Effect of Irrigation Plan on Wheat Performance and Water Use Efficiency in Esfahan Province, Iran

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Abstract

We studied the effect of four irrigation regime on Mahdavi wheat performance and water use efficiency, straw, weight of 1000 grains, protein percentage in Esfahan province, Iran according to randomized complete blocks design. Irrigation treatments included four irrigation interval after T1=50, T2=75, T3=100, and T4=125 mm evaporation from a Class A pan in four replications. Fertilizers were consumed according to the soil test, soil productivity, and plant nutrition as 350 kg/yr at the first year and 250 kg/yr at the second year and triple super- phosphate and potassium sulfate fertilizers, each 100 kg/ha in year. The results showed that the effect of year on grain weight, straw, water use efficiency, and protein percentage was significant in 1% level. Grain protein of the second year was more than that in the first year significantly. The effects of irrigation treatments on Grain yield, Grain protein percentage and water use efficiency by Grain production were significant in 5% for Grain and in 1% for straw. Grain and straw yield were decreased by changing irrigation interval in T1, T3, and T4 periods, which were significant in T3 and T4. Grain protein percentage in treatment T1 was most and its diference with T3 was significant. Water use efficiency significantly increased by elongation of irrigation interval. Least water use efficiency was for T1 with 0.99 and most water use efficiency was for T4 with 1.24 kggrain per m3.

Keywords: Irrigation plan; Protein; Evaporation pan; Water use efficiency (WUE)

I. Introduction

Arid and semi-arid climate and limited water resources are the most obstacles for stable agricultural development in Iran. Therefore, increment of Water Use Efficiency (WUE), especially in agricultural sector (as the most water consumer) in economic, social, and cultural development plans must be considered. WUE improvement in this sector includes various infrastructure, technical, and managerial strategies including irrigation monitoring, increment of water transfer efficiency, decrement of water loss, earth leveling, using rain and drop irrigation systems, volume delivery, suitable water tariffs, and suitable cultivation patterns.

Although water is an effective factor for product performance, WUE has not a direct and linear relation with irrigation, and maximum performance is not always the economic one. Irrigation management, among the other environmental, botanic and managerial factors affecting WUE is the most important effective factor on the other entities (Sadeghzadeh and Keshavarz, 2000). Notice to irrigation management is from the important strategies in optimal use of water and soil resources, environment protection, production with acceptable qualitative and quantitative standards, and decreased production costs. Irrigation management includes irrigation periods and depth. Up to now, there have been numerous studies for suitable irrigation management, which their results emphasize the importance of irrigation program and WUE.

There are different methods for determination of two irrigation time and volume, including Total Available Water (TAW), growth stages, aggregated evaporation factor from Class A pan, canopy and air temperature difference, and water potential in earth and plant. Zhang and Oweis (1999) had studied wheat irrigation plans by supplying 20, 40, 60, and 80% water in different climate conditions during 1985-96. The results showed that product performance falls by decrement of more than 55% required soil humidity. grain increases by increased water (irrigation and raining) up to 450 mm linearly, and its slope is lower after that up to 600 mm. Water use efficiency is used in arid regions to evaluate produced crops for used water rate and is obtained through marketable yield or biomass over plant evapotranspiration (Allison and Jones, 2005).

By studying the effects of complete and complementary irrigation plans on wheat WUE, Oweis et al. (2000) concluded that complementary irrigation had more WUE than complete irrigation. Li Feng et al. (2001) compared the effects of three irrigation regimes by different humidity fractions in lower and higher soil layers of wheat development area and three spring wheat genotypes and concluded that maximum WUE obtained by irrigation when 50-60% of TAW of lower layer is consumed. Deming et al. (1999) about irrigation optimization and WUE emphasized on irrigation management importance in optimal water usage in NW of China. Carefoot and Major (1994) studied the effects of irrigation period and depth in three complete, low, and combined irrigation regimes during growth and genesis steps on wheat and barley performance and WUE. The results showed that short irrigation periods had not a significant effect on seed performance and WUE, but increases straw. In addition, short irrigation period decreases barley WUE significantly. Adcocke and McNeil (2003) studied wheat performance and WUE in cultivation of rape, tare, lawn, barley and wheat in a lime earth in arid climate. The results showed that maximum wheat WUE was 8 kg/ha/mm after cultivation of rape, and its minimum was 6.8 kg/ha/mm after cultivation of tare. Hill and Allen (1996) studied the effect of irrigation plan on wheat WUE and concluded that fixed irrigation periods and depths improves WUE and production. Wang et al. (2001) studied the relation between irrigation, evaporation, plant growth and WUE for wheat-corn. The results showed that WUE increased by decreased evaporation by irrigation mulch for 800 m^3.

