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EFFECT OF IRRIGATION ON FIELD CROPS YIELD UNDER THE VARIABLE AGRO-CLIMATIC CONDITIONS OF SERBIA

SUMMARY

The main agricultural region of Serbia has favourable soil and climatic conditions for successful crop production. However, rainfall is frequently a limiting factor for high yields and production stability. The amount of rainfall and the distribution vary from one year to another. Rainfall variability is particularly pronounced during the growing season. Droughts of variable intensity, i.e., short or long periods with insufficient rainfall, occur practically every year. The need for irrigation in the agricultural regions is evident because the droughts occur frequently, cover vast expanses, significantly reduce yields and cause extensive damage, in general, to crop production and to agriculture. In the climatic conditions of Serbia, irrigation is a supplementary practice, which favourably affects the yield and the stability of the cultivated crops, especially in dry years. The effects of irrigation and cultural practices vary from one year to another. Annual yield variations are pronounced in favourable years. Yield losses in dry years may range from a few percent to 50%. In years with extremely severe droughts, the losses may be as high as 80–100%. The positive effects of irrigation are evident, to a variable degree, almost every year. In extremely dry years, irrigation can double the yields of field crops or lead to yields that are 3–4 times higher than those in nonirrigated conditions (Dragović et al., 2005).

Key words: Irrigation, field crops, climatic conditions, rainfall, water requirements, yields.

INTRODUCTION

The main agricultural region of Serbia has favourable soil and climatic conditions for successful crop production. However, rainfall is frequently a limiting factor for high yields and production stability. The amount of rainfall and the distribution vary from one year to another. Rainfall variability is particularly pronounced during the growing season. Droughts of variable intensity, i.e., short or long periods with insufficient rainfall, occur practically every year. The need for irrigation in agricultural regions is evident because droughts occur frequently, cover vast expanses, significantly reduce yields and cause damage to crop production and to agriculture in general.

An analysis of the last nine decades (as of 1924) has revealed precipitation deficits for most cultivated crops in about 80% of years in July and in August

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(Dragovic et al., 2008). As a result of these dry spells, the plants showed retarded growth, tending to shorten some stages of their growth and development. Irrigation provided the required amounts of water throughout the growing season, increasing and stabilising the yields and improving the effectiveness of agricultural production.

The water requirements and the yields of field crops depend on many factors. These include the site itself, the crops' nutritional level, cultural practices applied and species and genotype characteristics.

In the climatic conditions of Serbia, irrigation is a supplementary practice, which favourably affects the yield and the production stability of cultivated crops, especially in dry years. The effects of irrigation and cultural practices vary from one year to another. Annual yield variations are pronounced in favourable years. Yield losses in dry years may range from a few percent to 50%. In years with extremely severe droughts, the losses may be as high as 80–100% (Maksimovic et al., 2002). The positive effects of irrigation are evident, to a variable degree, almost every year. In extremely dry years, irrigation can double yields or lead to yields of field crops that are 3–4 times higher than those in nonirrigated conditions, (Dragović et al., 2005).

MATERIAL AND METHOD

Experiments have been conducted at Rimski Šančevi experiment field of Institute of Field and Vegetable Crops, Republic of Serbia, on the calcareous chernozem soil of the loess terrace. The trial established in a block design and adapted for sprinkling irrigation, included an irrigated variant (60-65% of FWC) and the non-irrigated control variant. Irrigation was scheduled on the basis of soil water dynamics measured sequentially in 10-20 cm soil layers to the depth of 60 cm, at 10-day intervals or at shorter intervals if necessary. Soil moisture was determined by the thermo gravimetric method, drying soil samples at 105-110 ^{0}C. At the beginning and at the end of corn growing season, soil moisture was measured to the depth of 2 m to calculate the consumption of water from pre-vegetation soil reserves.

Water requirement (ET) during growing season was calculated on the basis of water consumption from pre-vegetation soil reserves in the layer of 2 m, rainfall during growing season and irrigation requirement.

Sprinkling irrigation was performed on the basis of soil moisture the cultural practices were used as in the intensive crop production. Phosphorus and potassium were each applied in the fall during primary tillage and nitrogen in more times: during primary tillage, before planting and dressing. Ploughing to the dept of 30 cm, seedbed preparation and herbicide application, crop protection against diseases and insects and between-row cultivation was performed.

