THE EFFECT OF MOISTURE DEPLETION ON SOIL WATER EVAPORATION AND BARLEY WATER CONSUMPTIVE USE

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ABSTRACT

Three soil moisture depletion treatments of 10% (M_1), 25% (M_2) and 50% (M_3) of field capacity were used in a loamy sand soil. Moisture loss from bare soil by evaporation, transpiration and water consumptive use by barley grown in plastic pots was calculated using the soil moisture depletion method. There was a remarkable increase in water consumptive use with time , the highest values were recorded at the productivity stage for all moisture treatments.

The M1 treatment gave significantly higher total water consumptive use value (423) mm than the values 298 and 183 mm for the M_2 and M_3 moisture treatments, respectively. Moisture loss values from bare soil by evaporation from sowing to maturity stages were 266, 156 and 109 mm for M_1, M_2 and M_3, respectively.

The low values of the top and grain yield dry weights were related with the small amount of water available for plant use in the soil. The highest reduction in water consumptive use by plant and yield dry weight were recorded in M_3 moisture depletion treatment, which was attributed to the adverse effect of water stress during the growing season and seed formation. The highest water use efficiency was calculated for the M_2 moisture treatment.

The amount of water lost by evaporation from bare soil was higher than the amount used by the plant. This can be related with the availability of pore spaces in the loamy sand soil for air and water movement, which eventually reduce the amount of water available for plant use in the soil. The M_2 moisture depletion treatment gave highest water use efficiency values.

The highest monthly and daily water consumptive uses by plant were recorded during the maturity and seed formation stages. They were respectively, 129 and 5.25 mm for $M_{1,}$ 90 and 3.50 mm for M_2 and 77 and 2.48 mm for M_3.

Key Words: Moisture Depletion, Evaporation, Water Consumptive Use, Water Use Efficiency, Barley Growth.

INTRODUCTION

The relation between the plant and soil moisture is a complex one since it is influenced by a number of continuously changing factors (i.e. soil, water, nutrient and climate). The soil water is the largest element that restricts plant growth[1.2]. The amount of moisture available to plant depends largely on the amount of moisture stored in the soil profile at sowing time and the water added during the growth period. Some of the water may be run off or drained beyond the reach of the roots and some may be lost by evaporation from the soil surface. Loss of water can occur by transpiration, evaporation of intercepted water by vegetation and evaporation from bar soil [3]. The evaporation from soil surface and the interception of rainfall water by vegetation can cause large error in estimating consumptive water use and water flux. With wet soil and complete plant cover, transpiration will be dominant, but when plant leaf area is small, evaporation from soil surface will be high[4]. Therefore, the important of plant cover is the greatest when the soil surface is wet, especially ate the arid and semiarid areas.

Evaporation rate from soil surface decreases as soil water decreases and vice versa[5]. When the soil drying persists for a long time, moisture evaporation extracted from lower layers. Plant with good root system are able to extract water from good structure soil up to 75% to 80% of the available water without serious reduction in yield[6]. These results suggested that wheat crop can draw 52 to 57% of soil water, before plant growth reduced.

However, the available water in the soil varies with soil type, where a clay soil may contains three to four times as much water as a sandy soil both at 15 bar tension[7]. The uniformity, texture, depth and subsurface structure of the soil can affect rate of soil water flow, and consequent evaporation losses[8]. The change in particle size distribution of the soil greatly alter water movement and water loss in unsaturated soil[9]. The cumulative water loss by evaporation from bar soil found to be the least with coarse textured soil surface, related with their low water holding capacity[10].

In order to increase the consumptive water use efficiency in dry land, it is important to plane for a proper soil and water management program to increase the storage coefficient of water in the soil[11].

Regarding the increasing demand for water use, it is important to estimate how much water requirements for each crop in each soil and environmental area, in order to minimize the loss of water and optimize the use of the natural source of water in Iraq. However, so far little has been carried out to determine the water consumptive use by crops under southern conditions of Iraq. Therefore, an experiment was carried out to determine the use of irrigation water by barley crop and the loss of water by evaporation from a loamy sand soil under different levels of soils moisture depletion.

MATERIALS AND METHODS

The experiment was carried out at the Agriculture College, Basrah University, Basrah, Iraq, using a loamy sand soil of 100 clay, 30 silt and 870 gm. Kg^{-1} sand. The soil was collected from the surface layer of (0-10) cm depth of Al-Zubair Research Station of the Ministry of Agriculture, South Basrah, Iraq. It was air dried, mixed and passed through 8 mm sieve (in order to obtain soil particle sizes as near as possible to field soil) before being packed into eighteen plastic pots of 6.87 liter capacity and 40 cm depth. Each pot was filled with 8 Kg air dry soil up to a few cms. from the top. The resulting soil bulk density ranged from 1.46 – 1.50 Kg. M^{-3}.

