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THE WATER DEFICIENCY EFFECT OVER MAIZE YIELD CULTIVATED FOR GRAIN WITHOUT IRRIGATION IN THE REGION OF SOUTH-CENTRAL BULGARIA

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Abstract

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This study aims at pointing out parameters of water deficit during the critical for the maize moths, also, to follow the relations between yield and water deficit, provoked by the lack of rains, to establish the possibility of obtaining good yield in conditions without irrigation for the region of Central South Bulgaria. It has been analyzed 40 years data from monthly rain falls (mm), average monthly temperature of the air (°C) during the critical for this culture period (June, July, August) and the yield of maize grain, cultivated without irrigation and irrigated for the period 1972–2012. The soil of the two experimental fields was of the type vertisoil. For the purpose of the study are followed the yield of maize grain from two hybrids – middle late Knezha 530 and late H – 708, cultivated without irrigation (kg/da having 14% moisture) and optimal irrigation. The experimental studies were done by means of block method by four repetitions. The hybrids were cultivated by common agrotechnology for this country. A fertilizing was done by N P K. It was established that the average agroecological potential of the late hybrids maize in Central South Bulgaria in optimal irrigation, established experimentally in risky years was 12 230 kg.ha^{-1} and without irrigation – 5530 kg.ha^{-1}. In middle late hybrids the yield was respectively 6670 kg.ha^{-1} and 3990 kg.ha^{-1}. The parameters of the factor "water deficit" and establishment of the lost of grain when cultivated without irrigation could serve for decision making and planning in region of the Central South Bulgaria, as well as for formation of the state policy concerning compensations of the farmers during dry years. The established lost of grain in dry years and the role of irrigation can be used for further economical analysis for planning in risky, dry years and defining the cost and market price in such a meteorological situation.

Key words: water deficit, maize, yield, optimal irrigation, without irrigation

Introduction

The agricultural yield is in direct relation to the agrotechnological and soil-climatic conditions including meteorology in the period of vegetation. In the modern agriculture intensive conventional and extensive biological agro-technologies that are suitable for the soil specificity and culture requirements, are applied. Nevertheless, meteorology could not be ruled by the man, yet, and different risk situations (water deficiency, over-watering etc.) often seriously compromise the yield and production quality. In such conditions farmers suffer from serious financial lost and farms are exposed to risk of destabilization. In the most part of agrarian countries (including Republic of Bulgaria) the meteorological lost ate totally or partially compensated.

The maize is the second culture (after wheat) which is important for our country on a foodstuff supply basis. In the practice are cultivated Bulgarian and foreign hybrids having high productive potential. Modern technologies are applied. Unfortunately, the climate, in particular water deficiency, is a yield-limited factor over the period of every second year.

The effect of dry on the culture development was studied by different Bulgarian investigators. A remarkable number of scientific investigation on this problem have been done by Alex-

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andov, 2002; Slavov and Moteva, 2002; Moteva, 2005; Varlev, 2008; Popova, 2012 etc., over the last ten years. Generalizing the results from these studies for the period 1960 – 2000 authors have emphasized the tendency of increasing yearly values of the sum of the effective temperatures for the potential vegetative period of the maize. Slavov, Georgiev and Moteva (2005) have reported a clearly distinguished tendency of increased temperatures and decreased vegetation rain falls for a long period of 110 years, after 1890. The same tendency has been clearly established for a period of 40 years, after 1960.

It is well known, that not every dry has negative effect on the development of agricultural cultures. Therefore, for our agriculture of primary importance is the effect of dry on the yield of main arable cultures.