RESULTS AND DISCUSSION

Effect of irrigation of winter wheat

Winter wheat should occupy 15 to 20 % of acreage in irrigation systems, for following reasons:

- Winter wheat contributes to the maintenance and improvement of soil properties including soil fertility;
- Winter wheat prevents the multiplication of some insect pests, diseases and weeds;
- Early harvest of winter wheat makes possibility for double cropping;
- Winter wheat is irrigated in a period of the year when systems for irrigation are idle;
- Winter wheat increase yield in irrigation for 20 to 60%.

Under the climatic conditions of Serbia, the optimum planting date for winter wheat is October 5 to 25. Wheat planting after that period results in yield reduction. If, however, the fall is rainless and the topsoil dry, winter wheat won’t be able to emerge without irrigation regardless of planting date. Irrigation creates favourable conditions for timely emergence of winter wheat, and the planting within the optimum period ensured high yields.

Table 1. Effect of planting date and stand density on yield of winter wheat in irrigation

Date of planting	400 grain m2		600 grain m2		Average	
	Irrigation	Non-irrig.	Irrigation	Non-irrig.	Irrig.	Non-irrig.
5 October	8.04	5.80	8.48	6.96	8.26	6.38
15 October	8.69	7.40	8.46	7.50	8.50	7.45
25 October	8.58	6.99	8.71	7.88	8.65	7.44
5 November	7.01	6.14	8.09	7.18	7.55	6.66
Average	8.08	6.58	8.43	7.38	8.26	6.98
% of reduction	100	81.43	100	87.54	100	84.50

Yield reduction relating to planting date became apparent with November planting. There was no worthwhile yield reduction when wheat was planted between October 5 and 25, with or without irrigation. On the other hand, the planting on November 5, compared to a planting before October 25 reduced the yield, on average, by 0.92 t/ha or 12.2% in irrigation and by 0.43 t/ha or 6.4% without irrigation.

Stand density exhibited no significant effect on yield level, although the seeding rate of 600 seeds/m^2 brought a yield increase of 4.4% in irrigation and 12.2% without irrigation compared to the seeding rate of 400 seeds/m^2. Although the seeding rate of 600 seeds/m^2 is most frequently used for winter wheat cultivars in the commercial production, seeding rate is a cultivar-specific trait which is always specified in pedigreed seed declaration.

An earlier investigation by (Maksimović et al., 1991) showed that irrigation after planting, especially when a dry spell occurs in the first half of

October, the period of emergence is shortened by 23 days on average compared to non-irrigated wheat. This investigation also showed that the planting on November 10, compared to a planting before October 25, reduced the yield of the cultivar Zvezda by 15%. Evidently, in a dry fall, a single post-planting irrigation using the irrigation rate of 20 to 40 mm ensures a timely emergence of winter wheat.

The average requirement of winter wheat for water in the spring period is 300 mm, the actual values varying from 240 to 310 mm (Dragović et al., 2006). The beginning of irrigation practice in the spring season depends on weather conditions, or, more precisely, on soil moisture. Irrigation should be applied when the moisture in the soil layer 0-50 cm drops to 65-70% of field water capacity. This regimen of pre-irrigation soil moisture should be maintained to the stage of wax maturity. The irrigation rate should vary between 40 and 50 mm, depending on type and actual soil moisture.

Effect of irrigation on yield depends on the amounts and distribution of rainfall. The average effect is 20%, with the actual values varying from 0 to 60%.

Effect of irrigation of corn

Corn is the major agricultural crop in Serbia. It is annually grown at about 40% of the total arable land or at 1.3 to 1.6 million hectares. Yields of non-irrigated corn vary with the amounts and distribution of rainfall in the growing season. In irrigation and with all cultivation practices needed, corn yields range between 10 and 12 t/ha. Early hybrids perform somewhat below these figures, while late or full-season hybrids may exceed 15 t/ha.

Irrigated corn is planted in the course of April, the actual date of planting depending on soil temperature. Stand density varies from 55 to 90,000 plants per ha. The seeding rate for irrigated corn is higher by 10 to 20% than the rate for non-irrigated corn. The actual figure is depending on the water-physical properties and fertility of soil. Mineral fertilization too depends on soil fertility but again irrigated corn receives 20% more fertilizers than non-irrigated corn.

