Agricultural Water Management 146 (2014) 201–207

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Usefulness of selected weather indices to evaluation of yellow lupine yielding possibility

A. Podleśna*, J. Podleśny, A. Doroszewski

Institute of Soil Science and Plant Cultivation State Research Institute, Czartoryskich 8, 24-100 Puławy, Poland

ARTICLE INFO

Article history:
Received 5 December 2013
Accepted 13 July 2014

Keywords:
Yellow lupine
Genotype
Rainfall demands
Sielianinov's index (*K*)
CWB
Yield

ABSTRACT

The aim of the undertaken research was an evaluation of the weather condition effect on growth and development as well as the yielding of yellow lupine plants. Weather conditions were characterized on the basis of the amount and distribution of precipitation, Sielianinov's index (*K*) and climatic water balance index (CWB). Genotypes of yellow lupine: Polo – an indeterminate and Legat – a determinate genotype were included into the research. An experiment was established by using the split-plot–split-block method at four replications on good rye complex soil. It founded on dependencies among values of Sielianinov's index, climatic water balance index (CWB), dynamic of mass increase and physiological indicator of plant growth (RGR). It was found that an unprofitable effect of the precipitation deficit is dependent on the developmental phase of lupine and a genotype. A shortage in precipitation which occurred after sowing caused a prolongation of emergence; however, it did not significantly decrease the plant's density because seedlings were able to use water accumulated in soil during the winter. Whereas, a long period of water shortage in the soil occurred from the beginning of flowering (BBCH 60) to pod setting (BBCH 75) had great effects on morphological features and yellow lupine yield. Unsuitable weather in this period caused a decrease in the plant's height, reduction of leaf area, inhibition of relative growth rate (RGR) and a reduction of pods and seeds number per plant. Polo (an indeterminate genotype), appeared less sensitive on periodic water deficit in the soil than Legat (a determined genotype). This was also confirmed by the values of *R* index (a ratio of dry mass of root system to the aboveground part mass), which is generally admitted as an indicator of the plant's resistance to drought stress.

1. Introduction

One of the most important factor, which limits the yielding of legumes, is a shortage of precipitation (Baigorri et al., 1999; Costa-Franca et al., 2000). Drought stress causes a great reduction of yield and its structure features (Barrios et al., 2005; Khalil and Ismael, 2010; Specht et al., 2001; Ohashi et al., 2009). Consequently, the yielding of legumes is very variable over the years. This also refers to yellow lupine – a vulnerable fodder plant which contains about 44% of protein in the dry matter of seeds (Osiecka and Wiatr, 2010). Its great instability of yielding and low seed yield are the reasons for rather little interest in the cultivation of this species. In this situation, very important action is quest for genotypes that are more resistant to drought stress and can achieve a good yield, even under conditions of a precipitation deficit. This problem obtains a greater importance recently, because climatic changes cause long periods of water deficit in the soil (Gathara et al., 2006; Olesen and Bindi, 2002) and according to prognoses, the shortage of rainfalls will be increase in the future (Iglesias et al., 2009; Parry et al., 2004). In effect of conducted breeding researches have obtained a new yellow lupine genotype with determinate type of growth. It differs from indeterminate genotype in morphological habit as well as the rhythm of growth and development. Genotypes with determined growth do not form lateral shoots and therefore the whole yield origins from the main shoot, whereas about 50% of the indeterminate genotypes yield is produced on numerous lateral shoots (Podleśny and Podleśna, 2011; Prusiński, 2007). The second problem is quest for a proper indicator to an evaluation of weather conditions influence on the growth, development and yielding of yellow lupine. Until now an analysis of the results obtained from field conditions were based on the precipitation amount and a mean day temperature (Podleśny and Podleśna, 2011) or values of hydrothermal Sielianinov's index (Radomski, 1977). Besides the mentioned indicators, the climatic water balance index (CWB) was

* Corresponding author. Tel.: +48 818863421x251; fax: +48 8864547; mobile: +48 512818120.
E-mail addresses: ap@iung.pulawy.pl (A. Podleśna), jp@iung.pulawy.pl (J. Podleśny), ador@iung.pulawy.pl (A. Doroszewski).

http://dx.doi.org/10.1016/j.agwat.2014.07.008

elaborated recently. There was put a hypothesis that there is a difference in response of determinate and indeterminate genotypes of yellow lupine on prolonged precipitation deficit, and CWB better reflects the influence of weather on plant vegetation than Sielianinov's index or an analysis of precipitation.

The aim of the conducted research was the evaluation of weather conditions effect on growth, development and yielding of determinate and indeterminate genotypes of yellow lupine. As the weather conditions parameters were used: the amount and distribution of precipitation, Sielianinov's index (K) and climatic water balance (CWB).

2. Material and methods

2.1. Locations

The field experiments were conducted between 2005 and 2007 at the Agricultural Experimental Station in Grabów, situated on the eastern part of Poland (51°21′ N, 21°40′ E). The weather data originated from the automatic meteorological station AsterMet, which has an internet link to the data of the AsterGate system, and was placed about 200 m from the experiment.

