Short communication

Usage possibilities of standard climatic characteristics for agrometeorological purposes

Jiří Klabzuba[1], Věra Kožnarová[2]

Department of Agro-ecology and Biometeorology, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences in Prague, Czech Republic,
[1]E-mail: klabzuba@af.czu.cz, [2]E-mail: koznarov@af.czu.cz

Abstract

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This paper deals with the creation of 'optimal' weather model for the cultivation of rapeseed (*Brassica napus* L. var. *napus*). The starting point was parameterisation of negative meteorological conditions influencing growth, development and yield. We have processed, with the aid of standard climatologic characteristics of the semi-quantitative three-level evaluations, more than fifteen growing seasons with emphasis on unfavourable and high-risk meteorological factors (dryness or wetness during sowing, warm autumn, cold winter, high number of days with strong frost, low number of days with snow-cover, high number of days with precipitation during flowering). The result is a simple graphical model enabling us to express the accumulation of the effects of negative factors during the vegetation period.

Key words

rapeseed, growing season, yield formation, meteorological factors

Introduction and problems

In the Czech Republic, oil plants have in the last ten years become the second most important group of crops after cereals, which act as a significant stabilizer in agriculture economics. The most important role is played by rapeseed (Zukalová and Vašák, 2003). Rapeseed is a raw material for human consumption, oil meal, possibly oil cake or seeds comprising a major component of animal feed mixtures; biomass, used as green fodder or fertilizer; rapeseed oil, a possible material for chemicals industry (oil chemistry) and also a major source of renewable energy to replace fossil fuels and it also has an increasing role in the field of bio-fuels.

Its role is also indispensable in agro-ecology; it is a great pre-plant for cereals and it is a demanded interrupter of cereal sequences, increases soil yields, decreases the amount of weeds, decreases the usage of industrial fertilizer, is an alternative source of organic fertilizer, is an important food source for wild fauna, hinders soil erosion and ablation of nitrogen substances into groundwater. It further decreases soil pollution and water source pollution. Biomass is an important component of green fertilizer, especially due to its earliness. Cheap seeds, fast germination and growth even in lower temperatures enable the usage in green fertilization. Produced biomass is returned into the soil either directly (hay, pods, roots) or indirectly (animal production). In fats for human consumption only products of photosynthetic assimilation are lost from the circulation of nutrients.

Rapeseed (*Brassica napus* L. var. *napus*) has originally appeared in the Mediterranean area. Its current expansion reaches into all mild zone regions with significant cultivation areas on the Indian peninsula, in China, Western Siberia, Kazakhstan, in the European region from the Dnieper River to the British Isles, including Scandinavia, the Baltic region, Belarus, Northern America – especially in Canada, Argentina, Northern Africa and New Zealand.

The winter type is considerably less frequent and includes primarily Western and Central European regions, the Southern part of Scandinavia and Canada, Northern Caucasus, Western Ukraine, a part of Belarus, West and North of the USA.

Successful cultivation of rapeseed with high and stable yields and high quality is conditioned by several factors. One of the major factors is favorable weather during the full growing season, ie starting with soil preparation and sowing in August, ending with harvest in the following summer.

At the same time, the condition of small changes to weather in individual growing seasons is important, which is closely connected with the selection of appropriate climate of the growing areas. Almost all authors who dealt with rapeseed issues in long term studies (Fábry et al., 1991; Petr et al., 1991; Vašák et al., 1997; Zukalová and Vašák, 2003; Anonymus, 2003, 2004, 2005, 2006), agree that the ideal conditions are in regions belonging to the so called West European Atlantic climatic region with mild winters and adequate quantity of precipitation, evenly distributed throughout the year. Further East and Southeast Europe decreases oceanic character and increases continentality of the climate, which in its turn has an adverse effect of cultivation. Literature suggests that unstable weather conditions in each cultivation season in Germany result in yields not exceeding 20%, whereas in the Czech Republic it can be more than 40%.