In the agro-climatic conditions of Serbia, the corn requirement for water ranges from 450 to 550 mm, in dependence of weather conditions. In a four-year investigation on the chernozem soil, founded that the average potential evapotranspiration (ET) was 478 mm, with the following monthly ET values: 64 mm in May, 106 mm in June, 121 mm in July, 124 mm in August and 63 mm in September, (Maksimović et al., 1999). Late hybrids use a certain amount of water in October, since they typically mature in November. The average daily ET of corn is: 1.0 mm in April, 1.0-2.3 mm in May, 4.0-4.3 mm in June, 3.5-4.0 mm in July, 3.5-4.0 mm in August and 1.8-2.0 mm in September (Dragović et al., 2007). Here it should be mentioned that some authors report average daily water requirements of corn between 5 and 10 mm.

Corn is irrigated when the soil moisture drops down to 60-65% of field water capacity. If corn is irrigated at higher pre-irrigation soil moisture levels, amounts of water used per yield unit become too high and such inputs cannot be returned through yield.

Irrigation rate depends on soil type and the depth of soil that should be wetted. The rate typically varies between 30 and 60 mm. In this study, supplementary irrigation was used to maintain an optimum level of soil moisture throughout the corn growing season.

In the irrigated variant (60-65% FWC), 230 mm of water were added in 2003. As the 2004 and 2005 distributions of rainfall were much more favourable for corn growing, only two irrigation had to be performed in 2004 and one irrigation in 2005 (Table 3).

Table 2. Irrigation schedule and rate (mm), and irrigation requirement (mm)

Year	**Irrigation date**	**Irrigation rate (mm)**	**Irrigation requirement (mm)**
2001	18 July 9 August	40 60	100
2002	21 June 4 July 22 July 8 August	60 60 60 60	120
2003	30 April 5 May 5 June 20 June 5 July 27 July	30 20 60 60 30 30	230
2004	2 July 17 July	40 60	100
2005	25 June	60	60
2006	6 July 17 July 28 July	60 60 60	180
2007	21 June 19 July 31 July	40 60 60	160

Table 3. Yields of corn in trails with and without irrigation, on loamy chernozem soil in dry years (t/ha)

Year	Yield in irrigation	Yield without irrigation	Effect of irrigation	
			t/ha	%
1990	17.8	7.1	10.7	151
1992	14.5	8.5	6.0	70
1993	14.6	5.6	9.0	160
1994	13.0	10.0	3.0	30
2000	14.3	8.3	6.0	73
2002	14.1	10.6	3.5	33
2003	12.6	9.2	3.4	37
2004	14.3	11.2	3.1	28
2006	13.3	9.8	3.5	36
2007	14.9	10.3	4.6	45
Average	14.3	9.1	5.3	57

Yield of corn in irrigation depends in the first place on the hybrid's genetic yield potential, and then on soil fertility, other soil properties and weather conditions. In dry years, irrigation practice increases the yields of corn up to 100%. In extremely dry years, the increases soar up to 200%, (Dragović et al., 2004).

The highest yield in the trial, on average for the irrigated and nonirrigated variants, was achieved in the FAO maturity group 600 in 1990 which was highly significant and it amounted to 17.8 t/ha. Summer time of this year was exceedingly warm and dry (Table 3).

The lowest yield for the irrigated, 12.6 t/ha was obtained in 2003.

Extremely high mean daily air temperatures in the last third of July (23.6^{o}C) and in August (24.6^{o}C) caused a premature end of the growing season. In nonirrigated variants, 5.6 t/ha, was obtained in 1993. That year had balanced temperature conditions and a moderately low rainfall throughout the growing season. Drought occurred early, at the beginning of June, and it lasted till the end of July. The effect of irrigation on the yield was high in that year, amounting to 160%.

Effect of irrigation of sugar beet

In the Serbia, sugar beet is grown at 60-80 000 ha and is processed by 8 refineries. In order for the refineries to be able to operate successfully and profitably, they need a constant supply of sugar beet. Water deficits are particularly severe in July and August, resulting in yield losses that are often as high as 50% and may reach as much more in extremely dry years. This calls for high and stable yields each year, which is not possible under natural water supply conditions, so irrigation has to be used.

Potential evapotranspiration (ETP) of sugar beet calculate on the basis of long term data (1964-2006) is 524 mm, and monthly in May 78 mm (15% of the total requirement), in June 118 mm(22%), in July 139 mm (27%), in August 129 mm(25%), and in September 60 mm, 11% (Maksimović et al., 2002): The average potential ET in agro-climate condition of Serbia is 540 mm, raining from 500 to 600 mm (Dragović et al., 1999).

