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ARTÍCULO DE REVISIÓN

Canaryseed Crop

Cultivo de Alpiste

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Resumen

El alpiste (*Phalaris canariensis* L.) es una gramínea con un ciclo de cultivo y prácticas de producción similares a las de otros cereales invernales, tales como el trigo (*Triticum aestivum* L. y la avena (*Avena sativa* L.). Actualmente, sus granos se destinan, casi con exclusividad, a la alimentación de aves, solos o en mezcla con otros como mijo, girasol y lino. El alpiste es un cereal genuino con una composición única que sugiere un potencial para uso alimentario. *P. canariensis* se cultiva en muchas zonas de climas templados. En la actualidad, su producción se concentra en las provincias del suroeste de Canadá (Alberta, Saskatchewan y Manitoba) y en menor escala en Argentina, Tailandia y Australia. A nivel mundial es considerado como un cultivo menor, con pertinencia regional, con una producción de alrededor de 250 mil toneladas al año, lo que restringe la inversión privada y la investigación pública en su mejoramiento genético y tecnológico. Por esta razón, el tipo de manejo del cultivo que se aplica a esta especie depende en gran medida a las innovaciones hechas en otros cultivos similares. Este trabajo ofrece una revisión actualizada de la información disponible sobre esta especie, sus necesidades, distribución, recursos genéticos, prácticas de cultivo, usos potenciales, comercialización y otros temas de interés para los investigadores y productores.

Palabras clave: Alpiste, semillas para pájaros, gramínea anual.

Abstract

Canaryseed (*Phalaris canariensis L.*) is a graminaceous crop species with production practices and cycle similar to those of other winter cereal crops such as spring wheat (*Triticum aestivum L.*) and oat (*Avena sativa* L.). Currently its grains are used almost exclusively as feed for birds, alone or mixed with other grains like millet, sunflower seed, and flaxseed. Canaryseed is a genuine cereal with a unique composition that suggests its potential for food use. *P. canariensis* is cultivated in many areas of temperate climates. Currently, its production is concentrated in the southwestern provinces of Canada (Alberta, Saskatchewan and Manitoba) and on a smaller scale in Argentina, Thailand and Australia. Globally it is considered to be a minor crop with regional relevance, with a production about of 250000 tonnes per year, which restricts private investment and public research on its genetic and technological improvement. For this reason, the type of crop management that is applied to this species largely depends on innovations made in other similar crops. This work provides an updated summary of the available information on the species: its requirements, distribution, genetic resources, cultivation practices, potential uses, marketing and other topics of interest to researchers and producers.

Keywords: canaryseed, birdseed, anual canarygrass.

1. Introduction

Phalaris canariensis L., commonly known as canaryseed, annual canarygrass, canary grass, birdseed or alpiste, is an annual grass species originating from the Mediterranean region (Cubero, 2003). It is considered a minor cereal crop, with

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production practices and a life cycle similar to other winter grain crops like spring wheat (*Triticum aestivum* L.) (Robinson 1979a). *P. canariensis* is the only species of its genus grown for grain production; the others are used mostly as forage crops. The commercial production of canary seed in Argentina dates from 1900s (Bolsa de Cereales de Buenos Aires, 2008 - 2009). In North America commercial production started in the 1950s in the United States of America, and its cultivation spread to Canada in the 1970s (Li et al., 2010). There is little literature about canarygrass crop. The Australian New Crops Web Site (2008) found only 169 documents that cited *Phalaris canariensis* between 1926 and 2006.

Given the limited knowledge on specific management of this crop, most of the technical recommendations have been transferred from other cereal crops.

This work proposes to summarize updated available information on the species, its requirements, distribution, genetic resources, cultivation practices, marketing and other topics of interest to researchers and producers.

2. Taxonomy

Canarygrass belongs to the Poaceae (Gramineae) family, the Pooideae subfamily and the Agrostideae tribe. This places annual canarygrass in the same subfamily, but different tribe, from wheat, barley (*Hordeum vulgare* L.), and rye (*Secale cereale* L.) of the Triticale tribe, or oats (*Avena sativa L.*) of the Aveneae tribe (Putnam *et al*., 1996).

3. Description

Canarygrass is an herbaceous plant, of about 60–100cm tall, with several tillers and erect growing habit. It has glabrous pods, ligule obtuse 6 to 8mm, flat glabrous sheets, 20 to 40mm long by 5 to 10mm and wide compact oval-shaped panicles that retain the seed firmly. The mature fruits consist of a fertile floret and two reduced sterile basal florets. Common canarygrass has small elliptical grains with hulls covered with very fine siliceous hairs or trichomes. Annual canarygrass seed with an intact hull is shiny and golden yellow, while dehulled canary seed is dark brown in colour (Parodi, 1987) (Figure 1).

