

Chapter 1

AN INTRODUCTION TO THE SUNFLOWER CROP

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ABSTRACT

Sunflower (*Helianthus annuus* L.) belongs to the family Asteraceae. The *Helianthus* genus contains 65 different species of which 14 are annual plants. The sunflower plant originated in eastern North America. It is thought to have been domesticated around 3000 B.C. by Native Americans. In the late 1800s the sunflower was introduced in the Russian Federation where it became a food crop and Russian farmers made significant improvements in the way that the sunflower was cultivated. Since 3000 B.C. a wide range of uses of sunflower have been reported throughout the world such as ornamental plant, medicinal, alimentary, feedstock, fodder, dyes for textile industry, body painting, decorations, and so on. Sunflower species are allelopathic in nature and this crop appears to have a bright future, especially if the scientists can translate the cutting-edge research into technologies that will reduce the reliance on synthetic herbicides, pesticides, and crop protection chemicals. On the one hand sunflower is well known by its phytoremediation potential, thus it can be speculated that the good tolerance of sunflower towards pollutants coupled with an increased accumulation/degradation capacity might contribute to an efficient removal of pollutants from soil and water; on the other hand sunflower possesses the potential to develop bioenergy systems that allow for synergies between food and energy production. Because the sunflower has several potential markets, it is a good choice for growers on both small and large scales. However, it has to be remembered that scientific, technical or agricultural projects linked with sunflower have to include side effects elsewhere in order to shape a sustainable future.

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1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) belongs to the family Asteraceae. *Helianthus* genus contains 65 different species (Andrew et al., 2013). The name *Helianthus*, being derived from *helios* (the sun) and *anthos* (a flower), has the same meaning as the English name Sunflower, which has been given these flowers from a supposition that they follow the sun by day, always turning towards its direct rays. The sunflower that most people refer to is *H. annuus*, an annual sunflower. In general, it is an annual plant which possesses a large inflorescence (flowering head), and its name is derived from the flower's shape and image, which is often used to depict the sun. The plant has a rough, hairy stem, broad, coarsely toothed, rough leaves and circular heads of flowers (Khaleghizadeh, 2011). The heads consist of many individual flowers which mature into seeds on a receptacle base (Seghatoleslami et al., 2012).

Sunflower is the world's fourth largest oil-seed crop and its seeds are used as food and its dried stalk as fuel. It is already been used as ornamental plant and was used in ancient ceremonies (Harter et al., 2004; Muller et al., 2011). Additionally, medical uses for pulmonary afflictions have been reported. In addition, parts of this plant are used in making dyes for the textile industry, body painting, and other decorations. Sunflower oil is used in salad dressings, for cooking and in the manufacturing of margarine and shortening (Kunduraci et al., 2010). Sunflower is used in industry for making paints and cosmetics. A coffee type could be made with the roasted seeds. In some countries the seed cake that is left after the oil extraction is used as livestock feed. In the Soviet Union the hulls are used for manufacturing ethyl alcohol, in lining for plywood and growing yeast. The dried stems have also been used for fuel. The stems contain phosphorous and potassium which can be composted and returned to soil as fertilizer. Sunflower meal is a potential source of protein for human consumption due to its high nutritional value and lack of anti-nutritional factors (Fozia et al., 2008).

Sunflower was a common crop among American Indian tribes throughout North America. Evidence suggests that the plant was cultivated by natives in present-day Arizona and New Mexico about 3000 B.C. Some archaeologists suggest that sunflower may have been domesticated before corn (NSA, 2013). Although the scientific consensus had long been that sunflower was domesticated once in eastern North America, the discovery of pre-Columbian sunflower remains at archaeological sites in Mexico led to the proposal of a second domestication center in southern Mexico. However, evidences from multiple evolutionary important loci and from neutral markets support a single domestication event for extant cultivated sunflower in eastern North America (Blackman et al., 2011).

The objective of this chapter is to present and discuss a summary about the huge amount of information in which the sunflower is the main subject. The chapter aims to assist people involved in all aspects of sunflower management, including conservation, agriculture, mining, energy, food production, health and other industries, to obtain a broad knowledge of sunflower and of its ecosystem services.