The cultivation of rape in the Czech and Slovak Republics is successful everywhere where there is ploughed soil. It is possible to cultivate it effectively from lowlands to up to 700 m above sea level. The best conditions are in areas with average annual temperature of about 8° C (6.5–8.5 °C) and annual precipitation total of 500–750 mm. These conditions are best met by the potato and rape production type. The highest quality, yields and stability of production are in the potato regions, if all necessary requirements are met, especially nitrogen presence.

The vegetation period of rape in the Czech Republic lasts from 300 to 340 days, mostly 320 to 330 days; exceptionally it may be even one year in regions located more than 600 m above sea level.

Despite its exceptional plasticity, the rape does not tolerate soils which are wet for longer than a week during autumn or spring, as it is attacked by rots; sites with frost under –5 to –20 °C, as it freezes there. The same applies to sites where snow melts and glaciates for at least two weeks, to heavy soils with clods, as there rape will not grow during draught, further soils containing residues, especially sulfonylcarbamine with longer residual effects (Glean, Logran, Tel.), some triazin herbicides (eg Zeazin).

The climate requirements of rape during the vegetation phase are described by authors dealing with this issue as follows:

The vegetative, growth phases and generative, fertile phases occur during the ontogenesis, which lasts 11 to 12 months. Both phases overlap between November and February. This is the period of crypto-vegetation, when the growth of the above-ground biomass stops at already 5 °C. However, the roots often continue growing at 2 °C soil temperature. Changes in rape vegetation peak occur in this winter period, which advances by 2 stages in development into the generative phase. The yields can only be facilitated during vegetation growth, which occurs mainly at the end of March to beginning of May. Whilst the generative development is fairly continuous and most changes happen between February till May, the vegetative growth occurs in three phases.

The autumn vegetation phase – the most intensive growth, is in September to October. Stored substances are concentrated mainly in the root collar and the roots themselves. This phase should be finished in November, with the creation of a leaf rosette with 6 to 10 leafs, root collar with a diameter above 8 mm, leafs to 25 cm long, weight of the above ground biomass of 1.4–1.8 kg m^{-2}, large post-shaped root.

The transition into the generative phase occurs from the beginning of October. The plant requires at least 60–70 days of full vegetation. When the air temperature decreases under 5 °C (December to February), plants with a smaller number of leaves (less than four), are strongly susceptible to winter freezing injury. During this period, the length of the plants as well as leafs shrink by approx. 10%, the dry mass increases from approx. 12% to approx. 17%, the content of N in fibres decreases. Frosts reaching under –15 °C typically lead to the destruction of leaves, frosts lasting longer than 6 hours with temperatures under –18 to –20 °C usually destroy the leaf rosette. Weak or, on the contrary, oversized plants are devastated by frost under –13 to –15 °C. The winter period is unfavourable for the growth of above ground biomass. The roots are still growing in soil temperatures higher than 2 °C, in case of the Czech Republic this would represent most of winter. The developmental vegetation peak advances by about 2 stages.

When the soil temperature is above 2 °C, small white roots appear. The first dosage of N fertilizer is used (roots growth). This happens at the end of February – beginning of March. Mostly at the end of March when the air temperature is above 5 °C, the plants become green again.

This is immediately followed by the stem elongation growth (second dosage N). When the plant length is approx 20 cm, after the appearance of buds, the intensive stem elongation growth follows. This lasts about 14 days, ends when flowering begins, the plant creates about 50% of its above ground mass. It grows daily by about 5–8 cm, the content of all components, especially nitrogen, is diluted. During flowering, the plant loses all its stem leaves, but reaches 80% of its final weight. After the flowering phase, the volume of dry mass increases and although there is a loss of leaves, the yield of biomass increases by the growing pods (100% biomass). During the time of ripeness, the yield of dry biomass decreases by approx. 5% as well as the plants become smaller (Vašák et al., 1997).