4. Uses

Annual canarygrass grains are used almost exclusively as feed for birds, alone or mixed with other grains such as millet, sunflower seed, flaxseed and other cereal grains (Coscia and Castedo, 1967; Miravalles *et al*., 2002). It is widely recognized as a superior canary feed.

Yagüez (2002) mentioned that in small amounts, canarygrass grains have been used to produce sizing for cloth or distillates for alcoholic beverage production.

Figure 1. Illustration of canaryseed plant. References: (A) panicle; (B) spikelet; and (C) hairy hulled grain. Source: USDA-NRCS PLANTS Database.

On the basis of its chemical composition canarygrass caryopses have potential as a food crop (Robinson, 1979a). However, common canary seed is not safe for food consumption because, as mentioned above, the attached hulls are covered with small siliceous hairs or spicules that can contaminate the seeds during dehulling (Abdel-Aal *et al.*, 1997). These siliceous hairs have been linked to cancer of the esophagus when present as a contaminant in wheat flour used in baking bread (O'Neill *et al.*, 1980). Currently, there are three commercial varieties of hairless canary seed: CDC Maria, CDC Togo and CDC Bastia. These hairless materials have led to new studies on the composition of the grains aimed at assessing their value for human consumption or industrial purposes.

Pelikan (2000) reported that canary grass is a promising annual forage crop. However, its use as a forage crop is limited because it has low biomass production compared to other species (Fischer and Dall`Agnol, 1987).

Annual canarygrass is considered by traditional communities as a medicinal plant. Its seeds have been used for the treatment of renal disease and hypercholesterolemia (Ribeiro *et al.*, 1986; Albuquerque *et al.*, 2007; Wright *et al.*, 2007). However, more scientific information is needed to confirm these properties.

Thacker (2003) reported the potential use of canarygrass to feed pigs. He found that canarygrass grains can be successfully fed to growing-finishing pigs without dramatically affecting pig performance or carcass characteristics. Furthermore, inclusion of canarygrass in a diet based on barley and soybean showed an increase in the growth rate of the pigs. Therefore, in the future, the swine industry may provide an alternative to the caged bird market as an outlet for growers of canary seed to market their product. Canarygrass plants also have an ornamental value, they are used in wild-type gardens and their dried or dyed panicles are used in floral arrangements.

5. Distribution

Canaryseed is cultivated in many areas of temperate climates around the World (Parodi, 1987). Currently, it shows a concentration of production area in the sourthern provinces of Canada, and on a smaller scale, in Thailand, Argentina, Mexico and Australia (FAO, 2011).

6. Requirements

Climate

Temperature and photoperiod are the major environmental factors that control development in plants. Canarygrass is considered a cool season crop that grows best in long warm days and cool nights. Usually, it is grown where wheat is successfully cultivated, because it has similar temperature and photoperiod requirements to common wheat varieties. To maximise grain yield, the crop must maximise dry matter production and mature prior to the onset of high temperatures and summer drought (Norton and Ford, 2002). Annual canarygrass is frost tolerant at the seedling stage. Producers have reported that its seedlings survive daily minimum temperatures of - 5 ºC (Putnam *et al.*, 1996). However, it is sensitive to low temperatures in the heading stage, where the occurrence of frosts can reduce grain yield (Cogliatti *et al.*, 2011a). Also, in the grain filling stage, frosts and high temperatures can severely reduce grain yield (Norton and Ford, 2002). Higher temperatures increase the growth and development rate of canarygrass (Pascale and Giordano, 1962). As late planting dates range from late autumn to early spring, there is a shortening of the total crop cycle, because plants grow in an environment with higher temperatures (Bodega *et al.*, 2002).

Some species require a period of low temperatures to induce flowering. Vernalization can be defined as the acquisition of competence to flower by exposure to cold temperatures. Canaryseed has few vernalization requirements (Pascale and Giordano, 1961; Norton and

Ford, 2002; Bodega *et al*., 2003) and any necessity for low temperatures is covered by winter soil temperatures in most of the cases. Length of day affects apical morphogenesis, leaf production, tillering and other developmental processes in cereals (Kirby and Appleyard, 1980). Annual canarygrass is a long day plant, which means that it prefers to flower when the daylength is longer, i.e in spring (Norton and Ford, 2002). Regarding its photoperiodic requirements, Pascale and Giordano (1962) found that it needs a photoperiodic threshold slightly over 14 hours to start heading.