2.2. Treatments and design

An experiment was established by split-plot–split-block method, in four replications on good rye complex soil. In the experiments were sown the following genotypes of yellow lupine: indeterminate genotype Polo and determinate genotype Legat. Lupine seeds were dressed with Sarfun T 450 FS (a.s. karbendazym, tiuram) before sowing. The sowing of the lupine denoted as BBCH 00 (dry seeds) was performed 4.04.2005, 19.04.2006 and 6.04.2007. The planned density amounted to 100 plants per m^2 and the area of plots to harvest was 32 m^2. In the vegetation period the plantation was protected against weeds, and against fungal diseases (mainly anthracnose). Mineral fertilization with phosphorus (P) and potassium (K) was applied before sowing at a rates of 30 and 50 kg ha^{-1}, respectively. Harvest of matured plants was performed with using a plot combine-harvester Classic – Wintersteiger AG, Austria.

2.3. Measurements

2.3.1. Observations and counting

Detailed observations of growth and development of plants and an evaluation of their infestation by diseases and pests were led during the vegetation. The plants' density after emergence and before harvest was counted on the area of the 1 m^2 in order to evaluate plant losses during vegetation. Measurements of leaf area and SPAD were performed in flowering period (BBCH 60) on 50 randomly chose plants.

2.3.2. Leaf area

The measurements of leaf area were done at the plant's flowering stage (BBCH 60) by using a leaf area measurer AM 300 (ADC BioScientific Ltd., UK).

2.3.3. Values of SPAD

Measurements of the leaf greenness were performed with using a SPAD – 502 Chlorophyll Meter (Konica Minolta). The values of the SPAD were measured on the first, second and third, fully developed leaf, counting from the top of a plant. Every measurement of SPAD index was an average from 30 measurements performed on each plant.

2.3.4. Yield structure

The measurements of plant height and dry matter yield of straw, seeds and roots were made on 50 randomly chose plants during the last harvest performed at full maturity of lupine. The data of yield structure (number of pods and seeds per plant, weight of seeds per plant and 1000 seeds weight) were also collected. Directly after the harvest moisture of seeds was evaluated and then seeds yield was counted to 14% moisture. The roots were dug out from the topsoil (25 cm), washed on the sieves and then dried.

2.4. Calculations and analyses

2.4.1. Relative growth rate

Index of RGR was counted from a formula (Evans, 1972):

$$\mathrm{RGR} = (\ln W_2 - \ln W_1)(T_2 - T_1)^{-1} \quad [\mathrm{g(g\ day^{-1})^{-1}}] \tag{1}$$

where W_1 is the dry weight of plants at the beginning of the measuring period (g), W_2 is the dry weight of plants at the end of the measuring period (g), T_1 is the beginning of the measuring period (day) and T_2 is the end of the measuring period (day).

In order to evaluate the relative growth rate (RGR), seven harvests of plants from an area of 1 m^2 were taken at following stages: T_1 – emergence (BBCH 10), T_2 – 2 leaves unfolded (BBCH 12), T_3 – 5 leaves unfolded (BBCH 15), T_4 – beginning of flowering (BBCH 60), T_5 – end of flowering (BBCH 69), T_6 – 50% of pods have reached typical length (BBCH 75) and T_7 – full maturity (BBCH 90).

2.4.2. Climatic water balance

The climatic water balance index (CWB) was used in the aim of evaluation of the weather conditions effect on yield of lupine vegetative and generative organs (Legates and McCabe, 2005). Climatic water balance (CWB) index was counted from the formula:

$$\mathrm{CWB} = P - ETP \quad (\mathrm{mm}) \tag{2}$$

where P is the precipitation (mm) and, ETP is the potential evapotranspiration (mm) counted according to Doroszewski and Górski (1995):

$$\mathrm{ETP} = -89.6 + 0.0621t^2 + 0.00448h^{1.66} + 9.1f \tag{3}$$

where t is the air temperature measured 2 m above the ground surface (°C), h is the insolation (h) and, f is the length of a day (h).

2.4.3. Sielianinov's hydrothermic index (K)

Sielianinov's index (K) is called as a coefficient of water assure to plant or moisture balance (Radomski, 1977). K index is used at agricultural climatology for the evaluation of the duration and intensity of a drought ($K \leq 1$ – long period of drought, $K \leq 0.5$ – short period of drought). K was counted from a formula:

$$K = 10P \sum t \quad (\mathrm{mm\,^{\circ}C^{-1}}) \tag{4}$$

where P is the sum of precipitation (mm) and, Σt is the sum of mean day temperatures (°C).

2.4.4. R index

R index was calculated from a formula:

$$R = \frac{Y_R}{Y_{AGP}} \tag{5}$$

where Y_R is the dry weight of roots (g) and Y_{AGP} is the dry weight of aboveground parts (g).

2.5. Statistical analysis

The presented results of research are means from four replications and are elaborated by the Statgraphics Program v.5.1. The