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Variation of physiological determinants of yield in linseed in response to nitrogen fertilization

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ABSTRACT

Linseed, or oilseed flax, is an important source of edible and industrial vegetable oil and is grown widely in temperate regions of the world. Understanding the factors that can affect seed yield and therefore linseed production is important in order to meet the growing demand for this crop. Nitrogen, one of the most essential nutrients for linseed, is often applied to improve yield and quality. In the present study, a 2-year field study was conducted to determine the effect of N fertilization on various aspects of linseed growth, including phenological stages, seed yield and yield components, contribution of yield components to seed yield, biomass growth rate, and nitrogen uptake rate. Three different cultivars were used (Creola, Livia, and Lirina) and three rates of N fertilization were applied (0, 40 and 80 kg ha^{-1}). N fertilization was found to increase seed yield by an average of 37% above the control rate over the 2-year study period. Application of N affected yield components, especially the seed weight per plant, the number of capsules per plant, the number of capsules m^{-2}, and the number of seeds per plant, which were increased by an average of 54, 62, 45, and 56% respectively compared with the control. Phenological stages (time to reach flowering, seed maturity, and seed filling period) were also affected by N fertilization and the seed filling period was increased by 10% compared with the control. Plant height was also increased with N application and cultivar height differences were also apparent. Biomass growth rate, economic growth rate, and seed growth rate were all increased with N application, but much higher increases were found in the N uptake rate, economic N rate, and seed N uptake rate. Seed yield was correlated with the yield components, seed filling period, biomass growth rate (BGR), economic growth rate (EGR), seed growth rate (SGR), and nitrogen uptake rate (NUR). In addition, NUR was negatively correlated with the economic N uptake rate (ENUR) and seed N uptake rate (SNUR). In conclusion, the present study indicates that N fertilization promotes the growth of linseed, affecting the development and increasing the BGR, EGR, SGR, and also NUR, ENUR, and SNUR. These are important physiological determinants of seed yield that can be used as additional selection criteria for yield improvements.

1. Introduction

Flax (*Linum usitatissimum* L.) and linseed for seed production have emerged as an alternative crop species that allow increased diversification of cropping systems in temperate environments. However, in many regions dominated by winter wheat (*Triticum aestivum* L. and *Triticum turgidum* sub. *durum*), the acceptance and production of another crop requires that there is an important agronomic benefit to the cropping system and also that the farmers' economic position will be improved. Linseed is an important source of essential fatty acids for human diets (Millis, 2002) and has several human health benefits (Millis, 2002). Thus, there is growing interest in linseed for food, feed, and industrial products and more attention is now being given to meeting the growing demand for this crop.

In order to produce an economically viable crop, producers need to understand how different agronomic practices will affect linseed yield. One of the most important agronomic practices for linseed production is N fertilization as there is positive response to N, but the overall response is less than that seen in crops like wheat, barley or oilseed rape (Grant et al., 1999; Lafond, 1993; Hocking and Pinkerton, 1991; Nuttall and Malhi, 1991; Bailey and Grant, 1989). The response of linseed to N fertilizers is affected by the residual soil N (Grant et al., 1999; Nuttall and Malhi, 1991), soil type, linseed cultivar, climate, and growing season moisture conditions (Lafond et al., 2008; Lafond, 1993), N fertilizer form and placement (Nyborg and Henning, 1969), and seeding rate and seeding date (Lafond et al., 2008). N fertilization not only affects growth and development but also modulates N uptake rate and N use efficiency. However, there is currently not enough information for linseed regarding the effect of cultivar selection and N application on key biomass growth

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rate indices (such as biomass growth rate (BGR), economic growth rate (EGR), seed growth rate (SGR)), and N uptake indices (such as nitrogen uptake rate (NUR), economic N uptake rate (ENUR), seed N uptake rate (SNUR)).

Nitrogen fertilization can increase seed yield, biomass growth rate, and also N uptake rate (Diepenbrock and Porksen, 1992; Hocking and Pinkerton, 1991). In linseed, added nitrogen increases seed yield by increasing the number of capsules per plant and capsules per m^2, and the number of seeds per plant (Hocking and Pinkerton, 1991, 1993; Diepenbrock and Porksen, 1992; Bailey and Grant, 1989; Nuttall and Malhi, 1991; Dybing, 1964; Beech and Norman, 1968). In addition, genotypic variation for biomass growth rate, N uptake rate indices, and N efficiency has been reported for many small grain crops and for safflower (Koutroubas et al., 2009; Le Gouis et al., 1999; Dhugga and Waines, 1989; Moll et al., 1982). Thus, the possibility of improving seed yield and nitrogen efficiency through plant breeding has been investigated (Van Ginkel et al., 2001). However, research on the effect of N fertilization on physiological traits which affect linseed yield under rain-fed conditions is limited.

