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Seeding date influence on camelina seed yield, yield components, and oil content in Chile

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ABSTRACT

Camelina (*Camelina sativa* L.) was introduced for the first time in Chile in 2008 as a potential feedstock for biodiesel and also as high omega-3-containing seed oil for the salmon feed industry. The objective of this study was to determine the optimum seeding date to maximize camelina seed yield in South Central Chile. The experiment was conducted under dryland conditions in Chillán, El Carmen, Los Angeles, Gorbea, and Osorno in 2008 and in Chillán and Los Angeles in 2009. The experimental design was a RCB with a split-plot arrangement with four replicates, where the main plot was the seeding date (five dates) and the sub-plot the spring type cultivars (Gold of Pleasure, Suneson, and Blaine Creek). Seeding dates at each environment were targeted to 30 April, 15 May, 30 May, 30 June, and 30 July of 2008 and 2009. The combined analysis of variance indicated no cultivar main effect or interactions with cultivar. The date by environment interaction was significant for seed yield. There were no seed yield differences among seeding dates in Chillán and El Carmen. The first three seeding dates were the highest yielding in Los Angeles and Osorno, and only the first seeding date was significantly higher in seed yield in Gorbea. Highest seed yield at Los Angeles, Gorbea, and Osorno were 1995, 1310, and 2314 kg ha^{-1}. Seed oil content was not different among seeding dates in Chillán and El Carmen. Highest seed oil content occurred at Osorno and Gorbea on the first three seeding dates and ranged from 420 to 457 g kg^{-1}. Spring camelina cultivars are well adapted to South Central Chile as a winter annual crop when seeded before 15 May except in Osorno when seeded before 30 May. No disease or insectpests were observed except for Aster Yellow infestation at Chillán and Los Angeles. Camelina has great potential as an oilseed for biodiesel and as a source of omega-3 for the pharmaceutical industry but markets for it need to be developed locally for camelina to become an option for growers.

1. Introduction

Camelina sativa (L.) Crantz, is an annual plant belonging to the Brassicaceae family and is believed to be native to northern Europe (Montana State University, 2007), the Mediterranean region, and Central Asia (Hurtaud and Peyraud, 2007). Camelina is also known as 'False flax', because its fruits resemble flax (*Linum usitatisimum* L.) bolls, and also as 'Gold of Pleasure' a name coined by the Romans in the early centuries.

Commercial development of this crop did not happen until recently mainly in the state of Montana, USA, where it rapidly escalated from no commercial production in 2004 to more than 20,000 ha in 2007 (Pilgeram et al., 2007), and to approximately 30,000 ha in 2009.

Camelina is a short, very fast growing annual. There are winter, requiring vernalization, and spring types (Putnam et al., 1993). Camelina plant height at maturity is between 60 and 110 cm. Flowers are 5 to 7 mm in diameter, autogamous, pale-yellow in color, and arranged in a raceme inflorescence. The fruit is a small, pear-shaped silique, 5-mm in diameter, containing 8 to 15 seeds golden to brown in color. Seeds are very small where 1000-seed weight ranges between 0.8 and 1.8 g depending on cultivar and growing conditions during seed development (Zubr, 1997; Vollmann et al., 2007).

Seed oil content fluctuates between 320 and 460 g kg^{-1} (Vollmann et al., 2007). The seed oil is 90% composed by unsaturated fatty acid: 25–42% alpha-linolenic acid (18:3), 13–21% linoleic acid (18:2), 14–20% oleic acid (18:1), 12–18% eicosenoic acid (20:1), and 2–4% erucic acid (22:1) (Vollmann et al., 2007).

Camelina seed meal contains 390 to 470 g kg^{-1} of crude protein (Zubr, 2003) and also contains glucosinolates which fluctuate between 13.2 and 36.2 μmol g^{-1} dry seed (Schuster and Friedt, 1998). Although glucosinolate levels in camelina are lower than in

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many other *Brassicaceae* species, glucosinolates need to be below 15 μmol g^{-1} dry seed to feed fish. There are new camelina lines with very low levels of glucosinolates in the breeding pipeline of several private companies (D. Johnson, personal communication).