2. BOTANICAL AND MORPHOLOGICAL DESCRIPTION

Sunflowers are botanically classified as *Helianthus annuus* L. (Table 1). They are large plant and are grown throughout the world because of their relatively short growing season. Sunflower is an annual herb, with a rough, hairy stem, 3 to 12 feet high, broad, coarsely toothed, rough leaves, 3 to 12 inches long and circular heads of flowers, 3 to 6 inches wide in wild specimens and often a foot or more in cultivation. The flower-heads are composed of many small tubular flowers arranged compactly on a flattish disk: those in the outer row have long strap-shaped corollas, forming the rays of the composite flower. Each sunflower head, or inflorescence, is actually composed of two types of flowers. What appears to be yellow petals around the edge of the head are actually individual ray flowers. The face of the head is comprised of hundreds of disk flowers, which each form into a seed (achene).

The basic chromosome number for the *Helianthus* genus is 17. Diploid, tetraploid and hexaploid species are known. There are only 14 annual species of *Helianthus*. Plant breeders have made interspecific crosses within the genus and have transferred such useful characters as higher oil percentage, cytoplasmic male sterility for use in production of hybrids, and disease and insect resistance to commercial sunflower.

Table 1. Scientific classification of *H. annuus* L.; this genus counts 65 different species

Taxa	
Kingdom	Plantae
Subkingdom	Viridaeplantae
Infrakingdom	Streptophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Infradivision	Angiospermae
Class	Magnoliopsida
Superorder	Asteranae
Order	Asterales
Family	Asteraceae
Subfamily	Helianthoideae
Tribe	Heliantheae
Genus	<i>Helianthus</i>
Specie	<i>annuus</i>

The taxonomic classification has been in place since 1753.

3. PRODUCTION

In recent years, the sunflower cultivated area has been steadily increasing due to the breeding of dwarf high yielding hybrids that also facilitate mechanization and the emphasis given to polyunsaturated acids for human consumption. Global production grew steadily in last 25 years (PSD-USDA, 2011), and FAO expect a total world output close to 60 million tons towards 2050. The four largest producers (Russia, Ukraine, European Union and Argentina) account for 70% of global volume, with an exponential growth of production in

the last ten years in the Black Sea region, with increased acreage and higher yields achieved by replacing old varieties by hybrid seeds.

According to data from FAOSTAT (FAOSTAT, 2011) Russia Federation ranked first producing ca. 9.7 millions of tons of sunflower seeds or 26% of the world total. Ukraine and Argentina ranked second and third place with 8.6 and 3.6 tons of sunflower seeds, respectively. France, Romania, China, Bulgaria, Hungary, Turkey, and Spain produced between 1.0 and 1.9 millions of tons of sunflower seeds (Table 2). The United States produced ca. 1.0 millions of tons of sunflower seeds, or 5% of the world's total production. That is enough to make the United States rank eleventh in that category. South Africa ranked twelfth producing ca. 0.9 millions of tons of sunflower seeds.

Table 2. The highest twelve sunflower seed producing countries in the world during 2011

Place	Countries	Production (tons)
1	Russia Federation	9,696,450
2	Ukraine	8,670,500
3	Argentina	3,671,750
4	France	1,882,450
5	Romania	1,789,330
6	China	1,700,000
7	Bulgaria	1,439,700
8	Hungary	1,374,780
9	Turkey	1,335,000
10	Spain	1,084,300
11	United States of America	924,550
12	South Africa	860,000

Russia followed by Ukraine are harvesting almost half of the world sunflower seed production. The total sunflower seed production is reaching ca. 35 millions of tons

Data source: data obtained from FAOSTAT (2011).