The electric conductivity (EC), (PH) and organic matter (OM) were determined at the beginning of the experiment as described by Black et.al,[12] and their values were 4.30 $dS.m^{-1}$, 7.20 and 0.15%, respectively.

Fertilizers were mixed thoroughly with soil at sowing time, at rates of 120 $kg.ha^{-1}$ nitrogen (half of this amount was added tillering time). 60 kg. ha^{-1} phosphorus and 60 $kg.ha^{-1}$ Potassium.

On 11 December, seeds of local barley were sown at 2 cm depth in half of the pots (i. e. nine) each pot was sown with 12 seeds. The remaining nine pots were left without planting, in order to calculate the loss of moisture by evaporation from bare soil. Seven days after plant emergency plants were thinned to eight plants per pot. After maturity, the plants were harvested and dried at 70^{O} c. The dry weights of top and grain yield water determined.

The pots were exposed to field conditions and were protected from the rain by using a transparent polyethylene shelter. Water was added to each pot slowly until the soil had been saturated, using a small metal sprayer of five liter volume. Soil in each pot was saturated three times for a period of three days in order to ensure uniform saturation and to reduce electrical conductivity in the soil. The soil was saturated to provide enough water for good seed germination. After all excess of water had drained out of the soil, each pot was weighed and soil moisture content was calculated. The pots were then left without addition of water until soil moisture depletion treatments were began. Three moisture depletion treatments were used for each of the planted and unplanted part of the experiment. The moisture depletion treatments were 10%, 25% and 50% of field capacity (FC), and they were named M_1, M_2 and M_3, respectively. Each moisture depletion treatment was replicated three time in a completely randomized block design. The weight of each pot was taken every day throughout the experiment (using a digital balance with 0.003 gm), so that any deficit in soil moisture content from the designed moisture depletion treatments could be calculated and added slowly to the soil. The values in mm of water consumptive use by barley (ET) and water evaporated from bare soil (E) were calculated from the amount of water applied for each treatment using the formula cited in Hanks and Ashcroft[13]. The transpiration values (T), for each water treatment were calculated from the differences in values between ET and E at each time of measurement.

Results and discussion

There is an increase in trend of cumulative water consumptive use (CET) with time of the three planted moisture depletion treatments (Figure 1). The moisture depletion treatment of 10% FC (M_1) gave the highest values, while the 25% FC (M_2) and 50% FC (M_3) had the intermediate and the lowest values, respectively. There are significant differences in values between the treatment and time of measurement, i.e. F values at $P = 0.05$ were 106.24 and 27.21, respectively. Generally, the RLSD value indicated significant differences between the CET values of the three moisture treatments.

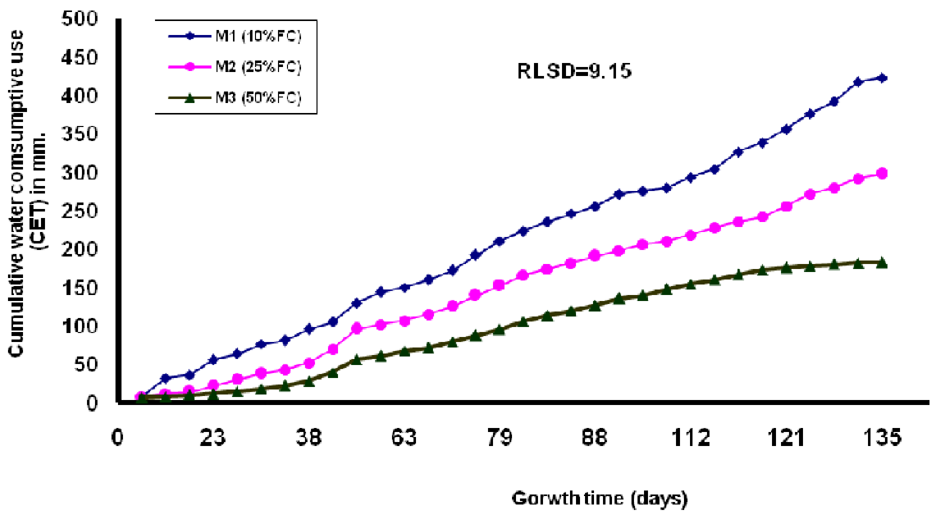

Figure 1. The relationship between cumulative water consumptive use (CET) in mm., and growth time in days of different moisture depletion treatments with plant. RLSD repsents the revise least significant differences at P=0.05.