The description of weather can be carried out in wide-ranging scope; from vague undefined terms such as 'dry', 'wet', 'warm', 'cold' to precisely defined characteristics of meteorological components. Even though these are usually very simple physical quantities, which can be described either quantitatively (eg air temperature or total precipitation) or qualitatively (eg presence of condensation, fog, storms or type of cloud) their cross determination is the decisive factor, which results in difficulties when assessing the respective years (Klabzuba and Kožnarová, 2000, 2002; Kožnarová and Klabzuba, 2002, 2003, 2004).

First of the aims of this paper is therefore the objectification of the input parameters, based on precise definitions of the terminology used. The second factor under consideration was the emphasis on high-risk and dangerous events during the cultivation of rape:

- o Dry when preparing soil for sowing, while sowing and emergency (ie especially in August)
- o Lack of precipitation resulting in reduction of plant quantity at the beginning of vegetation (August, September)
- o High quantity of precipitation together with a very warm autumn (resulting in excessive biomass growth)
- o Variation of relatively warm and cold periods in winter (December to March)
- o Strong frost in winter (December to February) especially with no snow-cover preceded by a warm and wet autumn
- o Dry conditions in spring at the beginning of vegetation
- o Rainy and cold weather during flowering.

Methodology

Among the contemporary problems in the meteorological field applied in biological disciplines belongs the evaluation of weather throughout the cultivation year. The possibilities of modern measuring methods (dataloggers, automatic stations) make many producers do their own measurings. Large capacity of data-saving media, the possibility of time intervals when gathering data and the resulting immense quantity of information, often obtained in non-standard manner; result in very difficult interpretation of the findings and further usage of the data.

We have customized the selection of the specific objective meteorological, or climatologic characteristics to the above mentioned negative and high-risk events. The main criterion of our selection was availability of information – especially materials of the Czech Hydro-meteorological Institute. Therefore, the characteristics are commonly used and their definition, significance and possible interpretation have already been published (Klabzuba et al., 1999). The seven-level scale expressing the percentage of given inputs availability (Table 1) was used when processing the data.

Regarding the given topic we have selected only the conditions which can be considered as dangerous or of high-risk. They are indicated in chronological order:

- o Dry, very dry and exceptionally dry months (August and September)
- o Very wet or exceptionally wet months (August and September)
- o Very warm or exceptionally warm months (October and November)
- o Very cold or exceptionally cold months (December to February)
- o High number of days with strong frost in winter months (December to February)
- o Low number of days with snow-cover (December to February)
- o High absolute temperature amplitude throughout cold 6 months (October to March)
- o Dry, very dry or exceptionally dry spring months (April to June)
- o High number of days with total precipitation larger than 1 mm (May and June).

We have created a three level diagram corresponding with Table 1 (Fig 1). The diagram presents the defined climatologic characteristics. Dangerous and high-risk factors are then classified in the following manner: event occurrence, high event occurrence and exceptionally high event occurrence. The diagram also allows us make visual assessment of the frequency of high-risk factor occurrence for each area, with regard to rape and rape-type plant cultivation.

Table 2 and Fig 2 illustrate the given events accumulation in respective rape years.

Table 1. Evaluation criteria

Normality evaluation	Quantile	Repetition probability	Temperature evaluation	Precipitation evaluation
Exceptionally above normal	<2.0%	less than once every 50 years	exceptionally warm	exceptionally wet
Significantly above normal	2.0 to 9.9%	less than once every 10 years	very warm	very wet
Above normal	10.0 to 24.9%	less than once every 4 years	warm	wet
Normal	25.0 to 75.0%	once every 2 years	normal	normal
Below normal	75.1 to 90.0%	less than once every 4 years	cold	dry
Significantly below normal	90.1 to 98.0%	less than once every 10 years	very cold	very dry
Exceptionally below normal	>98.0%	less than once every 50 years	exceptionally cold	exceptionally dry