According to FAO (FAO, 2010), there are some key production parameters which have to be known by farmers throughout the world:

- Sunflowers are grown in warm to moderate semi-arid climatic regions of the world from Argentina to Canada and from central Africa to the Commonwealth of Independent States (Esmaeli et al., 2012; Onemli, 2012).
- Frost will damage sunflowers at all stages of growth. The plant grows well within a temperature range of 20-25°C; temperatures above 25°C reduce yields and oil content of the seeds (Thomaz et al., 2012).
- Plants are drought-resistant, but yield and oil content are reduced if they are exposed to drought stress during the main growing and flowering periods. Sunflowers will produce moderate yields with as little as 300 mm of rain per year, while 500-750 mm are required for better yields (Gholamhoseini et al., 2013; Ghaffari et al., 2012).
- Sunflowers adapt to a wide variety of soil, but perform best on good soils suitable for maize or wheat production (Radanielson et al., 2012).

- Sunflower plant density of 5-8 plants per m² is required to form the optimum leaf area for plant photosynthesis. Kernel weight (40-80 g per 1000 kernels) and the average number of kernels in a sunflower head (1200-1500) are the other most important yield component (Seassau et al., 2012; Emami-Bistghani et al., 2012).
- Sunflower growth depends more on nitrogen than any other nutrient. Due to its deep rooting system, sunflower is able to use nitrogen from soil layers that are inaccessible to wheat, corn or other field crops. The plant requires a maximum of 150 kg of nitrogen per hectare to produce a three tons ha⁻¹ yield. Over fertilization may lead to sunflower lodging. Phosphorous, potassium, boron, magnesium and molybdenum are also needed to achieve the best yields (Jabeen and Ahmad, 2012; Babaeian et al., 2011).
- The average fatty acid composition of oil from temperate sunflower crops is 55-75% linoleic acid and 15-25% oleic acid. Protein content is 15-20% (Aznar-Moreno et al., 2013; Ali and Ullah, 2012).
- Planting in the Western Balkan countries, Eastern Europe and countries of the Former Soviet Union takes place during March and April (Zheljazkov et al., 2012; Saleem et al., 2008).
- Sunflower has one of the shortest growing seasons of the major economically important crops of the world. Early maturing varieties are ready for harvesting 90 to 120 days after planting, and late maturing varieties 120 to 160 days after planting. Delayed harvesting causes unwelcome changes in oil quality, with an increase in free fatty acid content. The seeds are ready to harvest when the heads turn black or brown and the seed moisture content reaches 10-12%. Grain combines are fairly easily adapted for the harvesting of sunflower by the addition of a head snatcher (Borbely et al., 2008).
- Depending on climatic and cultivation conditions, yields can vary from as much as 600 to 3000 kg ha⁻¹; irrigation is a key factor for obtaining high yields (Chigeza et al., 2013; Khan et al., 2013; Akhtar et al., 2012).

Table 3 shows the oil yields in gallons per acre of oil producing crops, the yields will vary in different agroclimatic zones. Sunflower produces 98 Gal oil acre⁻¹. That is enough to make the sunflower rank twenty-third in that category. Additionally, higher-yielding oil crops like safflower, mustards and sunflower have significant rotational benefits. For example, deep safflower and sunflower roots help break up hardpan and improve soil tilth.

4. GROWTH AND DEVELOPMENT

Sunflower is a broadleaf plant that emerges from the soil with two large cotyledons (Rawat et al., 2010). The emergence will take four to five days when planted an inch deep in warm soil, but will take a few days longer in cooler soils or when planted deeper. Soil crusting can make it difficult for the large seedlings to push out of the soil. Sunflowers grow rapidly, producing large and rough leaves. Current sunflower varieties reach an average height of six feet, varying between five and seven feet depending on planting date and soil conditions (Saensee et al., 2012). After reaching their full height and blooming, heads on

commercial cultivars turn downwards, designed to make it harder for birds to eat the seed. Commercial sunflowers have flowers that are self-compatible for pollination, meaning they do not require a pollinating insect, although some studies have shown bee pollinators providing a slight yield boost (de Carvalho and de Toledo, 2008). Some farmers prefer sowing their rows from north to south so that the capitula can lean into the row space, rather than bumping against an adjacent plant, causing some seed to fall (Olowe and Adeyemo, 2009).