The increased interest by food and pharmaceutical industries, in sources of omega-3 fatty acids has turned the attention to camelina seed oil because of its high content of alpha-linolenic acid (omega-3) and natural antioxidants (Pilgeram et al., 2007). Although the omega-3 content is not as high as the seed oil of chia (*Salvia hispanica* L.) and flaxseed, natural antioxidants (mainly gamma-tocopherol) make camelina oil very stable, with long shelf-life, and therefore, high value oil (Pilgeram et al., 2007).

There are several reports available on the use of oil and meal of camelina in animal rations, ruminants (Moloney et al., 2001; Hurtaud and Peyraud, 2007), poultry (Frame et al., 2007), goats (Pilgeram et al., 2007), pigs (Ni-Eidhin et al., 2003), and trout (McVay and Lamb, 2008). Ni-Eidhin et al. (2003) concluded that including camelina oil in pig diets increased the long chain omega-3 fatty acids, in particular EPA (eicopentasenoic acid) and improved the omega-6/omega-3 ratio in plasma. Similar results were encountered when steers were fed camelina meal. In this study, the levels of alpha linolenic-acid increased in the muscles (McVay and Lamb, 2008). Camelina meal has also been used successfully as a protein and lipid antioxidant for pork meat patties (Salminen et al., 2006). Camelina oil is used in cosmetics, soaps, and in other industrial applications (Pilgeram et al., 2007).

Recently camelina has been proposed as a low-cost feedstock for biodiesel (Aurore et al., 2003). The biodiesel from camelina has similar properties to that of canola (Fröhlich and Rice, 2005). One of the limitations of camelina oil as biodiesel is its alternative use value since it has much higher value for feed, food, and cosmetics use (>$1.6 L^{-1}) than for biodiesel ($0.4–0.6 L^{-1}) (Pilgeram et al., 2007). Camelina-oil based jet fuel has been developed recently and a 151 m^3 year^{-1} contract from the US Navy has been awarded to a private company producing the fuel (Biofuels Digest, 2009). Life cycle analysis indicates that camelina jet fuel cuts 84% of carbon emissions compared to that of petroleum-based jet fuel according to a study conducted at Michigan Tech University (Biofuels Digest, 2009).

Several studies in different countries indicate camelina has a wide adaptation to different climates and soils (Zubr, 1997; Vollmann et al., 2007), it although does not grow well in poorly drained clay soils (Zubr, 1997). It is tolerant to drought (McVay and Lamb, 2008) although French et al. (2009) indicated that a 20% reduction in water supply decreased grain yield 20% and minimum growing season water requirements were 333 to 423 mm in Arizona. Camelina does not thrive well when temperatures are above 25 °C during flowering and seed filling, this is the reason in Mediterranean or warmer climates camelina is grown as a winter annual and seeded in the late fall, December in Arizona, and harvested in April before temperatures rise above 25 °C. It is very resistant to spring frost and seed germinate in temperatures around 5 °C. Spring cultivar crop cycles takes about 120 days in Denmark (Zubr, 1997), 85 to 110 days in Havre, MT (McVay and Lamb, 2008), 90 days in Fargo, ND (Johnson et al., 2008), and in Austria (Vollmann et al., 2007). Seeding dates have been evaluated in Montana and there is a clear indication that planting at the end of February or beginning of March results in higher yield than mid-April or later dates (McVay and Lamb, 2008). Previous research in camelina seeding dates, planted as a winter annual, in a climate such as South Central Chile (cold-Mediterranean) is non-existent. The closest report to compare with would be camelina grown in Pisa, Italy, also cold-Mediterranean (Angelini et al., 1997). Although the Italian study included only spring plantings, the authors also observed that as the seeding date was delayed plant height decreased.

