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Agronomic performance of five rapeseed varieties grown for biodiesel in the northeast of Portugal

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1. Introduction

Rapeseed is an important crop for several European countries and for many others such as Canada and China. Rapeseed oil may have several industrial uses (Sonntag, 1995) and shows excellent properties for the manufacture of biodiesel (Körbitz, 1995). Rapeseed oil may also present high food quality, namely CANOLA (Canadian Oilseed Low-Acid) and European "double-zero" varieties (erucic acid in the oil and glucosinolates in rapeseed cake). World production of rapeseed has quadrupled in the past three decades (FAO, 2013). In Europe the increase in acreage has also been remarkable. Portugal is one of the few European countries where rapeseed is not yet extensively grown. However, field trials carried out in the country (Ferreira, 2009, Rodrigues et al. 2010, Rodrigues et al., 2011) have given good indications on its ecological potential to produce rapeseed if cultivated in the autumn/winter growing season. In the European market there are rapeseed varieties of high vernalisation requirements, suitable for cultivation of rapeseed as an autumn/winter crop, and varieties of smaller vernalisation requirements for cultivation as a spring/summer crop (Guerrero, 1999). In regions benefitting from a Mediterranean climate, rapeseed should be cultivated as an autumn/winter crop in order to mitigate drought problems during spring. In rainfed cropping systems of the Mediterranean region, rapeseed could be an interesting crop to increase the number of the few species that can be included in the crop rotations. In these rotations, rapeseed could be a good preceding crop for wheat since it left a nitrogen-rich residue in the soil (Marquard and Walter, 1995; Arlesa 2011a). If rapeseed is included in irrigated crop rotations, it may validate a double-cropping system, where rapeseed could be grown in winter previously to a second crop in the summer season. The present work aims to assess the potential of five rapeseed cultivars to be grown in rainfed conditions in Northeast of Portugal. These cultivars are being marketed in Spain by Arlesa-Euralis Company and were already grown with relative success in Spain close to the border with Portugal.

2. Experimental

The field trial was carried out in Bragança, NE Portugal, in the growing season of 2009/10. The soil is sandy-clay-loam (26% clay, 19% silt, 55% sand) textured and presents low organic carbon content (5,6 g kg^{-1}), acid reaction (pH_{H2O} 5,1) and average values of extractable phosphorus and potassium mean and high respectively. The climate of the regions is of Mediterranean type with some Atlantic influence. Mean annual temperature and precipitation are 11.9ºC and 741mm, respectively. The growing season of 2009/10 was abnormally rainy. February (200 mm) and April (107) were two months with precipitation records clearly above the annual average. Five hybrid varieties of the Arlesa-Euralis company, recommended for autumn sowing, were tested: *Es Hidromel*; *Es Alias*; *Es Artist*; *Es Mercure*; and *Es Neptune*. At sowing, a small seeds drill was used to distribute 4.3 kg seed ha^{-1}. The sowing takes place on September 21, 2009. Before sowing, a Napropamide based herbicide (Devrinol) was applied and incorporated in the soil. Lime was applied at a rate of 1000 kg ha^{-1}. A compound NPK (7:14:14) fertilizer, in a rate corresponding to the application of 30 kg N ha^{-1}, was also applied at preplant. Ammonium nitrate (22% N) was applied as topdressing, in a rate corresponding to 100 kg N ha^{-1}, on March 13, 2010. Plant population was evaluated on March 13, by counting the plants per unit of area, as well as the development of the crop at the end of the rosette phase through the evaluation of dry matter yield and nitrogen recovery. Tissue N concentrations were determined by a Kjeldahl procedure. At harvest, on July 6, dry matter yield and N recovery were determined separately by straw and seeds from samples of 1 m^2 and three replicates per treatment. The seeds were separated from the straw by a manual threshing process. The phenological stages of rapeseed were recorded during the growing season by using the decimal code reported by Mendham and Salisbury (1995).

3. Results and discussion

On March 13, plant populations ranged between 51.2 and 64.4 plants m^{-2}, values higher than the minimum established for this crop, which is 30 to 40 plants m^{-2} (Euralis, 2011). In the sampling date of March, dry matter (DM) yield was significantly different among varieties. Es Hydromel (1913.2 kg DM ha^{-1}), Es Neptune (1893.4 kg DM ha^{-1}) and Es Mercure (1756.3 kg DM ha^{-1}) presented the higher values followed by Es Artist (1389.9 kg DM ha^{-1}) and finally Es Alias (963.9 kg DM ha^{-1}) (Table 1). Although without being adequately demonstrated for local growing conditions, it is thought that the formation of a large rosette in the autumn/winter period is of crucial importance to obtain high rapeseed yields, since it is during the rosette phase that occurs the development of the root system (Guerrero, 1999) and photoassimilates are accumulated for the development of the raceme in the spring. In agreement with the previous statement, seed companies are advising an early sowing in the autumn and also an adequate rate of N application at preplant as a mean of promoting the early growth of the rosette (Arlesa, 2011b). In this work, the varieties of larger vegetative exuberance in the winter were those that accumulated more biomass at harvest and consequently higher seed yield, such was the case of Es Hydromel (Table 2). Taking into account the apparent importance of this subject, new experiments should be outlined to test different sowing dates for the same cultivars. Previous studies carried out in this region have mainly emphasized the importance of rainfall in early spring to achieve high rapeseed yields (Ferreira, 2009; Rodrigues et al., 2010; Rodrigues et al., 2011).

