aims of improving awareness and understanding of the various systems of regulatory oversight developed for agricultural products of biotechnology; identifying similarities and differences in various approaches; and identifying the most appropriate role for the OECD in further work towards harmonisation of these approaches. Approximately 80 experts in the areas of environmental biosafety, food safety and varietal seed certification, representing 16 OECD countries, eight non-member countries, the European Commission and several international organisations, participated in the Workshop. *The Report of the OECD Workshop on the Commercialisation of Agricultural Products Derived through Modern Biotechnology* was also published by the OECD in 1995 (OECD 1995b).

As a next step towards harmonisation, the Working Group on Harmonisation of Regulatory Oversight in Biotechnology instituted the development of **consensus documents**, which are **mutually acceptable** among member countries. The goal is to identify common elements in the safety assessment of a new plant variety developed through modern biotechnology, to encourage information sharing and prevent duplication of effort among countries. These common elements fall into two general categories: the first being the biology of the host species, or crop: and the second, the gene product.

Safety issues that could give rise to a safety concern are identified in the consensus documents on the biology of a specific crop and include the potential for gene transfer, weediness, trait effects, genetic and phenotypic variability, biological vector effects and genetic material from pathogens (OECD 1993a). They make no attempt to be definitive in this respect, however, as the many different environments in which the crop species may be grown are not considered individually.

This document is a "snap-shot" of current information that may be relevant in a regulatory risk assessment. It is meant to be useful not only to regulatory officials, as a general guide and reference source, but also to industry, scientists and others carrying out research.

In using this document and others related to the biology of crop plants, reference to two OECD publications which have appeared in recent years will prove particularly useful. *Traditional Crop Breeding Practices: A Historical Review to Serve* as *a Baseline for Assessing the Role of Modern Biotechnology* (OECD 1993b) presents information concerning 17 different crop plants. It includes sections on phytosanitary considerations in the movement of germplasm and current end uses of the crop plant. There is also a detailed section on current breeding practices. *Safety Considerations for Biotechnology: Scale Up of Crop Plants* (OECD 1993a) provides a background on plant breeding, discusses scale dependency effects, and identifies various safety issues related to the release of plants with “novel traits”.[2]

To ensure that scientific and technical developments are taken into account, OECD countries have agreed that consensus documents will be updated regularly. Additional areas relevant to the subject of each consensus document will be considered at the time of updating.

Users of this document are therefore invited to provide the OECD with relevant new scientific and technical information, and to make proposals concerning additional areas that might be considered in the future. ***A short, pre-addressed questionnaire is included*** ***at the end of this document*****.** ***The information requested should be sent to the OECD at one of the addresses shown.***

2 For more information on these and other OECD publications, contact the OECD publications Service, 2 rue André-Pascal, 75775 Paris Cedex 16, France, Fax: (33) 01.49.10.42.76; E-mail: PUBSINQ@oecd.org; or consult http://www.oecd.org

SECTION I - TAXONOMY OF THE GENUS *HELIANTHUS*, NATURAL HABITAT AND ORIGINS OF THE CULTIVATED SUNFLOWER

1.1. Taxonomy of the genus *Helianthus*

The sunflower belongs to the genus *Helianthus* in the Composite family (Asterales order), which includes species with very diverse morphologies (herbs, shrubs, lianas, etc.). The genus *Helianthus* belongs to the Heliantheae tribe. This includes approximately 50 species originating in North and Central America.

The basis for the botanical classification of the genus *Helianthus* was proposed by Heiser *et al.* (1969) and refined subsequently using new phenological, cladistic and biosystematic methods, (Robinson, 1979; Anashchenko, 1974, 1979; Schilling and Heiser, 1981) or molecular markers (Sossey-Alaoui *et al.*, 1998). This approach splits *Helianthus* into four sections: *Helianthus, Agrestes, Ciliares and Atrorubens.* This classification is set out in Table 1.

1.1.1. Section Helianthus

This section comprises 12 species, including *H. annuus*, the cultivated sunflower. These species, which are diploid (2n = 34), are interfertile and annual in almost all cases. For the majority, the natural distribution is central and western North America. They are generally well adapted to dry or even arid areas and sandy soils. The widespread *H. annuus* L. species includes (Heiser *et al.*, 1969) plants cultivated for seed or fodder referred to as *H. annuus* var. *macrocarpus* (D.C), or cultivated for ornament (*H. annuus* subsp. *annuus*), and uncultivated wild and weedy plants (*H. annuus* subsp. *lenticularis, H. annuus* subsp. *Texanus,* etc.).

Leaves of these species are usually alternate, ovoid and with a long petiole. Flower heads, or capitula, consist of tubular and ligulate florets, which may be deep purple, red or yellow.

1.1.2. Section Agrestes

This section includes only the annual species *H. agrestis* (2n = 34), characterised by reddish coloured tubular flowers, yellow styles and glabrous stems bearing leaves that are generally opposite and lanceolate (Bonjean, 1993). Its self-compatibility makes it different from other species (Heiser *et al.*, 1969). It is well suited to the moist soils of central Florida and Georgia.

1.1.3. Section Ciliares

This section includes six perennial species of small size originating in Mexico and the western United States. They are genetically quite distinct from the species in the other sections.

A distinction is made between two series in this section: *Ciliares* and *Pumili*. The first includes three species possessing powerful secondary root systems, making them redoubtable adventives. Their leaves are usually opposite, bluish in colour, virtually glabrous and with very short petioles. All the species in this series are diploid, with the exception of *H. ciliaris*, which includes tetraploid (2n = 68) and hexaploid (2n=102) populations.

The species in the *Pumili* series have opposite hairy leaves, growing from buds which appear at the crowns of the old roots. They are all diploid (2n = 34).

1.1.4. Section Atrorubens

This section includes thirty species divided arbitrarily into four series, including one cultivated species, the Jerusalem artichoke (*H. tuberosus* L.). Hybridisation between these species and their polyploid forms can make it difficult to classify them precisely.

The natural distribution of these species is the eastern and central United States, with the exception of *H. nuttallii* and *H. californicus*, which are found only in the West.

The *Corona-solis* series contains large species with tuberiform or rhizomatous roots. In some cases, leaves are alternate, large and numerous (*H. giganteus, H. grossesseratus*, *H. nuttallii*, etc.). Others have opposite, lanceolate leaves with three main veins (*H. divaricatus, H. mollis*). Seven species are diploid. *H. strumosus* and *H. decapetalus* can be found in tetraploid and hexaploid forms. *H. hirsutus* is tetraploid. Six species are hexaploid.

The *Atrorubentes* series comprises four perennial species from the southwest of the United States. Usually without rhizomes and with fibrous roots, they go through a very marked rosette stage. These species were formerly included in the *Divaricati* series in Heiser’s classification.

The *Microcephali* series includes four species which have a small capitulum and roots that are fibrous or perhaps slightly rhizomatous. Their stems may be covered with wax and bear leaves that are alternate in most cases. A fifth species, Porter’s sunflower (*H. porteri*) has been transferred from the genus *Viguiera* to the genus *Helianthus* (Yates and Heiser, 1979). This is an annual species found only in Georgia.

The species in the *Angustifolii* series are all diploid and located essentially in the southwestern United States. Their stems are hairy and the leaves usually alternate, lanceolate and with a leaf blade that may curl in toward the inside surface. Their roots are fibrous, thick or with rhizomes.

Table 1 – Classification of the genus *Helianthus* (Seiler and Rieseberg, 1997)

Section	Series	Species	Ploidy
Helianthus	-	*H. annuus* L. *	2n = 34
		H anomalus Blake *	2n = 34
		H. argophyllus T. & G. *	2n = 34
		H. bolanderi A. Gray *	2n = 34
		H. debilis Nutt. *	2n = 34
		H. deserticola Heiser *	2n = 34
		H. exilis A. Gray *	2n = 34
		H. neglectus Heiser *	2n = 34
		H. niveus (Benth.) Brandegee *	2n = 34
		H. paradoxus Heiser *	2n = 34
		H. petiolaris Nutt. *	2n = 34
		H. praecox Engelm & A. Gray *	2n = 34
Agrestes	-	*H. agrestis* Pollard *	2n = 34
Ciliares	*Ciliares*	*H. arizonensis* R. Jackson	2n = 34
		H. ciliaris DC.	2n = 68, 102
		H. laciniatus A. Gray	2n = 34
Ciliares	*Pumili*	*H. cusickii* A. Gray	2n = 34
		H. gracilentus A. Gray	2n = 34
		H. pumilus Nutt.	2n = 34
Atrorubens	*Corona-solis*	*H. californicus* DC.	2n = 102
		H. decapetalus L.	2n = 68, 102
		H. divaricatus L.	2n = 34
		H. eggertii Small	2n = 102
		H. giganteus L.	2n = 34
		H. grosseserratus Martens	2n = 34
		H. hirsutus Raf.	2n = 68
		H. maximiliani Schrader	2n = 34
		H. mollis Lam.	2n = 34
		H. nuttallii T. & G.	2n = 34
		H. resinosus Small	2n = 102
		H. salicifolius Dietr.	2n = 34
		H. schweinitzii T. & G.	2n = 102
		H. strumosus L.	2n = 68, 102
		H. tuberosus L.	2n = 102
Atrorubens	*Microcephali*	*H. glaucophyllus* Smith	2n = 34
		H. laevigatus T. & G.	2n = 68
		H. microcephalus T. & G.	2n = 34
		H. smithii Heiser	2n = 68
Atrorubens	*Atrorubentes*	*H. atrorubens* L.	2n = 34
		H. occidentalis Riddell	2n = 34
		H. pauciflorus Nutt. (synonym *H. rigidus* Cass.)	2n = 102
		H. silphioides Nutt.	2n = 34
Atrorubens	*Angustifolii*	*H. angustifolius* L.	2n = 34
		H. carnosus Small	2n = 34
		H. floridanus A. Gray ex Chapman	2n = 34
		H. heterophyllus Nutt.	2n = 34
		H. longifolius Pursh	2n = 34
		H. radula (Pursh) T. & G.	2n = 34
		H. simulans E.E. Wats.	2n = 34

* annual species. The others are perennial.