Soil

Canaryseed will grow successfully in most soil types. It has some tolerance to water logging, but will basically be suited to any situation where wheat can be grown (Norton and Ford, 2002). It is more tolerant to salinity and excess of soil moisture than wheat, and is best adapted to heavy, moisture-retentive soils. Therefore, due to its shallow rooting habits, it does not grow well in sandy soils and arid climates (Putnam *et al*., 1996). Canary-grass can grow excessively and may lodge when soil fertility and moisture are plentiful. Under these conditions, a large amount of vegetative growth, which does not necessarily lead to high seed production, may be produced (Mc Vicar *et al*., 2002).

7. Crop management

Sowing

Canaryseed may be no-till or conventionally sown, using common seeding equipment, as that used for other winter cereals. The optimal sowing time will depend on the environmental conditions of each particular site. For a given site, the different sowing times may lead to different growth temperatures and photoperiods that affect the duration of the developmental phase, biomass production and seed yield (Bodega *et al*., 2003). The optimum sowing time in North American countries - Canada and the United States - is early spring (Putnam *et ar.,* 1996; Miller, 2000), whereas in Argentina and Australia, the optimum sowing time is winter (Pascale and Giordano, 1962; Forjan, 1986; Bodega *et al.,* 2003; Norton and Ford, 2002). Due to its small seed size, care should be taken to ensure that seeds are placed into a humid firm soil no deeper than 5cm (Mc Vicar *et al*., 2002). Canarygrass seedlings are relatively weak and cannot force their way up through compacted and/or cloddy seedbeds. However, moderate compaction around the seeds will improve homogeneity and emergence rate (Norton and Ford, 2002). A study conducted by Holt (1989) showed that canarygrass has good adaptability to different seeding rates and row spacing. This fact is due to its high capability for compensation between heads per plant and seeds per head. However, plant density and row spacing can modify the crop's ability to compete with weeds. Forjan (1986) and Mc Vicar (2002) both showed that a density of about 550 plants per square meter is sufficient to obtain high grain yields and adequate competitiveness against weeds. Regarding the row spacing, producers usually use the same as for the rest of winter grains (15 to 20cm) to avoid modifying the configuration of the seeder between crops.

Fertilization

The most efficient fertilizer rate will depend on the residual soil nutrient level and the yield goal. Excessive use of fertilizers, especially nitrogen and phosphorus, has the potential to degrade ground and surface water quality. Establishing realistic yield goals, carrying out careful soil sampling in commercial field plots and fertilizing crops according to soil tests will help preserve environmental quality (Dahnke *et al*., 1992). Like other cereal crops, nitrogen and phosphorus are the main limiting nutrients in most of the environments. Lodging is often a problem at higher nitrogen levels. Biomass production of canarygrass is below that of other cereal crops, and so nutrient uptake is likely to be somewhat lower (Putnam *et al.,* 1990). The best method of fertilizer application will depend on the source used. In Argentina, canaryseed is often fertilized at sowing with diammonium phosphate, and broadcast with urea at tillering. Only a few studies on fertilization have been carried out with canarygrass. In a 5-year study in Saskatchewan, nitrogen fertilizer applied at seeding had no effect on the rate of plant development and 1000 grain weight, but had a positive effect on grain yield and plant height with a linear and quadratic relationship, where the nitrogen required for maximum yield varied from year to year over a range of 70 – 120 kg/ha. (Holt 1988). In accordance with the above, the Saskatchewan Soil Test Laboratory recommends a total of nitrogen (applied + available in soil) of 110kg/ha (cited by Holt, 1988). Table 1 shows the nutrient requirements recommended by Dahnke *et al.* (1992) to achieve different yield goals.

Table 1
Nutrient recommendations for canarygrass (Adapted from Dahnke *et al*., 1992).

Grain yield goal	Total nitrogen[a]	Soil test phosphorous[b]			
		VL	L	M	H
		0-5	6-10	11-15	16-20
($kg.ha^{-1}$)	($kgN.ha^{-1}$)	($kgP_2O_5.ha^{-1}$)			
1682	56	28	17	11	0
2242	78	34	22	17	0
2803	101	45	34	17	0

[a] *Total nitrogen= Soil N + Applied fertilizer N (in top 60 cm of soil).*
[b] *Phosphorus level (ppm, Bray I): VL= very low; L= low; M= medium and H= high.*

Weeds
Weeds compete with the crop leading to yield losses and sometimes hamper the work of harvesting and cleaning grain. Canarygrass is a poor competitor of weeds in its early stages due to low seedling vigour and slow growth-rate between emergence and tillering (Putnam *et al.,* 1996).

