

Evaluation of physiological indices of winter wheat under different irrigation treatments using weighing lysimeter

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ABSTRACT: : In order to evaluate physiological indices of winter wheat in different irrigation treatments in climatic condition of Beijing, an experiment was conducted in National Precision Agriculture Demonstration Station in Xiaotangshang Town of Beijing. Irrigation treatments were (I1) irrigation before sowing (60 L); (I2) Irrigation before sowing (30 L) + before freezing (30 L); (I3) irrigation before sowing (30 L) + before freezing (30 L) + at erecting stage (60 L) + flowering stage (60 L); (I4) Irrigation before sowing (30 L) + before freezing (30 L) + jointing stage (60 L) + flowering stage (60 L). The crop growth was low in the beginning of sampling, thereafter increased considerably up to 125 days after planting (22 g/m²/day) with a peak in 130 days after planting, then showed a declining trend after that. The decrease in crop growth rate towards maturity is due to senescence of leaves and decrease of leaf area index. The maximum and the minimum CGR was related to irrigation one and irrigation four, respectively. RGR decrease during plant growth and reached to a zero at 185-195 days after planting, and it reached into negative after these days until harvesting time. Moreover, the highest LAI was related to irrigation treatment number 2, and the lowest one was obtained for treatment number one. The NAR was low in the beginning of sampling, thereafter increased considerably up to 105 days after planting which was 8.6 g/m²/day. Then showed a declining trend after that toward zero (192 days after planting), then it has negative trend.

Keywords: Physiological indices, winter wheat, irrigation

INTRODUCTION

Water is the most limiting resource, rainfall is scarce and irregularly disturbed along the year, and climate change models predict even more arid conditions for the near future (Ragab and Prudhomme, 2002; Cifre et al., 2005; Abedi and Pakniyat, 2010). Wheat is the staple food for more than 1/3 of the world's population, and crop yield is significantly influenced by global climate changing and limitation of water resources in the environment (AL-Ghamdi, 2009). Zareian et al., 2013) reported that among the environmental stresses, drought is one of the most severe stresses for plant growth and productivity. (Bourke, 1984) reported the importance of measuring total dry weight, leaf area index (LAI), and crop growth rate (CGR). Crop growth depends on the ability of leaves to capture and use solar radiation, with that they can provide the energy to drive both CO₂ assimilation and water transpiration processes (Albrizio and Steduto, 2005; Seyed Sharifi et al., 2011). (Bavec et al., 2007) noted that the most

important photosynthesis acceptor-leaf area vary among cultivation measures and it is limited factor for creating exact growth models in winter wheat. Drought affects nearly all the plant growth processes; however, the stress response depends upon the intensity, rate, and duration of exposure and the stage of crop growth (Zareian et al., 2013). Morphological indexes such as leaf area and plant height complement plant growth quantitative analysis and enable the determination of the effects of the use of different crop management techniques (Poh et al., 2011). (Gordon et al., 1997) showed that historically models of leaf area index (LAI) have varied both in their complexity and physiological implications. Growth analysis is a way to assess what events occurs during plant growth (Hokmalipour and Hamele Darbandi, 2011). Growth analysis is a suitable method for plant response to different environmental conditions during life (Tesar, 1984). The determination and growth analysis, interpretation of how species respond to a given environmental condition (Zare-Feizabady and Ghodsi, 2004). To compare the physiological responses of growth, analysis should be independent of environmental changes (Zhaohui-Wang, 2005). For growth analysis, leaf area and dry weight measured parameters are mandatory and growth will follow through mathematical calculations (Paleg and Aspinall, 1981). Factors affecting growth dynamics such as dry matter accumulation, crop growth rate, relative growth rate and leaf area index are important investigative tools to facilitate the development of better agronomic management (Rahimzadeh et al., 2013). (Hunt, 1982) concluded that total dry matter compensation is influenced by crop growth rate, relative growth rate, relative leaf area growth rate and net assimilation rate. (Talebifar et al., 2013) reported that there is a reduction in net assimilation rate (NAR) and relative growth rate (RGR) under drought stress before flowering, after flowering of the indexes were not affected by stress. The aim of this study was to evaluate of some of physiological indices of winter wheat in relation to different irrigation treatments in Beijing, China.