1.2. The natural distribution of sunflowers *(Helianthus annuus* L.)

The species *H. annuus* comes originally from North America. It is the most diverse North American sunflower species not only in terms of its geographical distribution, but also with respect to its morphology and environmental and physiological adaptation (Seiler, 1984).

It is found at altitudes between sea level and 3,000 metres in areas with a range of different rainfall characteristics, but essentially in the western two-thirds of the United States, southern Canada and northern Mexico. It is usually found in open habitats already disturbed by human activity (Bonjean, 1993).

At maturity, these plants present a high degree of phenotypic variation: their size may vary from less than a metre to more than four metres. They may or may not be branched and may present varying degrees of hairiness. Their leaves, which are generally oval to cordate in shape, are alternate and petiolate, with a size in the range 5 cm to 35 cm wide and 10 cm to 50 cm long. The capitulum is at least 1.5 cm deep and supports relatively broad bracts which may be oval or lanceolate; it is rarely glabrous on the dorsal surface and is usually ciliate at the edges.

The ligulate flowers are approximately 25 mm in length and sterile. There are at least seventeen of these. The tubular flowers are shorter and have corollas with lobes that are purple, reddish or yellow in colour. The achenes are 3 mm to 15 mm in length and are found in a range of colours (for example white, black, black with white stripes, and brown).

In the natural state, the flowering of wild *H. annuus* is a lengthy process involving each capitulum in turn, and lasts from late July to early October. The species is diploid ($2n = 34$) and hybridises naturally with many other sunflowers.

Wild populations are usually strictly self-incompatible and markedly allogamous, cross pollination being obligate. They are pollinated by insects, first and foremost by bees. Cultivated forms of sunflower generally allow a higher degree of self-compatibility.

1.3. The origins of the cultivated sunflower

The cultivated sunflower probably comes originally from the western United States. It is certainly the case that wild sunflower seeds were a food resource for Native American populations living in this geographical region.

According to Heiser (1985), the most probable hypothesis as to the domestication of the sunflower is that it was an adventive found at the edges of Native American encampments. Inhabitants of these encampments gathered the achenes of wild sunflowers. In this way, the plant was carried from western to central North America. Based on this hypothesis, it was domesticated there and then introduced in the same period into the eastern and southern parts of the United States.

The fact that cultivated sunflower achenes have been found in several archaeological sites in the eastern and central United States, whereas archaeological digs in the southwest of the country and in Mexico have brought to light only the achenes of wild sunflowers, is one of the strongest pieces of evidence for Heiser's hypothesis.

Using isozyme systems and chloroplasmic DNA, Rieseberg and Seiler (1990) have been able to provide proof at the molecular level that the cultivated sunflower apparently derived from a virtually unique or adventive form of sunflower, which probably grew originally in the central United States.

The cultivated sunflower was introduced into Europe in the late 16th century, probably by Spanish sailors. It was initially grown as an ornamental. No mention is found of its advantages as an oilseed plant before the 18th century, and the sunflower has since seen major genetic advances. It was in Russia that the first such improvements were made to develop single headed, shorter, earlier flowering plants and to increase the oil content of the seeds. More recently, strains with high oleic acid content were developed by Soldatov (1976). For these reasons, Russia is considered as a secondary domestication centre for sunflower.

The cultivated sunflower presents a narrow range of genetic variability, notably with regard to certain agronomic and technical characteristics such as standability and oil content. This is all the more true of hybrids created during the last decade (Bonjean, 1993). Conversely, the wild species of the genus *Helianthus* present a high degree of genetic variability, the exploitation of which has enabled enormous progress to be made in the creation of varieties, especially with regard to increased oil content, as well as resistance to disease, insects and dry conditions (Leclercq *et al.*, 1970; Krauter *et al.*, 1991; Miller *et al.*, 1992; Serieys, 1984; Serieys, 1997). Interspecific hybridisation also enabled identification of many new sources of male cytoplasmic sterility (Serieys, 1999). Partial hybridisation mechanisms frequently observed between perennial *Helianthus* and cultivated sunflower (Faure *et al.*, 2002), represent another way for controlled introgression (Faure *et al.*, 2002).

SECTION II - THE BOTANICAL CHARACTERISTICS OF THE CULTIVATED SUNFLOWER

The principal morphological and physiological characteristics of the sunflower, such as height, diameter of the capitulum, duration of the growing cycle, size of seeds and oil content, are all highly dependent on the soil climate in which it is cultivated (Merrien, 1986).

2.1. Root system

The sunflower's root system is of tap root type. The tap root may go down as far as five metres if conditions are favourable, but it has little real penetrating power. The sunflower also develops extensive superficial root hair growth. If conditions are favourable, root spread in young cultivated plants may amount to as much as 70 kg per hectare per day (Maertens and Bosc, 1981).

2.2. Above-ground vegetation

The cultivated sunflower differs from the wild sunflower in that it has a single inflorescence (except male lines cultivated for seed production). The stem is topped by a single capitulum that may, in some cases, be very large.

Germination of the seed is epigeous. The height of the developed plant varies between 0.5 and 5 metres, but is usually 1.6 metres. The diameter of the plant's stem varies in the range of 0.5 cm to 10 cm. The size of a sunflower is related to the number of leaves and the duration of the "seed-to-flower" phase.

The stem has a tendency to bend slightly under the weight of the mature capitulum. The nature of this stem curve is largely under genetic control. The degree of stem curve is of fundamental importance since it determines the angle of the capitulum with respect to the stem and so the capacity to protect the florets and achenes from climatic stress (rain, hail, wind, sun) and birds (Bonjean, 1993; Seiler, 1997).

The leaf blade is continuous, cordate and irregularly toothed; it is frequently covered in short, hard hairs. It has pinnate veins, including three main veins. The first five pairs of leaves are opposite and the others are alternate, following a spiral phyllotaxy. The leaves may have a range of sizes and shapes, with the largest being between the fourth and tenth nodes. These are the intermediate leaves which play the most important part in the formation and accumulation of the seeds' fat reserves. It is worth noting that by the time the capitulum has formed the plant has developed almost half its total leaf surface, and by the beginning of flowering over 75% total leaf surface has developed (Merrien, 1986). The precise number of leaves may vary from 12 to 40, according to variety. However, the range is 20 to 40 in most of the hybrids currently cultivated (Bonjean, 1993).

2.3. The reproductive system

The inflorescence is a capitulum the diameter of which may vary on average between 10 and 40 centimetres in most of the hybrids currently cultivated. The capitulum includes a fleshy receptacle which bears two types of flowers: ligulate flowers at the periphery, and tubular flowers in the centre. The edge of the capitulum is surrounded by leafy bracts arranged in overlapping concentric circles (2 to 5 in number).

The ligulate flowers form one or two rows around the periphery of the capitulum. There are never more than approximately thirty of these flowers. They are asexual, or, very rarely, unisexual of female type (Arnaud, 1986).

The tubular flowers or florets make up most of the capitulum. They are arranged in arcs which converge toward the centre of the capitulum. The florets are hermaphrodite and after pollination and fertilisation produce the achenes, which are harvested. The potential number of disk florets varies with capitulum diameter in the range of 60 to 3500.

2.4. Flowering

The sunflower's flowering phase lasts between 9 and 15 days on average. The precise duration varies with the size of the capitulum and atmospheric conditions (Merrien, 1986). The flower unfolds centripetally from the periphery of the capitulum toward the centre (Marc and Palmer, 1978). Flowering begins with the ligulate flowers, which unfold their single petal immediately after the capitulum opens, and remain in flower until the florets have finished flowering (tubular flowers). The florets complete their flowering phase in 3-4 days in daily cycles involving one or two concentric rows. The flowering of each floret begins with the initial opening, its anthers projecting above the corolla with the extension of the filaments. The anthers are dehiscent and the pollen spills into the interior of the flower; this is the male stage. On the following day, the style extends through the interior volume of the flower and emerges above the anthers. The two stigmatic lobes separate and curl toward the style; this is the female stage. The stigma may remain receptive for 15 to 20 days (Arnaud, 1986; Bonjean, 1993).