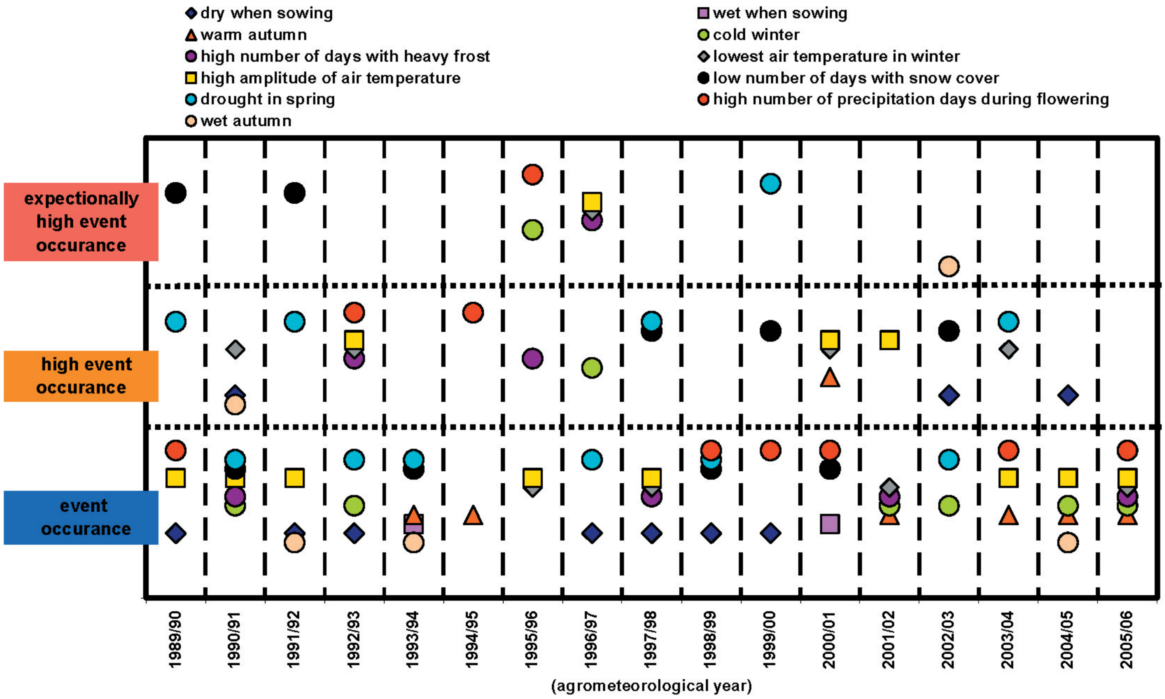

Fig 1. Evaluation of risk factors

Conclusions

The results gained, in accordance with the methodology presented, prove the commonly known fact, that the factors influencing the production or yields are always complicated and complex. The combinations of various negative and positive factors throughout the year affect the yields and their variability in each year. It is undisputable, that simple and multiple interactions may compensate the negative effect of individual factors or on the contrary, increase it. We are, however, convinced that the solution must be, on the basis of a wide debate, a selection of appropriate agro-meteorological characteristics, compatible with the databank of meteorological information, allowing for consistent processing method and a clear-cut interpretation of results. This should be followed by a study of interactions, using a longer time scale of data from specified cultivation areas, assessing validity of each parameter and resulting in a multiple factor statistical analysis in relation to yields.

