A DYNAMIC MODELLING OF THE REPRODUCTIVE PROCESS OF ZEA MAYZE

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Abstract: The interrelation between the productivity of Zea mayze and the increasing of it's generative organs during the phenological phase "tasseling - milky ripeness”, as far as the dependence of this relation on some factors influencing crop growth, provide a basis for a quantity analysis left to this work. The potential yield of the used hybrid was the only parametric index from the stock of the growth limiting factors, which take part in the analysis. As variables we used: duration of the indicated phenological phase; sum of effective temperatures; precipitation; the increase of maize dry biomass for this period as far as the content of the ammonium and nitrate nitrogen in the soil. The interrelation between these factors gave us a real possibility to determine the function of the reproductive growth and to prognosticate the yield.

Keywords: reproductive process; sum of the effective temperatures; precipitation; soil content of the ammonium and nitrate N; dry biomass of maize; productivity.

1. Introduction

Yield formation of maize is determined by interaction between a variety of vegetative factors, as far as by the crop adaptation ability to unfavourable environmental conditions. If a particular factor is not in optimal quantity (Shelford, 1964), the crop adaptation ability decrease as regards to the other factors. An established fact is that the effect of the limiting factor is manifested mainly during the reproductive period. Therefore the mathematical model of the reproductive process give a real yield prognosis with the least deviation. Relation between the growing function of the generative organs **aj** and crop yield **y*** is given by equation, where the known index is the potential crop yield of the hybrid used. As dependent variables **j** some of the yield limiting factors were used: duration of the period "germination - milky ripeness" $\boldsymbol{\tau}$; duration of the period "tasseling - milky ripeness" $\boldsymbol{\tau}_1$; sum of the effective temperatures for the period $\boldsymbol{\tau}$ - **T**; sum of the effective temperatures for the period $\boldsymbol{\tau}_1$ - $\mathbf{T}_1$; amount of precipitation to the beginning of "milky ripeness" **W**; dry biomass formation **B**, during the period $\boldsymbol{\tau}$; quantity of $N - NH_4^+$ and $N - NO_3^-$ in the soil at the beginning of "tasseling" - **N**. The choice of variables was in conformity with the juncture that their measuring in the field was easier than other quantities connected with solar and water conditions.

2. Materials and methods

2.1 Mathematical presentation of growth function during the reproductive period of Zea maize

We take that the crop yied **y** forming during the period germination to milky ripeness $\boldsymbol{\tau}$ is proportional to the growth function $\mathbf{a_j}$ during the reproductive period, i.e.:

$$\frac{dy^*}{d\tau} = \frac{daj}{d\tau} \tag{1}$$

The function $\mathbf{a_j}$ depends on the potential for the hybrid yield - **a**, as well as on the complex interaction of **j**-parameters - **B**, **N**, $\boldsymbol{\tau_1}$, **T**, $\mathbf{T_1}$, **W**. On account of that the equation (1) could be presented as a characteristic congruence from two indexes - **T** and **N** and it is expressed by particular derivatives i.e.:

$$\frac{daj}{d\tau} = \left(\frac{\partial}{\partial}\frac{aj}{T}\right)\frac{dT}{d\tau} + \left(\frac{\partial}{\partial}\frac{aj}{N}\right)\frac{dN}{d\tau} \tag{2}$$

According to the superposition the general integral of the equation (2) is a linear relation of particular integrals. At a given value of the argument **a** and r values for **T** and $\boldsymbol{\tau_1}$, got from observations, the first term of (2) could be presented by function:

$$\left(\frac{\partial}{\partial}\frac{aj}{T}\frac{1}{d\tau}\right)_{aj=a}.dT = f_1(a,\tau_1,T).dT$$

where

$$f_1(a,\tau_1,T) = \frac{a}{T.\tau_1}$$

From the integration of the first term of (2)a particular integral will be estimated:

$$I_1 = \frac{a}{T.\tau_1}\int_0^{T_1} dT = \frac{a}{T\tau_1}T_1 \tag{3}$$

After transformation of the second term of (2) the same equation could be expressed as :

$$\left(\frac{\partial}{\partial}\frac{aj}{N}\frac{dN}{d\tau}\right)_{aj=B} = \left(\frac{\partial}{\partial}\frac{B}{W}\frac{1}{\tau}\right)\left(\frac{\partial}{\partial}\frac{W}{N}\right)dN \tag{4}$$

Expression in the brackets in (4) is presented by function, which arguments are **B**, **W**, $\boldsymbol{\tau}$. Their numerical values are obtained from field measurements, so that this expression is presented as follows:

$$\left(\frac{\partial}{\partial}\frac{B}{W}\frac{1}{\tau}\right) = f_2(B,W,\tau) = \frac{B}{W.\tau} \tag{5}$$