2.5. Fertilisation

The sunflower tends to be allogamous, using a complex system of sporophytic self-sterility. Nevertheless, the degree of self-incompatibility of the pollen varies widely and self-fertilisation remains a possibility (Bonjean, 1993), especially in the cultivated material.

The sunflower's pollen grains are relatively large (25 µm to 35 µm). Each pollen grain comprises an outer coating (the exine) covered in sharp spines and a viscous wax. Due to these morphological characteristics, the pollen tends to form caked masses. As a consequence, it is usually carried by insects (Parker, 1981; Freund and Furgala, 1982; Bonjean and Pham-Delegue, 1986). An inventory carried out in France of pollinating fauna in a number of production areas has demonstrated that honey bees and bumble bees are the principal agents of pollination in the sunflower (Lecomte, 1962; Rollier, 1977; Madeuf and Leclercq, 1982). In other countries where sunflowers are cultivated, such as the United States or the Ukraine, surveys of pollinating insects reveal that domesticated bees are the principal pollinators (Bonjean, 1993).

It is unusual for the pollen to be carried on the wind; less than 0.2% of fertilisation occurs by wind pollination at a distance of less than one metre from the pollen source (Madeuf and Leclercq, 1982).

2.6. Fructification

Sunflower seeds are achenes (or fruits) that consist of a kernel (true seed) and a pericarp (hull). The kernel consists of an embryo, endosperm, and seed coat. The pericarp (maternal tissue) consists of several layers: cuticle (external layer), epidermis, hypodermis, phytomelanin layer, fibrose tissue, and parenchymal layers adjacent to the kernel (Nassonov, 1940, quoted by Vranceanu, 1977). Pericarp colour is determined by the pigmentation of the epidermis, hypodermis, and phytomelanin layers (Putt, 1940; Mosjidis, 1982). The epidermis can be uniformly unpigmented or have black or dark brown stripes of varying width. The hypodermis is below the epidermis and can also be either completely unpigmented or pigmented (white or purple). The third layer (phytomelanin), if present, has uniform dark brown to black pigments (Putt, 1944).

The achenes located at the periphery of the capitulum are usually larger than those in the centre. While most florets form a shell, they may remain empty. This is because in many cases those in the central area do not produce seeds. As a consequence, there is a “sterile patch” in the centre of the capitulum the diameter of which depends not only on the genotype, but also on the conditions in which the sunflower is cultivated (Arnaud, 1986; Bonjean, 1993).

Sunflower seeds can be of two types:

- oilseeds with an oil content greater than 40%, and 35% to 38% protein, usually black in colour; and

- edible seeds, which have a lower oil content (approximately 30%) and an outer shell that is usually dark brown or white.

SECTION III - THE PHYSIOLOGICAL AND AGRONOMICAL CHARACTERISTICS OF THE CULTIVATED SUNFLOWER

3.1. The sunflower growth cycle

The complete growth cycle of the sunflower lasts between 100 and more than 170 days according to the variety and the growing conditions. Given this, and assuming zero growth below 6°C, the required accumulated temperature varies from 1500 °C to over 1700 °C. Flowering usually begins between 65 and 70 days after the emergence of the first shoots, which will occur once the accumulated temperature reaches 850°C, assuming a minimum growing temperature of 6°C (Merrien, 1986). Variations are found according to variety and location of cultivation, which suggests that there is a high degree of interaction with levels of illumination, to which the sunflower is very sensitive.

Sunflower is usually sown in the beginning of spring (February to May in the northern hemisphere) and harvested in late summer. The harvesting period extends from late August to September in the northern hemisphere, varying according to the region concerned.

The growth cycle can be divided into five phases (Rollier, 1972):

3.1.1. The phase between sowing and the emergence of the first shoots

This phase lasts between 7 and 20 days. For emergence the temperature must be at least 4°C, the optimum level being around 8°C. This phase is important since it will determine the size of the plot's plant population.

3.1.2. The phase between the emergence of the first shoots and growth of 4/5 pairs of leaves

This is the phase in which the root system is put in place and it is particularly sensitive to problems of soil structure due to errors in preparing for cultivation. While the rate at which dry matter is accumulated in the part of the plant above ground is high (10 kg per hectare per day), the dry matter in the roots represents approximately 15% of total dry matter in the plant. This is also the stage at which the initial formation of the leaves, and especially the flowers, begins. A lack of water at this point can limit leaf formation, but flower formation will be especially affected by low temperatures, which may lead to malformation of the capitulum.

3.1.3. The phase between growth of the first five leaf pairs and the beginning of flowering

This is the most active growth phase for the crop, a phase during which the rate of formation of dry matter may be as high as 200 kg per hectare per day. The most spectacular increase is in leaf surface area, which is at a maximum during this period, as is also the case for the root system. This phase lasts between 40 and 50 days, and it is also the period of maximum intake of minerals such as nitrogen and boron.

3.1.4. Flowering

The length of this phase varies slightly according to variety: 15 to 21 days for the plot as a whole, or 10 days for the individual plant. This is a period of limited growth during which the capitulum becomes the main sink for plant assimilates.

During this phase, the sunflower is highly sensitive to low levels of moisture and infection of the capitulum by *Sclerotinia* spores.

3.1.5. The seed-building phase

Levels of accumulated dry matter increase only very little in this phase, largely because during this period assimilates are reallocated and plant food reserves migrate. This is also the phase typified by active formation of fatty acids and new proteins from the amino acids derived from the breakdown of leaf and stem proteins.

The total quantity of dry matter produced varies in the range of 10 to 15 metric tons per hectare (approximately 30 metric hundredweights per hectare). It may be as high as 20 tons per hectare for late hybrids grown in very good conditions.

The point of physiological maturity is reached once the seeds have a moisture content of approximately 28%.

Nitrogen compounds, carbohydrates and fat contents vary during the sunflower growth cycle (Table 2).

Table 2 – Qualitative breakdown of plant dry matter (%) over the sunflower growth cycle.

	Growth Stage								
	VE1 – Vegetative Emergence			F1 – Beginning of Flowering			M3 – Maturity		
	Nitrogen Compounds	Carbohydrates	Fats	Nitrogen Compounds	Carbohydrates	Fats	Nitrogen Compounds	Carbohydrates	Fats
Stem	15	15	-	13	37	-	6	25	-
Leaves	38	32	-	16	8	-	2	2	-
Capitulum	-	-	-	7	9	-	4	8	-
Seeds	-	-	-	-	-	-	11	7	35

Source: Merrien, 1986.

The marketing norms for sunflower seeds require 9% moisture content and 2% impurities; at these levels, oil content marketing norm is 44%.

3.2. The functioning of the plant and vegetation cover

The sunflower is characterised by a very high potential for photosynthesis compared with maize and soybean (Table 3). This performance can be explained by a number of factors:

- the numerous stomata distributed over the two leaf faces (surface and reverse side);

- low resistance to diffusion of CO_2 from ambient air toward active photosynthesis sites; and

- the very high level of RuBisCO activity, its high percentage in young leaves, and the greater accessibility of CO_2 to this enzyme in sunflowers compared with other crop plants.

Table 3 – Characteristics of the photosynthesis of selected crop plants.

Plant species	Carbon fixation mode	Enzymes involved	Average level of photosynthesis
Helianthus annuus (Sunflower)	C3	RuBisCO[1] + photorespiration losses	40 mg – 50 mg $CO_2/h/dm^2$
Zea mays (Maize)	C4	RuBisCO + PEPC[2]+PPDK[3] +NADP-ME[4] (little photorespiration)	40 mg $CO_2/h/dm^2$
Glycine max (Soybean)	C3	RuBisCO + photorespiration losses	20 mg $CO_2/h/dm^2$

Source: Merrien, 1986

[1] RuBisCO: ribulose-1,5-bisphosphate carboxylase/oxygenase; [2] PEPC: Phosphoenolpyruvate carboxylase; [3] PPDK : Pyruvate orthophosphate dikinase; [4] NADP-ME: NADP-Malic enzyme

The level of photosynthetic activity declines rapidly over time, largely as a result of shade and self-shading due to mutual coverage of vegetation. This decline is accelerated by dry conditions. In adult sunflowers, the best performance is found in the 15-20 leaf rank, which is the largest and therefore captures more illumination.

In the absence of limitations on the water regime, a sunflower will consume a great deal of water. It is capable of extracting large quantities from the soil if its root system is optimal.

Average daily water consumption may be up to 6 mm per day, with extreme daily values of 10 mm and above. This can be explained by the plant's high level of transpiration, at least double that of most species, which in turn is linked to the permeability of its leaves and the plant's overall high conductance.

When water is available in abundance, the sunflower tends to waste it. Conversely, in dry conditions, it is typically capable of regulating its consumption, improving the efficiency of water use. Thus the initial effect of limited water supplies will be reflected in the gradual closure of the stomata, leading to a reduction in water exchange, whereas photosynthesis will continue for some time.

There are two types of assimilate movement in the plant:

- translocation, involving movements from the leaves (the location of biosynthetic processes) toward sink regions, where assimilates can accumulate (roots, stems, petioles, young growing leaves, capitulum); and

- redistribution, involving movements of stored assimilates toward other plant organs (from the stem and leaves to the seeds, for example).