Canarygrass is susceptible to the soil residues of several herbicides like trifluralin, mazamethebenz, triasulfuron, metsulfuron-methyl, ethametsulfuron-methyl, sulfosulfuron, chlorsulfuron, flucarbazone-sodium and imazethapyr. Extended periods without rainfall during the growing season may extend the re-cropping restrictions on residual products. It is therefore important to record herbicide use each year and to avoid planting canarygrass in fields with a recent history of the products listed (Mc Vicar *et al*., 2008).

There are several herbicides capable of controlling annual weed species in canarygrass. A field study conducted in Saskatchewan to evaluate the effect of herbicides on canarygrass and associated weeds showed that postemergence application of bromixynil, MCPA or propanil is a good option to control broadleaf weeds without affecting canarygrass grain and dry matter yield. Also, postemergence application of difensoquat and flamprop, or preplant incorporated triallate, optimizes wild oat (*Avena fatua L.*) control, with consequently positive effects for grain yield (Holt and Hunter, 1987). There are several commercial herbicides available in Canada for the control of broadleaf weeds: BANVEL II (dicamba 48 %) + MCPA (MCPA amine 50 %), BUCTRIL-M (Bromoxynil 28 % + MCPA ester 28 %), PARDNER (Bromoxynil 28 %), and TARGET (MCPA 27.5 % + mecoprop 62.5 % + dicamba 62.5 %) and for the control of grassy weeds: ACCORD (quinclorac 75 %), AVADEX G (triallate 40 %), AVENGE (Difenzoquat 20 %) and STAMPEDE EDF (Propanil 80%), (Mc Vicar *et al*. 2002).

In other countries such as Argentina and Australia, the problem of chemical weed control is not yet resolved since they do not have herbicides available for grassy weed control in canarygrass (Norton and Ford, 2002; Cogliatti *et al.,* 2011b).

In Argentina, the main grassy weeds associated with canarygrass are darnel ryegrass (*Lolium temulentum L.*) and wild oats, both responsible for yield loss through competition and for decrease in the commercial quality of the grains. In the case of darnel ryegrass, there is a marked association between its presence and the cultivation of annual canarygrass, due to the fact that the grains of the two species are similar in size and weight, causing problems in their separation during seed purification procedures. Cogliatti et al. (2011b) report that the application of dichlofop-methyl with a dose between 200 and 400g ai/ha appears to offer acceptable control of darnel ryegrass without significantly affecting the yield of annual canarygrass. But in this dose range, there was no proper control of wild oats. Therefore, for this and other difficult weeds, the implementation of cultural practices such as avoidance of fields infested with these weeds and the use of clean seed to limit its dissemination are recommended.

Diseases

Few disease problems have been reported in Canarygrass. *Septoria* leaf mottle (*Septoria triseti*) was first observed in Canada in 1987 (Berkenkamp *et al*., 1989) and is believed to cause the greatest economic loss in this crop, primarily by reducing grain weight (Putnam *et al*., 1996). *Septoria* leaf mottle on canarygrass is a residue-borne disease. Canarygrass crops that have been sown on, or adjacent to, canarygrass stubble are considered at high risk. A cultural practice of crop rotation with at least a two-year break from canarygrass is the best economic way to reduce infestations of the disease (Mc Vicar *et al*., 2002).Foliar application of Tilt 250E (propiconazole) at a very early stage of disease development is recommended in Canada for the control of fungal disease in canarygrass. Best results have been achieved with applications just when the flag leaf emerges (Guide to Crop Protection, 2011).

A new leaf disease was observed in Argentina in year 2002 (Delhey *et al*., 2004; Monterroso *et al*., 2004) produced by *Rhynchosporium secalis*. The pathogen has been determined in different genera like *Hordeum*, *Agropyron*, *Agrostis*, *Lolium*, *Dactylis* and *Phalaris*, amongst others (Braun, 1995). However, there seem to be no citations specifically on canary-grass predating those given above. Little is known about the effects of this disease on grain yield in canarygrass.

Preliminary studies on the application of fungicides to control *Rhynchosporium* in canarygrass, showed that untreated plots produced a 60% respect to plots treated with the following fungicides: Orius 750 $cc.ha^{-1}$ (tebuconazole 25%), Bumper 500 $cc.ha^{-1}$ (propiconazole 25%) or Opera 1000 $cc.ha^{-1}$ (piraclostribin 13.3% + epoxico-nazole 5%) (Juan *et al.,* 2004).