The results of Farshi and Ghaemi (1996) for wheat WUE showed that maximum efficiency obtained by 95% decrement of soil humidity at root development area. But economic performance was obtained by 65% decrement of soil humidity. Vaziri (1999) studied five irrigation plans by 20, 40, 60, 80, and 100% soil humidity fractions on wheat grain performance and WUE and concluded that decrement of irrigation period decreased seed performance and WUE significantly. Most product was obtained after 60% decrement of soil humidity. Galavi and Akbari Moghaddam (2012) showed that yield, harvest index, water use efficiency and evaportrans piration efficiency were affected by deficit irrigation.

In Golpayegan, wheat is one of the most water products. Since water is one of the limitations due to special climate of the region, WUE is the goals of farmers. The present research studies irrigation plan effect on wheat WUE in Golpayegan, Iran.

II. Materials and Methods

2.1 Project Area Specifications

Golpayegan Station is located in 185 km NW from Isfahan, which has a cold step climate by Gaussian allotment and semi-arid and cold climate by Amberjeh Method. The height of this region is 1800 m above the sea level and its maximum temperature is 34°C and its minimum temperature is -8°C. Its raining level is about 265 mm/yr. According to pedological studies and terrestrial classification by Mohammadi and Ghazi Zahedi (1986), the regional soil is deep and its surface layer is brown to light brown with silty clay texture and compressed structure. The 25-50 cm layer has a weak cubical structure. There are many lime spots and hard grains with partial motling in its profile. According to Soil Taxonomy (Soil Survey Staff, 1999), this soil is among Typic, Mesic, mexed, fine Haplocalcids. Some studies (Li et al., 2001 and Shamsi et al., 2010) suggest that limited supplemental irrigation and fertilization during the growth season can significantly increase WUE and wheat yield.

The ground water was deeper than 5 m during test period. Fig. 1 shows raining during test period and its average for 11 years. Total raining at first and second year was 277.6 and 238.5 mm respectively, which were more than the average value of 243 mm. Total spring raining at the first and second year was 86.5 and 77.5 mm respectively, which most variance was in April. Total monthly evaporations during April to July (irrigation season) were 163, 272, 376, and 432 mm for the first year, and were 170, 314, 415, and 446 mm for the second year, respectively. Most monthly evaporation variance was in July.

In the adjacent areas of Golpayegan Station, regarding to the heavy earth texture, the average irrigation period was in May and June for 12 days. After cultivation in autumn, two irrigation turns are done in April.

2.2 Soil and Water Decomposition Results

Tables 1 and 2 show some of chemical and physical specifications of test station. This soil is not salty and alkali with low organic carbon, phosphor, and potassium. The surface texture is clay loam and its profile humidity up to 60 cm in farming capacity (FC) and Permanent Wilt Point (PWP) were 25 and 12 weighting percentage, respectively, and its apparent density (BD) was 1.5 g/cm^3. Utilizable water in each layer (W) is obtained from eq.

$$W = \frac{(FC - PWP)}{100} \times D \times BD$$

in which, D is layer depth. Utilizable water in 60 cm layer is 88 mm.

The results of chemical decomposition of irrigation water (Table 3) show that this water has no pH and Sodium Attraction Ratio (SAR) limitations. It has much chlorine and limited bicarbonate (Ayers and Westcot, 1985).