As soon as it is formed, the capitulum is the main sink site for assimilates. The biosynthesis of oil in the seeds occurs late and is essentially linked to the potential for post-flowering assimilation. It is preceded by protein synthesis, which uses amino acids previously held in store in the stems and leaves before being redistributed.

The quantity of protein present in the seed is largely dependent on the total quantity of nitrogen mobilised by the vegetation of the plant. Oil content is essentially related to the carbon fixation potential after flowering.

3.3. Building sunflower yield

Sunflowers are grown in order to produce oil and seed cake. The plant's yield (in terms of oil or protein) can be broken down into a number of distinct components:

- the number of plants per hectare;
- the number of seeds per plant;
- the 1,000 kernel weight; and
- the oil (and protein) content of the seeds.

Agronomic and plant physiology research directed at each of the above components of overall yield calls for a number of comments.

It is possible to modulate the "plants per hectare" parameter. This is because where plant density is high, the sunflower capitulum will be reduced in size; there will be more seeds, but each will be smaller. However, high densities increase lodging risks and facilitate the spread of plant diseases. It should also be borne in mind that it is preferable to ensure that the population is spread evenly over the plot, since sunflowers make poor use of free space.

The number of seeds per plant depends on the vigorousness of the plant concerned in its growth phase, total leaf area prior to flowering, and how long the foliage lasts after flowering. Capitulum vascularisation, a limiting factor in the central area, determines a quantitative and qualitative gradient for achene nutrition from the periphery toward the centre (see Table 4). A large-diameter capitulum can be seen to be an unsuitable objective in agronomic or genetic terms due to the limiting effect of vascularisation. Conversely, the search for varieties with an even distribution of vessels in the central area is a major goal for research and selection.

Table 4 – Characteristics of the seed in terms of its location on the capitulum.

Achene location	Average achene weight	Protein content		Oil content	
	(mg)	(mg / achene)	(% of seed weight)	(mg / achene)	(% of seed weight)
Periphery	56.4	9.8	17.4	25.4	45.0
Median zone	50.5	9.9	19.6	19.7	39.0
Centre	44.8	9.8	21.8	16.0	35.7

Source : Merrien, 1986.

The 1,000 kernel weight is largely dependent on how long the foliage lasts after flowering. It will vary with the position of the achenes on the capitulum, since those at the periphery are larger, although also less dense. The 1,000 kernel weight is always negatively correlated with the number of seeds. It compensates only imperfectly and unpredictably for a reduction in the number of seeds. To conclude, average seed weight varies according to density (large achenes being associated with low density) as well as the variety concerned.

Yield varies widely according to the growing environment. Water is the main cause of such variation. There is no critical period in the cycle as is the case for maize; it is more the case that the sunflower is sensitive to lack of water throughout its growth cycle. This sensitivity is at its peak around the time of flowering. Water-related stress will affect mainly the number of achenes per plant; seed-filling (1,000 kernel weight) is less affected. Lastly, over-rapid senescence of the leaves following flowering will lead to a lower oil content.

Nitrogen plays a very important role in the phase in which the number of achenes is determined (differentiation), this being a major factor in the yield. However, despite the sunflower's high nitrogen requirement, it is usually fairly unresponsive to nitrogen-based fertilisation. Due to a low utilisation coefficient, nitrogen-based nutrition input to the plant generally takes the form of soil nitrogen.

SECTION IV - POSSIBILITIES OF CROSSES OF CULTIVATED SUNFLOWER WITH WILD SPECIES

4.1. Intraspecific crosses

4.1.1. Wild populations of H. annuus

As has been mentioned in Section I, the cultivated sunflower derives from a wild species (*Helianthus annuus*) originating in North America and domesticated in recent times. In the wild form, the plants are branched, producing large multiple heads that flower over long periods of time, bearing seeds that are small and present varying degrees of dormancy allowing them to remain in the soil for several years.

In the United States, such wild populations are present in the sunflower cultivation area and genes may be easily exchanged between wild and domesticated populations through cross-pollination. The frequency of hybridisation is unknown, but the phenomenon is a recurrent one even when the wild species are several kilometres away from the sunflower fields (Faure *et al.*, 2002).

In Europe, several sub-spontaneous populations of wild *H. annuus* were observed, which are now increasing especially in some places in central Italy and Andalusia, Spain (Faure *et al*., 2002). The origin of these invading populations in Europe is under question (for example, through wild seed importation or de-domestication).

Due to the fact that such exchanges are possible, and in order to maintain purity of commercial and basic seeds, fields used for sunflower seed production in the USA are kept at least 800 metres distance from commercial sunflower fields and wild sunflower populations. For basic seed production, this distance, which was set initially at 3 km, has been increased to 6.4 km from commercial sunflower fields, 3.2 km from seed production locations and 4.8 km from oilseed crops. In Europe, the production of sunflower seeds requires at least 500 metres' separation from all other commercial sunflower crops, and 3 km to 5 km in the case of basic seed production (Faure *et al.*, 2002).

Wild populations of *H. annuus* are also present in Mexico, Canada, Australia and Argentina.

From extensive intraspecific crossing experiments, Heiser (1954) indicates that the *H. annuus* species are cytologically uniform and that intraspecific crossability level is high. In natural conditions, Rieseberg *et al.* (1998) showed that hybrids between cultivated and wild *H. annuus* occurred frequently. As much as 42% of progenies from wild plants near cultivars were hybrids, and cultivar genes have been shown to persist in wild populations for several generations. The conclusion was that introgression of cultivar loci is widespread in the sympatric wild *H. annuus* populations (Linder *et al.*, 1998).

4.1.2. Volunteer populations

Sunflower seeds may stay in the soil after harvesting and germinate several years later, thus creating quasi-self-sown or volunteer populations along the edges of fields and within later crops in the rotation (fallow, peas, soybean, maize, sunflower).

Unlike the wild populations of *H. annuus*, which have been thoroughly studied in the United States, little information, either in agronomic or genetic terms, is available on this topic in Europe. However, European wild populations of sunflower derive from North America seed import. Therefore, the knowledge of sunflower wild population biology and of management practices accumulated in the United States provides valuable information for Europe as well.

There have been no indications that such self-sown growth is problematic or adventive in relation to crops either in the United States or in Europe. It is usually eliminated over the two years following the harvesting of the sunflower crop (Snow, 1999).

4.2. Related *Helianthus* species and interspecific hybridization

In Europe, three wild annual species related to sunflower have been observed (*H. bolanderi, H. argophyllus* and *H. debilis*). They tend to be found more in private gardens than in sunflower growing areas.

Considering the annual wild species of the section *Helianthus (H. argophyllus, H. petiolaris, H. debilis, H. praecox, H. bolanderi, H. niveus, H. neglectus, H. paradoxus; H. anomalus, H. deserticola),* interspecific hybrids may be obtained (more or less easily) in crossings with the cultivated sunflower *H. annuus*, with (or without) embryo rescue techniques (Whelan, 1978; Christov, 1996). In such interspecific hybrids, semi-sterility is a common trait due to strong genetic barriers: chromosomal translocations, inversions, etc. (Whelan, 1978; Heiser *et al*., 1969). Viable hybrids and fertile interspecific progenies are generally produced. In natural conditions, hybrid zones are frequently observed in the United States, and various experimental procedures have revealed such gene flows between *H. annuus* and other wild species *H. argophyllus, H. bolanderi, H. debilis* and *H. petiolaris* (Rieseberg *et al*., 1998).

Among the perennial species related to the sunflower which are present at a significant level in Europe, there are two hexaploid forms belonging to the *Atrorubens* section, one in the *Corona-solis* series *(H. tuberosus)* and one in the *Atrorubentes* series *(H. rigidus).*

*H. tuberosu*s (Jerusalem artichoke) is a species still grown for its tubers and is used in animal feed. It is found in many places in France, Montenegro and Yugoslavia, as well as in central and eastern Europe.

Today, there are numerous self-sown populations of Jerusalem artichoke in a range of geographical regions but there is little information on their distribution or frequency.

H. rigidus is also a decorative perennial form frequently found in private gardens.

In Europe, the common forms of *H. tuberosus* and *H. rigidus* flower in September and in theory there is no overlap with the flowering stage of large-scale sunflower crops, at least where these are sown in spring. However, in botanical collections wild ecotypes exist that flower early, similarly to cultivated sunflowers.

Artificial F1 hybrids between the cultivated sunflower *H. annuus* L. and many perennial species of the *Atrorubens* section may be obtained, but they are difficult to perform due to the strong genomic and chromosomal divergencies. Successful hybridisation results are reported, with variable sterility levels of their F1 hybrids, for the following perennial species: *H. angustifolius*, *H. californicus, H. decapetalus, H. divaricatus, H. eggertii, H. floridanus, H. giganteus, H. glaucophyllus, H. grosseserratus, H. hirsutus, H. laevigatus, H. maximiliani*, *H. microcephalus*, *H. mollis, H. nuttallii, H. occidentalis, H. resinosus*, *H. rigidus, H. salicifolius, H. smithii, H. strumosus, H. tuberosus* (Whelan, 1978; Christov, 1996; Gravilova *et al.,* 2000).