In accordance to the soil and climatic conditions of the regions the yield of maize cultivated for grain significantly vary. In bad meteorological conditions very low yield is obtained, sometimes compromising the harvest. The maize, cultivated in the conditions of water deficit resulting from the limited rain falls during the vegetation period, has produced yield of 2390 kg ha^{-1} for the region of North Bulgaria and 5560 kg ha^{-1} for South Bulgaria (Varlev and Popova, 1999). Jhivkov and Matev (2005) reported, that as a result of many years experimental work on maize, cultivated for grain and green biomass in different meteorological conditions, irrigating by 2400 mm ha^{-1} has obtained on average 4500 kg ha^{-1} without irrigation and 9960 kg ha^{-1} with irrigation. Studies on maize, cultivated on two different types of soil in the same climatic conditions have been done in the region of Stara Zagora for 22 years (Eneva, 1993). For the first period (1972–1982) at soil type vertisoil the average yield was 5560 kg ha^{-1} without irrigation and 11500 kg ha^{-1} at optimal irrigation. At the second period (1983 – 1993) the average yield was respectively 4500 kg ha^{-1} and 13 000 kg ha^{-1}, showing that the dry had reducing effect, 1000 kg ha^{-1}, on the cultures without irrigation.

According to Moteva (2005), in the conditions of the IV agroclimatic group of XMP the yield from the hybrid Kn 560 under natural watering was about 5000 kg ha^{-1}, and under optimal watering – 11000 kg ha^{-1}. The additional yield, caused by irrigation has changed from 20% in middle range rain falls to 350% in dry year. A series of studies showed that the water deficit in the soil, accumulated at the end of the maize vegetation was in direct relation to the amount of rain fall distribution and irrigating norm (Lazarov and Mehandjhieva, 1982; Eneva, 1993; Rafailov, 1998; Mladenova, 1998). The water deficit caused by abolishing of watering depends on the phase of maize development, amount and distribution of rain falls, and water reserve of the culture up to the particular moment, as well (Petrov, 1994; Zhivkov, 1991; Popova, 2006).

The studies of Bergez and Nolleau (2003) showed a parallel decrease of the yield and irrigating norm, and the easy water in the soil, as well.

Farré et al. (2000) defined the effect of water stress on the maize, cultivated for grain and the yield obtained in the conditions of Spain, by the simulation model LINTUL. Manuela et al. (2007) offered to calculate the yield of maize under water deficit by means of a simulating method (CSM-CERES-Maize) and to define time of maturation in different hybrids, as it was done in the region of Brazil. Other authors, also, define the effect of water deficit over the yield by different models (Marica and Stancalie, 2003; Walker et al., 2005; Raes et al., 2006).

Songhao et al. (2004) studied the effect of different irrigating regimes in maize cultivated for grain and the distribution of the soil moisture after that. They calculate the effect of rain falls and irrigation on the size of evapotranspiration. On the base of these results they created a model by which they define the effect of water deficit on the growth and development of the maize for the whole year.

Studies on parameters defining the factor “water deficit” in maize and establishment the lost of grain when cultivated without irrigation can serve in the management practice for decision making process and planning the participation of maize in the field rotations, as well as for the need of state compensation policy directed to the farmers in dry periods. The establishment of grain lost in dry years and the role of irrigation can serve for future accomplishment of economical analysis when planning irrigation and risks, defining the costs and market price in similar meteorological situation.

The problems mentioned above can be solved by means of precise scientific studies in short and long term exact experiments.

This study aims at pointing out parameters of water deficit during the critical for the maize moths, also, to follow the relations between yield and water deficit, provoked by the lack of rains, to establish the possibility of obtaining good yield in conditions without irrigation for the region of Central South Bulgaria.

Materials and Methods

For the purpose of this study were processed many-years data from meteorological observations and exact field experiments with maize cultivated for grain, executed at the former Research station of irrigating agriculture – Stara Zagora.

It has been analyzed 40 years data from monthly rain falls (mm), average monthly temperature of the air (°C) during the critical for this culture period (June, July, August) and the yield of maize grain, cultivated without irrigation and irrigated for the period 1972–2012. The soil of the two experimental fields was of the type vertisoil.