Pedraza and Perez (2010) mentioned and described the following diseases associated with canarygrass crop: *Alternaria* on canary seeds (*Alternaria* sp.), *Bipolaris* on pepper seeds (*Bipolaris* sp.), Ergot on canary grass (*Claviceps purpurea*), Seedling blight by *Fusarium* in canarygrass (*Fusarium oxysporum*), *Gaeumannomyces* take-all root rot (*Gaeumannomyces* sp.), Seedling blight by *Gibberella* in canarygrass (*Gibberella gordonii*, *Gibberella intricans* and *Gibberella zeae*), *Magnaporthe* grey leaf spot on canary grass (*Magnaporthe grisea*), *Puccinia graminis* on canary grass (*Puccinia graminis*), Canarygrass scald (*Rhynchosporium secalis*), *Septoria* leaf mottle on canary grass (*Septoria macrostoma*), *Septoria* leaf mottle on canary grass (*Septoria triseti*), *Stemphylium* on pepper seeds (*Stemphylium* sp.), and Seedling blight by *Rhizoctonia* in canarygrass (*Thanatephorus cucumeris*). However, in Argentina, these pathogens have rarely caused economically important losses.

Floret blasting should not be confused with a disease. Canarygrass is shallow rooted and more sensitive to heat and drought than wheat. Mechanisms used by the plant to adjust for stress include tiller die-back and blasting of the top portion of the head. If these top florets are not pollinated, they will die and turn white (Mc Vicar *et al*. 2008). It is believed that floret blasting is also caused by late frost (Cogliatti *et al.,* 2011b).

Insects

Insects are not a major problem in canarygrass crop. Usually, they are not abundant enough to cause significant yield losses. The English grain aphid (*Macrosiphum avenae*) and the oat birdcherry aphid (*Rhophalosiphum padi*) are cited as the main insect pests in canarygrass in Canada. Research has not been carried out to determine economic thresholds for aphid infestations in this crop. Information from the USA based on other cereal crops, indicates that approximately 10 to 20 aphids on 50% of the stems and prior to the soft dough stage may cause enough crop damage to require insecticide application. It is not recommended to spray after the soft dough stage of the seed, because aphids do not cause significant economic damage after that time (Putnam *et al*., 1996; Agri-Fax, 1998).

Cordo *et al*. (2004) mentioned other insects associated with canarygrass crop in Argentina, like the cereal aphids *Metopolophium dirhodum* and *Schizaphis graminum*, and the worms *Faronta albilinea, Pseudaletia adultera* and *Spodoptera frugiperda*. Some insecticides, containing malathion or dimethoate, are registered in Canada for the control of aphids in canarygrass (Mc Vicar *et al*. 2008).

Harvest

Harvest time is critical to minimize yield losses and produce good quality grains. If harvest is too early, the plants will be very difficult to thresh and will leave unacceptable green seed. On the other hand, if harvest is too late, although it will be easier to thresh and contain fewer contaminants, the seed may be liable to cracking and dehulling, and some seed may be lost from the mature panicles of main stems.

The problem of uneven maturity is emphasized when crops are sown at low seeding rates, as the later tillers take much longer to mature, with the risk that the main stem can shed much of its seed before those tillers are ripe and free of green seed (Norton and Ford, 2002). In this sense, Argentinian producers prefer to windrow prior to crop threshing, to homogenize maturity and grain drying, when the top half of the panicles are yellow (Forjan, 1986). It is important not to do this when the straw is still green because canaryseed straw is very difficult to cut in these conditions. However, direct harvesting is feasible in canarygrass and is often adopted by producers.

Timely and careful harvesting could determine grain quality. Seed merchants buy based on visual characteristics such as uniform size, shine and colour (Norton and Ford, 2002). The harvesting challenge is to thresh the grains out of the head minimizing de-hulling and cracking of grains, to maintain sample quality. So, the combine harvester should be operated at the minimum cylinder speed for efficient threshing, and grain flow through the return elevator should be adjusted to prevent rethreshing (Putnam *et al.,* 1996).

Garrido (1994) measured grain losses during the harvest with a prior swath and found 6.5% of total losses. A yield loss trial conducted in 2002, at the Faculty of Agronomy in Azul (Argentina), showed a 6% loss with this method and 14% loss with a direct harvesting method (unpublished data). However, more work will be needed to clarify which of the two methods results in lower grain losses.

8. Processing and storage

The presence of tiny hairs on the hull (palea and lemma) of the seed makes canarygrass dust very irritating to the skin during harvesting and handling. The dimensions, composition and structure are similar to those of known carcinogenic mineral fibers and were associated with esophageal cancer (O'Neill *et al.*, 1980). The Crop Development Centre (CDC) at the University of Saskatchewan has developed canarygrass without these hairs, called the itchless (or glabrous) type. Canadian canarygrass varieties with the glabrous trait have been grouped under the marketing name Canario (Mc Vicar *et al.*, 2008).