In artificial conditions (isolation cages with bees), the hybridization level of cultivated sunflower with *H. tuberosus* is low and F1 seed set varies in the range of 2-5%, according to accessions (H. Serieys, Pers. comm.).

Partial hybridization between perennials and sunflower was observed under artificial crossing conditions (Faure *et al.*, 2002). The phenotype and genotype of F1 hybrids was very close to the female parent. This phenomenon, if observed in natural conditions, could be an opportunity for gene-flow from cultivated sunflower to the wild perennial forms.

In natural conditions, interspecific crosses within *Atrorubens* section species frequently occurred (Heiser *et al*., 1969), but little information is available on the natural crossings between sunflower and perennial species. Crosses of sunflower with the species of the *Ciliares* section appeared rather uncommon in natural conditions and the rare hybrids obtained via embryo rescue techniques exhibited strong sterility.

SECTION V - POTENTIAL INTERACTIONS WITH OTHER ORGANISMS

5.1. Sunflower insects

Several insect species attack sunflower (*Helianthus annuus* L.) worldwide. In North America, a large pest complex has evolved on wild sunflower and has moved from wild ancestors to commercial cultivars. In other countries and to a lesser extent in North America, some insects have adapted to utilise sunflower as an alternative host. Many of these insects develop or increase in number on earlier-planted crops and then after senescence move to sunflower.

The table in Appendix 1 is intended as an identification guide for categories of insects which interact with the cultivated and stored *H. annuus*. This table has been established from the article of Charlet *et al.* (1997) and summarises the present state of knowledge on this subject. It is representative of every continent, but should be probably completed by each environmental safety assessor.

5.2. Sunflower diseases

The distribution of sunflower pathogens around the world has followed the introduction of sunflower into each continent. So, most pathogens of sunflower can be found in every country today. However, with differences in climate and cultural practices among countries, the prevalence and the incidence of specific diseases will vary in each country.

The sunflower diseases related to the causal organisms are presented in Appendix 2.

5.3. Other sunflower consumers

5.3.1. Rabbits and hares

Some damage can be caused by rabbits and hares at the early sunflower stages, particularly when the fields are planted near woods or set-aside lands. They damage sunflower by cutting the stem of plant from 2 to 5 mm above the soil surface or by eating young leaves. Important losses have already been observed.

5.3.2. Birds

Bird damage is a problem in every sunflower-growing region of the world. It occurs from early maturation to harvest but seems greatest within 18 days after anthesis. Small sparrows (*Passeridae*) to large species such as crows (*Corvidae*) and parrots (*Psittacidae*) eat sunflower achenes (easily obtained) or seeds (Linz and Hanzel, 1997). The losses can be economically severe.

SECTION VI - BIBLIOGRAPHICAL REFERENCES

Anashchenko, A.V. 1974 - On the taxonomy of the genus *Helianthus* L. Bot. Zhurn. 59 : 1472-1481.

Anashchenko, A.V. 1979 - Phylogenetic relations in the genus *Helianthus* L. Bull. Appl. Bot. Genet. Plant Breed. 64 : 146-156.

Arnaud, F. 1986 - Cahier Technique tournesol : plante-sélection, Ed. Cetiom, 28 p.

Bonjean, A. 1993 - Le tournesol. Les éditions de l'environnement. 242 p.

Bonjean, A. and Pham-Delegue, M.H. 1986 - La pollinisation du tournesol. OPIDA 10.8.11 (99): 212-218.

Charlet, L.D., Brewer, G.J. and Franzmann, B.A. 1997 – Sunflower insects. *In* A.A. Schneiter (ed.) Sunflower technology and production. Agronomy Monograph n° 35. p. 183 – 262.

Christov, M. 1996 - Hybridization of cultivated sunflower and wild *Helianthus* species. In P.D.S. Caligari & D.J.N. Hind (eds). Compositae: Biology & Utilisation. Proceedings of the International Compositae Conference, Kew, 1994. Vol 2 pp. 603-615. Royal Botanic Gardens, Kew.

Faure, N, Serieys, H. and Bervillé, A. 2002 - Potential gene flow from cultivated sunflower to volunteer, wild *Helianthus* species in Europe. Agriculture, Ecosystems and environment, 89: 183-198.

Freund, D.E. and Furgala, B. 1982 - Effect of pollination by insects on the seed set and yield of ten oilseed sunflower cultivars. AM. Bee. J. 122: 648-652.

Gravilova, V., Nizova, G., Tolstaya, T., Tavoljansky, N., Akhtulova, E. and, Slyusar E. 2000 - Production, study and utilization of sunflower interspecific hybrids. Proceedings of the 15th International sunflower conference, 12-15 June Toulouse (France) Vol II O7-012

Gulya, T., Rashid, K.Y. and Masirevic, S.M. 1997 – Sunflower diseases. *In* A.A. Schneiter (ed.) Sunflower technology and production. Agronomy Monograph n° 35. p. 263 – 380.

HEISER, C. B., JR. 1954 - Variation and subspeciation in the common sunflower, *Helianthus annuus*. Am. Midl. Nat. **51**: 287-305.

Heiser, C.B., Smith, D.M., Clevenger, S.B. and Martin, W.C. 1969 - The North American sunflowers (*Helianthus*). Memoirs Torr. Bot. Club, 22: 1-218.

Heiser, C.B. 1985 - Some botanical considerations of the early domesticated plants north of Mexico. p.57 - 82. *In* R.I. Ford (ed.) Prehistoric food production in North America. Mus Anthropol., Univ. Michigan, Ann. Arbor.

Krauter, R., Steinmetz, A. and Friedt, W. 1991 - Efficient interspecific hybridisation in the genus *Helianthus* via embryo rescue and characterisation of the hybrids. Theor. Appl. Genet., 82: 521-525.

Leclercq, P., Cauderon, Y. and Auge, M. 1970 - Sélection pour la résistance au Mildiou du tournesol à partir d'hybrides topinanbour x tournesol. Ann. Amel. Plantes, 20: 363-373.

Lecomte, J. 1962 - Observations sur la pollinisation du tournesol (*Helianthus annuus* L.). Am. Abeille, 5 (I): 69-73.

Linder C.R, Taha I., Seiler G.J., Snow A.A., Riseberg L.H. 1998 - Long-term introgression of crop genes into wild sunflower populations. TAG, Vol 96, issue 3/4 pp. 339-347

Linz, G.M. and Hanzel, J.J. 1997 – Birds and sunflower. *In* A.A. Schneiter (ed.) Sunflower technology and production. Agronomy Monograph n° 35. p. 381 - 386.

Madeuf, J.L. and Leclercq P. 1982 – Tournesol : le rôle majeur de l'abeille. Revue Française d'Apiculture, 408 : 234-237.

Maertens, C. and Bosc M. 1981 - Etude de l'évolution de l'enracinement du tournesol (var. *Stadium*). Inf. Techn. CETIOM, no. 73, p. 3-11.

Marc, J. and Palmer, J.H. 1978 - A sequence of stages in flower development in the sunflower, Proc. 8th. Int. Sunfl. Conf., 130-137.

Merrien, A. 1986 - Physiologie du tournesol. Cahier Technique Tournesol, Ed. Cetiom, 47 p.

Miller, J.F., Seiler, G.J. and Jan, C.C. 1992 - Introduced germplasm use in sunflower inbred and hybrid development. In: Use of plant introductions in cultivar development, part 2. Crop Science Society of America, Madison, USA, p. 151-156.

Mosjidis J.A. 1982. Inheritance of color in the pericarp and corolla of the disc florets in sunflower. J. Hered. 73:461-464.

OECD (Organization for Economic Cooperation and Development) (1993a): Safety Consideration for Biotechnology: Scale-up of Crop Plants. OECD, Paris.

OECD (1993b): Traditional Crop Breeding Practices: An Historical Review to Serve as a Baseline for Assessing the Role of Modern Biotechnology. OECD, Paris.

OECD (1995a): Commercialisation of Agricultural Products Derived Through Modern Biotechnology: Survey Results. OECD, Paris.

OECD (1995b): Report of the OECD Workshop on the Commercialisation of Agricultural Products Derived Through Modern Biotechnology. OECD, Paris.

Parker, F.D. 1981 - Sunflower pollination: abundance, diversity and seasonality of bees on male-sterile and male-fertile cultivars. Environ. Entomol.: 10, 1012-1017.

Putt E.D. 1940. Observation on morphological characters and flowering processes in the sunflower (Helianthus annuus L.). Sci. Agric. 21:167-179.

Putt E.D. 1944. Histological observations on the location of pigments in the achene wall of the sunflower (Helianthus annuus L.). Sci. Agric. 25:185-188.

Rieseberg, L.H. and Seiler, G.H. 1990 - Molecular evidence and the origin and development of the domesticated sunflower (*Helianthus annuus*). Econ. Not., 44 : 79-91.

Rieseberg, L.H., Baird, S. and Desrochers, A. 1998 - Patterns of mating in wild sunflower hybrid zones. Evolution, 52: 713-726.

