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AN INFLUENCE OF MICROCLIMATIC FACTORS AND IRRIGATION REGIME ON PRODUCTIVITY OF A BULGARIAN WHEAT VARIETY SADOVO 1

Abstract. Results of twelve-year field agricultural experiments during 1995–1996, 2002, 2004–2012 with a Bulgarian wheat variety Sadovo 1, conducted on a leached meadow-cinnamon soil of the experimental base of the Institute of Soil Science, Agrotechnology and Plant Protection in Southern Bulgaria are presented in this paper. The aim of the research was to assess an influence of meteorological factors and irrigation on water use efficiency of plants and grain yield of a spring soft wheat variety Sadovo 1. In the early years, from 1995 to 2007, experiments on controlled watering when a difference between the temperature of a canopy and the surrounding air (measured with infrared thermometer) reached 1°C was carried out in comparison with the control without irrigation. In 2008 three experiments with irrigation at different temperatures between the canopy and the surrounding air were carried out in comparison with a not irrigated control. In 2009 there were applied variants without irrigation at different growth stages – spike development, ear formation and milk ripeness, as well as a variant of optimal irrigation and a control without irrigation. High correlations (>0,7) were shown between wheat yields and the climate factors and between wheat yields and irrigation depths. Single watering during interphase periods “heading” and “milk ripeness” increased the efficiency of water consumption and grain yield. The efficiency of water consumption (from 0.95 to 1.99 kg/m3) by the wheat variety Sadovo 1 was higher in the experiment with watering at the temperature difference of more than +1?C. With increasing the standard deviations of rainfall the efficiency of water consumption by plants and grain yield increased, too. When the standard deviations of the indicators of soil moisture decreased in the irrigation experiments, grain yield increased.

Keywords: wheat, yield, temperature, precipitation, irrigation, standard deviation.

Soft winter wheat is one of the most spread cereals in the world. The Southern Bulgaria and the area near the North Black Sea Coast have suitable conditions for cultivation of durum wheat.

Winter wheat is sensible to heat. The optimal temperature for wheat development up to the flowering is 18–20 °C and during the flowering – 21–22 °C. The temperature over 24–25°C slows down wheat growth and development. At 38–40 °C, the stomata leaves are paralyzing, the plants can not regulate their transpiration and mortify [1].

The shortage and excess of moisture in the soil has a more adverse effect on the development of the wheat root system than the changes of the temperature. In the dry soil the wheat roots stop growing , when the soil moisture is increasing the roots growing is increasing as well. If the soil moisture is over 80 % FC the process of growing slows down because of the air shortage in the soil.

Wheat can be marked as a cereal demanding a moderate moisture. The necessities and water consumption of wheat are not equal during different growth stages.

As wheat do not develop a wide transpiration surface before heading soil moisture must be no less than 65–70 % FC. From the beginning of the head development to the ear formation wheat transpiration surface increases intensely, wheat water consumption rather increases and soil moisture has to be 75–85 % FC. After the end of flowering, during grain filling, water consumption decreases again and soil moisture must be 65–75 % FC [1].

Maltzev and Moshkarev [2] implemented field experiments to establish that the hydro thermal coefficient (HTC) and the precipitation for the period May – the first decade of June are defining for wheat yield formation.

Years with insufficient reserves of winter soil moisture the vegetation watering contributes more in the spring tillering and head formation. According to Alpatev [3] at unlimited water supplying, the sum of water consumption depends on the climatic factors, the strongest of them is a temperature regime. According to Kosin [4] at irrigation wheat consumes a lot of water and at the same time it uses water more economically for grain yield then it does without irrigation. Except of this, at irrigation, the yields, and the water consumption per years are considerably more stable.

According to Mala [5], the quantity and stability of wheat yield for a lot of years is determined from the quantity and uniformity of distribution of the precipitation during the vegetation season. In the regions, where the precipitation quantity is lower than the biological and agronomical requirements, wheat has to be irrigated.

Wheat is demanding to soil. It grows well on a structural, rich of easily assimilated nutrient substances, with a good water capacity and moisture retentive ability and clean from weeds soils.

