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EFFECT OF APPLYING TWO AUXILIARY IRRIGATIONS AT DIFFERENT PHENOLOGICAL STAGES IN HISTORICAL WHEAT VARIETIES

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Abstract: Water availability is a recurring factor in agriculture, therefore, ways to optimize it are sought and in the case of wheat crops, to lower the irrigation depth. That is why, in early sowing dates, the best option is to carry out the first irrigation at the beginning of heading and the second at the formation of watery grain, with this we would be obtaining an increase of more than 10% in yield, than if we apply the first irrigation at the beginning of heading. Losses in production may also occur at the beginning of milky grain formation. In late sowing dates, the highest yield is obtained at the beginning of heading and the beginning of milky grain formation, with the first and second irrigation respectively.

INTRODUCTION

Reducing water use in wheat cultivation in Mexico's arid zones is of crucial importance due to the effects of climate change and the increasing scarcity of water resources in these regions. States such as Sonora and Baja California, which are important wheat producers, face significant challenges due to limited water availability and extreme weather conditions that are worsening over time. The National Water Commission (CONAGUA) has noted that overexploitation of aquifers and climate variability are reducing water availability in these areas (CONAGUA, 2023).

The climate change is exacerbating these problems with longer droughts and higher temperatures negatively affecting agricultural production (National Institute of Ecology and Climate Change [INECC], 2022). The implementation of efficient irrigation techniques and the adoption of drought-tolerant wheat varieties are crucial strategies to meet these challenges.

Furthermore, the development and adoption of wheat varieties genetically improved to withstand low water availability conditions are showing promising results (Mir et al., 2021; Hernández et al., 2024).

Water use efficiency is not only essential for the sustainability of water resources, but also for the economic viability of farmers and the country's food security. Studies have shown that controlled deficit irrigation can be an effective technique to reduce water use in wheat cultivation without significantly decreasing yield (Buenrostro et al., 2023).

Water stress (irrigation restriction) is one of the environmental factors that most limits growth, that is, plant development, as well as yield (Ali et al., 2018) and the quality of all crops (Prasad et al., 2008). This is considered the stress that has the greatest impact on plant growth and development (Gao et al., 2007).

MATERIALS AND METHODS

This experiment was developed in block 910 of the Norman E. Boralug Experimental Field in the Yaqui Valley, on soils with 55% clay, apparent density of 1.3 gr/cm3, low infiltration and low organic matter (0.9%), in the region they are known as compacted mud soils. Three irrigation treatments were tested, which consisted of applying two auxiliary irrigations at different phenological stages: a) Apply the first auxiliary irrigation at the beginning of heading stage (IE) and the second irrigation at the beginning of watery grain formation stage (IFGA), b) Apply the first auxiliary irrigation at the beginning of embuche stage (IEM) and the second irrigation at the beginning of watery grain formation (IFGA) and c) Apply the first auxiliary irrigation at the beginning of heading (IES) and the second auxiliary irrigation at the beginning of the milky grain stage (IFGL). These treatments were tested with three varieties: Rayón F89 (bread wheat), Altar C84 and Rafi C97 (durum wheat). They were studied on two sowing dates: the first on December 13 and the second on the 29th of the same month.

The experimental design was hierarchical with two factors and three repetitions taken throughout the treatment. The useful plot was 2 furrows by 8 meters long. The length of the furrows was 90 m and 0.80 m apart and with 8 furrows per treatment.

Irrigation Management: Irrigation siphons with a diameter of 1.5 inches were used to apply irrigation, which were previously calibrated to know the flow in liters per second and the depth used in germination irrigation was measured, as well as in the two auxiliary irrigations of each treatment. Soil moisture samples were also taken before and after each of the auxiliary irrigations, in order to obtain the water consumption by the plant in each treatment and to measure at what level of humidity the plant was punished for lack of water.

Agronomic Management: The previous crop was vegetable watered with drip irrigation where the concept of ferti-irrigation was applied, the preparation of the land was fallow, a harrow pass, total fertilization before applying the irrigation of emergence with the formula of 149-52-00 of N-P-K (nitrogen, phosphorus and potassium) based on urea and phosphorus 11-52-00 (monoammonium phosphate), respectively, incorporation of the fertilizer with a harrow, then the furrows were drawn. The sowing was done dry with a precision seeder with 45 kg/ha of seed and later the irrigation of emergence or germination was applied.