Robinson, H. 1979 - Studies in the *Heliantheae* (Asteraceae). XVIII. A new genus *Helianthopsis*. Physiologia, 44: 257-259.

Rollier, M. 1972 – Ples besoins nutritifs du tournesol. *In* 5ème Conférence Internationale sur le Tournesol, 25-29 Juillet 1972, Clermont-Ferrand, France, p. 73-76.

Rollier, M. 1977 - Pollinisation et modalités de production des semences hybrides de tournesol. Inf. Techn. CETIOM, 56: 15-24.

Schilling, E.E. and Heiser, C.B. 1981 - Infrageneric classification of *Helianthus* (Compositae). Taxon, 30 393-403.

Seiler, G.J. 1984 - Variation in agronomic and morphological characteristics of several populations of wild annual sunflower (*Helianthus annuus* L.). Helia, 7: 29-32.

Seiler, G.J. 1997 - Anatomy and morphology of sunflower. p. 67-111. *In* A.A. Schneiter (ed.) Sunflower technology and production. Agronomy Monograph n° 35.

Seiler, G.J. and Rieseberg, L.H. 1997 - Systematics, origin and germplasm resources of the wild and domesticated sunflower. p. 21-66. *In* A.A. Schneiter (ed.) Sunflower technology and production. Agronomy Monograph n° 35.

Serieys, H. 1997 - L'apport des espèces sauvages a l'amélioration du tournesol. CETIOM-Oléoscope: (42) 14-17.

Serieys, H. 1999 - Progress Report of the FAO Working Group "Identification, Study and Utilization in breeding Programs of new CMS sources. "IX° FAO technical Consultation of the ECRN on Sunflower. Dobritch, Bulgaria July 27-30. Helia, 22: 71-116.

Serieys, H. 1984 - Collection, evaluation and conservation of wild species and their use in sunflower breeding programs. *In* FAO Progress Subnetwork, Novi-Sad, Yugoslavia, p. 109-113.

Snow, A. 1999 - Report of the sunflower working group. In: Proceedings of a workshop on ecological effects of pest resistance genes in managed ecosystems, Bethesda, Maryland, p. 113-118.

Soldatov, K.I. 1976 - Chemical mutagenesis in sunflower breeding. Proc. 7th Sunflower Conf. Krasnodar 7: 352-360.

Sossey-Alaoui, K., Serieys H., Tersac, M., Lambert, P., Schilling, E., Griveau, Y., Kaan, F., Berville, A. 1998. Evidence for several genomes in Helianthus. Theor Appl Genet 97: 422-430.

Vranceanu A. V. 1977. The Sunflower (in Spanish). Ediciones Mundi-Prensa. Madrid. Spain.

Whelan, E.D.P., 1978 - Cytology and Interspecific Hybridization. Pp 371-386. *In* Carter J.F. Editor. Sunflower Science and Technology. The American Society of Agronomy. Agronomy Monograph Number 19, 505 pages

Yates. W.F. and Heiser, C.B. 1979 - Synopsis of *Heliomeris* (Compositae). Proc. Indiana Acad. Sci., 88: 364-372.

APPENDIX 1 – INSECT PESTS IN SUNFLOWER

	CONTINENT OR REGION IN WHICH THEY OCCUR						
Insect pests	**USA/CANADA /MEXICO**	**SOUTH AMERICA**	**AFRICA**	**WESTERN EUROPE**	**CENTRAL & EASTERN EUROPE**	**ASIA**	**AUSTRALIA**
Cutworms [Lepidoptera : Noctuidae] Dark-sided cutworm *Euxoa messoria* (Harris), *Euxoa temera* (Hübner) Red-backed cutworm *E. ochrogaster* (Guenee) Dingy cutworm *Feltia ducens* (Walker)	X X X				X X		
Sunflower Bud Moth, *Suleima helianthana* (Riley) [Lepidoptera : Tortricidae]	X (Mexico to the central USA)						
Sunflower Stem Weevil, *Cylindrocopturus adspersus* (LeConte) [Coleoptera : Curculionidae]	X						
Black Sunflower Stem Weevil, *Apion occidentale* Fall [Coleoptera: Curculionidae]	X (North Dakota, Minnesota & Texas)						
Sunflower Root Weevil, *Boris strenua* (LeConte) [Coleoptera : Curculionidae]	X (Illinois to California & Montana to Guatemala)						
Sunflower Maggot, *Strauzia longipennis* (Wiedemann) [Diptera : Tephritidae]	X (USA, Canada)						
Long-horned Sunflower Stem Girdler, *Dectes texanus* LeConte [Coleoptera: Cerambycidae]	X (North & South Dakota, Florida)						
Ligyrus gibbosus (DeGreer) [Coleoptera: Scarabaeidae] *Ligyrus* spp. (Scarabaeidae).	X (USA, southern Canada, & northern Mexico)	X X					

Insect pests	CONTINENT OR REGION IN WHICH THEY OCCUR						
	USA/CANADA /MEXICO	SOUTH AMERICA	AFRICA	WESTERN EUROPE	CENTRAL & EASTERN EUROPE	ASIA	AUSTRALIA
Grasshoppers [Orthoptera: Acrididae] **The most important :** *Melanoplus differentialis* (Thomas) ; Migratory grasshopper, *M. sanguinipes* (Fabricius) ; Twostriped grasshopper, *M. bivittatus* (Say) ; Redlegged grasshopper, M *femurrubrum* (DeGeer) Clearwinged grasshopper, *Camnula pellucida* (Scudder) *Dichroplus platensis* (Burner) ; D. *conspersus* (Burner).	X X X X X	X X					
Painted Lady or Thistle Caterpillar, *Vanessa cardui* (L.) [Lepidoptera: Nymphalidae]	X						
Sunflower Beetle, *Zygogramma exclamationis* (Fabricius) [Coleoptera: Chrysomelidae]	X						
Sunflower Moth, *Homoeosoma electellum* (Hulst) [Lepidoptera: Pyralidae] *Homoeosoma nebulellum* Denis and Schiffermiiller *Homoeosoma heinrichi (*Pastrana) *Homoeosoma vinciniae* (Pastrana),	X	X (Argentina) X (Argentina)		X X	X	X (Iran)	
Sunflower Midge, *Contarinia schulzi* (Gagne) [Diptera: Cecidomyiidae]	X						
Sunflower Seed Midge *Neolasioptera helianthis* (Felt) [Diptera: Cecidomyiidae]	X						
Red Sunflower Seed Weevil, *Smicronyx fulvus* (LeConte) [Coleoptera: Curculionidae]	X						
Gray Sunflower Seed Weevil, *Smicronyx sordidus* (LeConte) [Coleoptera: Curculionidae]	X						
Banded Sunflower Moth, *Cochylis hospes* (Walsingham) [Lepidoptera: Cochylidae]	X (USA, Canada)						
Sunflower Receptacle Maggot, *Gymnocarena diffusa* (Snow) [Diptera: Tephritidae]	X Great plains from Montana south to Arizona, east to Missouri						

Insect pests	CONTINENT OR REGION IN WHICH THEY OCCUR						
	USA/CANADA /MEXICO	SOUTH AMERICA	AFRICA	WESTERN EUROPE	CENTRAL & EASTERN EUROPE	ASIA	AUSTRALIA
Sunflower Seed Maggot, *Neotephritis finalis* (Loew) [Diptera : Tephritidae]	X (Southern Canada to northern Mexico; throughout continental North America)						
Sunflower Headclipping Weevil, *Haplorhynchites aeneus* (Boheman) [Coleoptera: Curculionidae]	X (USA, Canada)						
Nymphalid butterfly, *Chlosyne lacinia saundersii*		X (Brazil)					
Noctuid, *Rachiplusia nu* (Guenee)		X (Argentina)					
The black cutworm, *Agrotis ipsilon* (Hufnagel) *Agrotis segetum* (Denis, Schiff.) [Noctuidae] *Agrotis* spp. [Lepidoptera: Noctuidae] brown cutworm, *Agrotis munda* (Walker); bogong moth *A. infusa* (Boisduval); variable cutworm, *A. prophyricollis(* Guenee). Pale western cutworm *Agrotis orthogonia* (Morrison)	 X	 X (Brazil)	 X X	 X		 X (Iran)	X X X X X
The chrysomelid, *Diabrotica speciosa* (Germar)		X					
The scarab beetle, *Cyclocephala melanocephala* (Fabricius)		X (Brazil)					
Aphids [Homoptera: Aphididae], *Bemisia* sp. ; **The Brazilian leafhopper,** *{Protalebrella brasiliensis* (Baker) ; *Empoasca* sp. (Cicadellidae) The leafhoppers, *Empoasca pteridis* Dhlb. ; *Empoasca devastans (Disi.)* *Liriomyza* sp. (Agromyzidae) ; *Leptocorisa tipuloides* (DeGreer) (Coreidae) ; **The noctuids,** *Pseudoplusia includens* (Walker), **The velvetbean caterpillar,** *Anticarsia gemmatalis* (Hubner), **The fall armyworm,** *Spodoptera frugiperda* (Smith) *Spodoptera exigua* (Hubner) *Spodoptera litura* (Fabricius)		 X X X X X X X X	 X (Egypt)	 X	 X X	 X	 X