Canarygrass is considered dry at 12 percent moisture. In these conditions, it can be stored safely for a long time without quality losses. It is a relatively small seed and will easily flow out through gaps in storage bins or silos. Sealing of joints with a silicone based compound is recommended (Norton and Ford, 2002). Special attention is advised in grain movement to avoid cracking and dehulling. Generally, canarygrass does not have major problems with grain storage insects. However, canarygrass is preferred by rodents over other seeds and their droppings are difficult to separate from the grains by a common cleaning process (Putnam *et al.,* 1996).

Canarygrass should be cleaned before it is shipped for export. It is cleaned to exporters' specifications, usually a minimum purity analysis of 99 per cent pure seed with a maximum of 4 per cent dehulled seed. Some seed, like Flax and *Lolium* sp., are difficult to separate from canarygrass, and buyers will avoid purchases containing these seeds. Most canarygrass is sold to export markets in bulk or in bags (Mc Vicar *et al.,* 2002).

9. Genetic resources

Little work has been published on the genetics and breeding of this species. Cultivars have been produced in various countries, although little effort has been spent on genetic improvement in one of the major producers, Argentina.

Annual canarygrass is a self-pollinated diploid plant (Matus-Cadiz and Hucl 2006) (2n = 12) with a genome size of 3800 Mbp (Bennett and Smith, 1976). Several authors have found that canaryseed has little genetic variability in its morphology, phenology and its productivity (Poverene *et al.,* 1994; Bodega *et al.,* 1995 and 2003; Putnam *et al.,* 1996; Miravalles *et al*., 2002; Matus-Cadiz and Hucl, 1999 and 2002) and this may be the reason why there has been little progress in genetic improvement of this species. Nonetheless, Cogliatti *et al.* (2011a) found potentially useful variation amongst a collection of accessions obtained from nineteen different countries (details below). Currently, there are about 12 cultivars of annual canarygrass in the world, among them the three Northamerican varieties "Alden", "Keet" and "Elias", developed by Dr. Robert Robinson of the University of Minnesota, in 1973, 1979 and 1983, respectively (Robinson 1979b and 1983); the three cultivars from Hungary "Abad", "Karcsu" and "Lizard"; the old variety from the Netherlands "Cantate" developed by Joordens Zaden company in 1985; the cultivar "Judita" from the Czech Republic and the three hairless (glabrous) Canadian cultivars "CDC María", "CDC Togo" and "CDC Bastia" developed by Dr. Pierre Hucl.

"CDC Maria" is an annual canarygrass variety registered in 1997 by the Crop Development Center of the University of Saskatchewan. It has glabrous hulls that reduce the skin irritation encountered by farmers during the harvesting process. "CDC Maria" has higher test and kernel weight, but lower grain yield in relation to the pubescent cultivar "Keet" (Hucl *et al.,* 2001a).

A complete quality evaluation was conducted on the cultivar "CDC Maria". Phytochemical analysis of canarygrass showed similarity with wheat in most cases. Alkaloids and other antinutritional factors did not appear to be present in significant amounts. "CDC Maria" canarygrass flour exhibited dough-forming characteristics, permitting blending with wheat. Canarygrass products such as flour, starch, protein, oil and fiber showed potential for utilization in food and non-food products. Poultry feeding trials indicate that glabrous canarygrass can replace wheat in feed rations. Toxicology experiments suggest that dehulled glabrous canarygrass behaves in much the same manner as common wheat (Hucl *et al.*, 2001b).

"CDC Togo" is a glabrous cultivar released in 2007. This variety was obtained at the Crop Development Center of the University of Saskatchewan, from the cross of "Cantate" / "CDC Maria" (Canadian Food Inspection Agency. Crop Report CDC-Togo, 2009). "CDC Togo" showed a grain yield increase of about 12% over "CDC Maria". This means it is now possible to grow canarygrass without the irritating itch as well as no yield penalty. Therefore, it is believed that "CDC Togo" could rapidly replace old varieties. "CDC Bastia" was released in Canada in 2008 and offers higher performance than "CDC Maria" and "CDC Togo" when grown in drought conditions (Hucl, 2009).

The glabrous-hulled trait is controlled by a single recessive gene in annual canarygrass (Matus-Cadiz *et al.,* 2003), meaning this trait can be transferred easily by crossing to conventional varieties.

Although Argentina is one of the three major canarygrass producers, it has, as implied above, no commercial varieties yet. So, the materials used are populations that were kept in each region by the farmers themselves (Pascale and Giordano, 1962). Bodega *et al.* (1995) found that populations from different canarygrass growing regions did not differ significantly in grain yield and its components, phenology, biological yield and harvest index. Therefore, at least from an agronomical point of view, they could be considered as belonging to one population (local Argentinian population).