The weed control was done manually and mechanical cultivation was done, there was a high incidence of aphids so it was necessary to make applications of chemical products, likewise the Roya or Chauixtle was presented only in the hard wheats, but in this case no fungicide was applied.

Variables measured. Grain yield and the amount of water applied were measured.

Statistical analysis was done using SAS 9.4 software

RESULTS AND DISCUSSIONS

Based on the results obtained in the grain yield variable for the sowing date of **December 13**, no statistical difference was detected between the irrigation treatments, nor between the varieties and only a 5% difference for the variety x irrigation interaction, the coefficient of variation was 6.5%.

The highest grain yield regardless of the variety was 8,022 kg/ha when the two auxiliary irrigations were applied at the stages of early embuchement (63 days after sowing) and at the stage of watery grain formation (33 days after the first auxiliary irrigation), for the first and second auxiliary irrigation respectively, resulting in a calendar day of 00-63-33. The amount of water applied was 5.1 thousand m3/ha (51 cm of sheet), the allocation that has been managed for the producer is 7.5 thousand and the one that was managed was 5.7 thousand, the efficiency was 710 liters to produce one kilogram of wheat and the commercial efficiency is 1350 liters. The above information coincides with Ortiz (1999) who at that time recommended applying the first auxiliary irrigation at the stage of embuche and the second auxiliary irrigation at the stage of watery grain, that is, when two auxiliary irrigations are managed under situations of water shortage in the region.

The following yield was 6,947 kg/ha when the first auxiliary irrigation was applied at the stage of beginning of heading (70 days after sowing) and the second at the beginning of milky grain formation (30 days after the first auxiliary irrigation) resulting in a calendar of days of 00-70-30, with a volume of water applied of 5.4 thousand m3/ha, the efficiency was 777 liters of water to produce one kilo of wheat. This yield of 6947 kg/ha is equivalent to a reduction of 13% compared to when irrigation is applied at the beginning of formation of watery grain.

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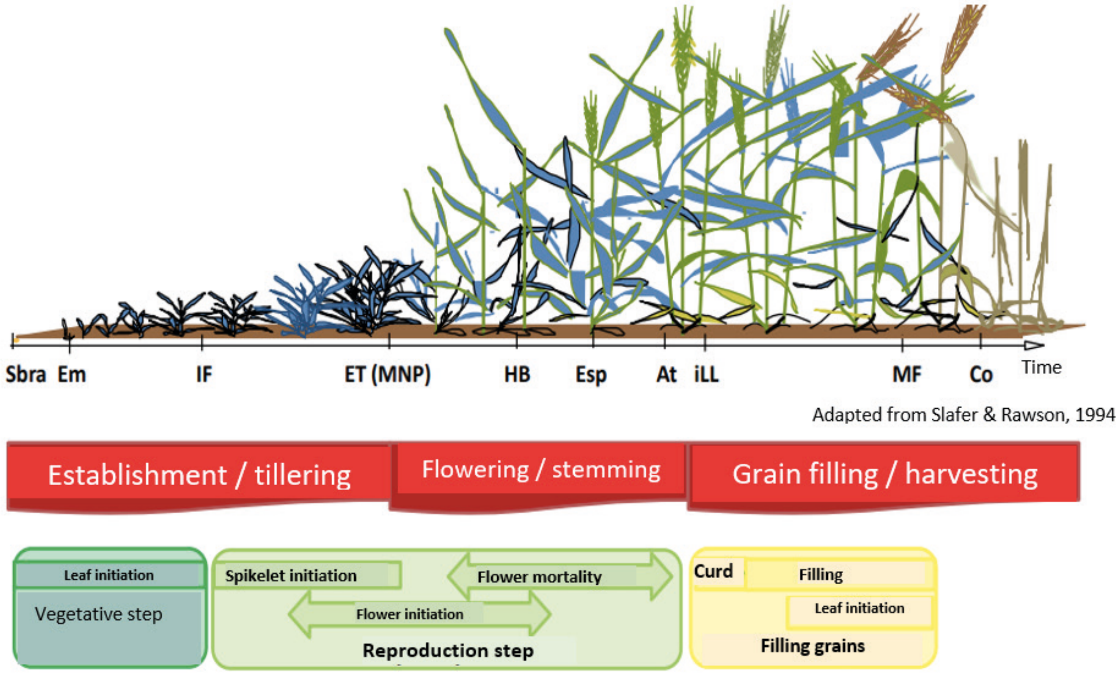

Figure 1: Phenological stages of wheat cultivation

The lowest yield was 6,848 kg/ha with the treatment where the first auxiliary irrigation was applied earlier in the stage of beginning of cane cultivation at 55 days after planting, the volume of water applied was 5.1 thousand m3/ha, the efficiency was 745 liters.