The higher increase in cumulative water evaporation (CE) values with time of the unplanted treatments were recorded on the M1 moisture depletion treatment compared with the other treatments (Figure 2). The RLSD value gave significant differences between the CE values of all depletion treatments. The differences in CE values between M_1 and M_2 were smaller than those between M_2 and M_3 treatments. The reason can be related with the larger amount of moisture available for evaporation in soil of M_1 and M_2 than of moisture in soil of M_3 treatment. Darusman et. al.[14] and Kang et. al.[4] found that, the treatment with the high soil moisture content gave higher evapotranspiration values than the treatment with the low soil moisture content. The F values indicated significant differences at $P = 0.05$ between moisture treatment (80.11) and time of measurement (19.29). However in the planted treatments the CET values were higher than the CE values for the treatment without plant. This must be related with the transpiration of water by plant.

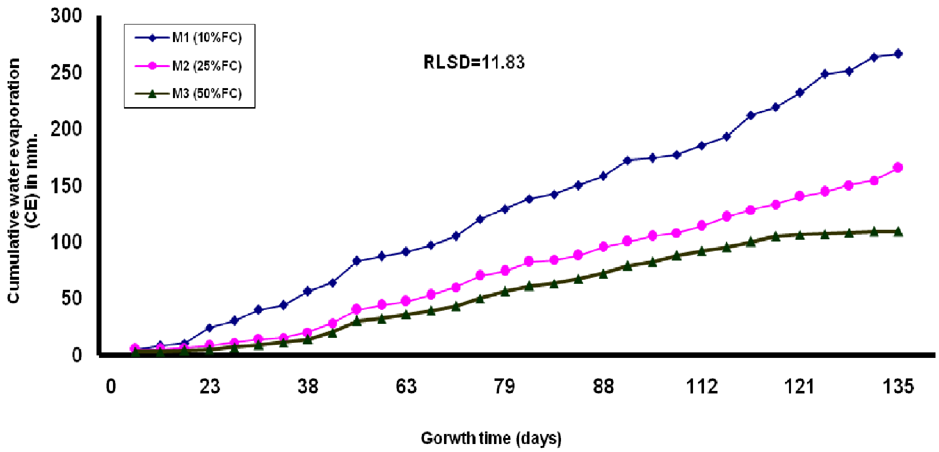

Figure 2. The relationship between cumulative water evaporation (CE) in mm., and growth time in days of different moisture depletion treatments with plant. RLSD repsents the revise least significant differences at P=0.05.

The cumulative transpiration of water by plant (CT) was calculated from the differences in cumulative soil moisture loss values for the planted and unplanted moisture deletion treatments. There is an increase in cumulative transpiration (CT) with the increase in the period of growing (figure 3). The moisture depletion of M_3 treatment showed lowest increases in trend of CT values throughout the time of the experiment. The M_1 and M_2 treatments gave similar increases in CT values with time. The highest values were recorded at March and April. This can be attributed to the large amount of water available to plant in the soil. The plant need more water at productivity stage than the vegetative stage[15]. The RLSD value (10.49) indicated insignificant differences between M_1 and M_2 treatments. However the analysis of variance of CT values gave significant F values at $P = 0.05$ for moisture depletion treatments (64.25) and for time of measurement (15.05).