III. Methodology

During two cultivation years (2012-2014), the effects of four irrigation plans on wheat performance and WUE were studied. This project was executed in the framework of Full Random Blocks (FRB) statistical plan with four irritation repetitions and four treatment after T1=50, T2=75, T3=100, and T4=125 mm aggregated evaporation from a Class A pan. Irrigation depth was calculated by earth humidity weight percentage by root depth (max. up to 60 cm) by eq. (2). Earth humidity before each irrigation period was determined by weighted method for three layer of 0-15, 15-30, and 30-60 cm.

$$I = \frac{(FC - \theta)}{100} \times D \times BD$$

In which,

I: Irrigation depth (cm)

FC: Humidity weight of root depth earth by farm capacity (%)

θ: Humidity weight of root depth earth during irrigation (%)

D: Root depth (cm)

BD: Apparent earth density by root depth (g/cm^3)

Fertilizer volume was determined by earth decomposition results (Table 1) and recommendations of Chemical Research Center for first and second years equal to 350 and 250 kg/ha for urea, respectively. In addition, 100 kg/ha superphosphate triple and 100 kg/ha potassium sulfate were used for each year. All phosphorous and potassium fertilizer and one-third of nitrogen fertilizer were used during cultivation and the rest were used in spring. Consumed seed was 180 kg/ha from Mahdavi wheat. Irrigation was done by terracing method and water was measure by ParshalFlom. Terrace area was 60 m^2 (5×12 m) and terrace gap was 1.6 m and repetition gap was 2 m.

Wheat grain was harvested from a certain area (5 m^2) and seed and straw performance, weight, and protein were measured. WUE was calculated by produced seed volume and straw by ratio of grain performance to irrigation. The results was analyzed by MSTATC software and the averages were compared by Danken multi-area test.

Figure 1: Raining level in test station

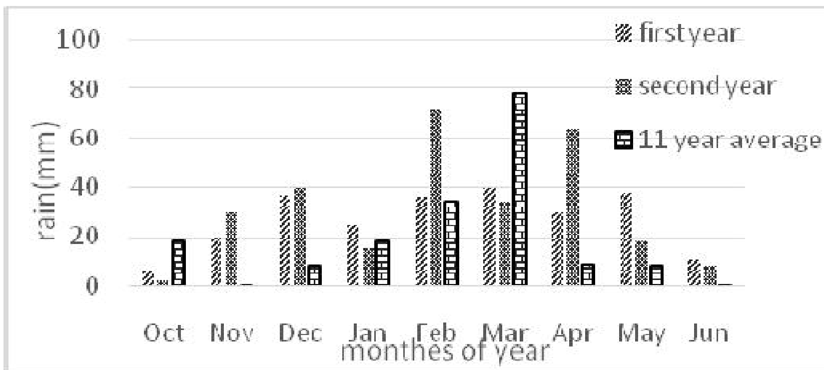


Table 1: Earth chemical and texture characteristics in test station (0-30 m depth)

Depth (cm)	Density (gr/cm^3)	FC (w%)	PWP (w%)	Humidity (mm)
0-15	1.44	23	12	24
15-30	1.55	26	13	30
30-60	1.52	27	12	34
Average or total	1.50	25	12	88

Table 2: Physical soil characteristics in test station

Year	pH	ECe (dS/m)	Neutralized material	Organic carbon	Azote	Phosphor	Potassium	Sand	Clay	Silit	Texture
			(%)			(mg/kg)		(%)			
1	7.7	2.6	24.5	0.92	0.09	7.9	190	22	34	44	Clay Loam
2	7.6	3.5	24.5	1.1	0.10	11.6	216	-	-	-	

Table 3: Results of chemical decomposition of irrigation water

pH	EC (dS/m)	mEquivalent/lit							SAR
		HCO^{3-}	Cl	SO_4^{2-}	Total anions	$Ca^{2+}+Mg^{2+}$	Na^+	Total cations	
7.0	1.4	2.8	12	0.8	15.6	9.8	5.5	15.3	2.48

IV. Results and Discussion

According to variance analysis, irrigation effects on grain volume for the first and second year were not significant, but seed performances for T1 were 8425 and 7225 kg/ha and for T4 were 7000 and 6000 kg/ha for both years, respectively. The effects of irrigation treatments for the first year on straw were significant, and its maximum value was for T1 for group 1 and 3 treatments for group 2. For the second year, the effects of irrigation treatments on straw performance were not significant. The effects of irrigation treatments on seed protein and weight of 100 grains were not significant for both years.

The variance analysis for treatments for average qualitative and quantitative performance and WUE shows that the effect of year on grain and straw performance, protein, and WUE was significant by 1% and was not significant on weigh to 100 grains and WUE (Table 4). Most grain, straw, and WUE for the first year were 7525, 13980, and 2.18 kg/ha/m^3, respectively. grain protein for the second year was more than that in the first year and was equal to 13.52% (Table 5).