As mentioned above, Cogliatti *et al.* (2011a) evaluated canarygrass accessions from nineteen countries, comprising fifty included in the United States Department of Agriculture (USDA) collection and seven cultivars "Cantate", "Judita", "Lizard", "Abad", "Karcsu", "Kisvárdai-41" and "CDC María". These were agronomically evaluated in the Province of Buenos Aires in 2004, 2005 and 2006, and useful genetic variation was found for grain yield and its components (grain weight, grain number per square meter, grain number per head and head number per square meter), harvest index and phenological characters (emergence to heading, emergence to harvest maturity and heading to harvest maturity). Although genotype x environment interaction was observed for all traits, differences observed between accessions were sufficient to allow promising breeding materials to be identified. Accessions superior in performance to the local Argentinian population, which in general rendered values close to the overall mean of the accessions evaluated, were identified.

The studies of genetic variability in *P. canariensis* revealed limited intraspecific differences as determined by different methodologies: isoezymatic (Matus-Cadiz, 1999; Poverene *et al.,* 1994), morphological (Matus-Cadiz, 2002), agronomical (Cogliatti, 2011a; Bodega *et al.*, 1995, 2000, 2003), protein-electrophoretical (Cogliatti, 2009) and molecular (Li *et al.,* 2010). Consequently, it has not been possible to develop a methodology for the comprehensive differentiation of cultivars.

10. Composition

Studies on the chemical composition of canaryseed grains made by Robinson (1979a) suggest that it has good nutritional value. Also, the composition of small granule starch and gluten-like proteins, rich in tryptophan, suggests unique functional and nutritional properties (Abdel-Aal *et al.,* 1997). In this sense, in recent years, studies on the composition of the grains of birdseed looking for new industrial and alimentary uses have been intensified.

According to Putnam *et al.* (1990), canarygrass seed is similar to oat in mineral composition, is higher in ash, oil, and phosphorus, but lower in fiber, than commonly found in corn, pea, or fieldbean, has higher concentrations of all eight essential amino acids than does wheat or corn, and is higher in sulfur-containing amino acids than pea or fieldbean. Abdel-Aal *et al.* (2011a) concluded that canarygrass is a genuine cereal with a unique composition, and used light and fluorescence microscopy to visualise starch, protein, phenolics and phytate in glabrous canarygrass seed to show that its microstructure is similar to that of other grasses (wheat, oats, barley, rice), with a bran layer surrounding the starchy endosperm and germ. It has higher concentrations of some minerals and nutrients than wheat. The canaryseed caryopsis has an average of 55.8 g/100 g of starch, 23.7% g/100 g of protein, 7.9% of crude fat, 7.3 g/100 g of total dietary fibre, 1.8 g/100 g of soluble sugar and 2.3 g/100 g of total ash in the whole grain. Bread made with up to 25 % of canary seeds showed similar performance for loaf volume, specific volume and crust colour compared to that made from wheat alone (Abdel-Aal *et al.,* 2011a), and canary seed has been shown to possess a phytochemical and heavy metal profile similar to that of wheat (Abdel-Aal *et al.,* 2011b). These findings confirm its potential for food use.

The antioxidant activity of canary grass seeds infusions was demonstrated by Novas *et al*. (2004) by the influence of these over the chemiluminescent emission of a luminol reaction in an oxidizing medium (hydrogen peroxide). The antioxidants compounds have potential beneficial effects in disease prevention and health promotion. Among them, carotenoids are considered as one group of important natural antioxidants. Li *et al.* (2012) reported that the major carotenoid compounds identified in glabrous canaryseed were lutein, zeaxanthin and b-carotene, with the latter present in the most quantities. Phenolics compounds have also antioxidant properties and can protect against degenerative diseases. In cereals grains these are located mainly in the pericarp. Phenolic acids, flavonoids, condensed tannins, coumarins, and alkylresorcinolls are phenolics compounds examples (Dykes and Rooney, 2007). Li *et al.* (2011) performed the quantification and identification of phenolic constituents in glabrous canaryseed. They found three major phenolic acids, ferulic, caffeic and p-coumaric. The LC–MS/MS analysis showed that acetone extracts of glabrous canaryseed were rich in flavonoid glycosides, with the bran being mainly composed of O-pentosyl isovitexin and the flour having a compound at m/z 468.

Therefor, canaryseeds with high carotenoid and phenolic constituent's contents could be used in functional foods with potentially health promotion properties.