Table 1. Selected agronomic parameters at the end of winter (March 13th): plant population; total dry matter yield (DM total); plant N concentration (Plant Nc); and N recovery (Nrec).

Variedades	Plant number (m^{-2})	DM total (kg/ha^{-1})	Plant Nc ($g\ kg^{-1}$)	Nrec (kg/ha^{-1})
Es Alias	51,2 b	963,9 c	21,4 b	20,6 c
Es Artist	51,2 b	1389,9 b	19,9 c	26,3 b
Es Mercure	55,6 b	1756,3 a	21,8 a	38,3 a
Es Neptune	64,0 a	1893,4 a	19,4 d	36,8 a
Es Hydromel	64,4 a	1813,2 a	21,2 b	38,4 a

Means followed by the same latter are not statistically different by Tukey HSD test ($\alpha = 0.05$).

At harvest the production of straw and seed was statically different among cultivars (Table 2). Es Hydromel produced the higher values of straw (13.7 Mg ha^{-1}) and seed (3837 kg ha^{-1}). In Spain, Es Hydromel has also been presented very good results (Arlesa, 2011b). Es Alias showed the lowest vegetative exuberance at the rosette phase and produced the lowest values of straw (7.3 Mg ha^{-1}) and seed (2318 kg ha^{-1}) at harvest.

Table 2. Selected agronomic parameter at harvest (July 5th): dry matter (DM) in straw (Str); seed yield; N concentration (Nc) in straw and seed; N recovered (Nrec) in straw, seed and total.

Variedades	Str, DM ($Mg\ ha^{-1}$)	Seed ($kg\ ha^{-1}$)	Str, Nc ($g\ kg^{-1}$)	Seed, Nc ($g\ kg^{-1}$)	Str, Nrec (kg/ha^{-1})	Seed Nrec (kg/ha^{-1})	Tot Nrec (kg/ha^{-1})
Es Alias	7,3 c	2318 c	1,3 c	21,3 c	9,3 b	49,4 b	58,7 c
Es Artist	13,7 a	2489 bc	1,6 a	24,5 b	22,2 a	61,1 b	83,3 b
Es Mercure	7,8 bc	2600 b	1,4 b	21,4 c	11,2 b	55,7 b	66,9 c
Es Neptune	8,7 b	2964 a	0,6 d	21,1 d	5,0 c	62,5 b	67,5 c
Es Hydromel	13,7 a	3837 a	1,7 a	25,9 a	23,0 a	99,4 a	122,4 a

Means followed by the same latter are not statistically different by Tukey HSD test ($\alpha = 0.05$).

Es Hydromel presented the highest N concentration if straw (1.7 g kg^{-1}) and seed (25.9 g kg^{-1}) being also the variety recovering more N in straw (23.0 kg ha^{-1}), seed (25.9 kg ha^{-1}) and total (122.4 kg ha^{-1}). Taking into account that all the varieties (treatments) were similarly fertilized with N, it seems that the cultivar Es Hydromel has a greater ability to use the residual N available from the soil. Given that Es Hydromel is a variety of high vigor (Arlesa, 2011b), probably it was able to uptake N from deeper layers of the soil before the N applied as topdress has been leached out with April rains.

Table 3 shows the phenological growth stages of rapeseed varieties expressed in a decimal code reported by Mendham and Salisbury (1995). Based on records taken during the growing season, from March 13 to June 22, which included the extended flowering period, it was not possible to detect relevant differences between varieties, even taken into account that Es Artist, for instance, is classified as an early-season cultivar and Es Hydromel as a medium-flowering and early-maturing cultivar (Arlesa, 2011a). These results seem indicate that in the conditions of this experiment, the development of the crop was mainly influenced by environmental variables rather that by genetic factors.

Table 3. Phenological stages of rapeseed plants during the growing season according to the Mendham and Salisbury (1995) decimal code. Average values for all varieties since they showed similar phenological stages.

Dates	Codes for stages of development in oilseed rape (B. napus)
March, 13th	2.03 – Stem extension (three internodes detectable)
March, 30th	3.6 – Flower bud development (first flower stalks extending)
April, 6th	3.7 – Flower bud development (first flower buds yellow)
April, 17th	4.4 – Flowering (40% all buds on raceme flowering or flowered)
April, 26th	5.4 – Pod development (40% potential pods on raceme more than 2 cm long)
May, 6th	5.8 – Pod development (80% potential pods on raceme more than 2 cm long) 6.1 – Seed development (seeds present)
May, 18th	6.2 – Seed development (most seeds translucent but full size)
May, 27th	6.3 – Seed development (most seeds green)
June, 9th	6.4 – Seed development (most seeds green-brown mattled)
June, 22th	6.7 – Seed development (most seeds black but soft)

4. Conclusions

Seed yields close to 2000 kg ha^{-1} were achieved with the most productive cultivars. It seems also important to have vigorous plants from the autumn by selecting the adequate variety, sowing early and supplying some N at preplant.

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