In Serbia, sugar beet is planted in the first half of March, if weather conditions permit it. The row-to-row distance is 45-50 cm and the distance between plants in the row is 20 cm. Stand density in irrigation is about 100,000 plants per ha. The seeding rate for irrigated sugar beet is higher by 10 to 20% than the rate for non-irrigated sugar beet, (Dragović et al., 1995).

The average daily water requirements of sugar beet are 2.7 mm from emergence till June, 4.5 mm from the beginning of July till August 20 and 2.5 mm from late August till technological maturity. Irrigated sugar beets are monitored at regular intervals and irrigation is performed when soil moisture drops to 65 to 70% of field water capacity. Irrigation rate depends on soil type, stage of development of sugar beet roots and the depth of soil layer that has to be wetted. The depth of wetting is mostly 40 to 60 mm.

Table 4. Average yields of sugarbeet in trails with and without irrigation, on loamy chernozem soil in dry years, t/ha.

Year	Yield in irrigation	Yield without irrigation	Effect of irrigation	
			t/ha	%
1990	81.3	54.0	27.3	50
1992	79.2	39.9	39.3	98
1993	101.9	66.o	35.9	54
1994	123.3	65.8	57.5	87
2000	76.6	36.2	44.4	112
2002	107.1	77.6	29.5	38
2003	94.5	65.3	29.2	45
2004	113.4	93.2	20.2	22
2006	97.7	73.1	24.6	34
Average	97.2	63.4	34.0	54

Intensity of sugar beet fertilization depends on soil fertility. When grown on the chernozem soil, irrigated sugar beets typically receive 120, 110 and 150 kg/ha of N, P and K, respectively, (112).

The average yield of irrigated sugarbeet for the nine analyzed dry years was 97.2 t/ha. The rain fed sugarbeet yielded 63.4 t/ha, i.e., the effect of irrigation was 34.0 t/ha, or 54%. The highest yield in irrigation 123.3 t/ha, was obtained in 1994, the highest increase by irrigation, 112% in the year 2000. In 1992 the increase in irrigation in relation to the non-irrigated control was 98%, (table 4).

In the trails conducted on a loamy soil over a period of 38 years (1966-2003), the average yield in irrigated conditions was 80.7 t/ha, ranging from 58.2 to 124.0 t/ha, (Dragović et al., 2003).

In non irrigated conditions it was 60.9 T/ha, and ranged between 33.2 and 93.7. Irrigation effects for the period in question were 37% on average, varying from 4% in 1966 to 181% in 2000 (Figure 1). The highest effect of irrigation, 75.7 t/ha or 112% was found in the extremely dry year of 2000, in which the water deficit during the growing season was 427 mm, (Figure 1). The highest average yield in the experiment with sugarbeet was obtained in irrigation, 112.96 t/ha, (Maksimović and Dragović, 2004).

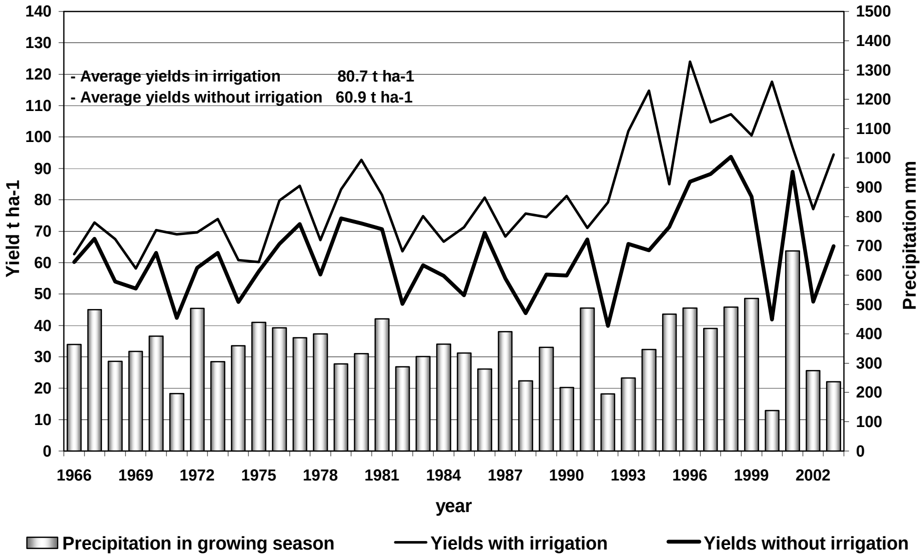

Figure 1. Average sugar beet yields in trial with and without irrigation conducted at Novi Sad on a loamy soil

In Macedonia, which typically has less rainfall than the Vojvodina Province the effect of irrigation on sugarbeet yield to be even higher in some years, ranging from 38 to 51 t ha-1 or 131 to 176%, (Cukalijev, 1996).