11. Production and market

Worldwide, canarygrass is considered a minor crop, compared to other grain producing species. For example, over the decade 2000 - 2009, world canaryseed production was 242,621 tonnes per year, compared to 142,930,946 tonnes for barley and 615,415,472 tonnes for wheat. World canaryseed production hence represents only 0.17% of that of barley and 0.04% of that of wheat (FAO, 2011).

Historically, Argentina and Canada have been the main producers of canaryseed. Until the end of the 70s Argentina was the world leader; later Canada took over and since then has remained the most important producer of this commodity. During the last decade, Canada, Thailand and Argentina have been the main producers of canaryseed. Analysis of canaryseed world production between 1961 and 2008 shows an increasing trend, but with stagnation during the last decade (Table 2) with a minimum of 46,000 t/year in 1966 and a maximum of 375,000 t/year in 2004 (FAO, 2011).

Table 2
Canaryseed world production and country contribution (source: www.fao.org).

	1961/69		1970/79		1980/89		1990/99		2000/09	
Country	t	%	t	%	t	%	t	%	t	%
Argentina	319600	51.9	449700	47.1	463500	32.9	306321	12.8	153846	6.3
Australia	71098	11.5	106778	11.2	87363	6.2	52071	2.2	50649	2.1
Canada	0	0.0	0	0.0	653900	46.5	1720400	71.6	1848900	76.2
Czech Republic	0	0.0	0	0.0	0	0.0	0	0.0	3677	0.2
Hungary	0	0.0	0	0.0	0	0.0	255217	10.6	98836	4.1
Mexico	46005	7.5	119349	12.5	95067	6.8	18564	0.8	3376	0.1
Morocco	42200	6.8	166410	17.4	48540	3.4	3200	0.1	0	0.0
Netherlands	11707	1.9	400	0.0	0	0.0	0	0.0	0	0.0
Spain	17653	2.9	64266	6.7	21238	1.5	2524	0.1	575	0.0
Thailand	3600	0.6	9200	1.0	16400	1.2	21200	0.9	233522	9.6
Turkey	80100	13.0	25690	2.7	5531	0.4	3051	0.1	2355	0.1
Uruguay	24294	3.9	12096	1.3	15600	1.1	19700	0.8	30475	1.3
Total	616257		953889		1407139		2402248		2426211	

Figure 2 shows the evolution of the price of canaryseed grains received by producers, in American dollars per tonne for the main countries between 1991 and 2008, which highlights a clear disparity between countries and the lack of a unique international price.

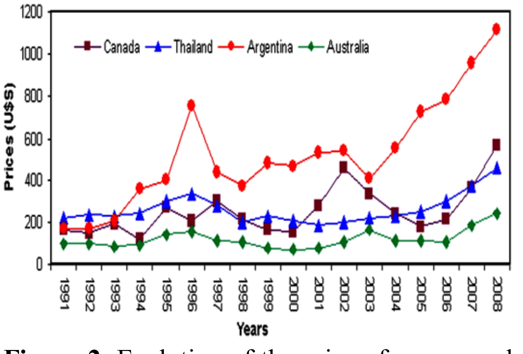

Figure 2. Evolution of the price of canaryseed grains.

On the other hand, Argentinian producers have profited in respect to the rest; and it is evident that although prices obtained in Thailand were higher than those of Australia, there is a certain similarity in their behaviour for both countries.

Argentinian canaryseed is considered a speculation crop. This is due to the high volatility experienced by grain prices and the facility with which producers adopt this crop since it requires neither equipment nor technologies different to those used in traditional crops (Coscia and Castedo, 1967).

12. Conclusions

The main constraint for the expansion of birdseed crops is the lack of alternative uses, resulting in a rigid and limited market. Future research should be directed to the discovery of new potential uses. In this sense, the development of glabrous cultivars has expanded the possibilities of using the canarygrass grains for human consumption. Beyond the genetic improvements already made in canary-grass, there are still some pending issues, such as: the development of dwarf or semi-dwarf varieties to minimize plant lodging problems, the finding of sources of resistance to diseases and herbicides, and the obtention of varieties with greater productive potential. Breeding techniques not hitherto applied in the crop may facilitate progress in these and other aspects; for example, Li *et al.* (2010) developed microsatellite markers in order to characterize the biodiversity present in the crop, opening up possibilities for marker-assisted selection in the future.

Most canaryseed management practices have been adapted from other major crops such as wheat and barley. Therefore, improvement in crop productivity is expected by means of the adjustment of agronomical practices and the development of new specific technologies.

The availability of commercialization tools for canaryseed such as the future markets and sowing contracts could favour the seeding of this crop since it would minimize risks and provide greater foresight to the business.

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