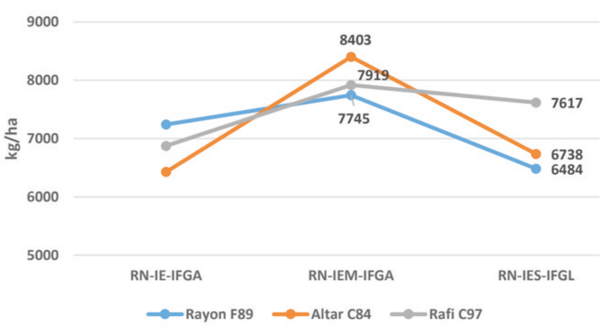

Figure 2: Wheat yield as a function of irrigation treatments and varieties. First sowing date

RN: Irrigation at birth, IE: Beginning of stem formation, IEM: Beginning of stem formation, IES: Beginning of heading, IFGA: Beginning of watery grain formation, IFGL: Beginning of milky grain formation.

During plant development, physiological processes vary at each phenological stage. For this reason, it is crucial to distinguish the different growth stages of a species, not only for scientific research, but also for the agronomic management of the crop (Celestina et al., 2023). Regarding drought, genotypes of the same species may have different water requirements, which affects their vulnerability to water stress. This vulnerability also changes depending on the phenological stage at which drought occurs (Mukherjee, et al., 2019). A common factor in the three varieties is when the second irrigation is applied at the beginning of watery grain formation.

It can be determined that the early development stages are particularly susceptible to water deficit, however, these are the stages where irrigation can be restricted in wheat, and severe yield reductions can also be caused if they occur at stages close to heading (Sarto et al., 2017).

Figure 3 shows the grain yield for the sowing date of December 29, with a statistical difference being detected for the irrigation treatments and for the varieties, but not for the interaction. The highest yield was obtained when the second irrigation was applied at the milky grain stage. The highest yielding variety for this phenological stage was Altar C84 with 8257 kg/ha, followed by the Rafi C97 variety with a reduction of 14%. If we compare it with the earlier date, we obtain a reduction in yield, therefore, the application of the second auxiliary irrigation will depend on the sowing date, since if we sow in the first half of December, it is better to apply the second irrigation at the watery grain stage. On the later sowing date, the Altar variety behaved in a more stable manner than on the first sowing date, with yields exceeding 7000 kg/ha.

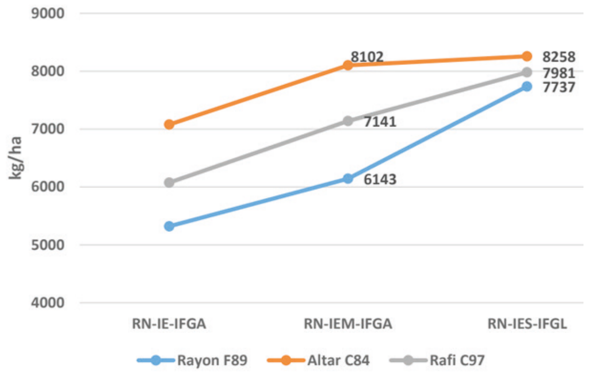

Figure 3: Wheat yield as a function of irrigation treatments and varieties; second sowing date.

RN: Nativity irrigation, IE: Beginning of stem formation, IEM: Beginning of stem formation, IES: Beginning of heading, IFGA: Beginning of watery grain formation, IFGL: Beginning of milky grain formation.

In Table 1, the soil moisture values are observed based on dry weight, where RN-IES IFGL, where the moisture through the soil profile at 00-30 and 30-60 cm before applying the first irrigation did not vary significantly, but the moisture was low close to the permanent wilting point and after applying irrigation it increased to values of 20 to 25% moisture (around 30% usable), but it varied throughout the length of the furrow being greater at the end.

Sampling depth (cm)	% humidity at 25 m	% humidity at 50 m	% humidity at 75 m
00-30*	10.1	9.0	10.3
30-60*	9.4	13.5	10.5
00-30**	22.9	23.6	54.9
30-60**	20.4	24	23.5

Table 1: Soil moisture (%) behavior, based on dry weight along the furrow before and after the first auxiliary irrigation at the beginning of heading.