Effect of irrigation of soybean

Water supply is the most important parameter for soybean production technology because, in order to achieve high and stable yields, soybeans need large amounts of water which cannot be provided by the natural rainfall in Serbia. Soybean production in irrigation is important not only from the point of yield performance but also from the point of rotation of irrigated crops.

The soil in irrigation systems is intensively used and repeated application of water degrades its water-physical properties. Being a legume, the soybean improves the water-physical properties of soil and increases its nitrogen level.

The soybean acreage in Serbia ranges between 120 and 140,000 ha. The acreage reaches to 150,000 ha in some years. Soybean is planted like corn, in the first half of April, when soil temperature exceeds 10°C. The row-to-row distance is 50 cm; the distance in the row is 4 to 5 cm. Although as a legume it does not have high requirements for mineral nutrients, it is recommended to fertilize the irrigated soybean with 30 to 40 kg of nitrogen, 50 to 60 kg of phosphorus and 40 to 50 kg/ha of potash. The recommended doses are increased by 50% for medium fertile soils and doubled for poor soils.

The soybean has low water requirements at the initial stages of growth and development, but the requirements increase considerably after the full flower stage.

Highest requirements are seen from pollination to the end of seed filling and after that the requirement drops down. In other words, the critical periods for water are July and August (Dragović, 1992). Under the agro-climatic conditions of Serbia, the soybean potential ET is 450 mm, the actual figures varying from 390 to 550 mm, (Bošnjak, Dragović, 1998). In addition to agroclimatic conditions, the soybean water requirement depends also on cultivar and its maturity group.

Soybeans are irrigated at the pre-irrigation soil moisture of 60 to 65% of field water capacity. Irrigation at higher pre-irrigation moisture is not profitable – over-irrigated soybean plants tend to develop a large vegetative part which is prone to lodging which, in its part, causes yield reduction. Soybean may also be successfully irrigated according to critical stages for water. However, to achieve high yields, it is necessary to maintain the optimum soil moisture level throughout the growing season.

Effect of irrigation on soybean yield depends from amount and distribution of rainfall. Similarly to other crops, drought impact and irrigation effectiveness are highest in extremely dry years (table 5). In trails conducted on loamy soil in seven years the irrigated soybean yielded in average 4.80 t/ha, the non-irrigated one 2.60 t/ha. The average effect of irrigation was 2.2 t/ha or 113%. In 1990 the irrigated soybean yielded 4.20 t/ha, the non-irrigated one 0.95 t/ha. The irrigation effectiveness in this year was 3.3 t/ha or 366%.

Table 5. Average yields of soybean in trails with and without irrigation, on loamy chernozem soil in dry years, t/ha.

Year	Yield in irrigation	Yield without irrigation	Effect of irrigation	
			t/ha	%
1990	4.2	0.9	3.3	366
1992	4.7	2.6	2.1	84
1993	4.5	2.8	1.7	62
1994	5.3	3.2	2.1	66
2000	5.1	2.8	2.3	82
2002	5.0	2.8	2.2	78
2003	4.8	3.1	1.7	55
Average	4.8	2.6	2.2	113

Effect of irrigation of sunflower

Serbia has a significant sunflower acreage, about 180-200 000 ha. A large part of this acreage is cantered in the Vojvodina province. In climatically normal years, high yields are obtained even without irrigation. This is why only a limited acreage is irrigated. In rainy and cool years, fungal pathogens reduce sunflower yield, but in very dry years, drought takes its toll, (Dragović et al., 2005).

The sunflower hybrids have a well-developed root system which is capable of taking up soil water from the depth of 2 m. Due to this characteristics, they are more drought tolerant than other field and vegetable crops and they achieve high yields in dry years. Still, in years with insufficient or unfavourable distributed rainfall, sunflower yields may be significantly reduced because sunflower plants need large amounts of water on the development of large green bulk. Natural rainfall is frequently insufficient to secure high and stable yields of sunflower and irrigation is applied to remedy the situation.