The variance analysis for average of both years (Table 4), irrigation effect on grain and straw performance, protein, and WUE in 5% level, and WUE and straw in 1% level was significant. Most grain performance for T2 was 7825 kg/ha and most straw performance for T2 was 13625 kg/ha, which their differences with T3 and T4 were significant. Seed performance for T1 had decrease than T2 significantly (Table 6). Comparison of grain protein and 1000 grains weight in different irrigation treatments (Table 7) shows that maximum grain protein for T1 is 12.79% and its difference with T3 is significant. Maximum 1000 grains weight for T3 is 53.06%, which was not significantly different with the other treatments. Maximum WUE for production of grain and straw for T4 were 1.24 and 2.22 kg/m^3, respectively (Table 8). The mutual effect of year and irrigation of qualitative and quantitative performance was not significant. Frequency of irrigation was 6-14 turns and irrigation volume was 5224-7345 m^3/ha (Table 9).

Changes of grain and straw performance against irrigation water increment is shown in Fig.2. grain performance is 13 and 20% by increments of irrigation water of 40 and 23% for T1 and T2 than T4, respectively. grain and straw volume was non-significantly decreased by increment of 15% of irrigation water for T1 than T2. Also, straw volume was increased for T1, T2, and T3 than T4 equal to 8, 17, and 2%, respectively.

Table 4: Variance analysis for irrigation treatments on wheat performance (1997-99)

Source	F					
	grain (1)	**Straw (2)**	**Protein (%) (3)**	**1000 grains weight (4)**	**grain WUE (5)**	**Straw WUE (6)**
Year	7.95**	36.41**	166.43**	1.61 ^{ns}	1.93 ^{ns}	15.31**
Irrigation	3.47*	3.96*	4.24*	0.91 ^{ns}	3.09*	7.41**
Irr. × year	0.11 ^{ns}	0.22 ^{ns}	2.36 ^{ns}	0.60 ^{ns}	0.32 ^{ns}	0.67^{ns}

* Significant difference in 5% level

** Significant difference in 1% level

ns: no significant difference

(1) CV=14.56% (2) CV=10.32% (3) CV=3.86% (4) CV=6.71% (5) CV=15.64% (6)

CV=11.33

Table 5: Wheat performance and WUE during two years of test period

Year	grain (kg/ha)	Straw (kg/ha)	Protein (%)	1000 grains weight (gr)	grain WUE* (kg/m^3)	Straw WUE* (kg/m^3)	Spring raining (mm)
1	7525 A	13800 A	11.33 b	52.48 a	1.19 a	2.17 a	86.5
2	6506 B	11062 B	13.52 a	51.46 a	1.11 a	1.86 b	77.5
Average	7015	12431	12.42	51.82	1.15	2.02	82.0

* Excluding raining

Table 6: Grain and straw performance for different treatments (1997-99)

Treatment	grain performance (kg/ha) (1)			Straw performance (kg/ha) (2)		
	Year 1	Year 2	Average	Year 1	Year 2	Average
T1	7900	6725	7313 A	13700	11550	12625 A
T2	8425	7225	7825 A	15200	12050	13625 A
T3	6775	6075	6425 B	13300	10375	11837 B
T4	7000	6000	6500 B	13000	10275	11637 B

(1) LSD (5%) = 1025 kg/ha (2) LSD (5%) = 1682 kg/ha

Table 7: Protein and 1000 seeds weight for different treatments (1997-99)

Treatment	Protein (%)			1000 grains weight (gr)		
	Year 1	Year 2	Average (1)	Year 1	Year 2	Average (2)
T1	11.92	13.66	12.79 a	52.27	51.00	51.64
T2	11.03	13.51	12.37 a	51.87	52.62	52.25
T3	10.77	13.41	11.97 b	53.55	52.62	53.09
T4	11.65	13.48	12.56 a	52.22	48.37	50.30

(1) CV=3.86% LSD (5%) = 0.67 (2) CV=6.72%

Table 8: Grain and straw WUE for different treatments (1997-99)

Treatment	grain WUE (kg/m^3)			Straw WUE (kg/m^3)		
	Year 1	Year 2	Average (1)	Year 1	Year 2	Average (2)
T1	1.05	0.94	0.99 B	1.82	1.61	1.72 B
T2	1.23	1.20	1.22 A	2.23	2.00	2.11 A
T3	1.16	1.13	1.14 A	2.27	1.93	2.10 A
T4	1.33	1.15	1.24 A	2.47	1.98	2.22 A

