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Certified Sunflower Seed Production in Chile

Rebeca Unghiatti Rosales
Departamento de Ciencias Vegetales
Facultad de Agronomía e Ingeniería Forestal
Pontificia Universidad Católica de Chile
raunghia@uc.cl

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There are two types of sunflower based on their use: The primary differences are in oil content and seed size. Oil seeds are generally characterized by black hulls and the seed is crushed for its oil content.
Smaller oil seeds and seeds scuffed during transport and processing are used for bird food. The size of oil seeds ranges from 4.5 to 8.0 mm and their oil content ranges from 46 to 50%.

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The second type of sunflower is for confectionary uses. These seeds have mostly white striped hulls.
Confectionary kernels are roasted and salted, or roasted and no salt added and marketed as edible chips.
The size of these seeds ranges from 8 to 12 mm and their oil content is 30 to 40%.

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From 1939 to 1994, Chile produced and processed sunflowers commercially, but there currently is neither commercial oilseed nor commercial confectionary production of sunflowers in the country.
However, Chile remains a commercial multiplier of sunflower seed for international seed companies. As a result, 100% of the sunflower seeds produced in the country is exported, with the majority going to Argentina, France, Spain and the United States.

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This table identifies the export locations for sunflower seeds produced in Chile. Argentina is the most important client for sunflower seeds. There have been recent reductions in exports to the United States and France, while Spain has become increasingly important as an importer of sunflower seed produced in Chile.

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Many genes in sunflower have been identified using molecular biology, This process, along with traditional breeding methods, improves the incorporation of specific desirable genes into sunflowers as well as reduces the time to obtain hybrids. Some of these genes include:

Downy mildew resistance
Rust resistance
Restoration of cytoplasmic male sterility
Multiple flowers with more branches
Nuclear male sterility

In particular, one advance has been sunflower resistance to Imidazolinone (IMI) herbicides.

This resistance was discovered in 1997 by weed scientists at Kansas State University who identified a population of wild sunflower resistant to ALS inhibitors. Sunflower geneticists crossed the resistant wild sunflower with cultivated sunflowers and found these plants were able to maintain tolerance through backcrosses. Since this naturally occuurring gene was incorporated into cultivated germplasm via traditional plant breeding procedures, it is not considered a genetically modified organism (GMO).

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IMI herbicides are inhibitors of the enzyme Acetolactate synthase (ALS), an early enzyme in the biosynthetic pathway for the production of the essential amino acids leucine, isoleucine, and valine.

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The basis for the herbicide tolerance is the expression in the sunflower plant of a mutant acetohydroxyacid synthase (AHAS = ALS). Clearfield sunflowers are hybrid sunflowers bred to be resistant to a specific herbicide in the IMI family. Some herbicides labeled for use on Clearfield sunflowers are imazamox and imazapyr.

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If the same herbicide is used continually, there is risk that sunflower plants will acquire herbicide resistance. Resistance may occur through selection pressure; susceptible plants will be killed, but herbicide-tolerant plants will survive and reproduce without competition from susceptible plants. As a result, resistant plants will successfully reproduce and become dominant in the population if the herbicide is continually used.

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To preserve the efficacy of the CLEARFIELD Sunflower Production System, and to prevent or delay herbicide resistance, it is necessary to:

1. Always grow CLEARFIELD sunflower in rotations with other crops.
2. Use alternate (non-ALS) mode-of-action herbicides with activity on sunflower in the rotational crop.
3. Do not plant CLEARFIELD sunflower on land with a history of heavy infestation of wild sunflowers.
4. Control wild sunflowers in areas adjacent to CLEARFIELD sunflowers through the use of non-ALS herbicides and/or mowing prior to seed set.
5. Control emerged wild sunflowers prior to planting CLEARFIELD sunflowers with non-ALS burndown herbicides (no-till/min-till) or tillage (conventional-till).

In Chile, many of these control measures are easier because wild sunflowers do not exist and therefore are not encountered in commercial sunflower seed production. So, most of the attention is focused on the two first points to prevent herbicide resistance.

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Chile produces both parental sunflower seed lines as well as hybrid sunflower seed using cytoplasmic male sterile lines. Both oil and confectionary hybrid seed is produced in Chile. To ensure adequate pollination, the male lines are selected that produce multiple flowers.

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Chile only produces sunflower seed because it does not have sunflower germplasm that is supplied by other countries. When sunflower seed arrives in Chile for seed increase from different countries, it is inspected by the Servicio Agricola y Ganadero (SAG), an official government agency. The seed must contain an ISTA or AOSA Seed Analysis Certificate or an Official Certificate of Analysis from the country of origin. SAG then conducts a phytosanitary inspection of the seed to ensure that is does not carry undesired diseases into the country. The seed is also inspected for weeds, especially troublesome weeds in sunflower fields such as *Orobanche* spp. and *Cirsium arvensis*. Once SAG approves the seed for entry into Chile, the seed is released from the Customs Agency to the local Chilean seed company responsible for seed multiplication.