MATERIALS AND METHODS

The weighing lysimeter system is located in National Precision Agriculture Demonstration Station in Xiaotangshang Town of Beijing (40°10'N, 116°27'E). The system was consisted of 24 lysimeters with 1.0 m* 0.75 m* 2.3 m (L*W*H). The machine structure of the lysimeter was counter-balanced and the schematic diagram of the lysimeter is shown in Fig. 1.

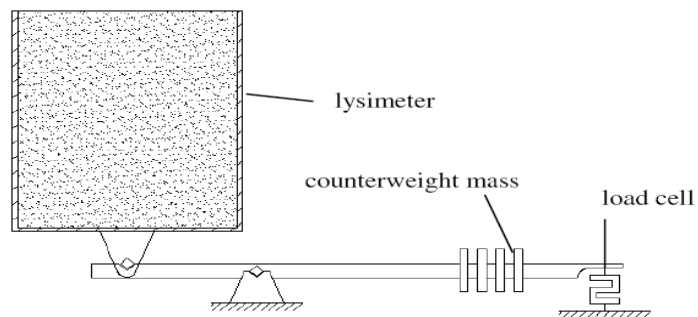


Fig. 1. The schematic diagram of the weighing lysimeter

The plantation was done on 10th Oct in 2012. 500 seeds per each lysimeter was used in each small lysimeter. In big lysimeter, 20 lines were planted (each line had 300 seeds). The fertilization for big lysimeter was consist of 337.3 g urea to supply nitrogen, 337.3 g diamonium phosphate to provide phosphorus, 26.68 g zink sulfate to provide zink, 202.4 g potassium sulfate to provide potassium and 27 kg chicken manure is used. For small lysimeter, to supply N 28.125 urea g per each lysimeter, 17 diamonium phosphate per each lysimeter, 17 g magnesium sulfate per each lysimeter, and 2.25 g zink sulfate per each lysimeter and 2.25 kg, chicken manure. The distance between rows was 15 cm, and the distance between seeds was one com. Irrigation treatments were (I1) irrigation before sowing (60 L); (I2) Irrigation before sowing (30 L) + before freezing (30 L); (I3) irrigation before sowing (30 L) + before freezing (30 L) + at erecting stage (60 L) + flowering stage (60 L); (I4) Irrigation before sowing (30 L) + before freezing (30 L) + jointing stage (60 L) + flowering stage (60 L). Pre-irrigation was done on 6th Oct. Hand weeding was done for weeds management. Lunxuan 987 was used in this experiment. All practices such as control of weeds, pests and diseases were done regularly during period. Leaf area index was determined by dividing leaf area over ground area and was estimated using equation 2. The variance trend of total dry matter

(TDM), leaf area index (LAI), net assimilation ratio (NAR), crop growth rate (CGR), and relative growth rate (RGR) were determined with using of 1-5 equations (Acuqaah, 2002; Gupta and Gupta, 2005).

$$W = e^{a_2 + b_2 t + c_2 t^2} \quad (1)$$

$$LAI = e^{a_1 + b_1 t + c_1 t^2} \quad (2)$$

$$NAR = (b_2 + 2c_2 t) e^{(a_2 - a_1) + (b_2 - b_1)t + (c_2 - c_1)t^2} \quad (3)$$

$$CGR = NAR * LAI = (b_2 + 2c_2 t) e^{a_2 + b_2 t + c_2 t^2} \quad (4)$$

$$RGR = b + 2ct + 3dt^2 \quad (5)$$

RESULTS AND DISCUSSION

TOTAL DRY MATTER

The influence of different irrigation treatment on total dry matter trend was measured from 80 days after planting until the final maturity. For all, irrigation treatments, from 80 days after plantation until 180 days after planting, the total dry matter trend increased slowly, then it increased rapidly. The highest total dry matter was obtained for 180 days after planting. Then, from 180 days after planting until harvest time, accumulated dry matter decreased due to increasing aging of leaves, decreasing of leaf area index. The increase in dry matter is related to accelerating the photosynthesis activity that is caused dry matter accumulation increased (Seyed Sharifi and Raei, 2011). The highest total dry matter after big lysimeter, was obtained for irrigation number four. Increasing leaf area index is one of the ways of increasing the capture of solar radiation with canopy and production of dry matter (Seyed Sharifi and Raei, 2011). The efficiency of the conversion of intercepted solar radiation in to dry matter decrease with decreasing of leaf area index (Seyed Sharifi and Raei, 2011). Total dry matter trend (TDM), and crop growth rate (CGR), the most important traits in plant growth analysis (Hokmalipour and Hamele Darbandi, 2011).