(1) LSD (5%) = 0.2472 kg/ha (2) LSD (5%) = 0.3385 kg/ha

Table 9: Irrigation volume and frequency for different treatments (1997-99)

Treatment	Irrigation volume (m^3/ha)			Irrigation frequency		
	Year 1	Year 2	Average	Year 1	Year 2	Average
T1	7520	7171	7345	15	13	14
T2	6827	6018	6422	10	9	9
T3	5854	5381	5617	8	7	7
T4	5254	5201	5227	6	6	6

Comparison of grain and straw WUE for different treatments show that grain and straw performance increases by increment of irrigation frequency, but WUE is different by seed and straw (Fig.3). The results of other studies for relation of water and wheat product show that increment of irrigation frequency increases grain significantly, but WUE is more in low water volumes, and it has a slow or negative slope by water increment, which may be due to bad water consumption and providing unsuitable conditions for wheat roots.

AnabiMilani (2003) studied different wheat irrigation plans in East Azerbaijan and concluded that increment of irrigation depth from 80 to 100 would increase aggregated evaporation percentage from Class A pan, but would not increase product significantly. In other words, WUE would decrease by grain production.

Mostafavi (1998) studied the effects of different irrigation volumes by 50, 70, and 90% evaporation from Class A pan in different irrigation periods on wheat in Yazd and concluded that wheat product of Roshan and Qods types would be 3150 and 4040 kg/ha, respectively, for irrigation in a depth of 70% aggregated evaporation and a period of 12 days (7480 m^3/ha of water consumption). Yazdani (1992) studied the effects of irrigation volumes by 60, 80, and 100% evaporation from Class A pan on wheat in Isfahan, and the most wheat performance was for Roshan Type with 100% evaporation; however, water performance decreased by increment of irrigation depth. Raeissi (1992) studied the effects of irrigation volumes by 15, 30, 45, 60, and 75% evaporation from Class A pan and concluded that irrigation plan by 60% evaporation would increase water WUE.

QajarSepanlou et al. (2000) studied the effect of irrigation on grain performance and WUE for four wheat types and concluded that seed WUE would increase by decrement of irrigation volume significantly. Vaziri (2000) studied arid strength of wheat by WUE in a cold region of Kermanshah, and reported that maximum grain WUE was for 3750 m^3/ha of water in 5 irrigation turns. Vaziri (1999) studied the effects of five irrigation plans in Mahidasht, Kermanshah, by 20, 40, 60, 80, and 100% of soil humidity in root development area on seed WUE. The results showed that grain WUE decreased by decrement of irrigation period and increment of water volume in 20 and 40%. Asadi et al. (2000) studied the effect of arid stress on water-performance relation and concluded that if irrigation was accompanied with sensitive steps of wheat growth, grain WUE increased.

The results of studies on wheat irrigation plans by North (2001) showed that if Class A pan factor (Kp) is equal to 0.8 in equation $ET_{crop}=E_{pan} \times K_p \times K_c$ (in which, ET_{crop} is wheat water need, E_{pan} is pan evaporation, and K_c is herbal factor) and inclusion of raining, WUE for production of 5 ton of wheat was 2 kg/ha. The results of different irrigation plans by humidity changes of different earth layers in wheat root development area by Oweis et al. (2000) showed that most WUE was for an irrigation plan with higher period by 50-60% of humidity in lower earth layers. The results of studies of Zhang et al. (1999) for wheat irrigation showed that WUE slope decreases by increment of water consumption from 450 to 600 mm. Carefoot and Major (1994) reported that wheat grain performance and WUE would not significantly decrease by irrigation during the end stages of growth.

Study of relation between wheat grain protein percentage and irrigation in different treatments showed that seed protein percentage would decreased by increment of irrigation period and water volume from T1 to T3, and would increase after that. Bauder (2003) concluded that wheat grain protein would decrease in high performance levels. The results of studies of Sayre et al. (2000) showed that nitrogen consumption management and wheat variety affected wheat grain protein. McGinley (2002) concluded that irrigation with short frequency, especially in the end stages of growth, decreased wheat seed protein.