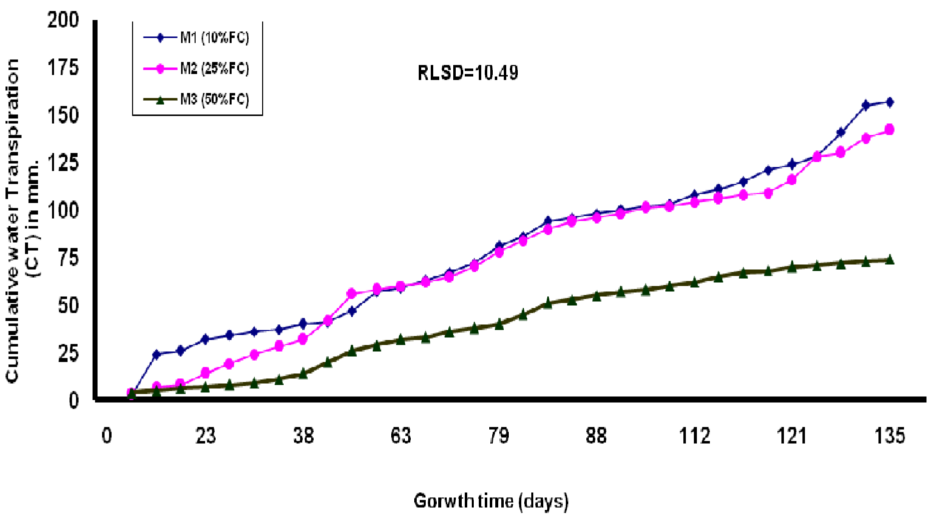

Figure 3. The relationship between cumulative water transpiration (CT) in mm., and growth time in days of different moisture depletion treatments with plant. RLSD repsents the revise least significant differences at P=0.05.

The total amount of water consumptive use by barley at each moisture depletion treatment was higher than the total water evaporation from bare soil (Table 1). The total amount of water removed by evaporation from bare soil was higher than the total amount of water transpired by plant. This is related with the low soil water retention and rapid loss of water by evaporation from loamy sand soil, which consequently, leave small amount of water available fro plant use. When soil moisture content is relatively low, most of the pore space will be available for air and water vapor movement, which cause an easy water evaporation from the soil[16.17]. It has been stated by Kopec et. al.[18] that at the high evaporation demand (i.e. at limited water supply), the rate of water use by plant can be restricted, either by a physiological factor inside the plant, or by the complex movement of water from soil to plant roots. However, the percentage values of water evaporated from bare soil throughout the growing period of the M_1, M_2 and M_3 moisture depletion treatments were 63%, 52% and 60% of the total water consumptive use by plant, respectively. These results indicate that more water had been transpired by the plant from M_2 treatment. With wheat grown in the field of Australia, Doyle and Fisher[19] found that the evaporation from bare soil ranged from 18% to 41% of crop evapotranspiration, while the values found by Kang et. al.[4] in China were ranged from 25% to 40% of winter wheat evapotranspiration. The RLSD values for all parameters in table 1 indicated significant differences between the three soil moisture depletion treatments.

Table 1: Total amount of water removed from soil by plant or by evaporation for each moisture depletion treatment (mm).

Moisture depletion treatment	Total moisture loss (mm)		
	Water consumptive use (ET)	Evaporation (E)	Transpiration (T)
M1	423	266	157
M2	298	156	142
M3	183	109	74
RLSD at P = 0.05	9.15	11.83	10.49

RLSD represents the revise least significant differences.

The top and yield dry weights values had shown no significant differences between the M_1 and M_2 moisture depletion treatments (Table 2). The total water consumptive use values gave significant differences between all treatments.

The highest water use efficiency value was calculated for the M_2 moisture depletion treatment (i.e. top or yield dry weight / ET). The lowest values in all cases were recorded for the M_3 treatment. Proffitt et. al.[20]. Found that water stress reduced yield of spring wheat grown in South African by 40%. These results suggested that the highest top and yield dry weights in M_1 treatment are corresponding with the largest amount of water use by plant. Similar results were found by Aoda et. al.[21] on yield dry weight of wheat grown for two years in silt clay loam soil in the field. They found an increase in total dry weight with the increase in water use by plant.

In general the low yield which had been obtained in all moisture depletion treatments resulted from the late sowing of seed on 11 December. Although, barley is the least affected by drought, seeds sown late in the season with lack of water for most of the growing period showed early ripen with little grain yield[22].

Table 2: Effect of moisture depletion treatment of top and yield dry weights (g. pot^{-1}), total water consumptive use (mm) and water use efficiency (g. pot^{-1} mm^{-1})

Moisture depletion treatment	Top dry weight (g. pot $^{-1}$)	Yield dry weight (g. pot $^{-1}$)	Total water consumptive use (mm)	Water use efficiency (g. pot^{-1}. Mm^{-1})	
M1	25.03	4.11	423	0.06	0.009
M2	21.07	3.29	298	0.07	0.011
M3	7.68	1.09	183	0.04	0.006
RLSD at P = 0.05	7.46	1.76	9.15	0.021	0.003

RLSD represents the revise least significant differences.

Moreover, the monthly and daily rates of water consumptive use by barley were higher for the M_1 than for the M_2 and M_3 treatments (Table 3). The highest rate values of water consumptive use by barley were occurred on March at seed formation stage. There was an increase in the rates from December to March, after which a decrease was recorded in April. This decrease occurred on the seeds ripening stage due to the death and drying of most of the vegetative part of the plant. Variability in rate values were higher in M_1 compared with the other moisture depletion treatments. Similar results for monthly and daily rates of water consumptive use by wheat under various moisture regimes were obtained by Naoom and Kerefa[(23)].