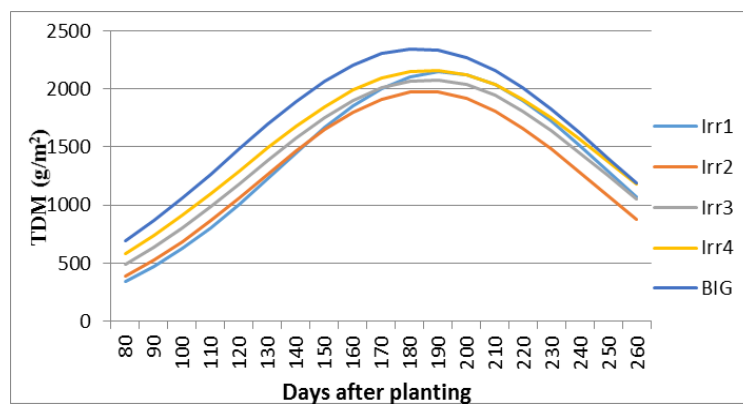


Figure 2.

CROP GROWTH RATE

Study of trend of variances crop growth rate showed that in all treatments, the crop growth was low in the beginning of sampling, thereafter increased considerably up to 125 days after planting (22 g/m²/day) with a peak in 130 days after planting, then showed a declining trend after that. The decrease in crop growth rate towards maturity is due to senescence of leaves and decrease of leaf area index (Seyed Sharifi and Raei, 2011). (Beadle, 1987) found that crop growth rate in early stages due to the complete absence of vegetation and low percentage of light absorption is lower, but with the rapid increase in the rate of plant growth that occurs because the level of developed leaves and thus absorption of solar radiation increase. Should be noted that negative values of crop growth rate is due to loss of leaves at the end of the growing season (Hokmalipour and Hamele Darbandi, 2011). In

190 days after planting, crop growth rate was zero, then it had negative trend until 105 days after planting, which became stable. The increase in CGR may be due to accelerating the photosynthesis activity. The decrease in crop growth rate towards maturity is due to senescence of leaves and decrease of leaf area index (Seyed Sharifi and Raei, 2011). The maximum and the minimum CGR was related to irrigation one and irrigation four, respectively. (Beadle, 1987) showed that crop growth rate in the early stages due to the complete absence of vegetation and low percentage of light absorption is lower, but with the rapid increase in the rate of plant growth that occurs, because the level of developed leaves and thus absorption of solar radiation increases. Crop growth rate (CGR) is an index of crop growth, which can be used to indicate the change in crop growth over time on an individual plant basis, for a population of plants or for a community. Crop growth rate is directly affected by light interception by the crop.

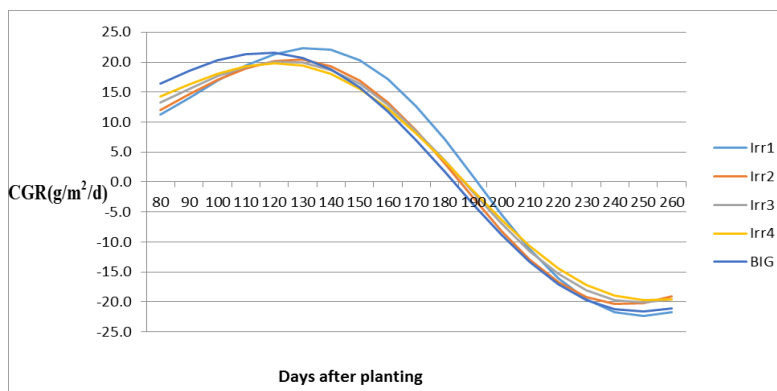


Figure 3.