The results of studies show that under the optimum conditions of all factors, effecting the winter wheat growing a sustainable rich yield of more than 8 t/ha can be obtained. A basic decisive factor is a soil water regime. On the base of our and other's knowledge high effect from irrigation is possible if a soil water regime during all vegetation season is optimizing.

According to Kramer and Boyer [6] losses of the potential yield from biotic factors are 12 % in comparison with the genetic potential of the USA, 70 % of the losses are from physical-chemical factors, and 45 % from them are due to drought. In our country, as a result of unprecedented drought during 2000 year, the wheat yield was under 100 kg/da [7] and bean yield in Dobrudja was 30–80 kg/da.

In the drought regions irrigation is a decisive factor for yield increasing, but only if it is realized in time and with the necessity for plants of the quantity of irrigation water [8].

The irrigation makes the agriculture possible in the infertile regions and has a priority for water supplying when it is necessary and the yields can to be more predictable and stable [5, 9]. This makes successfully the investing in irrigation for agricultural practice and increases the interest to improving water use efficiency (WUE).

During the last years in foreign and our countries for prognostication of the watering there have been used coefficients, that express a correlation between the real evapotranspiration (ET) and the sum of the air humidity deficit (ΣD) or temperature sum (ΣT), as meteorological factors, determining ET. According to Varlev [10] the irregularity of irrigation reflects on the yield and gives rise to a yield loss of crops. The uniformity of irrigation was the object of the other our studying [11, 12].

The aim of the study is to evaluate the influence of the meteorological factors: air temperature, precipitation and their distribution, as well as their improving by irrigation, on the values of the yield and WUE.

MATERIAL AND METHODS

Twelve-year (1995–1996, 2002, 2004–2012) field experiments with Sadovo 1 Bulgarian winter wheat variety were conducted on leached meadow – cinnamonic soil in the Experimental station of the ISSAPP "N.Pouashkarov" in Tzalapitza, Plovdiv district (East Middle South Bulgaria) on an area of 4 da in rotation couple "bean-wheat" and ", "soybean-wheat". The experiment with wheat was sowing in October with population density 600 germinated seeds per 1 m^2.

During the first years the variants of the soil moisture regimes were only non irrigated control and irrigated when the temperature difference (dT) between the canopy temperature (T_c), measured by hand manipulating Infrared thermometer, and ambient air temperature (T_a) became 1 ^oC. The canopy temperature (T_c), gives the possibility to manage the plant water-supplying, the irrigation planning and more effectively water resources using. The experiment with irrigation when the dT > 1 ^oC, dT > 0 ^oC and dT > –1 ^oC and non irrigated control was conducted in 2008. During the next 2009 were realized variants with missed irrigation in: 1/head development, 2/ear formation and 3/milk ripeness 4/optimal irrigated and 5/ non irrigated control. The Various irrigation variants were realized by sprinkling irrigation. All experimental variants were conducted in 3 replications.

Agrotechnics and fertilization were optimal [1], not limiting the yield, and only the soil water regime was the yield limiting factor. The suitable technologies and preparations were applied for canopies without weeds, diseases and enemies.

During 2002 an experiment with bread and durum wheat was conducted on leached vertisoil on the experimental base of the ISSAPP "N. Pouashkarov" in Bojurishte, Sofia region. Soil moisture and plant water status were evaluated respectively by gypsum blocks, designed at "N. Poushkarov" ISS / ISSAPP/ [11] and Infra red thermometer ("TECPEL 510", spectral response 6–14rm, analog output 1mV/^{o}C) (difference between canopy and ambient air temperature-T_c–T_a, every day at 14 o'clock [13, 14] during the vegetation season. The precipitation, air temperature and relative air humidity were evaluated. Relationships "yield-precipitation", "yield-given water (precipitation + irrigation) water", "WUE-SPI(III – VI months)", "WUE – given water", "Yield-stdev of precipitation", "Yield-stdev/aver. precipitation", "WUE-stdev/aver.given water" were obtained.