Table 3. Oil producing crops

Number	Crop	Scientific name	Yield (Gal oil acre ⁻¹)
1	Oil palm	<i>Elaeis guineensis</i> Jacq.	610
2	Macauba palm	<i>Acrocomia aculeata</i> Jacq.	461
3	Pequi	<i>Caryocar brasiliense</i> Camb.	383
4	Buriti palm	<i>Mauritia flexuosa</i> L.	335
5	Oiticica	<i>Licania rigida</i> Benth	307
6	Coconut	<i>Cocos nucifera</i> L.	276
7	Avocado	<i>Persea americana</i> Mill.	270
8	Brazil nut	<i>Bertholletia excelsa</i> Humb & Bonpl.	245
9	Macadamia nut	<i>Macadamia ternifolia</i> F.V. Muell.	230
10	Jatropha	<i>Jatropha curcas</i> L.	194
11	Babassu palm	<i>Orbignya martiana</i> Mart.	188
12	Jojoba	<i>Simmondsia chinensis</i> Link	186
13	Pecan	<i>Carya illinoensis</i> Wangenh.	183
14	Bacuri	<i>Platonia insignis</i> Mart.	146
15	Castor bean	<i>Ricinus communis</i> L.	145
16	Ghoper plant	<i>Euphorbia lathyris</i> L.	137
17	Pissava	<i>Attalea funifera</i> Mart.	136
18	Olive tree	<i>Olea europaea</i> L.	124
19	Rapessed	<i>Brassica napus</i> L.	122
20	Opium poppy	<i>Papaver somniferum</i> L.	119
21	Peanut	<i>Arachis hypogea</i> L.	109
22	Cocoa	<i>Theobroma cacao</i> L.	105
23	Sunflower	<i>Helianthus annuus</i> L.	98
24	Tung oil tree	<i>Aleurites fordii</i> Hemsl.	96

Yields of common energy crops are associated with biodiesel production. This is not related to ethanol production, which relies on starch, sugar, and cellulose content instead of oil yields.

Experiments have been carried out to improve the growth and development of sunflower under natural or stress conditions (Gerardo et al., 2013; Nasim et al., 2011; Da Silva et al., 2012). Naz and Bano (2013) reported that the adverse effects of salt stress on sunflower growth could be alleviated by foliar application of salicylic acid alone or in combination with *Azospirillum* and *Pseudomonas* inoculations (Table 4). Gholamhoseini et al. (2013) shown that the application of *Glomus musseae* and *Glomus hoi* could be critical in the cultivation of sunflowers under arid and semi-arid conditions, where water is the most important factor in determining plant growth and yield. Additionally, Akbari et al. (2011) reported that inoculating the sunflower seeds with plant-growth promoting rhizobacteria increased the

qualitative and quantitative properties of sunflower significantly, as compared to the control treatment.

Table 4. Recent uses of the sunflower during the last years; main or alternative uses make evident the diversity of sunflower

Area	Description	References
Food		
	Blends of high linoleic sunflower oil with selected cold pressed soils.	(Ramadan, 2013)
	Production of florets of sunflower.	(Liang et al., 2013)
	Tocopherols and phytosterols for the human food market.	(Fernández-Cuesta et al., 2012)
	Sunflower flour as a rich source of high quality proteins.	(Levic et al., 2012)
	Protein hydrolysis using proteases.	(Tavano, 2013)
Animal Feed		
	Sunflower products fed to finishing pigs.	(González-Vega and Stein, 2012)
	Ingestive behavior and physiological responses of goats fed with sunflower cake.	(Agy et al., 2013)
	Nutritional value of sunflower meal on broiler chickens.	(Moghaddam et al., 2012)
	Potential nutritive value as source of feed for ruminants in Kenya.	(Osuga et al., 2012)
Energy		
	Methane production.	(Fernández-Cegrí et al., 2013; Todorovic et al., 2013)
	Biodiesel production.	(Iriarte and Villalobos, 2013; Iglesias et al., 2012)
	Bioenergy: biotechnology progress and emerging possibilities.	(González-Rosas et al., 2013)
	Anaerobic digestion of sunflower oil cake.	(De la Rubia et al., 2013)
	Oil production.	(Spinelli et al., 2012)
Sustainability		
	Of sunflower cultivation within the EU Renewable Energy Directive.	(Spagnoli et al., 2012)
	Sustainable sunflower processing.	(Weisz et al., 2013)
	Economic sustainability of sunflower production.	(Keskin and Dellal, 2011)
	Symbiosis and Plant-Growth Promoting Rhizobacteria	
	Effect of arbuscular mycorrhizal inoculation on sunflower.	(Naz and Bano, 2013; Audet and Charest, 2013; Gholamhoseini et al., 2013)

