THE AGROCLIMATICAL ANALYSIS OF PRODUCTION PROCESS OF SPRING BARLEY

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Abstract
Relationship between phytomass yield, as well as economic yield (grain of spring barley) and characteristics of energy (temperature T in °C) and water balance (precipitation P in mm) was analyzed according to nonlinear correlation and linear regression. There was designed simple agrometeorological, mathematical - statistical model of phytomass production (U_F in $kg.m^{-2}$) according to analysis, which can be used for making yields prognosis.

Key words: *phytomass, mathematical - statistical model, temperature, precipitation*

INTRODUCTION

Autotrophic plants are characterized by a unique capability - in the process of photosynthesis, they can create bio production, i.e. biological but also economical harvest. However, the amount of harvest is a resultant interaction of genetic potential of plants and external environmental factors, especially agro meteorological factors i.e. agroclimatical.

In highly productive variety of the plant species is energy and water balance of ecosystem of which is the plant part of, limiting factor in the creation of organic matter. Every divergence from optimal energy and water conditions of plants at optional phenophase interval should the total yield.

In the presented work is analyzed the relationship between biological phytomass production in knot to economic yield of spring barley with using of mathematical-statistical methods and characteristic of energy and water balance, which are expressed by the average air temperature and total atmospheric rainfall for growing period or its part.

MATERIAL AND METHODS

Data about economic yields were obtained from field polyfactorial experiments with spring barley (variety Xanadu), which were established by Department of Plant Production, Faculty of Agrobiology and Food Resources of Slovak University of Agriculture in Nitra on the experimental basis in Dolná Malanta in the years 2005-2009. This research task was solved as the part of the VEGA projects accredited with number 1/0551/08 and 1/0110/08.

Experimental base lies at an altitude of 135 m, latitude 48 º 07 `and longitude 18 º 07`. According to agroclimatical indicators this base belongs to very hot region with the sum of average temperatures for main growing period TS 10: 3000°C and more, sub region very dry with moisture deficit in the summer months $K_{VI-VIII}$: 150 mm and more and to the precinct of mainly medium winter, which is defined with average absolute minimums in winter T_{min}: -18 °C and more.

To the agrometeorological, analyses were included 15 variants with using of the standard agrotechnics and average diet (from 3 variants) after sugar beet as sub-plant. Economic yield - grain (UH in kg.m-2) was adjusted into biological yield - phytomass (UF in kg.m-2) with using conversion relation:

$$U_F = U_H \times a_u$$

Where a_u is the conversion coefficient from the economical yield to phytomass of spring barley

Agroclimatic characteristics: air temperature (T in ° C) and precipitation (Z in millimetres) were measured on a specific agrometeorological stations in the area of experimental bases. Agrometorological analysis are relating to the months of the growing season evaluated plant, limited by seeding and technical maturity (Table 1)

Effect of temperature and precipitation to yield were analyzed by Šalitov (1975) and Krajčírová et al. (1982):

a) After months of growing season and by their grouping according to the program of non-linear correlations. Using the selection test of the best suitable function of evaluated relation (quadratic and cubic parabola, hyperbole, exponential and polynomial functions) was the coefficient of determination (R^2). Evidence boundary of relation N = n-2 = 15, for $\alpha = 0.05$ is for $R^2 = 0.4821$.

b) The interaction relation between yield and agrometeorological characteristics of the months and their grouping with the highest R^2 was mathematical-statistically analyzed by multiple linear regression programs.