RESULTS AND DISCUTION

Years 2001 and 2007 were extremely wet, 2000, 2009, 1996 and 1995-were moderately dry and the others are in norm. For the nonirrigated variant during 1995 WUE biomass (WUE_b) is higher than that for the irrigated one, but WUE grain (WUEg) is higher for irrigated variant. During 2002 WUE is the highest at the bread /soft/ wheat in Bojurishte.

The relationship "WUE-SPI" when SPI is standard (-0.99-+0,99), the WUE is near to constant. When it is moderately dry (−1,0—1.49), very dry (−1,5... −2) or extremely dry (SPI >−2), WUE increases. In the same zones, but positive (the humidity increases, the WUE decreases.

When the given water (precipitation + irrigation depth) increases, WUE decreases (Fig. 1)

The precipitation during 2006 and 2008 were the most plentiful in March and April. Grain yield in those years was the highest. Grain yield at the nonirrigated variant was the highest in 2010, followed by 2008, 2006, 2009 (Fig. 2). The sum of days with canopy temperature (T_c) $17 < T < 30$ °C (thermal kinetic temperature for wheat) was the highest in 2009 and 2006 and the lowest in 2010.

The sum of precipitation in IV (April) during the years 2004−2012 were with good correlation to grain yield of nonirrigation variants, i.e. it had the most influence on the yield.

The number of days with T_c>30°C at the nonirrigated variants was the highest in 2010 and the lowest in 2009 (Fig. 3).

The yield at the irrigated variants (Fig. 4) was the highest in 2009, followed by 2004 and the others were nearly equal.

Grain yield depends on the year humidity and the canopy temperature regime. When given water increases, the yield increases too.

Grain yield in 2009 was the highest at the optimal irrigated variant. Grain yield was the lowest at the nonirrigated variant (Fig. 5). The relationship "wheat yield-stdev of precipitation for months III−VI on days" (Fig. 6) had a high correlation (R^2=0.86).

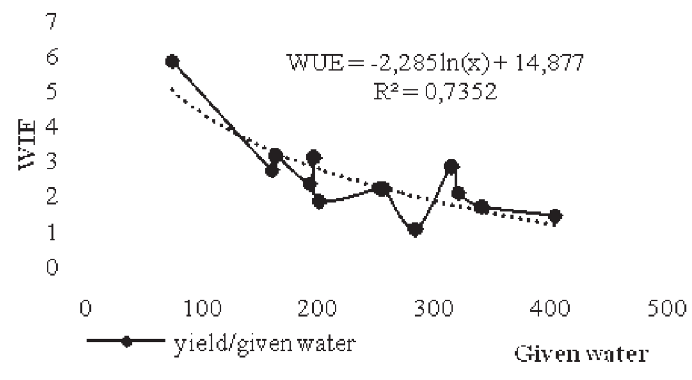

Fig. 1. Relationship "WUE-given water" at the irrigated wheat canopy during the experimental years.

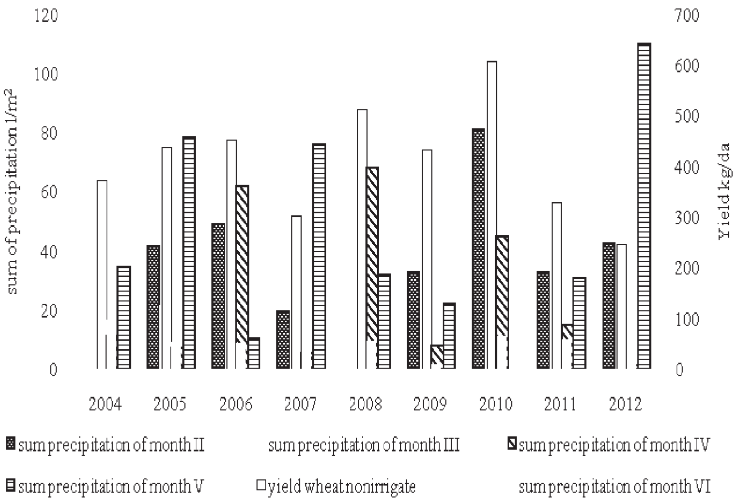

Fig. 2. The precipitation per months and wheat yield during 2004–2012.