The results of this test indicates a non-significant decrement of 1000 grains weight against long irrigation and low water volume. Although different studies emphasize on decrement of 1000 grains weight in arid stress conditions, arid stress range in this test did not affect 1000 seed weight. Asadi et al. (2000) reported that 1000 grains weight would not decrease by stoppage of irrigation till growth of stem and then continuation of irrigation up to the end.

Figure 2: Grain and straw performance increment in irrigation treatment than T4

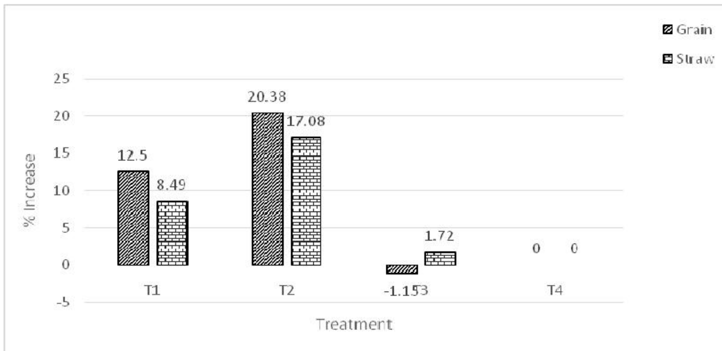
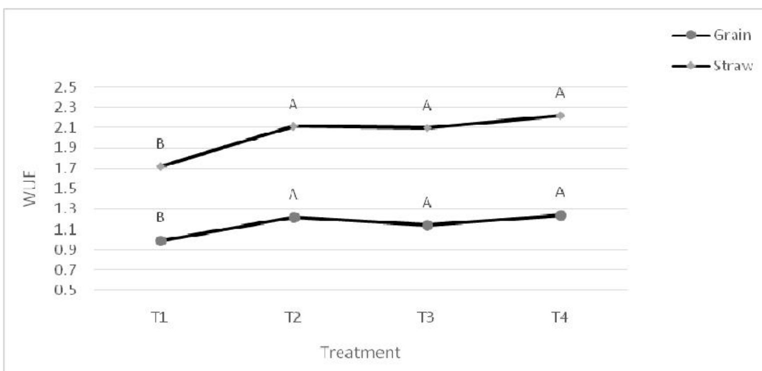


Figure 3: Changes of WUE in different treatments



V. Conclusion and Proposals

The results show that irrigation plan is one of the most important tools for water consumption optimization. In test conditions, irrigation after 75 mm of aggregated evaporation from Class A pan with grain and straw performance of 7825 and 13625 kg/ha, respectively, and grain and straw WUE of 1.22 and 2.11 kg, respectively, was the best treatment. Irrigation frequency was 9 turns from cultivation to harvest in this treatment, and water volume was about 6420 m^3/ha. Thus, it is recommended that in similar conditions, if there is no limitation for water resources, irrigation frequency will be set by 75 mm of aggregated evaporation from Class A pan, with 75 mm for each irrigation turn (excluding irrigation efficiency).

The results show that irrigation plan is one of the most important tools for water consumption optimization. In first year, grain and straw yield was more than second year.Average grain yield in first year was 7525kg/ha and in second year was 6506 kg/ha. In first year, grain and straw water use efficiency were 1.19 and 2.17 kg/m3 respectively. In two years, grain and straw yield of irrigation interval after 75 mm of aggregated evaporation from Class A pan was more than other treatments but this treatment had not different significant toward irrigation interval after 50 mm of aggregated evaporation.

Amount grain protein of irrigation interval after 100 mm of aggregated evaporation from Class A pan was less than other treatments but other 3 treatments had not significant different with each other.

Consumption water of irrigation after 50 mm of aggregated evaporation from Class A pan was the most and for irrigation after 125 mm of aggregated evaporation was the least.

In test conditions, irrigation after 75 mm of aggregated evaporation from Class A pan with grain and straw performance of 7825 and 13625 kg/ha, respectively, and grain and straw WUE of 1.22 and 2.11 kg/m3, respectively, was the best treatment. Irrigation frequency was 9 turns from cultivation to harvest in this treatment, and consumption water volume was about 6420 m3/ha. Thus, it is recommended that in similar conditions, if there is no limitation for water resources, irrigation frequency will be set by 75 mm of aggregated evaporation from Class A pan, with 75 mm for each irrigation turn (excluding irrigation efficiency).

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