Table 4. (Continued)

Area	Description	References
Symbiosis and Plant-Growth Promoting Rhizobacteria		
	Bacterial inoculation speeds zinc release from ground tire rubber.	(Khoshgoftarmash et al., 2012)
	A strain of <i>Bacillus subtilis</i> stimulates sunflower growth.	(López-Valdez et al., 2011)
Remediation		
	Biodegradation of PAHs.	(Tejeda-Agredano et al., 2013)
	Plant response to lead.	(Doncheva et al., 2013)
	Metal accumulation on sunflower.	(Mahmood et al., 2013; Hao et al., 2012)
Fertilization, pesticides and environment		
	Foliar fertilization with molybdenum.	(Skarpa et al., 2013)
	Fertilization affects the agronomic traits of high oleic sunflower hybrid.	(Mohammadi et al., 2013)
	Gas exchange in sunflower plants.	(Da Silva et al., 2013)
	Effect of different nitrogen level on yield components.	(Rafiei et al., 2012)
Biological control		
	Encrusting offers protection against phytotoxic chemicals.	(Szemruch and Ferrari, 2013)
	Biological control of <i>Macrophomina phaseolina</i> on sunflower.	(Ullah, 2010)
Allelopathic effects		
	On growth of rice and subsequent wheat crop.	(Bashir et al., 2012)
	On seed germination and seedling growth of <i>Trianthema portulacastrum</i> .	(Rawat et al., 2012)
Health		
	<i>In vivo</i> evaluation of an oral health toothpaste with sunflower oil.	(Schafer et al., 2007)
	Health benefits of the sunflower kernel.	(Holliday and Phillips, 2001)

5. SUNFLOWER ALLELOPATHY

Sunflower species are allelopathic in nature; as well cultivated sunflower has great allelopathic potential and inhibits weed-seedling growth of velvet leaf, thorn apple, morning glory, wild mustard and other weeds (Macías et al., 1998a). Two members of the genus *Helianthus* contain a great quantity of allelopathic compounds. *H. annuus* is well known for its allelopathic compounds, including sesquiterpene lactones, heliespirones A, annoionones, helibis-abonols and heliannols (Macías et al., 1998b). Heliannols A, D and E have special relevance due to high phytotoxic activity (Macías et al., 1999).

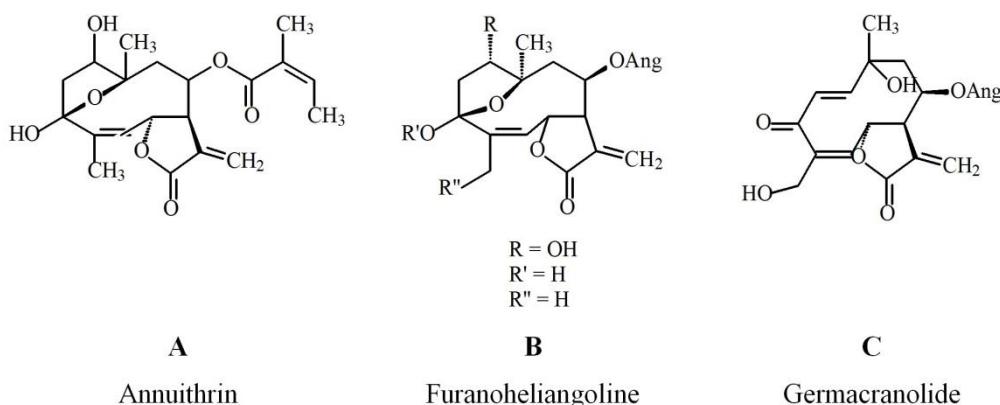


Figure 1. Some molecular structures of allelopathic compounds presents in sunflower cultivars. A) Annuithrin (sesquiterpene lactone) or Niveusin C, a growth inhibitor. B) Furanolheliangoline, a biologically active molecule. C) Germacranolide, a toxic sesquiterpene lactone (a potent feeding deterrents).