Therefore, the objective of the study was to investigate the effects of N application rate and cultivar choice on seed yield, yield components, growth rate and N uptake rate in linseed.

2. Materials and methods

2.1. Site description

The experiment was carried out at the experimental farm of the Aristotle University of Thessaloniki, Greece during the 2005–2006 (2006) and 2006–2007 (2007) growing seasons. The farm is located in Northern Greece (22°59′6.17″ N, 40°32′9.32″ E). The soil type of the experimental site was a calcareous sandy loam (Typic Xerorthent) with wheat (*T. turgidum* subsp. *durum* L.) as the preceding crop. Wheat straw was baled and removed after harvest. Seedbed preparation included moldboard ploughing, disk harrowing, and use of cultivator. Soil samples (0–30 cm depth) were taken prior to the application of fertilizers and analyzed. Briefly, the soil contained an average of 28% clay, 15% silt, and 57% sand, with a pH of 7.96 (1:2 water), organic matter content 0.72%, N-NO_3 15.56 ppm, P (Olsen) 6.69 ppm, and K 51.00 ppm. Weather data (rainfall, maximum and minimum temperatures) were recorded daily and are reported as mean monthly data for the 2-year study duration (Fig. 1).

2.2. Crop management and experimental design

The experimental design was a split plot with N levels as the main plots and the different cultivars (Livia, Lirina, and Creola) as the subplots; there were five replications. The three cultivars had different characteristics and were obtained from different German seed companies (Deutsche Saatveredelung Lippstadt-Bremen GmbH Zu Lippstadt and De-Vau-Ge Gesundkostwerk GmbH). Creola was an early flowering cultivar, while Livia and Lirina were later flowering cultivars. Creola also had larger seeds of lighter color.

The treatments were the following: 0, 40, and 80 kg N ha^{-1} applied pre-planting in the form of $(NH_4)_2SO_4$ (N–P–K 20.5–0–0). The $(NH_4)_2SO_4$ form was selected as it is the major N fertilizer used in the area and also was less likely than the NO_3 form to leach from the soil. The fertilizer was incorporated into the soil with a disk harrow. A pre-planting application of P and K was at a rate of 60 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1}, in the form of superphosphate (0–46–0) and potassium sulfate (0–0–50), respectively. Seeds were hand-planted on November 7, 2005 and on November 10, 2006. Each plot, consisting of ten 5-m rows, 0.25 m apart, was sown at a density of 400 seeds m^{-2}. The crop was kept free of weeds by hand hoeing when necessary. Plants were grown without supplemental irrigation in both growing seasons.

2.3. Variables measured

2.3.1. Crop phenology

Dates of emergence, anthesis, and maturity were recorded. Anthesis was defined as the point when 50% of the plants in a plot had flowered. Maturity was defined as the point when 75% of the capsules in a plot had turned brown, as described by Gubbels et al. (1994).

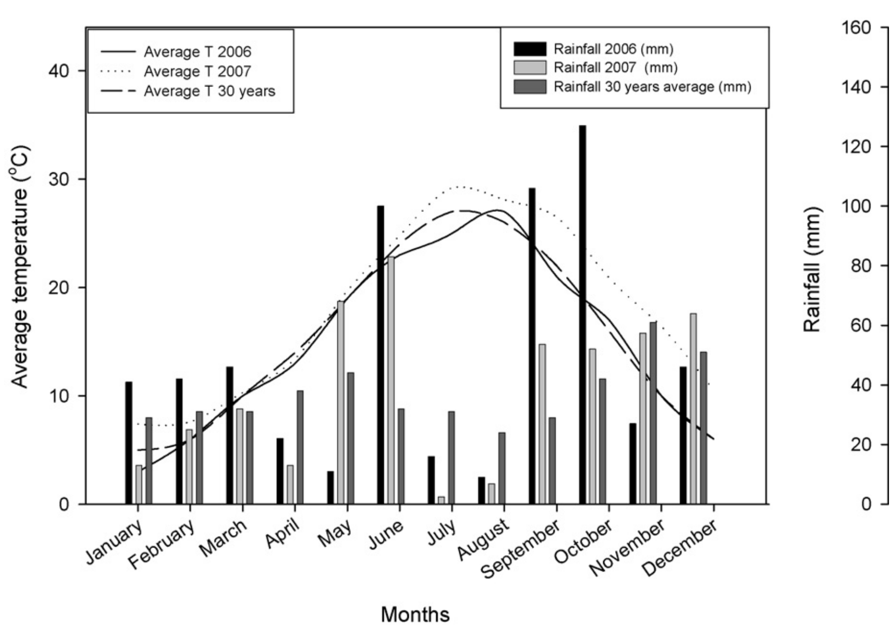

Fig. 1. Monthly means of average air temperatures and rainfall for 2006, 2007 years and the 30-year average at Thessaloniki, Greece.