According to Bazitov (1995) the soil type vertisoil is characterized by powerful humus horizon (over 60 cm), where the physical part is 63.6–67.7%, the mass is 1.18–1.31 g/cm^3 and relative mass – 2.59. For this reason, this soil is known as a soil having heavy mechanical composition and unsuitable physical characteristics – when moisture it strongly increase its mass and in the dry conditions it decreases significantly generating big clefts between 0.8 and 1.2 m in depth. The humus content in the layer 0–60 cm is 2.9–3.2%, the soil reaction is neutral (pH in water 6.9–7.1). The reserve of this layer of mineral N and P_2O_5 is weak, respectively 27–33 mg/1000 g и 2.8–4.2 mg/100 g, and the reserve of K_2O is good (over 25–30 mg/100 g).

For the purpose of the study are followed the yield of maize grain from two hybrids – middle late Knezha 530 and late H – 708, cultivated without irrigation (kg/da having 14% moisture) and optimal irrigation. The first hybrid has been cultivated for ten years and the second – for 15 years. These periods were sufficient to get significant relations of the yield by the water deficit, provoked by lack of rain falls and good water reserves.

Table 1

Variability in rain falls in June, July and August in the period 1972–2012

Month	VC, %
June	65.67
July	77.26
August	91.4
June – August	50.34

The experimental studies were done by means of block method by four repetitions. The hybrids were cultivated by common agrotechnology for this country. A fertilizing was done by N P K.

In order to establish the variability of the factors and relations between them, the data were processed by Statistic for Windows.

Results and Discussion

The statistical processing of the rain falls during the summer period, when the yield is formed showed a high degree of variation, thus, relatively lowest variability was found in June (65.67%), followed by July (77.26%) and the highest one was found in August (91.40%) – Table 1.

The amount and security of rain falls have been different during the same months for the 40 years period. The years where the months June, July and August have been define as "humid", the rain falls were in a very wide diapason, respectively from 101.1 to 205.0, from 70.5 to 153.0 and from 58.1 to 236.2; as „middle humid" – from 53.9 to 85.0, from 40.9 to 62.9 and from 29.9 to 53.8; as „middle dry" – from 37.3 to 53.6, from 27.2 to 36.2 and from 16.0 to 24.0 and as „dry" – from 0.0 to 35.8, from 0.0 to 26.2 and from 0.4 to 13.7 – Table 2.

The middle dry and dry months, having clearly distinguished water deficit, could be defined as "risky" for the maize in the region with strong need of irrigation and middle humid and humid as "favorable" for the development and yield of this culture, without any need of irrigation.

The month July was the most risky (54% of the years of the long period were dry and middle dry), followed by

Table 2

Characteristic of the months June, July and August, according to security of rain falls for the period 1972–2012

Character	Month					
	June		July		August	
	From – to	Number of years	From – to	Number of years	From – to	Number of years
Humid	101.1–205.0	6	70.5–153.0	9	58.1–236.2	9
Middle humid	53.9–85.0	10	40.9–62.9	10	29.9–53.8	15
Middle dry	37.3–53.6	12	27.2–36.2	10	16.0–24.0	6
Dry	0.0–35.8	13	0.0–26.2	12	0.4–13.7	11
Average (years)	56	41	48.5	41	41.5	41

Table 3

Risky and favorable for maze years concerning monthly rain falls for the period 1972 - 2012

Character of the year	Month					
	June		July		August	
Risky (dry and middle dry)	*16	**39%	22	54%	17	42%
Favorable(middle humid and humid)	25	61%	19	46%	24	58%

Notes: * – number of years in the period; ** – % of the years in the period

Table 4

Average daily and diurnal temperatures of the air in the risky and favorable for the maze months June, July, August for the period 1972–2012 г. (°C)

Character of the year	Month		
	*June	*July	*August
Risky (dry and middle dry)	from +0.7 to + 1.4	from +0.4 to + 3.2	from + 1.4 to + 2.4
Favorable (middle humid and humid)	from – 0.4 to – 1.3	from – 0.4 to – 2.2	from – 0.4 to – 4.2
Average (years)	21.2	23.4	23.2

Note: Temperature variation, expressed by the minimal and maximal deviation to the average (years) values (+/–)

August (42% of the years of the same period were dry and middle dry) only in 1/3 of the years water deficit in June was a problem – Table 3.