Grain yields reported in different countries are 1500–3250 kg ha^{-1} in Austria (Vollmann et al., 1996, 2007), 2600–3300 kg ha^{-1} in Denmark (Zubr, 1997), 700–1600 kg ha^{-1} in MT (McVay and Lamb, 2008), 600–1700 kg ha^{-1} in Rosemount, MN, (Putnam et al., 1993), 720–2000 kg ha^{-1} in ND, and about 1000 kg ha^{-1} in AZ, USA (French et al., 2009).

Camelina is a low-input crop; it does not require great amounts of fertilizers or pesticides. Preliminary research indicates that camelina has a low response to N, P, and K (McVay and Lamb, 2008). Grant (2008) reported camelina requires 78.5 to 100.9 kg N ha^{-1} to obtain the maximum seed yield. This is a lower requirement compared to that of other oilseed in the *Brassicaceae* such as canola.

Camelina was introduced to Chile in 2008 as part of a national effort to increase the quantity of feedstocks for biodiesel. Chile imports 90% of fuels used in the country. Increasing foreign fuel prices prompted the Chilean government to fund initiatives to evaluate bioenergy crops to produce low-cost feedstocks for the biofuel industry (Ministerio de Agricultura, 2007). A grant was awarded to evaluate the adaptation of camelina to Chilean oilseed production areas as a cheap source of oil for biodiesel.

Camelina has a great potential as a high omega-3 feed for the salmon industry, but research on the use of camelina oil and meal in fish feed needs to be developed locally.

The objective of this study was to evaluate the effect of seeding dates on seed and oil yield of camelina in South Central Chile.

2. Materials and methods

The experiments were conducted in Chillán, El Carmen, Los Angeles, Gorbea, and Osorno, in 2008 and in Chillán and Los Angeles in 2009. Chillán is located in the Ñuble province, Bío-Bío Region, Chile at 36°35′43.2″S, 72°04′39.9″W, 140 m elevation. Soil at Chillán is from the Arrayán series (medial, thermic, Humid Haploxerand), plain and good drainage with an average rainfall of 1000 mm (Stolpe, 2006). The climate of this location is classified as temperate Mediterranean (Del Pozo and Del Canto, 1999). El Carmen is located in the Ñuble province, Bío-Bío Region, Chile at 36°56′S, 72°00′W, 263 m elevation. Soil at El Carmen is from the Santa Bárbara soil series (medial amorphic, mesic, Typic Haploxerand), slightly hilly and with annual rainfall from 1200 to 1500 mm (Tosso, 1985). The climate is classified as cold Mediterranean. Los Ángeles is located in the Bío-Bío province, Bío-Bío Region, Chile at 37°27′S,72°18′W, 210 m elevation. The soil at Los Angeles is from the Santa Bárbara series (medial, amorphic, thermal, humic, Typic Haploxerand), slightly hilly with an annual rainfall from 1000 to 1500 mm (Tosso, 1985). The climate is classified as temperate Mediterranean (Del Pozo and Del Canto, 1999). Gorbea is located at 39°05′S,72°40′W in the Región de la Araucanía of Chile. Soil at Gorbea is from the Gorbea series (ashy, mesic, Typic Dystrandept).

Osorno is located at 40°22′45.6″S,73°04′13.4″W and elevation 72 m, in the Lakes Region of Chile. The experiments were conducted under dryland conditions and no-till. Soil at Osorno is from the Osorno series (ashy, mesic Typic Haploxerand), slightly hilly and rainfall from 1200 to 1500 mm. Climate is classified a cold Mediterranean (Novoa et al., 1989). Each location–year combination was defined as an "environment" and was considered a random effect in the statistical analysis.

2.1. Experimental design

The experimental design was an RCBD with a split-plot arrangement with 4 replicates, where the main plot was the seeding date (five dates in 2008 and three dates in 2009) and the sub-plot was the cultivar (Gold of Pleasure, Suneson, and Blaine Creek). Commercial seed was obtained from Greats Plain Inc., MT, USA. Seeding