Helianthus tuberosus contains helian-gine and *H. annuus* contains a sesquiterpene lactone; a heliangolide [Annuithrin or Niveusin C (Figure 1A)] (a growth inhibitor); furanolheliangolide [(Figure 1B) a biologically active]; three additional sesquiterpene lactones: the known compound niveusin B, a germacranolide (Figure 1C) (the tifruticin-type); a 3-ethoxy-niveusin B; an ethoxyheliangolide (Spring et al., 1982) and coumarins (only accumulate in healthy sunflower plants as a response to the variation in environmental conditions that affect field-grown plants). In sunflower, it was reported that the concentrations of scopolin exceeded those in both infected and uninfected plants (Gutiérrez-Mellado et al., 1996).

Scopoletin have been described as phytoalexins and allelopathic compounds, being accumulated in response to fungal and parasitic plant infection, insect attack, mechanical injury and treatment with abiotic elicitors such as sucrose and CuCl_2 , and plant hormones; besides scopoletin has also been shown to have a physiological activity, including the promotion of stomatal closure in sunflower and inhibition of bud growth in pea at very low concentrations (Gutiérrez-Mellado et al., 1996).

Annuithrin was tested using a bioassay with *Avena* straight growth test. The addition of a concentration range from 50 to 180 μM resulted in a linear reduction of growth between 10 and 90%. In fact, annuithrin was shown to have antibacterial qualities. However, fungi and yeast were either less inhibited or not inhibited (minimal inhibitory concentration, MIC 45 $\mu\text{g mL}^{-1}$ on *Bacillus brevis*; MIC 90 $\mu\text{g mL}^{-1}$ on *Proteus vulgaris*; MIC 90 $\mu\text{g mL}^{-1}$ on *Eremothecium ashbyi*; Macías et al., 1996). In addition, *in vivo* DNA and RNA synthesis in cells of the ascitic form of Ehrlich carcinoma was drastically reduced by annuithrin (at an annuithrin concentration of 20 $\mu\text{g mL}^{-1}$ about 50% inhibition of DNA synthesis and about 75% inhibition of RNA synthesis) (Spring et al., 1981).

It is well known that there are examples of allelopathic cover crops being used for weed management in other crops, as well as other cultural methods to employ allelopathy (Duke, 2010). However, there are still no cultivars of crops being sold with allelopathic properties as a selling point (Cheema and Khalid, 2000; Tesio and Ferrero, 2010). Enhancement or impartation of allelopathy in crops through the use of transgenes could eventually be used to

produce such a cultivar. The study of allelopathic crops appears to have a bright future, especially if the scientists can translate the cutting-edge research into technologies that will reduce the reliance on synthetic herbicides, pesticides, and crop protection chemicals. Tesio and Ferrero (2010) reported that the use of allelopathic traits from crops or cultivars with important weed inhibition qualities, together with common weed control strategies, can play an important role in the establishment of sustainable agriculture. It has to be noted that allelopathy may also be another component of desired improved weed management. It will not solve all weed problems in any field, but may help considerably to reduce the population of weeds in the fields (Labrada, 2008).