The quantity of the N - NH_4^+ and N - NO_3^- in soil linearly depends on the volumetric moisture **W′**, so that the derivative in the right part of (4) is converted to:

$$\frac{\partial}{\partial}\frac{W}{N}dN = -\frac{dN}{N}\frac{\partial}{\partial}\frac{W}{W'}W' \tag{6}$$

From (5)and (6) the following expression for the second particular integral in (2) is generated:

$$I_2 = -\frac{B}{W.\tau}\iint_D \frac{dN}{N}\frac{\partial}{\partial}\frac{W}{W'}W' = -\frac{B}{W.\tau}\int_0^N \frac{dN}{N}\int_0^{Wk} f_3(W')dW \qquad (7)$$

The solution of the integral in (7) is by means of the parameter **Wk** /the mean critical soil moisture for dissolving and suction of the mineral salts from the soil solution/. The optimal value of **Wk** is 0.75 of field capacity (N.Tomov & Jordanov, 1984, 1989). The general integral in (2) will be:

$$aj = \frac{a}{T.\tau_1}T_1 - 0.75\frac{B}{W.\tau}\ln N$$

and the equation for yield prediction takes on the following expression:

$$y^* = \left(\frac{a}{T.\tau_1}T_1 - 0.75\frac{B}{W.\tau}\ln N\right)\tau \qquad (8)$$

2.2 Plant material and growing conditions

The data we used in the model were obtained from three years field experiment - 1994 - 1996 in South - West Bulgaria 42^o 45' latitude and 23^o 7' longitude on chernozem smolnitca, which typical properties were: low content of N and P, pH 6.2 and high presence of clay fraction - 60% (Stoimenova, 1990). Each year the sowing of the hybrid “Kneja 530” was done during the first decade of may at soil temperature /10 cm depth/ 10^{o}C, according to randomized block scheme in 4 replications. The size of each plot was 200 m^2 with lenght of the row 16 m and distance between rows 70 cm. The depth and density of sowing were 8-10 cm and 47000 plants.ha^{-1} accordingly. In the autumn before deep ploughing /25-27 cm/ a phosphate fertilization /50 kg. ha^{-1} P_2 O_5 / was done. Before sowing 70 kg.ha^{-1} N was introduced. Weeds were treated by the herbicide mixture atrazin /1500g. ha^{-1} a.i./ + alachlor /680 g. ha^{-1} a.i./ introduced after sowing. The vegetative biomass was determined in milky ripeness of the crop, using 25 plants from each plot. Quantity of N - NH_4^+ and N - NO_3^- was determined in the phase “tasseling” from a soil extrct 1 M solution of KCl by means of calorimetric method (Jagodina, 1987) - Table 1. The amount of precipitation and the sum of the effective temperatures were daily measured and calculated for each phenological phase.

Table 1. Climatic, soil and bio - parameters used in the model

Parameters, symbols	Dimensions	1994	1995	1996
Period germination-milky ripeness **τ**	days	100	104	112
Period tasseling-milky ripeness **τ_1**	days	20	18	27
Sum of the effective temperatures for **τ -T**	^{0}C	869.0	797.2	976.9
Sum of the effective temperatures for **τ_1 -T_1**	^{0}C	228.1	150.0	247.7
Amount of precipitation for the period **τ - W**	mm	164.3	227.2	124.7
Content of N - NH_4^+ and N - NO_3^- in tasseling - **N**	mg.100g-1 soil	18	15	27
Dry biomass formation for the period **τ - B**	kg.ha-1	15260	14490	12746

3. Results and discussions

3.1 Maize growth depending on climatic conditions

A high biomass formation and high grain yield respectively were observed in 1994, when combination between **T** and **W** was in optimum. The lowest quantity biomass and the lowest yield were registrated in 1996, when **T** was extremely high - 976.9 and **W** - comparatively low - 124.7 mm

/Table 1/. Hybrid “Kneja 530” /groupe 530 according FAO/ has genetic yield potentialities for 5000 kg.ha^{-1} without irrigation. In 1995 the combination of climatic conditions favoured getting this yield.

3.2 Quantitative valuation of the model

A comparative valuation between the real and estimated by the model yield was done /Table 2/

Table 2. Valuation of the model precision

Parameters, symbols	Dimensions	1994	1995	1996
Real yield - **y**	kg.ha-1	6360	5350	4942
Estimated yield - **y***	kg.ha-1	6276	5415	4984
Relative error **ε = (y*- y) / y**	%	-1.3	1.22	0.85

4. Conclusion

The yield estimated by means of the model works with a maximum relative error **ε =** ± 1.3%. This give us a reason to use it successively for yield prediction during the whole growing period.

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