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Upon receipt of the seed for multiplication, the seed company conducts both a purity and germination test. The purity test is important to know the contamination of the seed lot with other crops, weeds, and inert matter. Of particular importance during the analysis is the determination of sclerotia from *Sclerotinia* spp. Sunflower seeds are tested for germination to determine the incidence of seed dormancy and the ability of the seed lot to produce a stand in the field. If germination is low due to dormancy, the seed lot is given a cold stratification treatment for 5 days at 5^oC and then retested for germination.

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Hybrid sunflower seed production is accomplished using female parent lines that have the cytoplasmic male sterile trait that prevents the formation of pollen. However, some male fertility persists in these lines and greenhouse trials are necessary to determine the percentage male fertility in the female parent. This information is used to identify the number of workers required to eliminate the male fertile female parents in the field at flowering to assure genetic purity.

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Since sunflower is cross pollinated by insects, isolation distances of at least 1500 m between fields is required for hybrid seed production and 3000 m for parental lines. The field location is identified using Global Positioning System (GPS) technology and the exact coordinates of the field determined in order to ensure appropriate isolation. Another criterion that must be satisfied for certification by SAG is that the field must not have been planted to sunflowers within the last two years for two reasons. First, there may be the presence of sclerotia which remain viable in the soil for at least two years and can cause devastating attacks of Sclerotinia in the sunflower crop. Second, sunflower seeds possess seed dormancy and volunteer plants are possible if planted immediately after another sunflower crop thus reducing the genetic purity of the seed crop.

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The planting pattern depends primarily on the pollinator or male parent. In sunflower, these usually produce multiple flowers on a single pant to increase pollen availability.
Female to male rows are arranged in combinations of:

female	male
6	2
8	4
8	2

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In many cases of hybrid sunflower seed production, the male and female parents may have differing flowering periods. When this occurs, seed production practices must be altered to ensure that the male and female parents flower at the same time. Two approaches are used in hybrid sunflower seed production: Split Date Planting and Changes in Seeding Depth. In Split Date Planting, for example, the male parent may be planted first if it takes longer to flower than the female followed by planting the female parent one week later.

In this slide, the male parent is planted one week earlier than the female parent and is at the VE or cotyledon emergence stage. This delay in planting the female assures that both parents flower at the same time.

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Another, less common, approach to achieve synchronous nicking of inbred parents with differing maturities is to alter the depth of seeding of one parent. The parent that has the longer flowering period can be planted deeper in the soil compared to the parent with the shorter flowering period. To plant one parent deeper than the other, a person stands on the planter box of the deeper planted seed while the tractor passes through the field. The advantage of this approach is that both parents can be planted on the same day. The disadvantages are that the parent planted deeper in the soil must have sufficiently vigorous seeds that can emerge from the deeper depth and the soil moisture content must be high to ensure that the shallow planted seeds do not dry out and die.

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Schneiter and Miller categorized growth stages throughout sunflower development. This scheme is important as since it gives producers, scientists, and the industry a common language to describe what events occurred during crop development. For example, first irrigation was conducted at V7 or seven leaf stage. In this slide, vegetative stages are shown. Ve means that cotyledons have emerged from the soil surface and V1, V2, V3 - V20 represent the number of true leaves at least 4 cm in length.

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The main goal in seed production is to produce the maximum yield possible of high purity seed of saleable kernel size. Oil seed is small in seed size. Thus, in sunflower oil seed production, the highest yields are obtained by planting at low density. This results in a higher leaf area, resulting in the production of good head size and adequate seed size. Another, less common way is to use a planting pattern of 2 males:8 females. This approach assures that all flowers are not fertilized resulting in less seed, but larger seed size.

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Confectionary sunflower seeds produce large seeds. As a result, in order to obtain smaller size seeds during seed production, the crop must be planted at higher density.

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Once both parents have been planted in the field, SAG is notified by the seed company about the establishment of the seed field and the need for certification of that field.

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The application form requires the following information

Species

- Variety and class of seed
- Kind of Certification: 1. Final: commercial container
  . 2. Not final: these containers weigh 600 to 900 Kg
- Seed destination country
- Size and location of the field

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- Previous crop history
- Planted area
- Female planting date
- Planting pattern

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- Class of seed grown, particularly if it is a transgenic crop which can only be exported from Chile.
- Planted seed category
- Harvested seed category
- Other pertinent information such as the absence of *Orobanche* spp. and *Circium arvensis*.

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When increasing fields of parental materials to be used for the production of commercial hybrids and in the male rows of commercial hybrid production fields, all off-types must be removed before pollination takes place. This is done before the flowers open at stage R2 so there is no possibility of genetic contamination thus ensuring a high genetic purity level. The heads of rogued plants must be disposed of in a manner which will prevent their pollen from being disseminated in the field.