6. PHYTOREMEDIATION WITH SUNFLOWER

Phytoremediation consists of mitigating pollutant concentrations in contaminated soils, water, or air, with plants able to contain, degrade, or eliminate contaminants and its derivatives (Malaviya and Singh, 2012). *H. annuus* is a plant with not only food and energy values, but also with phytoremediation potential (Seth et al., 2011; Mukhtar et al., 2010). It is one of the most widely studied plants for heavy metal phytoremediation (Kara et al., 2013). However, it is well known that sunflower is able to contain, degrade or eliminate metals (Chen et al., 2012; Ker and Charest, 2010; Lee and Yang, 2010), polycyclic aromatic hydrocarbons (Tejeda-Agredano et al., 2013; Gan et al., 2009) and polychlorinated biphenyls (Fiebig et al., 1997) from soil or water. Investigations with *H. annuus* have revealed that several heavy metals, including lead, cadmium, copper, zinc and cobalt, accumulate at high concentrations in shoots as well as in roots. Heavy metal uptake is minor in seeds than in roots and shoots. However, few attempts have been made to use plant-growth promoting rhizobacteria to facilitate phytoextraction and cadmium uptake in *H. annuus* planted in cadmium-contaminated soil (Prapagdee et al., 2013). Sunflower is a documented metal accumulator and its growth on contaminated soil for simultaneous remediation and further energy production has been studied (Marques et al., 2013; Madejon et al., 2003). The good tolerance of sunflower toward pollutants coupled with an increased accumulation/degradation capacity might contribute to an efficient removal of pollutants from soil and water. Clearly it is not an easy job, thus scientists of multidisciplinary areas have to work hard. Additionally, there is a lack of knowledge concerning the pollutants accumulation and antioxidant responses during the growth and development of sunflowers.

7. SUNFLOWER AS A RENEWABLE ENERGY SOURCE

Thousands of years ago, people in many regions throughout the world began to process vegetable oils, utilizing whatever food stuffs they had on hand to obtain oils for a variety of cooking purposes. The Chinese and Japanese produced soy bean oil as early as 2000 B.C., while southern Europeans had begun to produce olive oil by 3000 B.C. In Mexico and North America, sunflower seeds were roasted and beaten into a paste before being boiled in water; the oil that rose to the surface was skimmed off (FAO, 2010). During the last decade, an

increased attention would be observed being paid on the use of sunflower as renewable energy source.

Oilseed sunflower is quickly gaining popularity as a feedstock crop for biodiesel because it shares several positive agronomic features with other common oil crops such as canola and soybean; yields well in a variety of conditions, and can be grown easily and profitably at both small farm and large field scales. It is well known that a number of crops can be used for both food and bioenergy production such as sunflower (Kibazohi et al., 2012). Under some circumstances, the potential exist to develop bioenergy systems that allow for synergies between food and energy production. Integrated food and energy systems could produce food crops while simultaneously addressing energy needs (Bogdanski et al., 2010).

There is a trend world-wide to grow crops in short rotation or in monoculture (such as sunflower), particularly in conventional agriculture (Bennett et al., 2012). This practice is becoming more prevalent due to a range of factors including economic market trends, technological advances, government incentives, and retailer and consumer demands. Land-use intensity will have to increase further in future in order to meet the demands of growing crops for both bioenergy and food production, and long rotations may not be considered viable or practical. Notwithstanding, evidence indicates that crops grown in short rotations or monoculture often suffer from yield decline compared to those grown in longer rotations or for the first time (Zambrano-Navea et al., 2012). Numerous factors have been hypothesized as contributing to yield decline, including biotic factors such as plant pathogens, deleterious rhizosphere microorganisms, mycorrhizas acting as pathogens, and allelopathy or autotoxicity of the crop, as well as abiotic factors such as land management practices and nutrient availability (Sun et al., 2011). This section identifies gaps in our understanding about the energy production of biomass and the interaction of the ecosystems. Additionally, it has to be remembered that each bioenergy development projects have to include side effects elsewhere in order to shape a sustainable future.

CONCLUSION

Sunflower was domesticated in eastern North America and since 3000 B.C. this crop was bred by natives. Thenceforth a wide range of uses of sunflower have been reported throughout the world. Sunflowers are a permanent source of food, oilseed and biofuels because they are well adapted to a variety of conditions and often require fewer agricultural inputs than other more common crops, while under some circumstances, the potential exist to develop bioenergy systems that allow for synergies between food and energy production. Because the sunflower has several potential markets, it is a good choice for growers in both small and large scales. However, scientific, technical or agricultural projects linked with sunflower have to include environmental side effects such as pollution, greenhouse gases emissions, salinization, or energy consumption elsewhere in order to shape a sustainable future.

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