The water deficit in the risky months was accompanied by higher temperatures of the air (in comparison with average total years temperatures) – Table 4. In the favorable months the rain falls were followed by lower average month temperatures. In the first case the maize was in risky situation concerning feeding regime, plant development, pollination, grain maturation etc. In the second case, better conditions were established, better utilization coefficient of the soil and fertilizer, lower rate of development, fuller realization of the biological potential of the hybrids.

Table 5

Correlations between maze yield, cultivated without irrigation and the rain falls in June, July and August for the period 1972–2012 (R%)

Type of hybrid	Rain falls			
	June	July	August	∑ June – August
Middle late	0.22	0.33	0.13	0.58
Late	0.34	0.32	0.56	0.34

Table 6 Maze yield variation, cultivated with and without irrigation for the period 1972–2012 (40 years)

Hybrids	VC, %	
	Without irrigation	With irrigation
Middle late	27.54	15.83
Late	25.9	15.1
Totally for 40 years	21.78	20.72

For the purpose of a better analysis was calculated the relation of the grain yield from late and middle late hybrids, cultivated without irrigation and rain falls in June, July, and August. On the Table 5 are presented correlation coefficients of different relations. The yield from the late hybrids, cultivated without irrigation was in higher relation (dependence) from the rain falls in comparison with middle late ones. Thus, the yield of the late hybrids was in the highest dependence by the rain falls in August, and the yield of middle late hybrids – in July.

The meteorological situation, pointed out in this study for the period 1972–2012, has affected significantly the maize yield and played an important role as yield limitation factor. The yield variation in the two hybrids, cultivated without irrigation was similar and within 25.90 to 27.54% – see Table 6.

The irrigation decreased variability twice (15.83% и 15.10%), but did not compensate totally the negative effect of the water deficit.

The fullest characteristic of the effect of the meteorological factors could be done after yield comparison obtained with and without irrigation on average for the long-term period – Table 7.

The yield data could serve for establishment the relative yield without irrigation (Y_0) by means of the formula:

$$Y_0 = V_0 / Vir,$$

where Vo – average yield without irrigation, Vir. – average yield with irrigation.

The coefficient values showed that irrigation increased the yield twice in late hybrids in the risky years (middle dry and dry). The increase in the yield in middle late hybrids was higher (y – 0.418) in comparison with the late hybrids in the favorable years (middle humid and humid).

Concusions

The average agroecological potential of the late hybrids maize in Central South Bulgaria in optimal irrigation, established experimentally in risky years was 12 230 kg.ha^{-1} and

Table 7

Maze yield and irrigation effect in favorable and risky years kg.ha^{-1}

Character	Hybrid	Without irrigation	With irrigation	Relative yield
Risky years	late	5530	12230	$Y_0 = 0.417$
Middle dry and dry	Middle late	3990	6670	$Y_0 = 0.598$
Favorable middle humid	late	6950	11400	$Y_0 = 0.609$
and humid	Middle late	5530	13230	$Y_0 = 0.418$

without irrigation – 5530 kg.ha^{-1}. In middle late hybrids the yield was respectively 6670 kg.ha^{-1} and 3990 kg.ha^{-1}. The parameters of the factor "water deficit" and establishment of the lost of grain when cultivated without irrigation could serve for decision making and planning in region of the Central South Bulgaria, as well as for formation of the state policy concerning compensations of the farmers during dry years. The established lost of grain in dry years and the role of irrigation can be used for further economical analysis for planning in risky, dry years and defining the cost and market price in such a meteorological situation.

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