At the right and top of this slide is an obvious off-type. Do you think this should be rogued from the field?

The answer is No because it is too late. This flower is at the R 5.3 stage and pollen has already released. At the bottom of this slide, the off-types can be compared. Note the brown anthers and purple color on the leaves and stem.

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These female flowers show a degree of male fertility and must be removed. For this job, the number of persons needed is dependent on the percentage of FMF. For example:
1.5 % FMF requires 1.5 persons per hectar.

Sunflowers are insect pollinated and require bees to carry the pollen from one plant to the other. To ensure successful pollination of all flowers at the time the flowers open for optimum seed set, bee hives are set in the field. The optimum population of bees is five hives per hectare.

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To assure that all seed production practices have been rigorously conducted and are of high quality, the hybrid seed produced in the field must be certified by an independent agency other than the seed company. In Chile, this agency is the Servicio Agricola y Ganadero (SAG). For hybrid sunflower seed production, there are three inspection periods during flowering by SAG:

- First inspection – between 10 and 20% flowers blooming
- Second inspection – between 40 and 50% flowers blooming
- Third inspection – over 90% flowers blooming

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The inspections have the general objectives of verifying the correct roguing times, the cleanliness of the fields from a weed and pathogen perspective, and the success of nicking between the male and female parents. Specific factors that an inspector examines are shown in this slide.

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After the final SAG inspection where greater than 90% of the flowers are opened, any remaining unopened or R3 female flowers must be cut from the plants. This is because of the possibility that they may open later when the desired male parent pollen is no longer present and pollen from these plants may compromise the genetic purity of the harvested seed.

After the male flower head petals dry out as shown here, the male parent rows are destroyed. This can be done manually in small fields or mechanically in larger fields.

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Sclerotia are very difficult to remove during cleaning from harvested sunflower seed. When found in the seed lot, they must be removed by hand which is an expensive and time-consuming process. As a result, it is important to minimize the presence of sclerotia before harvest. To accomplish this, flower heads are inspected in the field by laborers to determine the incidence of sclerotia. When found, the entire plant is removed and destroyed from the seed field. In addition, workers also have the responsibility for inspecting for troublesome weeds such as *Xanthium spinosum*.

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Sunflower seeds are typically ready for harvest when the backs of the heads are yellow and the outer bracts begin to turn brown as shown here. At this stage, the seed moisture content is approximately 12%, the ideal moisture content for seed harvest.

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Prior to harvest, the combine is thoroughly cleaned to remove all seed and inert matter from previous crop harvests to reduce contamination from other sunflower varieties harvested with the same combine. Harvesting of sunflower seeds requires special extensions at the front of the combine cutter bar called sunflower pans. The harvested seed is trucked to the seed company.

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On arrival at the seed company, the harvested seed is probed to obtain a representative sample. The seed company conducts both a purity and germination test. The purity test is important to know the contamination of the seed lot with other crops, weeds, and inert matter. Of particular importance during the analysis is the determination of sclerotia from *Sclerotinia* spp.

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The seed is unloaded from the truck and a pre-cleaning conducted to remove gross impurities such as:

Leaves
Head pieces
Dust
Stems

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The seed is dried using cold air for two hours. After this process, the temperature is increased to no greater than 34°C. Seed drying is complete when the seed reaches 8 to 10% moisture content.

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The air-screen cleaner is the first step in cleaning the seed. The seed is passed over the air-screen cleaner that separates pure seeds from other materials based on a shaking motion of the screens and air flow that blows light materials away from the desired seed. The air-screen cleaner alone does not completely clean sunflower seeds.

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As a result, the seed is also passed over a gravity table or density separator. The gravity table functions by blowing air up through a perforated deck. Since the table is at an angle and is shaking, this air suspends lighter seeds that float to the bottom of the table as seen here. Heavier seeds stay on the table and are “walked” to the top of the oscillating deck where they fall from the table and are collected. In this way, the desired sunflower seeds are separated from other lighter materials based on density.

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Finally the seed is bagged and ready for the SAG final inspection. SAG takes a final sample and the bags are appropriately sealed and labeled.

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If the international seed company desires, SAG will issue an orange international seed certificate.

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The SAG representative provides the seed company approved tags regarding fulfilling governmental certification requirements. On the outside of a jumbo bag, a visible green label indicates that the jumbo is certified and ready for export. Jumbo bags also have a yellow tag that contains such information as the number of the Jumbo bag, variety, weight, seed class (breeder, foundation, registered or certified) and date of certification.

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When the seed is ready for shipment, it is lifted by forklift to trucks. The fork lift moves over a dock onto the bed of the trailer where the bulk seed is deposited for transit. The jumbo bags are covered with a tarp to ensure no contamination from road dust and debris. The bulk seed will be transported by truck if the seed is destined for Argentina or locally or to containers at docks if the seed is transited by ship to other countries. In both cases, the container is sealed with official seals to verify that the contents of the seed do not change during shipment.