Table 3: Monthly and daily rates of water consumptive use (mm) under different soil moisture depletion treatments.

Period	M_1		M_2		M_3	
	Monthly	Daily	Monthly	Daily	Monthly	Daily
December	36	1.08	14	0.70	10	050
January	69	2.23	56	1.81	30	0.97
February	105	3.62	82	2.83	56	1.93
March	129	4.16	90	2.90	77	2.48
April	84	5.25	56	350	10	0.63
Total	423	17.06	298	11.74	183	6.51
Average	84.60	3.41	59.60	2.35	36.60	1.30

CONCLUSION

The management of water in a loamy sand soil under arid or semi-arid conditions is a very difficult aspect. It is very important to make the best use of the irrigation water and the storage water in the soil in order to obtain a high yield production and best water use efficiency. Therefore, to minimize the large loss of water by evaporation which was recorded in the low soil moisture depletion treatment (10% FC), it is optimal to use 25% FC moisture depletion treatment for growing barley in a loamy sand soil under Basrah climate. This treatment resulted in high water use efficiency (WUE) with low loss of moisture by evaporation from bare soil. Also, it showed a significant differences in results of ET with no significant differences in yield dry weight when it was compared with the 10% FC moisture depletion treatment. The reduction in the loss of water evaporated from bare soil can be very important in the arid and semiarid areas when there are shortages in irrigation water.

Further experiments are needed for determining accurately the water consumptive use in the field for different cereal crops, climate and types of soil. This will be useful in developing an irrigation plan for cereal crop production under limited water supply conditions in the South of Iraq.

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تأثير الاستنزاف الرطوبي على تبخر ماء التربة والاستهلاك المائي للشعير

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الخلاصة

استخدمت ثلاث معاملات استنزاف رطوبي 10% (M_1), 25% (M_2), 50% (M_3) من السعة الحقلية في تربة رملية مزيجية. حسب الفقد الرطوبي من التربة بالتبخر, النتح والاستهلاك المائي لمحصول الشعير المزروع في اصص بلاستيكية باستخدام طريقة الاستنزاف الرطوبي. بينت النتائج ان هنالك زيادة ملحوظة في الماء المستهلك للنبات حيث ان اعلى زيادة سجلت عند مرحلتي النضج وتكوين الحبوب ولجميع المعاملات الرطوبية.

المعاملة الرطوبية M_1 اعطت اعلى قيمة معنوية للاستهلاك المائي الكلي (423) ملم مقارنة بالقيم 298و 183 ملم للمعاملات الرطوبية M_2 و M_3, وعلى التوالي. قيم الفقد الرطوبي من سطح التربة بالتبخر من الزراعة حتى النضج كانت 266 ,156و 109 ملم للمعاملات للمعاملاتM_1 M_2 M_3, و على التوالي. ان الانخفاض في قيم الوزن الجاف للجزء الخضري والحاصل كان مرتبط مع انخفاض كمية الماء الجاهز في التربة للاستهلاك المائي من قبل النبات. ان اعلى انخفاض في كمية الماء المستهلك من قبل النبات وكذلك الانخفاض في الحاصل كان قد سجل في معاملة الاستنزاف الرطوبي M_3, والذي يرجع سببه للتاثير العكسي للشد الرطوبي خلال موسم النمو وتكوين الحبوب. اعلى كفاءة للاستهلاك المائي قد حسبت للمعاملة الرطوبية M_2.

ان كمية الماء المفقودة بالتبخر من سطح التربة كانت اعلى من كمية الماء المستخدمة من قبل النبات, وهذا له علاقة بحجم الفراغات المسامية المتوفرة في التربة الرملية المزيجية لحركة الهواء والماء, والتي بالنتيجة تؤدي الى التقليل من كمية الماء الجاهز في التربة لاستهلاك النبات. معاملة النقص الرطوبي M_2 اعطت أعلى القيم لكفاءة الاستهلاك المائي. أعلى استهلاك مائي شهري ويومي للنبات سجل خلال مرحلتي النضج وتكوين الحبوب. حيث كانت القيم, وعلى التوالي, 129 و 5.25 ملم لمعاملة M_1 و 90 و 3.50 ملم لمعاملة M_2 و 77 و 2.48 ملم لمعاملة M_3 .