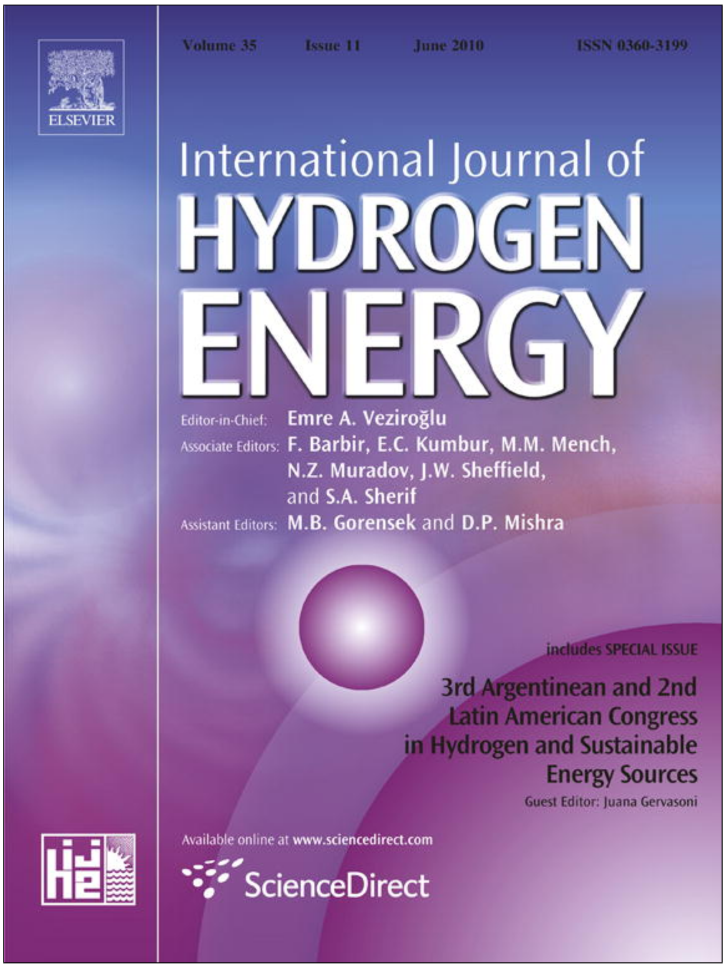
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Crambe abyssinica: An almost unknown crop with a promissory future to produce biodiesel in Argentina

S.L. Falasca [a,*], N. Flores [a,1], M.C. Lamas [b], S.M. Carballo [a], A. Anschau [a]

[a] Institute Climate and Water, INTA, Las Cabañas y Los Reseros, S/N. Castelar, Buenos Aires, Argentina
[b] School of Agronomy, University of Buenos Aires, Buenos Aires, Argentina

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ABSTRACT

The aim of this paper was to delimitate the suitable agroclimatic area for the development of *Crambe abyssinica* (Hochst) in Argentina, using the biophysical limits observed in other parts of the world.

To find a division into zones, the isohyet of 350 mm per year, the annual average temperature of 5.7 °C, the isoline corresponding to the frost free 100 days and the summer average temperature of 15 °C–25 °C were considered to delimit the *spring crambe*.

To delimit the *winter crambe* area the same hydrological limits were used. For thermal limits the temperature of −6 °C was used, with an expected returning period of once every 5 years was added, as lower temperatures would produce destruction of the crops.

To delimitate the optimal zone temperatures of 8 °C–14 °C during spring were considered. Afterwards, maps with all the thermal and hydric limits were superposed to define the probable areas for the crop. Areas of very suitable, suitable, suitable with constrains, marginal and not suitable were identified.

1. Introduction

During the last decade an approach in advance of the environmental and food crisis which is coming over the world could be observed. Climatic change is altering the conditions of the cultivable lands. The scarcity of petroleum is pushing farmers to use agricultural soils to produce biomass for energetic purposes, thus contributing to increase the lands and foods costs. In the 2007–2008 years crude oil prices reached up to a peak disheartening investors and researchers on alternate sources of energy. Facts seems to place us in a dangerous non return way.

