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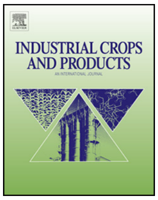

Oil productivity of seven Romanian linseed varieties as affected by weather conditions

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ABSTRACT

In order to meet the linseed (*Linum usitatissimum* L.) oil growing demand it is necessary to understand the factors that influence the oil productivity. Among these factors, weather conditions (temperature and rainfall regime) may have an important effect on the development of the linseed plant in different growth stages and eventually on the oil productivity, in the context of a rational water use in drought susceptible agricultural areas. The aim of this study was to establish the influence of weather conditions on linseed oil yield and quality through an extensive field study carried on seven Romanian linseed cultivars grown in the South-Eastern agricultural area of Romania. Nine consecutive crops were analyzed in terms of seed production, seed oil content, oil production, fatty acids profile and iodine index. In order to have a global perspective on the oil production (both quantitatively and qualitatively), two new descriptors (*quality coefficient* and *cultivar efficiency*) were defined and computed. Linseed cultivars were classified according to the oil unsaturation degree by means of Principal Component and Linear Discriminant Analysis techniques. The influence of the weather conditions on the linseed crop was analyzed on the basis of a multivariate regression equation correlating cultivar efficiencies with temperatures and rainfall levels (globally expressed as Sielianinov hydrothermal coefficients) within each oil unsaturation group. Based on the results, the May–June period was found critical for the linseed development, because of the accelerated plant growth both in terms of height and branching; during this period, rainfalls are a key factor for obtaining good crops. On the contrary, pronounced drought during May–June may compromise the crop, therefore irrigation is recommended. Irrigation is not necessary during July–August since high temperatures and low levels of precipitations were found beneficial for obtaining good linseed productivities.

1. Introduction

Linseed (*Linum usitatissimum* L.) oil is generally interesting as raw material for industrial applications, due to its high degree of unsaturation which makes it more reactive in comparison to other oil types and thus suitable for tailoring various synthons, especially monomers for polymerization/polycondensation products (Dixit et al., 2012; Lazko et al., 2011; Alam et al., 2014). Recently, linseed oil has attracted considerable attention as an important source of dietary ω-3 essential fatty acids (Valencia et al., 2008; Gallardo et al., 2013).

In order to obtain an economically viable linseed crop, it is important to understand the factors the linseed yield depends on. These factors can be grouped into three main categories: genetic, environmental and agronomic factors. Referring to the first category, genotype largely influence linseed crops in terms of both seed production, seed oil content, oil composition, plant resistance to injuries (Zajac et al., 2012). Few papers focus on how linseed production is influenced by the environmental factors: climate conditions (Zajac et al., 2012; Froment et al., 1999; D'Antuono and Rossini, 1995), insect injury (Ferguson et al., 1997), site location (Froment et al., 1999), light interception and light use efficiency

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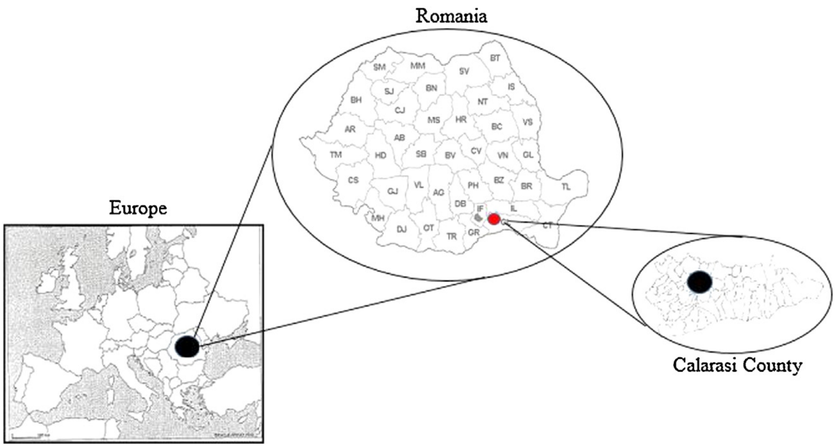

Fig. 1. Map localization of the cultivation field.