* Before irrigation, ** after irrigation

The table 2 shows the humidity for RN-IE-IFGA, when the first auxiliary irrigation was applied earlier in the tilling stage and the humidity is compared with the most punished treatment, the humidity value changes slightly throughout the soil profile, that is, when the soil is under strong tension, there is a moment when as time goes by the changes in the humidity content are small, but a higher humidity content is observed in the 30-60 stratum than in the 00-30 cm. Along the furrow the humidity content presents few changes, the values after irrigation are very close to 60% of usable humidity since the sampling was carried out approximately 5 days after irrigation, the humidity conditions were better in RN-IE-IFGA than in RN-IES-IFGL

Sampling depth (cm)	% humidity at 25 m	% humidity at 50 m	% humidity at 75 m
00-30*	10.2	9.4	9.3
30-60*	17.6	15.0	16.4
00-30**	27.0	27.6	27.0
30-60**	23.1	27.5	26.3

Table 2: Soil moisture (%) behavior, based on dry weight along the furrow before and after the first auxiliary irrigation at the beginning of tillering.

* Before irrigation, ** after irrigation

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In the plant height variable Figure 4. when the sowing date is early, the greatest height is obtained when the first auxiliary irrigation is carried out at the beginning of the stem setting and the second irrigation at the formation of watery grain, a decrease of close to 2% occurs, unlike the treatment where the first irrigation is carried out at the beginning of the stem setting and the second at the formation of watery grain with a decrease of 6% in the case of the Rafi C97 variety. In figure three, at the latest sowing date but considered within the date established for southern Sonora.

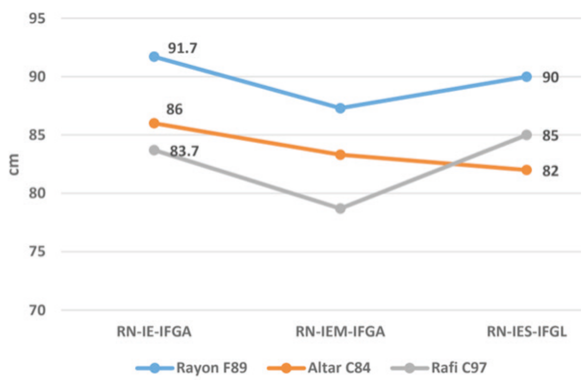

Figure 4: Plant height at first sowing date. RN: Irrigation at birth, IE: Beginning of stem formation, IEM: Beginning of stem formation, IES: Beginning of heading, IFGA: Beginning of watery grain formation, IFGL: Beginning of milky grain formation.

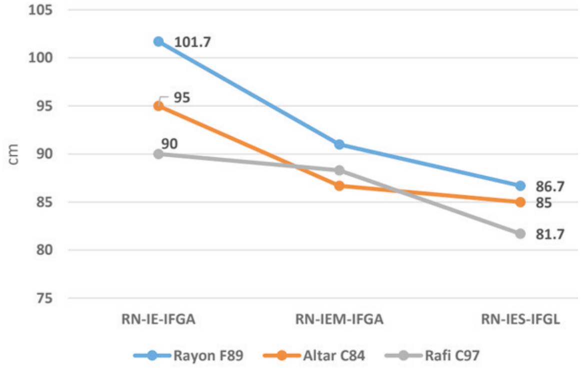

Figure 5: Plant height at the second sowing date. RN: Nativity irrigation, IE: Beginning of stem formation, IEM: Beginning of stem formation, IES: Beginning of heading, IFGA: Beginning of watery grain formation, IFGL: Beginning of milky grain formation.

The decrease in height is higher when the second irrigation is carried out at the milky grain formation stage than when it is carried out in the watery grain formation stage. In all cases, the decrease in height was between 4.5% and 15%. Therefore, it is recommended to give the first auxiliary irrigation at the beginning of the stem formation and the second one at the watery grain formation stage. Plants use strategies to resist water stress, which involves a set of responses that lead to avoiding or tolerating it, and are closely related to the genotypic characteristics of the crop in question, which may involve evasion, escape and tolerance (Moreno, 2009). Among the resistance mechanisms of plants, there are the early development of precocity, smaller size, through reducing the size of the leaf and regulating stomatal closure, efficient use of water with an improved root system and a lower loss in productivity (Semenov et al., 2009).

CONCLUSION

All varieties responded better when applying the first auxiliary irrigation at the heading stage and the second irrigation at the milky grain stage, this will generate a water saving of 1.3 thousand m3 compared to extra irrigation.

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