The International Treaty on Global Warming requires the signers nations to reduce gases of greenhouse effect and consequently to replace the fossil fuel by some form of alternate energy. Although some countries go on holding the use of fossil fuel and contradictions grow more than clear resolutions to reach the goal, as it was observed in the last world summit meeting in 2009 at Copenhagen, the Protocol of Kyoto still contains the main ideas in force for future action.

At present, gas and petroleum are the most important energy sources in Argentinean energy system. Due to the institutional organization (open market) of Argentinean energy system, current dependence on hydrocarbons seems to be a result of the strategies of private agents [8]. The Argentinean Law 26.190 proposes the participation of 8% of renewable energy in 2015 but the National Law of Biocombustibles 26.093 which established the obligatory proportion of 5% of bioethanol and biodiesel in petrol and

* Corresponding author.
E-mail address: sfalasca@conicet.gov.ar (S.L. Falasca).
[1] Tel.: +54 11 4621 0125/1684/1463/5663/8496.

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diesel respectively since the 1st of January of 2010 is not still in practise.

According to LBST analyses, the critical transition period will be between 2015 and 2025 when conventional energy supplies are declining globally. Transportation fuel supply is the bottleneck due to its high dependency on oil [18]. Few discussion exist about the fact that biomass used as renewable fuel offers benefits to reduce emission of CO_2, but many different opinions still persist on its economical effects on population. Zidanšek et al. (2008) [19] suggest that biofuels in general and hydrogen from organic waste in particular seem to be well-positioned to play an important role in the near future, providing that they are economically viable and that their effect on rising food prices can be eliminated. Meanwhile Zerta et al. [18] suggest that biomass potentials are limited and cannot cover the current world energy demand on its own, so land use competition for fuel and food production is a very critical issue which needs to be addressed in order to avoid distortions in food provision.

For the above mentioned reasons it is outstanding that energetic crops should be located in marginal areas, those no apt for traditional food crops. The aim of this work is to analyse the possibilities of *Crambe abyssinica* biofuel to substitute the fossil fuel in marginal areas.

1.1. *Characteristics and origin*

Crambe abyssinica (Hochst) or ''*crambe*'' as it's commonly known, is an oil plant of the cruciferous family. It can reach up to 1–2 m height depending on the season and plant density. The flowers are white or yellow. The seeds are held into little capsules and each capsule only contains one greenish brown spherical seed of 0.8–2.6 mm diameter. The capsules generally stay around the seeds after harvesting, the hull has a volume of 25 to 30%. The weight of 1000 seeds is approximately 6–10 g.

This specie is native of the Mediterranean region, from Ethiopia to Tanzania. Being its origin the Mediterranean zone and the high lands of the East of Africa, it adapts very well to the cold weather of the wide extensions of Europe [16].

Only a little part of its history as crop is known. Its cultivation probably started in the URSS [10]. It does exist evidence of experimental research work in Russia, Sweden and Poland after the 2nd world war [13,7,17,20].

It can grow as spring crop (like rape Canola of spring, *B. napus*) in Europe or as winter crop (like rape of winter, *B. napus*) in Mediterranean climates. If *spring crambe* crops were sown in Argentina in October (April in the Northern Hemisphere) the harvest would occur at 90–100 days after emergence, this is in February (August in Northern Hemisphere).

It looks like a promissory crop for Argentina because of its great tolerance to draught and frost, its very short cycle as it blooms at 35 days and can be harvested at 90 days and because of its uniform maturity which let a mechanized harvesting.

Sub-period from sowing to flowering has a duration of 52 days. Flowering takes 12–15 days. The commercial cultivars require 83–105 days from sowing to maturation. Their seeds contain 35.6–42.8% of oil [2].

Lately, Brazilian farmers producing soybean have showed great interest on *crambe* because of its low cultivation costs, mechanized harvesting and because it can be sowed as winter crop in March or April after soybean.