(D'Antuono and Rossini, 1995) while others deal with the agronomical practices: nitrogen fertilization (Dordas, 2010), water management (Kar et al., 2007), seeding rate (Zajac et al., 2012, 2005; Easson and Molloy, 2000), seed priming treatments (Rehman et al., 2014), mixed cropping (Zajac et al., 2013). Most of the cited papers refer only to the influence of different factors on seed production, but not on linseed oil fatty acids profile. There are several reports of a marked response of linseed to water stress and irrigation (Casa et al., 1999; Dutta et al., 1995; Gabiana et al., 2005; Hocking and Pinkerton, 1991; Kar et al., 2007). The main effect of water stress on linseed yield is on the number of capsules and seeds *per* plant or unit area (Hocking and Pinkerton, 1991) which consequently results in seed yield decrease. Yield losses may also be caused by the hastening of linseed development rate and the consequent shortening of the growing cycle due to high temperature and drought (Casa et al., 1999). Seedling growth was also found to be inhibited by water stress, as well as roots' growth. The physiological mechanisms involved in root adjustments to highly negative external water potentials may be the key to water-stress resistance in linseed. It was recently suggested (Guo et al., 2012) that linseed seedlings may initially sense a drought environment and then offset its harmful effects by altering the distribution and accumulation of carbohydrates, proline and betaine. On the other hand, significant seed yield increases were reported (Gabiana et al., 2005) due to irrigation.

There is a general consensus that the yields of linseed are highly variable in different European countries, due to the strong influence of climate conditions on the linseed productivity (Zajac et al., 2012; D'Antuono and Rossini, 1995). Temperatures and rainfalls play an important role in the linseed development and should be discussed in relationship with the plant growth stages. The most accurate scale for the assessment of growth stages of the most cultivated crops and weeds is the BBCH scale, which is a uniform system created by uniting many different scales. It is a decimal key, based on the universal decimal growth stage key proposed by the BBCH group of agrochemical companies (BASF, Bayer, Ciba-Geigy & Hoechst). The key is divided into distinct decimal stages (0–9), each main stage being subdivided into sub-stages which are referred to by the second digit in the code (Smith and Froment, 1998). According to Diepenbrock, the ontogenetic development of linseed plant during its vegetative period comprises the following growth periods (Diepenbrock, 2001), with one or several BBCH main stages (Meier et al., 2009; Smith and Froment, 1998): germination (BBCH-0), juvenile growth, flowering and capsules formation (BBCH-6) and post-anthesis growth. The juvenile growth period comprises four BBCH stages: leaves development on the main shoot (BBCH-1, also known as the "herring bone" stage), formation of side shoots (BBCH-2), stem elongation (BBCH-3), inflorescence emergence (BBCH-5). During post-anthesis growth, the development of capsules and seeds (BBCH-7), ripening of capsules and seeds (BBCH-8 stage, also divided into green maturity, green-yellow maturity and brown or full maturity) and stem senescence (BBCH-9) occur. The first two main stages (BBCH-0 and 1) are also referred as slow development stages, generally covering in Romania the March (last decade)-April (whole month) period. During the fast growing stages (BBCH-2 and 3, during May), stem elongation and branching occur; by the last decade of May the flower bud formation begins, followed by the flowering period, which generally lasts for 15–40 days, depending on linseed cultivar and environmental conditions (Jităreanu and Samuil, 2003). In the next stages the linseed plant achieves its physiological maturity: development of linseed capsules (generally in June), ripening of capsules and seeds (July–August) and senescence.

Weather conditions are best described by the *Sielianinov hydrothermal coefficients* (*SHC*) which correlate both temperatures and amount of precipitations for a given period (generally a month). According to the work of Wilczewski et al., 2012 (citing the original source in Polish of Skowera and Pula, 2004), the weather conditions can be classified, based on Sielianinov hydrothermal coefficients values, as extremely dry (≤0.4), very dry (0.4–0.7), dry (0.7–1.0), rather dry (1.0–1.3), optimal (1.3–1.6), rather wet (1.6–2.0), wet (2.0–2.5), very wet (2.5–3.0) and extremely wet (>3.0). Even if classification ranges may slightly differ, there is a consensus that the optimal values for *SHC* range within 1.0–1.5. (Dirse and Taparauskiene, 2010).

The characterization of natural resources and products is often performed by multivariate analysis techniques allowing the identification of naturally clustering patterns and group variables based on the similarities among samples (Isopescu et al., 2014). Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) have been widely used in food characterization applications (Lazarevic et al., 2012; Major et al., 2011). PCA approach is a multivariate technique aiming to extract important information and display the patterns of similarity from data tables in which observations are described by several inter-correlated quantitative dependent variables (Abdi and Williams, 2010). LDA approach is assuming a defined structure by assigning data samples to specific groups. The goal of this technique is the maximization of "between-group" variance with respect to "within-group" variance (Isopescu et al., 2014).

As a continental climate crop (Heller et al., 2015), linseed may find favorable pedologic and climate conditions for cultivation in Romania throughout its plain area, accounting for approximately half of the total country surface (Jităreanu and Samuil, 2003);