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Table 2. Unfavorable and high-risk agro-meteorological events throughout 1989/90–2005/06

	Dry when sowing	Wet when sowing	Warm autumn	Cold winter	High number of days with heavy frost	Lowest air temperature in winter	High amplitude of air temperature	Low number of days with snow cover	Drought in spring	High number of precipitation days during flowering	Wet autumn
1989/90	+						+	+++	++	+	
1990/91	++			+	+	++	+	+	+		++
1991/92	+						+	+++	++		+
1992/93	+			+	++	++	++		+	++	
1993/94		+	+					+	+		+
1994/95			+							++	
1995/96				+++	++	+	+			+++	
1996/97	+			++	+++	+++	+++		+		
1997/98	+				+	+	+	++	++		
1998/99	+							+	+	+	
1999/00	+							++	+++	+	
2000/01		+	++			++	++	+		+	
2001/02			+	+	+	+	++				
2002/03	++			+				++	+		+++
2003/04			+			++	+		++	+	
2004/05	++		+	+			+				+
2005/06			+	+	+	+	+			+	

+ event occurrence; ++ high event occurrence; +++ exceptionally high event occurrence

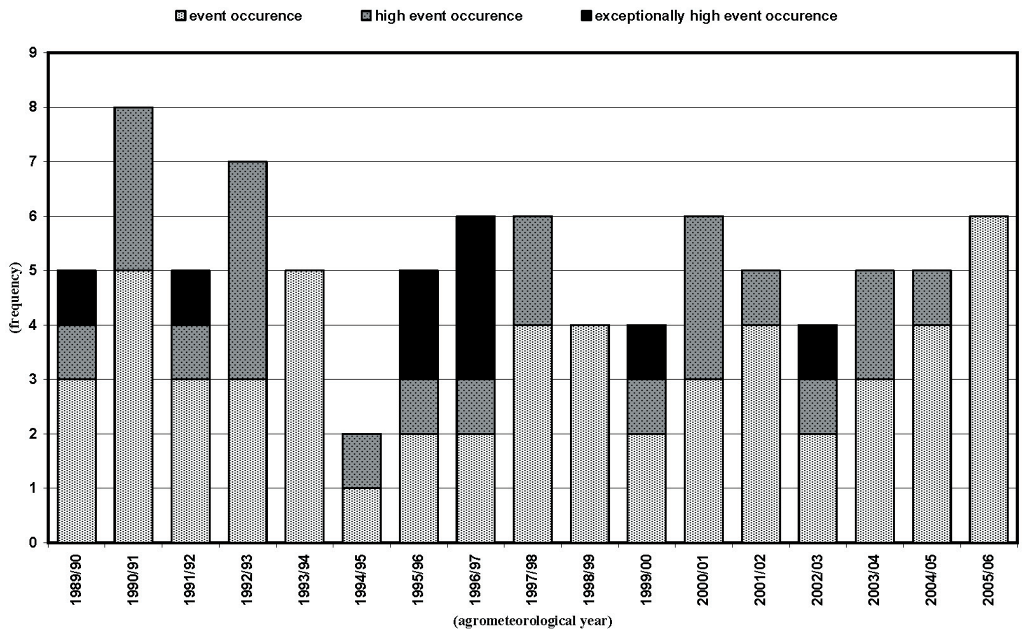

Fig 2. Frequency of dangerous and high-risk agro-meteorological events in three levels throughout 1989/90–2005/06

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Možnosti použitia štandardných klimatologických charakteristík pre agrometeorologické účely

Súhrn

Predkladaná práca sa zaoberá vytvorením modelu „optimálneho" počasia pre pestovanie repky olejnej (*Brassica napus* L. var. *napus*). Východiskom bola parametrizácia negatívnych meteorologických podmienok ovplyvňujúcich rast, vývoj a výnos. Pomocou štandardných klimatologických charakteristík, semikvantitatívneho trojstupňového hodnotenia sme spracovali viac než pätnásťročné obdobie s dôrazom na nepriaznivé a rizikové meteorologické faktory (sucho či mokro pri siatí, teplá jeseň, chladná zima, veľký počet dní so silným mrazom, malý počet dní so snehovou pokrývkou, veľký počet dní so zrážkami v období kvetu). Výstupom je jednoduchý grafický model, ktorý umožňuje vyjadriť kumuláciu účinkov negatívnych faktorov v priebehu vegetačného obdobia.

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