1.2. *Uses and yields*

Its oil can be distinguished from other ones because of its high content of erucic acid (50–60%, $C_{22:1}$), a fatty acid of long chain which has special industrial uses. In U.S.A., *crambe* has been cultivated to replace importation of rape of high erucic content from Poland and Canada.

Oil extracted from their seeds can be used as industrial lubricant, as an inhibitor of the corrosion and as an ingredient to manufacture synthetic rubber. It also can be used to produce plastic films, plasticizers, nylon, adhesives and electrical isolation. From the oil it is obtained ''erucamide'', a substance used to prepare cosmetics, besides other industrial uses.

Crambe flour can be used as protein supplement for livestock. It contains 25–35% of protein when siliques are included, and 46–58% when they are removed. Because of its well balanced amino acid composition, a dairy ingestion till 5% has been approved for cattle ration in U.S.A [12]. Non ruminants are not fed with it as it contains glucosinolates, which can be broken down into parts in the digestive system, yielding compounds which can cause damage to liver and kidneys and loss of appetite. However, if the entire seed is humid warming before being processed, the enzimes which liberate toxic compounds are deactivated and glucosinolates stay intact after oil extraction.

As *crambe* is a new crop, there is only few yield data available. But because of the specific demand of its oil, many european countries are actually making experimental trials to know about it.

Yields vary widely between 1125–1622 kg/ha in Russia and 450–2522 kg/ha in U.S.A., with higher yields in lands free of weeds. Yields in irrigated and nitrogen fertilized fields can reach up to 5 ton/ha [1], with 1,129 kg/ha being considered to calculate yield.

In 1995, the Experimental Institute for Industrial Crops of Bologna, Italy, obtained a new genotype: ''Mario'', selected for the central and northern conditions of Italy. After three years of experimental trials this genotype showed mean values of seed yields of 2.9 ton/ha [5]. In a three years essay of yields including modern cultivars, Mario produced seed yields higher than 4 ton/ha [4]. In Austria were reported yield values from 0.97 to 3.33 ton/ha with an oil content of 23%–38% [14].

In the Fundação MS de Maracajú MS, researchers are trying to reach to a production of 1000–1500 kg/ha. The CEE which supported the programme DiCRA (Diversification with *crambe*) has calculated that if the seed yields were over 1.8 ton/ha its cultivation could be developed on a large scale. Under different environmental situations in Europe and with a broad range of cultivars, plots of *crambe* yielded an average of 2353 kg of seed/ha or 846 kg of oil containing an average of 57.8% of erucic acid.

1.3. *Bioclimatic requirements*

Crambe can grow in sites with rainfall in the range of 350 to 1200 mm, an annual average temperature in the range of 5.7 °C to 16.2 °C and soils with a pH range of 5.0 to 7.8 [9].

The crop is normally made in unirrigated conditions and without complementary irrigation. Roots can reach more than 15 cm depth giving to the plant a great tolerance to dry periods. They don't tolerate very wet or waterlogged soils [3,9].

It does not grow well in rocky soils or without enough soil depth. Seeds of *crambe* are moderately tolerant to saline soils during germination within a range of moderate soil temperature of 10 °C to 30 °C. When soil temperatures decrease down 10 °C in saline soils, the velocity of germination is reduced. Contrarily, when plants are established, the *crambe* shows similar behaviour than wheat respecting salinity tolerance [6].

Success of the crop greatly depends on good emergence. Best results have been obtained under spring favourable weather with enough rainfall with 10 °C to 14 °C of optimal average temperature and with good control on weeds.

During the main vegetative period it needs temperatures of 15 °C–25 °C although it can tolerate higher temperatures during blooming. *Crambe* can be considered a winter crop when it is not under temperature lower than −6 °C and as spring crop in cold climate, when having a free frost period of 60–100 days since emergence to harvesting.

It requires water at blooming. The crop can be lost or oil content reduced because of hydric deficiency. Early maturity is critical in areas under low pluviometric regime [2].