The sunflower efficiently uses winter reserve water in the soil layer 0-200 cm. Depending on the amount and distribution of rainfall during growing season, the sunflower without irrigation uses winter reserve water from 23 mm in humid years to 254 mm in dry years. These figures make 40 to 50% of the total requirement of water (Dragović et al., 2001) (see Table 6).

In dray years under the local conditions, sunflower provides 35% of their total requirement from soil reserve and 65% from rainfall and irrigation.

Sunflower requirement for water varies in dependence of weather conditions between 440 and 500 mm, in average value of 457 mm, (Maksimović and Dragović, 2003).

Table 6. Sunflower utilization of water (mm) from winter reserve across the soil profile

Year	Irrigation	Soil layer, cm				Total
		0 – 60	60-100	100-150	150-200	
1998	Irrigated	8	2	28	40	78
	Non- irrigated	10	0	9	4	23
2000	Irrigated	73	41	57	73	244
	Non-irrigated	94	58	37	65	254

Yield performance of the sunflower was found to depend on weather condition, especially in the phases of seed filling and maturation. Positive effects of irrigation were exhibited in the extremely dry year like 1990, 1993, 1994, and 2000, (Table 7). In the seven drought years the average yield in irrigation was 4.3 t/ha (from 3.4 to 5.2), and 3.1 t/ha without irrigation. The effect of irrigation was 40%.

Table 7. Average yields of sunflower in trails with and without irrigation, on loamy chernozem soil in dry years, t/ha, (Dragović et al., 2004).

Year	Yield in irrigation	Yield without irrigation	Effect of irrigation	
			t/ha	%
1990	3.4	2.4	1.0	42
1992	4.6	2.9	1.7	58
1993	5.2	2.5	2.7	108
1994	3.9	3.2	0,7	22
2000	5.0	3.9	1.1	28
2002	4.2	4.2	0,0	0.0
2003	3.5	2.8	0.6	21
Average	4.3	3.1	2.2	40

In the trails the irrigation increased the yield of sunflower seed by 30% on average, but in dry year by 44%.

Effect of irrigation of alfalfa

The alfalfa is grown in Serbia at about 200,000 ha. This acreage decreases gradually, first because of stagnant cattle production and second because of a steady increase of the acreage under annual legumes, field pea, sorghum, Sudan grass, etc. Yields of non-irrigated alfalfa in farming are fairly low, about 8 to 10 t/ha of hay.

Primary soil cultivation and seedbed preparation are important in alfalfa production because the length of exploitation period depends on the quality of establishment of alfalfa field. Primary tillage is performed in the fall; at the depth of 30 to 35 cm. planting is performed in the second half of March, if weather conditions are favourable. Alfalfa can also be planted in the second half of August and the first half of September if is it possible irrigated

The row-to-row distance is typically 12.5 cm, although the distances of 25 cm are also used. Favourable soil moisture and adequate protection against weeds, diseases and insects are important for timely emergence and good rooting. As irrigation practice encourages weed development, correct choice of herbicides is essential for successful alfalfa production.

The alfalfa has high water requirements because of the large bulk of organic matter it produces and because of long growing season. The average annual water requirement of alfalfa grown under the agro-climatic conditions of the Vojvodina Province is 655 mm, with annual variations from 545 to 729 mm (Table 8), (Bošnjak, 1993). That the daily water requirement of alfalfa varies between 5 and 11 mm, (Bošnjak, 1993).

Table 8. Evapotranspiration of alfalfa growing with and without irrigation on a chernozem soil in the Vojvodina Province

Year	Number of swath	Evapotranspiration (mm)		
		75-80% FWC	60-65% FWC	Control
1986	3	584.7	545.0	474.0
1987	5	728.6	695.7	617.1
1988	5	673.1	669.9	546.2
1889	5	712.2	678.9	354.9
Average		654.6	647.4	498.1

Alfalfa is irrigated when the pre-irrigation soil moisture in the soil layer 0-60 cm drops to 60 to 65% of field water capacity. The irrigation rate needed to wet this soil layer is 60 to 80 mm. The common practice in Serbia, if the rainfall is short, is to irrigate alfalfa fields 8 to 10 days after each cutting. In dry periods of the year, two irrigations are performed between cuttings.

