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Optimization of Water Consumption in a Polyethylene Greenhouse Used in Semi Arid Region

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Abstract: The use of plasticulture as means of plants protection and safeguarding of the hydrous resources in the hostile environments constitutes the hot line of our research tasks. In this context, we carried out several experiments to characterize the various physical and microclimatic parameters governing water consumption of the protected cultures. The device of Fisher s' blocks is used there for the study of two factors, namely:

- The quantity of water applied
- The opportunity of its application

Adopted methodology is based on a regular monitoring of the water needs by using a probe with neutrons and a lysimeter with pot; as well as restrictive water contributions at the stages of flowering and formation of fruits. The required principal objective is to appreciate the incidences of a hydrous constraint on the agricultural output of melon and to determine the fraction of the water needs to satisfy, likely to ensure a level of suitable production while sparing the mobilizable hydrous resources for this purpose. The preliminary results show that only the flowering phase of flowering allows a substantial saving in water (from 15% to 30% of the ETm) and a level of optimal production.

Key words: Plasticulture · Water needs · Hydrous constraint · Water saving · Arid zone

INTRODUCTION

The Mediterranean basin is characterized by a hot, dry summer, combined with low precipitation in winter. Despite the apparent uniformity of the Mediterranean climate, a detailed analysis shows very large differences between close geographical areas [1, 2].

In Algeria the drought period ranges from seven months in the north to almost 12 months in some regions of the Sahara [3], which is certainly a drawback, but has the advantages of a large brightness and high temperatures [2].

The tension on the water use by major user sectors (agriculture, industry and households) continues to increase. It is mostly aggravated by the scarcity of rainfall in recent years. Crop irrigation that consumes over 75% of available water is an important source of economy of this resource [4].

Irrigated areas with traditional techniques are dominant. They are characterized by low efficiency, compounded by poor control of applied volume.

Experiments conducted at the Hydro-meteorological Institute of Training and Research (IHFR, Oran, Algeria), are part of a research project aimed at improving the productivity of vegetable crops by optimizing water supplies [5].

This contribution concerns a test carried out on melon (Cucumis melo) grown in greenhouses. The objective is to determine the fraction of theoretical water needs to satisfy various life stages of the plant to reach adequate production levels.

The study of crop response to different doses of watering allowed us, among others to address other aspects such as relations between water the cultivated soil and microclimate of the greenhouse [5].

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MATERIALS AND METHODS

Plant Material: The used crop is the Charentais melon, variety of Cucumis melo. This cucurbit is well represented in the Algerian market gardening [6].

Fruits are relatively rounded and ribbed, embroidered with little or no bark and yellowish and the orange-colored flesh is sweet and very fragrant. However, this variety has a poor conservation.

The Soil: Deep soil (greater than one meter) has a sandy-clay texture, with a notable presence of silt (15%) and slightly calcareous (Table 1). The pH is near neutral (between 6.9 and 7.3). The electrical conductivity is less than 1.73 mS / cm. The organic matter content is less than 1.5% (Table 1).

The Greenhouse: The system used for monitoring agro meteorological data and studying the natural aging, considering the number of measurable parameters, is a unique device of its kind nationally (Figure 1). The facility is located within the Hydro meteorological Institute of Training and Research (IHFR) in Oran city (Latitude 34° 40' North, Longitude 00 ° 36' west, altitude 120 m).

This is a tunnel greenhouse, oriented from east to west and with dimensions:

- Length L = 32 m
- Width W = 8 m
- Height H = 3.5 m
- Surface soil S = 256 m^2
- Total area of the wall A = 390 m^2

The greenhouse structure is a metal frame consisting of seventeen arches with two meters apart from each other. Iron son of 5 mm in diameter, stretched between the poles, helps to reinforce the rigidity of the structure.

LDPE films were obtained by extrusion of granules supplied by Skikda-ENIP Company (reference B24/2, east Algeria). The density and melt index given by the supplier are, respectively, d=0.923 and Mi=0.3 g/min.

This extrusion performed at ENPC-Chlef Company (west Algeria) leads to the formation of films with a thickness of 0.2 mm.

Experimental Protocol: Fischer blocks device is used [7,8]. Two variables are tested: the dose applied to the culture (fraction of maximum evapo-transpiration) combined with the time of application (vegetative stage of growth cycle).