At seedling stage it can tolerate down to −5 °C. So *crambe* must be sowed as soon as threat of temperature down to −4 °C to −5 °C had passed [3].

Crambe can tolerate frosts from −4 °C to −6 °C [3,9]. Basal temperature for vegetative growing is 6.8 °C [11]. In regions where *crambe* should be sowed in autumn-winter, when early flowering and more resistant to cold cultivars were available, high yields could be expected [15].

2. Experimental

As it was said above, *crambe* can be cultivated as a spring or winter specie, depending on the thermal regime of the region where it is going to be planted.

To look for a possible zonification in Argentina, agroclimatic indexes were obtained using dairy temperatures and precipitation values from the meteorological and agrometeorological stations existing in the country during the 1961–2000 period.

Then, the annual average isohyets were mapped standing out the corresponding to the 350 mm to delimit the appropriate area for the crop by hydric regime.

At a first instance, an annual average temperature of 5.7 °C was considered to fix thermal limit for *spring crambe*. For the same record of years, the isoline corresponding to 100 days frost free was calculated to delimite suitable and not suitable areas. Afterwards the area between 15 °C and 25 °C was made graphically as average temperature of summer. Then mentioned above maps were superposed to define the agroclimatic aptitude of the *spring crambe*.

For *winter crambe* the map of annual isohyets which was referred to was also employed.

As thermal limit, the absolute temperature at −6 °C was added, which produces crop destruction during winter (J, J, and A) and spring (S, O, N) months. To delimitate the optimal area, the crop was restricted to those with an average dairy temperature of 8 °C–14 °C during spring.

In the same way that for *spring crambe,* maps were superposed, resulting the map of agroclimatic aptitude for the *winter crambe*.

3. Results and discussion

For the case of *spring crambe* it was nor necessary to make maps for annual average temperature equal or higher than 5.7 °C, as all the national territory exceeded those values, neither the corresponding for the free frost period higher than 100 days, because all the country was over that mean values expressed in days, except for the pre-cordilleran and cordilleran areas from where no temperature registrations were available.

Results are presented in Fig. 1, where three sectors can be observed in the very suitable area: 1) Northwest Argentina (NOA) sub-region includes great part of the Salta, Jujuy, Tucuman and Catamarca provinces, 2) Patagonic sub-region includes south of Neuquen, west of Rio Negro and northwest of Chubut and 3) Pampean plains sub-region, exceeding the limit of the pampean prairie, includes almost all the San Luis, Entre Rios and Cordoba provinces, centre east of Mendoza and south of Santiago del Estero, centre and south of Santa Fe, the half eastern part of La Pampa, Buenos Aires and a little sector of Rio Negro.

The remaining parts of the Chaco plains and Mesopotamia result suitable with constrains because of their high summer temperatures.

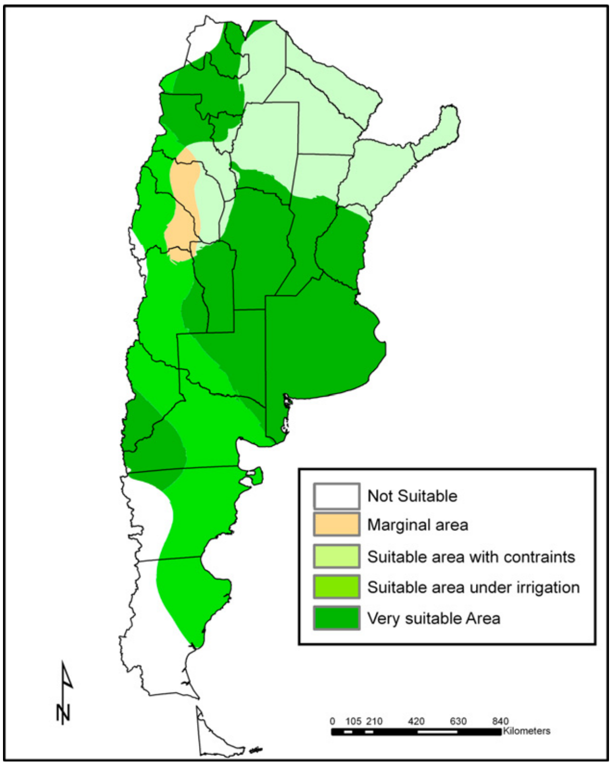

Fig. 1 – Agroclimatic aptitude for the cultivation of spring *Crambe abyssynica*.