Table 1

Phytomass yield of spring barley and agrometeorological data
(Nitra, 2005-2009)

Year	Uaf [kg.m^{-2}]	T [°C]					P [mm]				
		Month					Month				
		3.	4.	5.	6.	7.	3.	4.	5.	6.	7.
2005	0.71	3.0	11.4	15.5	18.4	20.8	7	64	55	29	60
2006	1.50	3.2	12.1	15.0	19.7	23.5	32	27	88	37	37
2007	0.62	7.6	11.9	16.9	20.8	22.2	54	0	91	57	21
2008	1.03	5.6	11.3	16.3	20.6	20.6	61	35	48	90	82
2009	0.73	5.4	14.7	16.3	18.1	21.8	52	12	31	67	53

RESULTS AND DISCUSSION

1. Temperature in the relationship to production process

Temperature as a part of energetical component of environment affects: the nutrient intakes, transpiration, photosynthesis, breathing, and other environmental functions of plants, which directly or indirectly participate in the production of crop's yields.

With using mathematical - statistical analysis was found out intervals of optimal air temperatures for the creation of above-average yields and they are listed in the table 2. The tightness of each relation is expressed as a coefficient of determination (R^2). From the table results that the temperature was in the tightest relation to production process in the spring months i.e. in vegetative part of vegetation especially in may ($R^2 = 0,5857$), in which we can consider the most beneficial air temperature in the interval from 15,0 to 16,0°C. Temperatures over this interval were connected with lower yield, which should be subjoined with high evapotranspiration and negative water balance in the high temperature.

For generative period – production of grain may be consider –temperature in interval from 20, 0 to 21, 5°C. For this period is on the one side is eligible sufficiency of energy for biochemism of grain production, and on the other side high temperature shorten the period of ripening, decreasing of grain weight and thus the total yield.

2. Precipitation in relation to the production process

Water in plant cells forms dispersed environment for colloidal plasma, in which progress the biochemical processes of metabolism - production of new organic matter i.e. a new yield. To optimize these processes, cells must be equally saturated with water - hydrated. For each water deficit give out to decreasing of the biochemism intensity of production process and thus to the decreasing of yields. The mathematical-statistical analysis listed in table 2 shows the closest direct relation of precipitation to the phytomass yields (U_F in $kg.m^{-2}$) and deriving economic yields - grains (U_H in $kg.m^{-2}$) in April (R^2 = 0,6534). This fact is generally valid for all spring months. The results of precipitation analysis in April and May confirmed accordance with the theory of the production process, according which the vegetative period of barley is typical with increasing demands for moisture, one of the conditions for optimal future yields. In the generative period, their effectiveness is decreasing.

For the optimal, in the months April and May it can be consider totals rainfall from 85 to 120 mm.

3. Modelled biological yields of spring barley

Interactive relation of air temperature and precipitation on biological yield of spring barley was analyzed with using the program of multiple linear regressions. The temperature and precipitation characteristics analyzed in relation to the yields in individual months and their grouping and according the highest determination coefficient were defined:

- Average temperature in May T_5 (R^2 = 0.5854)
- Precipitation for April Z_4 (R^2 = 0.6534)
- Average temperature from March to July T_{3-7} (R^2 = 0.5598)

Based on multiple correlation analysis was compiled following functional equation of the modelled calculation of biological crop - phytomass (U_{mF} in $kg.m^{-2}$)

$U_{mF} = 1.03656T_5-14179-T_{3-7} +2.0439 +0.04389\ Z_4$

R = 0.93866

Presented equation expresses the proportion of the temperature and precipitation characteristics impact on the production of phytomass. Estimated functional equation can be considered as a simple agrometeorological mathematical-statistical model of spring barley harvest. A comparison of actual yields and modelled yields can be seen on figure 1 and in table 3. Analysis showed that the modelled yields were occurred in the reporting period with an average probability of 93%. Economic yield (grain) can be determined by the following equation:

$U_H = U_F: a_u$ ($kg.m^{-2}$)

$a_u = 1.77$

Obtained results can be compared to results of several other authors: Koza, Gozdowski, Wyszyński (2006), Krajčírová, Špánik (1982), Kurpelová (1982), Špánik, Čimo, Kováč (2008).