Insect pests	CONTINENT OR REGION IN WHICH THEY OCCUR						
	USA/CANADA /MEXICO	**SOUTH AMERICA**	**AFRICA**	**WESTERN EUROPE**	**CENTRAL & EASTERN EUROPE**	**ASIA**	**AUSTRALIA**
Caterpillar [Nymphalidae], *Actinote pellena pellena* (Hubner)		X (Argentina, Venezuela, Brazil, Paraguay,Uruguay Peru)					
The yellow woolly-bear, *Spilosoma virginica* (Fabricius) *Spilosoma casignetum* (Kollar) *Spilosoma obliqua* (Walker)		X (Argentina)				X X	
The spotted maïze beetle, *Astylus atromaculatus* Blanchard (Melyridae)		X (Argentina)					
Athaumastus haematicus (Stal) [Coreidae] ; *Edessa meditabunda* (Fabricius) [Pentatomidae]		X X (Argentina)					
Nezara viridula (L.) [Pentatomidae] *Gargaphia torresi* (C.L.) [Tingidae]		X X	X (Egypt)				X
the black cutworm ; **the variegated cutworm**, *Peridroma saucia* (Hubner) (Noctuidae); *Melanagromyza cunctanoides* (Blanchard) [Agromyzidae] ; *Hylemyia* spp. [Anthomyiidae] ; *Disonychodes exclamationis* (Boheman) (Chrysomelidae) ; *Conoderus* spp. (Elateridae) ; *Epicauta leopardina* (Haag-R.) (Meloidae) *Acromyrmex* spp. (Formicidae) ; *Acromyrmex heyeri* (Forel) *Diloboderus abderus* (Sturm.) *Discynetus gagates* (Burmeister)		X X X X X X X X X X (Uruguay) X X					
A. lundi (Guerin) *B. striatus* (Roger)		X (Uruguay) X					
The Scarabs of the genera, *Phyllophaga, , Dyscinetus Phileurus*		X					
Larvae *of Hylemyia cilicrura* (Rondani) [Anthomyiidae]		X					
Myzus persicae (Sulzer)		X (Uruguay)				X	
Mallocephala deserticola (Bergman) [Noctuidae]		X					
Schizonycha sp. [Scarabaeidae]			X (Nigeria)				
*Gonocephalum simplex (*Fabricius) [Tenebrionidae]			X				
The noctuid, *Plusia orichalcea* (Fabricius) *Plusia* spp. (Noctuidae)			X			X X	
Piercing-sucking Hemiptera			X (Nigeria)				
Macrosteles sp. [Cicadellidae]			X				
Dacus cucurbitae Coquillett [Tephritidae]			X				

	CONTINENT OR REGION IN WHICH THEY OCCUR						
Insect pests	**USA/CANADA /MEXICO**	**SOUTH AMERICA**	**AFRICA**	**WESTERN EUROPE**	**CENTRAL & EASTERN EUROPE**	**ASIA**	**AUSTRALIA**
The noctuid moth, [Lepidoptera: Noctuidae] *Helicoverpa armigera* (Hubner) *Helicoverpa* spp. *Helicoverpa punctigera* (Wallengren)			 X		 X	 X	 X X X
Callidea dregei (Germar) C. *bohemani* (Stal)			X X				
Nysius stall (Evans) [Lygaeidae].			X				
Lygus spp. (Miridae) *Lygus pratensis* L. (Hemiptera: Miridae) *Lygus rugulipennis* (Poppius) [Miridae] *Lygus Gemelatus* (HS)				X X X	 X X		
The aphids, *Brachycaudus helichrysi* (Kaltenbach)				X (Germany)	X (Yugoslavia, Hungary Romania, Bulgaria, former USSR)		
*Aphrodes bicinctus (*Schrank) [Homoptera : Cicadellidae]				X			
Aphids [Homoptera: Aphididae] *Aphis fabae* Scop. *Aphis gossypii* (Glover *Aphis helianthi* (Monell) *Masonaphis masoni* (Knowlton) *Dolycoris baccarum* (L.) (Hemiptera Pentatomidae) ; *Ostrinia nubilalis* (Hilbner) ; *Phlyctaenodes sticticollis* (L.) (Lepidoptera : Pyralidae) ; *Phytomyza geniculata* Macq. (Diptera : Agromyzidae).	 X X			 X X X X X	 X	 X	
Acanthiophilus helianthi (Rossi) [Diptera : Tephritidae]				X (Italy)			
Eurydema ventrale Kolenati [Hemiptera : Pentatomidae]				X (Italy)			
Opatum sabulosum L. (Coleoptera: Tenebrionidae)				X (France)			
Eupteryx atropunctata (Goeze) (Cicidellidae) ; The leafminer, *Phytomyza horticola* (Goureau)				X X			
Acheta deserta Pall. [Orthoptera: Gryllidae]					X (Yugoslavia Hungary Romania and the former USSR)		
Lethrus apterus (Laxm.) [Coleoptera: Scarabaeidae]					X (Bulgaria, former USSR)		
The Wireworms [Coleoptera: Elateridae] *Agriotes* (especially *A. ustulatus* Schall. *A. sputator* L., *A. gurgistanus* Fald, *A. ponticus* Stepanov, *A. lineatus* L., *A. obscurus* L.). *Selatosomus* and *Melanotus* (including *M. fusciceps* Gryll.)					 X X X X		

	CONTINENT OR REGION IN WHICH THEY OCCUR						
Insect pests	**USA/CANADA /MEXICO**	**SOUTH AMERICA**	**AFRICA**	**WESTERN EUROPE**	**CENTRAL & EASTERN EUROPE**	**ASIA**	**AUSTRALIA**
Athus haemorrhoidalis (Fabricius)					X X		
Psalidium maxillosum (Fabricius) [Coleoptera: Curculionidae]					X (Yugoslavia, Hungary Bulgaria, former USSR)		
Tanymecus dilaticollis Gyllenhal [Coleoptera: Curculionidae]					X (Yugoslavia, Hungary Bulgaria, former USSR)		
Miscellaneous Coleoptera [Cerambycidae, Mordellidae] *Agapanthia dahli* (Richt)					X		
Beet Webworm, *Loxostege sticticalis* (L.) [Lepidoptera: Pyralidae]					X (Yugoslavia, Hungary Romania, Bulgaria, former, USSR)		
Mamestra brassicae L. [Lepidoptera: Noctuidae]					X		
Adelphocoris lineolatus (Goeze),	X (North America)						
Miscellaneous Plant Bugs [Pentatomidae, Lygaeidae, Coreidae]					X		
Tingidae (Hemiptera), *Galeatus helianthi* (Onder and Lodos) *Galeatus scrophicus* (Saunders)						X (Turkey) X	
S. littoralis (Boisduval) (defoliation),						X (Iran)	
Strawberry spider mite, *Tetranychus turkestani* (Ugarov and Nikolski)						X (Iran)	
The western flower thrips, *Frankliniella occidentalis* (Pergande) **Thrips [Thysanoptera],** *Thrips tabaci* (Linderman), *Frankliniella schultzei* (Trybom), *Desmothrips tenuicornis* (Bagnall), **the plague thrips**, *T. imaginis* (Bagnall).						X (Israël)	X X X X
Predators: *Orius spp.*						X	
Ostrinia damoalis Walker (Lepidoptera: Pyralidae)						X	
Rhopalosiphum erysemi (Kaltenbach)						X	
Cirphis unipuncta (Haw.) *Cirphis loreyi* (Dupt.)						X X	
Grasshoppers, *Carpophilus* sp. (Nitidulidae) ; *Disonycha* sp. (Chrysomelidae) ;						X X	
Leafhopper (Homoptera: Cicadellidae), *Amrasca biguttula biguttula* (Ishida)						X	
Phytomyza atricornis (Meigen) (Diptera: Agromyzidae)						X	

Insect pests	CONTINENT OR REGION IN WHICH THEY OCCUR						
	USA/CANADA /MEXICO	**SOUTH AMERICA**	**AFRICA**	**WESTERN EUROPE**	**CENTRAL & EASTERN EUROPE**	**ASIA**	**AUSTRALIA**
Black Scarab Beetles, *Pseudoheteronyx* spp. [Coleoptera: Scarabaeidae]							X
False Wireworms [Coleoptera: Tenebrionidae] **the striate false wireworm**, *Pterohelaeus alternatus* Pascoe, **the eastern false wireworm,** *P. darlingensis* Carter ; **the southern false wireworm**, *Gonocephalum macleayi* (Blackburn) **Another species,** *Celibe* sp. (= *Saragus* sp.)							X (South Australia, New South Wales) X X X
Wingless Cockroaches, *Calolampra* spp. [Orthoptera: Blaberidae] *Calolampra elegans* Roth and Princis and C. *solida* Roth and Princis							X X (Central Highlands of Queensland)
Black Field Earwig, *Nala lividipes* (Dufour) [Dermaptera: Labiduridae]							X
Field Crickets, *Teleogryllus and Lepidogryllus* spp. [Orthoptera: Gryllidae]							X
Black field crickets *Teleogryllus commodus* (Walker) and *T. oceanicus* (Le Guillou), **Brown field crickets,** *Lepidogryllus parvulus* (Walker) and *L. comparatus* (Walker).							X X
Sugarcane Wireworm *Agrypnus variabilis* (Candeze) [Coleoptera: Elateridae]							X
Soybean Looper, *Thysanoplusia orichalcea* (Fabricius) [Lepidoptera: Noctuidae]							X
Greenhouse Whitefly, *Trialeurodes vaporariorum* (Westwood) [Hemiptera: Aleyrodidae]							X
Rutherglen Bug, *Nysius vinitor* (Bergroth) [Hemiptera: Lygaeidae] *N. clevelandensis* (Evans)							X X (Queensland and northern New South Wales)