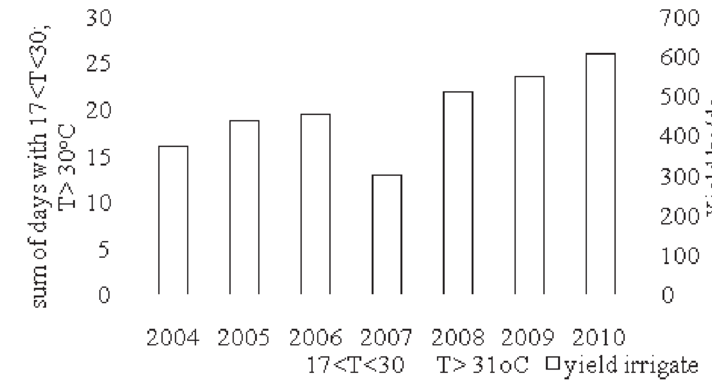

Fig. 3. Yield and number of days with $T_c > 30$ °C during 2004–2010, nonirrigated variants.

When the quantity "stdev/average precipitation" increased, the yield decreased (Fig. 7).

WUE decreased too, when the quantity "stdev/average given water" for the irrigated variants increased.

During 2007 for non irrigated variant stdev was on the depth of 20cm –3.82, 40 cm – 4.45, 70cm – 2.75 and 100 cm – 2.55 (Table 1), and grain yild was 301 kg/da. At the irrigated variant it was: on 20 cm – 3.90, 40cm – 3.95, 70 cm – 2.07, 100 cm – 2.51, and grain yild was 580 kg/da. The next year (2008), stdev for the variants, irrigated at dT>+1°C and dT > 0°C was approximately equal to given above. At the variant, irrigated at dT>–1°C, i.e. the soil moisture was higher, stdev was on 20 cm depth–3.18, 20 cm – 3.51, 70 cm – 1.96, 100 cm – 1.70, i.e. with irrigation stdev decreased, which means that soil moisture became more constant in time. As the result the yield increased.

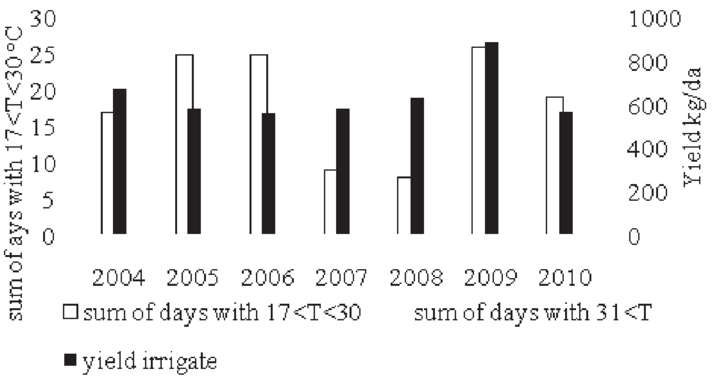

Fig. 4. Yield and number of days with 17<Tc<30°C and Tc>30°C during 2004–2010, irrigate variants.

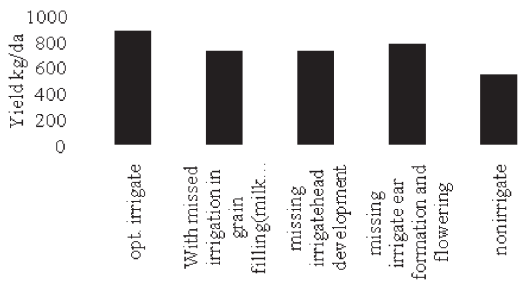

Fig. 5. Wheat yield at the different variants, field experiment, Tzalapitza, 2009.