A little area appears as marginal because of the irrigation needs or the excessive summer temperatures. To be able to develop with 350 mm of annual precipitation is considered one of the goodness of the crop. In Fig. 1 the zones of the country for possible localization of the *spring crambe* in the semiarid Argentinean region in unirrigated conditions (part of La Pampa, San Luis, La Rioja, Catamarca, Mendoza, etc.) are presented.

In Fig. 2, which shows the agroclimatic aptitude for the *winter crambe*, it can be observed a different situation, as the mayor part of the national territory has been classified as not suitable. This is mainly due to the intensity of frost in winter. Probability of damage or crop destruction of once every five years ($P = 20\%$) because of temperatures lower than the level of $-6\ ^\circ C$ has been included.

The very suitable zone is located in the south and south-east of Buenos Aires province.

The suitable zone with thermical constraints because of very high temperatures in spring include almost all the northern and eastern part of Argentina, besides a strip of land located in centre west of the country.

The suitable under irrigation and marginal sectors are located in part of the Mendoza, San Juan, La Rioja and Catamarca provinces.

In the south-eastern part of Buenos Aires the *winter crambe* could be perfectly included into a rotation with soybean. In a great part of our country, the *winter crambe* would be the ideal crop to be seeded during this 2009–2010 growing period replacing the wheat, whose yields could be in serious risks due to the low water storage in soil.

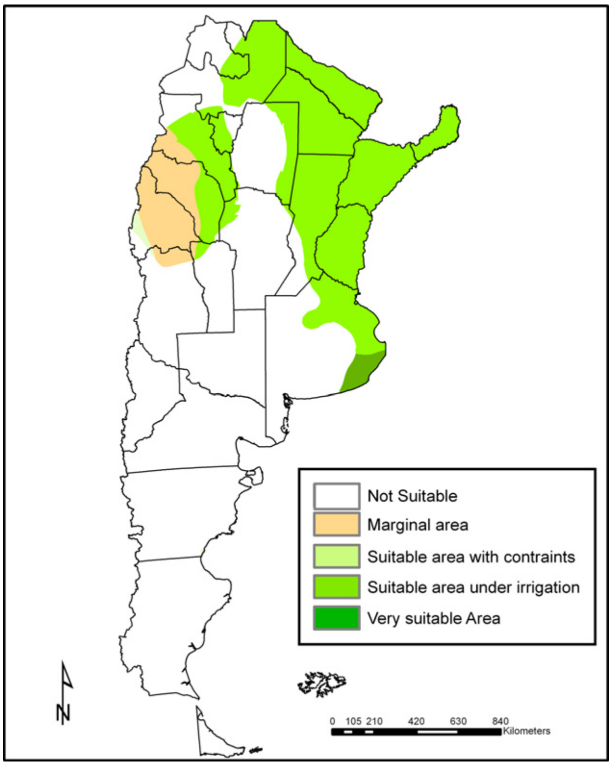

Fig. 2 – Agroclimatic aptitude for the cultivation of winter *Crambe abyssinica*.

Although it has been raining in April, May and June those volumes are under normal values not reaching to recover the water stock reserve in the soil profile destinated to the little grains sowing. Besides, precipitations lower than normal for the second half of the autumn and winter have been forecasted. So, in the short time great changes in the water storage in soil can not be expected.

Contrarily, in normal years, its cultivation should be moved to marginal lands like the provinces of Mendoza, San Luis, La Rioja and Catamarca, to study its behaviour and yields in those environments in order to reduce the competence for the use of soil between biodiesel and the food production.

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