Table 1: Chemical analysis of the soil

Depth	Active lime stone %	Organic matter %	pH (water)
10-20 cm	1	1.07	7.3
20-25 cm	1.25	0.77	7.1

Table 2: physical composition of the soil

Profondeur	Clay %	Silt %	Sand %
10-20 cm	24.8	15.5	58.9
20-25 cm	25.7	17.7	56.9

Table 3: Treatment of plots based on Maximum Evapotranspiration (ETm)

Treatment	Flowering stage	Stage of fruit formation
1	70 % ETm	70 % ETm
2	70 % ETm	85 % ETm
3	70 % ETm	100 % ETm
4	85 % ETm	70 % ETm
5	85 % ETm	85 % ETm
6	85 % ETm	100 % ETm
7	100 % ETm	70 % ETm
8	100 % ETm	85 % ETm
9	100 % ETm	100 % ETm

Fig. 1: Measuring apparatus under the greenhouse

The nine treatments adopted are presented in Table 3. Fisher's exact test considers all the possible cell combinations that would still result in the marginal frequencies as highlighted. The test is exact because it uses the exact hypergeometric distribution rather than the approximate chi-square distribution to compute the value. It's appropriate to use Fisher's exact test, in particular when dealing with small counts. Fisher's exact test is used to test the differences between the averages and the overall average. The observed value is compared to the values in the F Fisher table. If the calculated F value is greater than the critical value of F from the table, then we deduce that one or more regression coefficients are different from 0, so that the model is (very) significant (according to the threshold significance). If the model is not globally significant, it is important to see wha(s) coefficient(s) is not significant(s) using the Student t test. A calculated F exceeds the F table reflects, a significant difference between the averages and the overall average, a significant overall model, according to the use of Fisher's exact test.

Measurement Methods

Greenhouse Climate Parameters: Thermometers are placed at different heights (0.70; 1.50 and 2.0 m) for measuring the temperature. For humidity, temperature sensors provided with a platinum psychrometer and coupled to a Speedo-max recorder. Solar and surface radiations are measured by a thermopile KIPP ZONEN pyranometer which the sensors are placed at 70 cm of soil in the center of the greenhouse.

Measurement of the Etm: The maximum evapotranspiration of the crop is calculated from daily weightings using a pot lysimeter placed in the middle of the greenhouse.

Soil Water Content: The soil water content at depths of 10, 20, 30, 50 and 70 centimeters is estimated by the method using a neutron moisture meter.

Each treatment was repeated three times, on 1.76 m^2 surfaces each one. Standard spacing is allowed between blocks to minimize intermolecular interactions blocks.

The irrigation water is provided by direct rays and the applied rate and volume are controlled and subject to plant water needs.

The seeding was done in place on March 3, the conduct of the experiment was made using the standard pattern [9.10]: fertilization, pruning, pest control treatments, repeated hoeing and hand weeding.

RESULTS AND DISCUSSION

Effect of Water Treatments on Flowering: The number of flowers is an important feature of plant development, including in water stress conditions. The accelerated rate of flowering in adverse water conditions is slowed by high humidity of the soil. The most abundant flowering, measured in number of flowers per meter of stem, is observed for the first two treatments. There seems to be a correlation between the degree of reduction in water intake, particularly during the first phase of treatment and the importance of flowering.

This result is consistent with a physiological behavior common to several plants; water restriction directly promotes flowering at the expense of vegetative growth (Figure 2).

Water Stress Effects on Crop Production: Production is estimated using the calculation of yields in quintals per hectare. The best crop yield is obtained by treating 6 (85% of ETm during the flowering stage and 100% of the Etm in the last stage). This performance is followed by that obtained by the treatment corresponding to a dose equivalent to 70% of Etm during the first stage and 100% during the formative stages of the product or treatment 3.

A lower yield is observed when application rates are reduced during the last stage even if they reach 100% of the value of ETm during the stage of fruit formation (Figure 3). This summary analysis is completed by applying the Student test to the various components of production (Table 4). The number of fruits, their average diameter and incidentally their weight are not really influenced by water stress.The comparison of two