It follows that a simple agrometeorological mathematical-statistical model can provide the reliable assumption of biological and economic yields according to the basic temperature and precipitation characteristics of the vegetation period of spring barley.

Table 2.

Optimal temperature interval and amount of precipitation for the production of spring barley yield (Nitra, 2005-2009)

Month	Interval of optimal characteristics			
	T (ºC)	R^2	P (mm)	R^2
3.	3.0 – 5.0	0.2828	15 - 55	0.328
4.	11.2 – 14.2	0.2094	15 – 55	0.6534
5.	15.0 – 16.0	0.5857	55 – 90	0.1165
6.	19.0 – 20.7	0.0374	40 – 88	0.0981
7.	21.0 – 22.5	0.3129	50 – 80	0.143
4.– 5.	13.5 – 14.5	0.2201	85 – 120	0.1406
5.– 6.	20.0 – 21.5	0.2483	85 – 165	0.311
3.– 7.	14.0 – 15.5	0.5598	220 – 320	0.1226

Table 3.

Agroclimatical analysis of spring barley yield according to program of linear regresion (Nitra, 2005-2009)

Year	U_{af} [kg.m^{-2}]	T [°C]		P [mm]	U_{mod} [kg.m^{-2}]
		Month 5.	Month 3.- 7	Month 4.	
2005	0.71	15.5	13.8	64.0	0.81
2006	1.50	15.0	14.7	27.0	1.50
2007	0.62	16.9	15.9	0.0	0.76
2008	1.03	16.3	14.88	35.0	0.87
2009	0.73	16.3	15.3	12.0	0.64

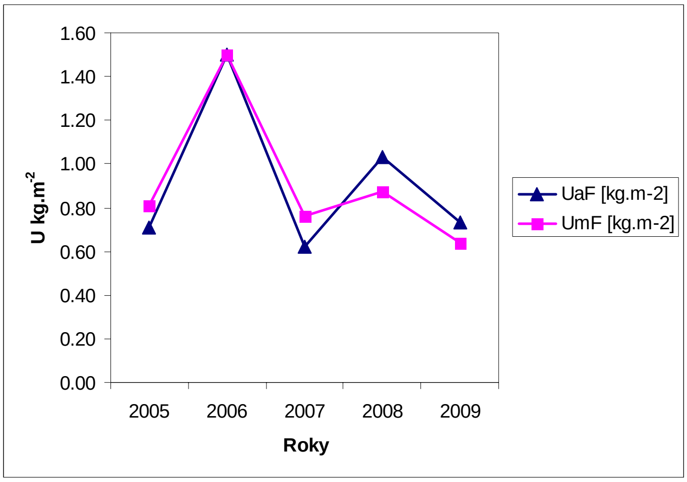

Figure 1. Actual (U_{aF}) and modelled (U_{mF}) phytomass yield of spring barley (Nitra, 2005-2009)

The work methodology gone out from the principles of agroclimatical modelling of field crops yields which was elaborated by Šatilov (1975). This method is based on mathematical-statistical determination of the relationship between the biological potential of crops and environmental factors, which are most often expressed by monthly average temperature and total amount of atmospheric precipitation.

The others characteristics of energetical balance and water balance were showed as important and very effective as well.

Kováč, K. et al (2005) in polyfactorial experiments of field crops and analysis of yields applied the amount of active and effective air temperatures for the different parts of the growing season, Špánik, F. et al (1987) evaluated yields in relation to photosynthetically active radiation, Krajčírová, Z. (1982) evaluated yields in the relation to the characteristics of soil moisture in root zone, Kurpelová, N. et al (1975) evaluated yields in the relation to evapotranspiration deficit and hibernation indicators.

Mathematical-statistical analysis of the production process of cereal crops validated the greatest significance of energy and water balance characteristics in the months April and May. Similar issues were soluted by others authors, e.g. Krajčírová, Špánik (1982), Kurpelová (1982), Špánik, Čimo, Kováč (2008).

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