Insect pests of stored sunflower

the sawtoothed grain beetle *(Oryzaephilus surinamenis* L.) (Coleoptera: Cucujidae),
red flour beetle *(Tribolium castaneum* (Herbst)) (Coleoptera: Tenebrionidae),
Indian meal moth (*Plodia interpunctella* (Hübner)) (Lepidoptera: Pyralidae)

APPENDIX 2 – THE PATHOGENS OF SUNFLOWER

(Classification proposed by Gulya *et al*., 1997)

Disease	Causal organism	Country or region in which they occur
Downy mildew	*Plasmopara halstedii* (Farl.) Oomycetes	Every continent with the exception of Australia.
Sunflower rust	*Puccinia helianthi* (Schwein.) *Puccinia xanthii* (Schwein.)	Worldwide. Only in Australia.
Alternaria	*Alternaria helianthi* (Hansf.), syn. *Helminthosporium helianthi* Hansf.) *Alternaria zinnia* (Pape) *A. helianthinficiens* (Simmons) *A. helianthicola* (Rao & Rajagopalan) *A. protenta* (Simmons) *A. tenuis* Nees (Simmons)	Worldwide. Worldwide. North Dakota, Manitoba, Hungary; Yugoslavia. India, Yugoslavia. Uganda, Rhodesia. India, Iran.
Septoria leaf spot Septoria leaf speck	*Septoria helianthi* (Ell & Kell) *Septoria helianthina* (Petrov & arsinijevic)	Worldwide except South America. Yugoslavia.
Bacterial foliar diseases	*Pseudomonas tagetis,* reclassified as *Pseudomonas syringae (Ps)* pv. *tagetis* (Hellmers) Young, Dye, Wilkie ; *Pseudomonas syringae* pv. *Helianthi* (Kawanua) Young, Dye, Wilkie. *Pseudomonas cichorii* (Swingle) *Xanthomonas campestris* pv. *phaseoli*	Every continent. Japan, Canada, Mexico, USA, Europe, Africa, India, New Zealand. Subtropical climates, Brazil. India and Russia.
Powdery mildews	*Erysiphe cichoracearum* DC. ex. Meret *Sphaerotheca fuliginea* (Schlecht. ex Fr.) Poll *Leveillula tarucia* (Lev.) Arn.	All continents. Africa, Asia, Europe, and South America. China, India, the former Soviet republics, and the Middle East.
White Rust	*Albugo tragopogonis* (DC.) S. F. Gray [Syn.= *Albugo tragopogi* (Pers) Schroet]	Every continent
Virus diseases		
Aster Yellows (rarely observed)	Mycroplamas	USA, Canada, Argentina.
	Other sunflowers diseases with mycoplasmas	France, Israël, India, Sudan.
Cucumber Mosaic	Cucumber Mosaic Virus (CMV)	China, India Once from a nursery in Maryland.
Sunflower Mosaic	Sunflower Mosaic Virus (Potyvirus) (SMV)	Argentina, Texas, Czech Republic.
Sunflower Ringspot	Sunflower Ringspot Virus (Ilarvirus) (SRV)	Queensland, Australia.
Sunflower Yellow Blotch and Leaf Crinkle	Luteovirus	African countries and England.
Tobacco Ringspot	Tobacco Ringspot Virus (Nepovirus) (TRV)	Rio Grande Valley of Texas (on wild *H. annuus*).

Disease	Causal organism	Country or region in which they occur
Tobacco Streak	Tobacco Streak Virus (Lilarvirus) (TSV)	On garden sunflower in the Netherlands.
Tomato Spotted Wilt	Tomato Spotted Wilt Virus (Tospovirus) (TSWV)	Ukraine.
Minor Foliar Diseases (leaf spots)	*Ascochyta compositarum* (J.J. Davis) – Coelomycetes	USA, Kenya, Japan, Russia.
	Cercospora helianthi (Ell &Ever) – Hyphomycetes ; Cercospora helianthicola (Chupp &Viegas) *Cercospora pachyrus* (Ell & Kellerman)	USA, Brazil, Russia.
	Colletotrichum helianthi J.J. Davis - Coelomycete	-
	Entyloma compositarum Farl - Tilletiaceae	Montana.
	Epicoccum neglectum Desm. - Hyphomycetes	Yugoslavia, Romania.
.	*Itersonilia perplexans* Derx - Basidiomycete	Canada, Uruguay.
	Myrothecium roridum Tode:Fr. (Alb. & Schw.) – Hyphomycetes *M. verrucaria* Ditmar:Fr – Hyphomycetes	Pakistan. Argentina.
	Phialophora asteris (Dowson) Burge & Isaac f. sp. *Helianti* Tirilly & Moreau – (Soilborne fungus)	Canada, Italy.
	Phyllosticta Wisconsinensis H.C. Green - Coelomycete	-
	Sordaria fimicola (Rob. Ex Desm.) Ces & Not. - Ascomycete	Yugoslavia, USA.
Miscellaneous Foliar Pathogens		
	Species of : *Botryodiplodia, Cladosporium, Cornyespora, Curvularia, Helminthoporium, Mycosphaerella,Pyrenophora, Sphaceloma*	Tropical climates.
Sclerotinia Wilt	*Sclerotinia sclerotiorum* (Lib.) de Bary	Worldwide.
	Sclerotinia minor Jagger	Australia, Argentina, Uruguay, Chile, California.
Phomopsis Stem Canker	*Phomopsis helianthi* Munt.-Cvet et al.	Worldwide
Phoma Black Stem	*Phoma macdonaldii* (Boerema)	Northern Great Plains of USA, California, Kansas. Countries of Africa, Asia (with the exception of China), Argentina, Europe.
Verticillium Wilt/Leaf Mottle	*Verticillium dahliae (*Klebahnis)	Europe, Argentina, Mexico, former USSR, England, north-central plain in the USA, Canada.
Charcoal Rot	*Macrophomina phaseolina* (Tassi) Goid Synonyms *Sclerotium bataticola* Tabu and *Rhizoctonia bataticola* (Taub.) Briton Jones.	Most around the world but more prevalent in Egypt, India and Pakistan.

Disease	Causal Organism	Country or region in which they occur
Southern blight or collar rot	*Sclerotium rolfsii* Sacc. (syn. *Corticum rolfsii* Curzi*)* - Basidiomycete	Tropical and subtropical climates.
Minor root and stalk pathogens :		
Stem rot Root rots ans seedling damping off Texas root rot Wilt	*Phytophthora cryptogea* Pethyb. & Kaff. Several species of *Pythium* including *P. aphanidermatum* (Edson) Fitzp., *P. debaryanum* Auct. Non-Hesse, *P. irregulare* Buisman, *P. rostratum* Butler *P. splendens* Braun *Phymatotrichum omnivorum* *Fusarium moniliforme* (sheld) *Fusarium oxysporum* (Schlect) *Fusarium tabacinum* (Beyma)	California, Iran. USA, Iran. Texas. India, North America. India, North America. Italy.
Sclerotinia Head rot	*Sclerotinia sclerotiorum*	Argentina, several European countries, Japan, North America.
Rhizopus head rot	*Rhizopus* (at least three species)	Australia, India, South Africa, USA, Canada, the Mediterranean areas of Europe, Egypt and Russia
Botrytis head rot	*Botrytis cinerea* Pers.	All European countries, Egypt, Turkey, India, Pakistan, Russia, Canada, USA
Bacterial head rot	*Erwinia carotovora* Jones, Holland	USA, Mexico, several European countries, several central African countries, Russia
Nematodes	*Meloidogyne* spp. (Volvas & Sassanelli) *Meloidogyne incognita* *Meloidogyne javanica* *Rotylenchulus* (Robinson & Orr*)* *Tylenchorhynchus* (stunt), *Helicotylenchus* (spiral), *Pratylenchus* (pin), *Xiphinema* (dagger), *Hoplolaimus* (lance), *Quinisulcius* (stunt) *Trichodorus* *Belonolaimus* *Scutellonema, Paratrichodorus, Rotylenchus*	California, Florida, Tennessee, Texas, India, South Africa, Italy, Egypt, Serbia. Brazil, Egypt, India, Italy, Serbia, South Africa, Zambia. Brazil, Egypt, India, Italy, Serbia, South Africa, Zambia. India. California. California, Florida, Tennessee, Texas. California, Florida, Tennessee, Texas. California. Florida, Tennessee, Texas. Florida, Tennessee, Texas. South Africa.

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