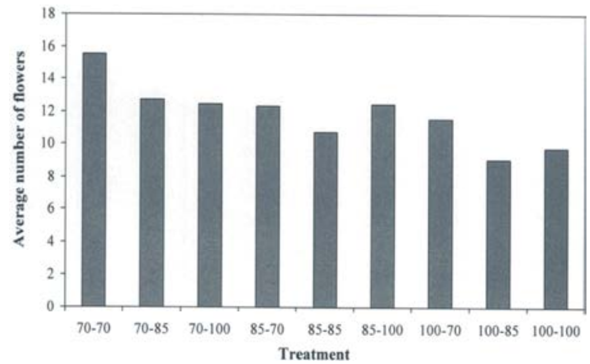

Fig. 2: Average number of flowers according to the treatment

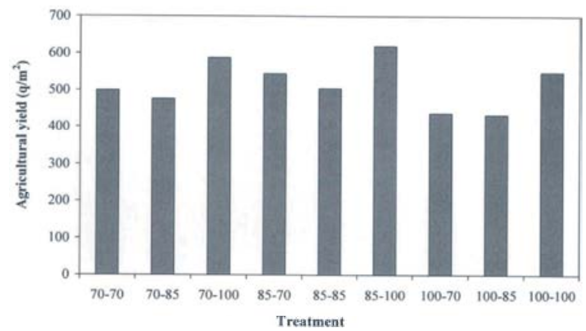

Fig. 3: Crop Productivity by treatment

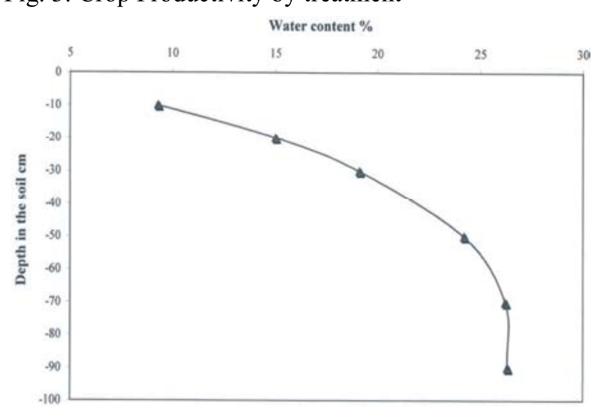

Fig. 4: Post irrigation water profile in soil

Table 4: Test for comparison of means of production parameters

Treatment Parameter	70% compared to the witness	85% compared to the witness	70% relative to treatment 85%
Average weight	NS	S	S
Number of fruits	NS	NS	NS
Average length	S	S	S
Mean diameter	NS	NS	NS

S and NS respectively denote significant and not significant test at 5%.

Table 5: Profile of soil water content

Depth	10	20	30	50	70	90
Water content %	9.30	15	19.1	24.2	26.2	26.3

Table 6: Change in water storage during the two stages for treatments 1, 5 and 9

Treatment	1 (70-70)	5 (85-85)	9 (100-100)
Variation in the water storage during the flowering stage in mm	9.78	4.71	14.67
Variation in the water storage during the fruit formation stage	10.72	18.18	24.68

treatments 70% and 85% shows that the average length and average weight have a more favorable response to scarcity of irrigation.

Monitoring of Soil Moisture Profile: The general appearance of water profile in the soil has two distinct zones (Figure 4). A first zone between the surface and 50 cm deep is characterized by a progressive increase in water content from the surface (Table 5).

A second zone beyond the first 50 cm is characterized by very low differences in water content.

The variation of water storage is the difference between the water reserves in the soil before and after watering. This variation of water storage is the actual evapotranspiration of vegetation cover.

By comparing the variation of water stocks for three successive irrigations for each treatment and for each stage (Table 6), we can draw the following conclusions:

- Real evapotranspiration (RET), estimated from the change in stocks, is significantly higher during the stage of fruit formation. This is explained by a high water consumption at the end of melon's cycle.
- The RET is even closer to the ETm (represented by the treatment 100% - 100%) as the dose of watering is important.

CONCLUSION

Our principal objective was to appreciate the incidences of a hydrous constraint on the agricultural output of melon and to determine the fraction of the water needs to satisfy, likely to ensure a level of suitable production while sparing the mobilizable hydrous resources for this purpose.

The microclimate of the greenhouse decreases evapotranspiration, thus a crop under greenhouse is not as demanding in water than in open fields.

The preliminary results show that only the flowering phase of flowering allows a substantial saving in water (from 15% to 30% of the ETM) and a level of optimal production.

Production is estimated by calculating the yields in quintals per hectare. The best performance is obtained by the agricultural processing 6 (85% of the ETM during the flowering stage and 100% of ETM during the last stage). A lower yield is observed when application rates are reduced during the last stage even if they reach the value of 100% of ETM during the stage of fruit formation.

The number of fruits, their average diameter and secondarily their weight are not really affected by water stress.

By comparing the variation of soil water during three successive irrigations for each treatment and at each stage we can conclude that the real evapotranspiration (RET), estimated from the change in stocks, is significantly higher during the stage of fruit formation. This is explained by a high water consumption at the end of melon's cycle and that the RET is even closer to the ETm (represented by the treatment 100% - 100%) as the dose of watering is important.

However, this economy cannot be done without proper monitoring of the culture, the monitoring of the greenhouse microclimate and agricultural practices used throughout the experiment.

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