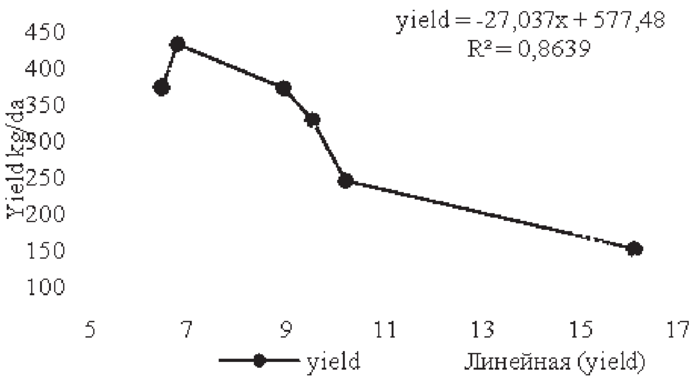

Fig. 6. Relationship wheat “yield-st dev of precipitation for month III-VI on days”.

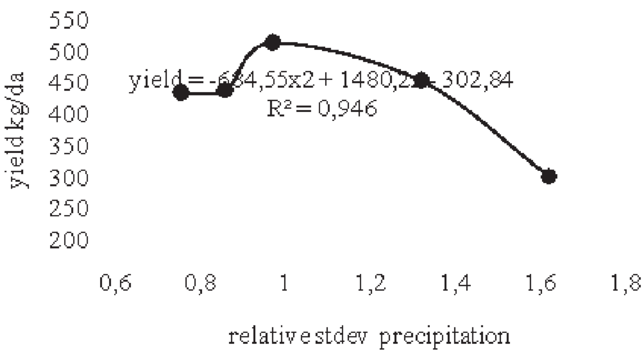

Fig. 7. Relationship “yield-stdev/aver. precipitation” at the non irrigated variants.

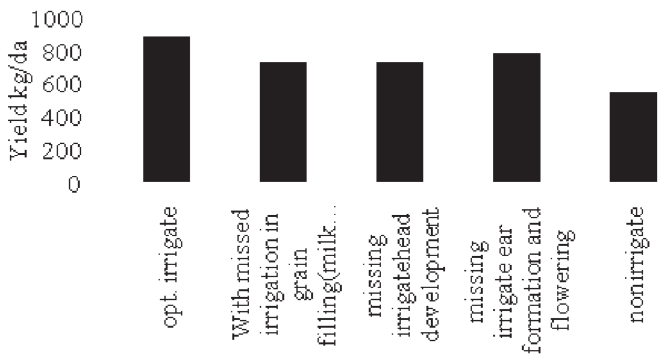

Fig. 8. Wheat yield and stdev/average soil moisture on 20 cm depth for the variants during 5 years.

Table 1

Stdev of soil moisture at different depths and yield in irrigated and nonirrigated variants, 2007

Variant of watering	Yield, kg/da	Stdev of Soil moisture at depth:			
		20 cm	40 cm	70 cm	100 cm
Nonirrigated	301.3	3.8208	4.451044	2.746639	2.555043
Irrigated	603.6	3.898386	3.951796	2.069145	2.506519

Stdev were the lowest for the nonirrigated variants (Table 2) and the absolute values of the soil moisture were very low. In order to eliminate the influence of the absolute value of the quantity, we divided stdev on the average value of the soil moisture.

The values of the quantity “stdev/average soil moisture at 20 cm depth were the highest for non irrigated variant in 2008, 2010 and for the variants with missed irrigations in 2009 (Fig. 8) and at 40cm depth the highest values were for nonirrigated in 2008 and 2010 and for irrigated variants in 2010 (Fig.9).

Table 2

Stdev of soil moisture at different depths and yield in irrigated and nonirrigated variants, 2009

Variant number	Yield	20cm	40cm	70cm	100cm
1	549.093	0.925578	0.975439	0.938407	2.504125
2	891.6038	3.159278	3.434545	1.02918	1.981787
3	790.3017	2.608462	0.785815	0.505033	1.623055
4	733.7463	3.705947	4.176303	0.687921	0.934235
5	737.0625	3.156635	0.880174	0.589939	1.471746