Alfalfa yield performance depends mainly on water provision during growing season. Because of the unstable precipitation pattern in Serbia, the rainfall may be insufficient at any time during the growing season and this makes the availability of irrigation facilities exceedingly important. In addition, the centre pivot and linear machines in irrigation systems are fully mechanized and automated, so that the irrigation effects are correspondingly high.

In spite of the irrigation practice, the yields of hay in Serbia in production are frequently low, from 8 to 10 t/ha, which is much below the genetic yield potentials of the alfalfa cultivars. Following yields of hay were obtained in irrigation trials established on the chernozem soil (Dragović et al., 2001), see Table 9.

Table 9. Yield of dry matter (hay) of alfalfa (t/ha) in trail on the chernozem soil

Year	Yield of dry matter (hay) t/ha		Irrigation effect	
	Irrigation	Non irrigation	T/ha	%
1991	13.59	11.95	1.64	13.7
1992	20.03	18.09	1.94	10.7
1993	20.45	16.69	3.76	22.5
1994	16.48	14.80	1.68	11.3
1995	15.10	11.11	3.99	35.9
Average	17.13	14.52	2.61	22.1

CONCLUSION

On the basis of the results obtained in the field trial on the effect of irrigation on yields and on the water requirements of field crops grown under different climatic conditions of the year under the agro-climatic conditions of Serbia, it was possible to draw the following general conclusions. Field crop production under natural conditions in Serbia was found to be risky because it depended on weather conditions, especially the amounts and the distribution of rainfall.

The average water requirement of winter wheat was 300 mm. One or two irrigations were necessary in the spring, with a total of 50 to 100 mm of water needed. Yields of irrigated winter wheat ranged between 6 and 8 t/ha, with irrigation increasing yields by around 20%.

The average water requirement of corn was around 500 mm (450–550 mm). The number of irrigations varied from two to four, and the irrigation rate varied from 40 to 60 mm. The irrigated corn produced highly significant yields in relation to the dry farmed corn. The average yields of the irrigated corn ranged between 10 and 12 t/ha, whereas yields of late hybrids exceeded 15 t/ha. The effect of irrigation was 40% on average over the long term, and it may reach 100% in individual years.

The average water requirement of sugar beet was 540 mm (500–600 mm). The yields of irrigated sugarbeet ranged between 60 and 80 t/ha. The effect of irrigation in dry years varied from 45 to 131%.

The average water requirement of soybean was 450 mm. In dry years, the yields of irrigated soybean varied between 4 and 5 t/ha, and the effect of irrigation was about 70%. In extremely dry years, the effect of irrigation was 300 to 400%.

The effect of irrigation on sunflower depended on weather conditions at the stages of grain filling and maturation. Irrigation practices may even have a negative effect on the performance of the sunflower in terms of yields. Otherwise, in dry years, the effect of irrigation was around 40%.

Technology of production resulted in significant yield increases in irrigated alfalfa. The effect of irrigation was around 20% in moderately humid to moderately dry years, but it exceeded 100% in dry years.

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UTICAJ NAVODNJAVANJA NA PRINOS RATARSKIH KULTURA POD PROMENLJIVIM AGRO-KLIMATSKIM USLOVIMA SRBIJE

SAŽETAK

U glavnim poljoprivrednim područjima u Srbiji postoje povoljni klimatski i zemljišni uslovi za uspešnu biljnu proizvodnbju. Međutim, količina padavina, kao i njihov raspored u periodu vegetacije često je ograničavajući faktor visokih prinosa. Padavine variraju iz godine u godinu, tako da je suša prisutna skoro svake godine sa manjim ili jačim intenzitetom što značajno smanjuje prinose i prouzrokuje velike štete u boljnoj proizvodnji, a time i poljoprivredi u celini. U ovakvim uslovima primena navodnjavanja je potrebna skoro svake godine manjim ili većim intenzitetom.

Proizvodnja ratarskih biljaka u navodnjavanju se razlikuje u odnosu na proizvodnju bez navodnjavanja. Iz tog razloga, izloženi su rezultati mnogobrojnih istraživanja potreba za vodom i efekti navodnjavanja u gajenju ratarskih biljaka, koje su najviše zastupljene u proizvodnji u Srbiji i to ozime pšenice, kukuruza, šećerne repe, soje, suncokreta i lucerke.

Ključne riječi: navodnjavanje, ratarske kulture, klimatski uslovi, padavine, prinosi.