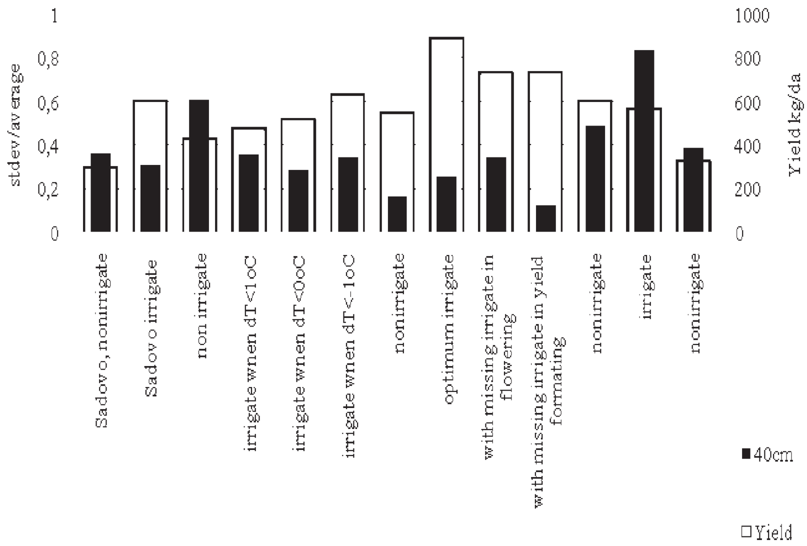

Fig. 9. Wheat yield and stdev/average soil moisture on 40 cm depth for the variants during 3 years.

CONCLUSIONS

The relationships “wheat yield-microclimatic factors” and “wheat yield-irrigation depth” were with good correlation ($R^2 > 0,7$).

One time watering during the growth stages “head formation” and “milk ripeness” increased the yield and WUE.

WUE of Sadovo 1 – a Bulgarian variety of common wheat was the highest for the variant, irrigated at dT > +1 °C. The values of WUE for the variants were within the limits from 0.95 to 1.99 kg/m^3.

When stdev and relative stdev of precipitation increased, the yield and WUE decreased.

When results of the irrigation stdev and relative stdev of moistening decreased grain yield increased.

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ВЛИЯНИЕ ФАКТОРОВ МИКРОКЛИМАТА И РЕЖИМА ОРОШЕНИЯ НА ПРОДУКТИВНОСТЬ БОЛГАРСКОГО СОРТА ПШЕНИЦЫ САДОВО 1

Представлены результаты двенадцатилетних полевых опытов с болгарским сортом пшеницы Садово 1 (1995–1996, 2002, 2004–2012 гг.). Исследования проведены на выщелоченной лугово-коричной почве экспериментальной базы Института почвоведения, агротехники и защиты растений (Южная Болгария). Цель исследований – оценка влияния метеорологических факторов и искусственного орошения на эффективность использования воды растениями и урожайность зерна яровой мягкой пшеницы сорта Садово 1. Начиная с 1995 по 2007 г. проведены опыты по регулируемому поливу при достижении разницы в 1 °С между температурой покрова листьев и окружающего воздуха в сравнении с контролем без полива. Измерения проводили инфракрасным термометром. В 2008 г. проведены три опыта с поливом в условиях разных температур между покровом листьев и окружающего воздуха в сравнении с неорошаемым контролем. В 2009 г. применены варианты без полива на разных стадиях роста: развития колоса, колошения и молочной спелости, а также вариант оптимального полива и неорошаемый контроль. Показана высокая корреляция (> 0,7) между урожайностью пшеницы и факторами микроклимата, урожайностью пшеницы и глубиной полива. Одноразовый полив во время межфазных периодов «колошение» и «молочная спелость» увеличивали эффективность усвоения воды и урожайность зерна. Эффективность потребления воды (от 0,95 до 1,99 кг/м^3) сортом пшеницы Садово 1 была наивысшей в опыте с поливом при разности температур свыше 1 ^{o}С. При увеличении стандартных отклонений количества осадков возрастала эффективность потребления воды растениями и урожайность зерна. При уменьшении в поливных опытах стандартных отклонений показателей влажности почвы увеличивалась урожайность зерна.

Ключевые слова: пшеница, урожайность, температура, осадки, орошение, стандартное отклонение.