RELATIVE GROWTH RATE

In the initial stages of the plant growth the ratio between alive and dead tissues is high and almost the entire cells of the productive organs are activity engaged in vegetative matter production (Seyed Sharifi et al., 2011). In conclusion, the relative growth rate of winter wheat crops is high. In all of treatment compounds, RGR decrease during plant growth and reached to a zero at 185-195 days after planting, and it reached into negative after these days until harvesting time. The reason of decreasing in RGR at the final stage can be related to increasing of the dead and woody tissues comparing to the alive and active texture. Similar observations have been reported by (Jeffrey et al., 2005). (Karimi and Siddique, 1991) reported that variation in relative growth rate during the growth period is decreased, so that the high growth rate in the early period and then decreases (Karimi and Siddique, 1991). Relative growth rate of plants depends on environmental factors and genetic characteristics. Changes in the relative growth rate of plant photosynthesis and respiration changes with time, and thus, increasing the amount of plant respiration at the end of the period is negative (Robertson and Giunta, 1994).

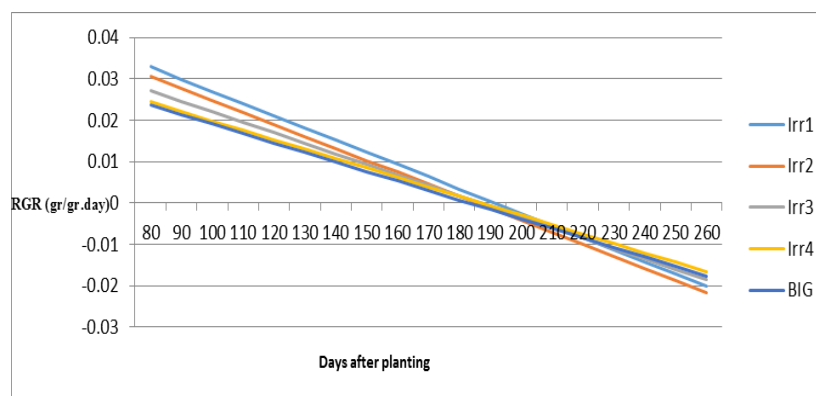


Figure 4.

LEAF AREA INDEX

LAI trend in all growth and development stages for different irrigation treatments were measured. Leaf area index increased during plant growth and reached to a maximum level at 200 days after planting, which was 5.1 for big lysimeter and 4.2 for irrigation treatment number 2. From 200 days after sowing until harvest time, leaf area index decreased due to increasing aging of leaves, shading and competition between plants for light and other resources. For irrigation treatments, the highest LAI was related to irrigation treatment number 2, and the lowest one was obtained for treatment number one. Leaf area index (LAI) is an index of the size of the photosynthetic system.

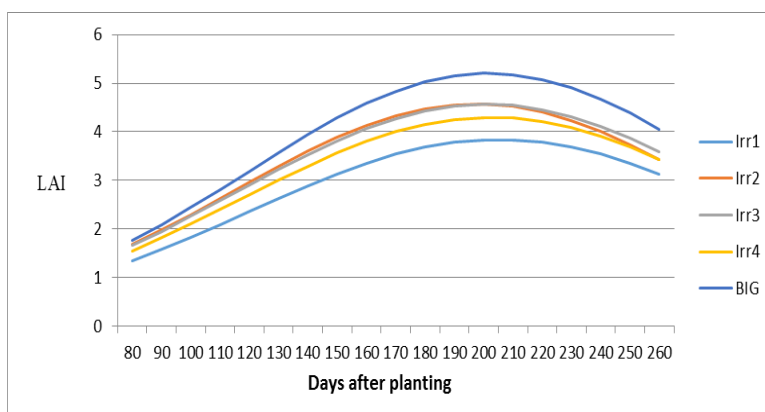


Figure 5.

NET ASSIMILATION RATIO

Study of trend of net assimilation ratio (NAR) showed that in all treatment, the NAR was low in the beginning of sampling, thereafter increased considerably up to 105 days after planting which was 8.6 g/m²/day. Then showed a declining trend after that toward zero (192 days after planting), then it has negative trend. Net Assimilation Rate (NAR) is an indirect photosynthetic activity. This is based on the principle that the increase in dry weight of plants in a given period is a measure of net photosynthesis. Growth analysis is still the most simple and precise method to evaluate the contribution of different physiological processes in plant development (Seyed Sharifi and Raei, 2011). (Hokmalipour and Hamele Darbandi, 2011) indicated that physiological growth analysis is the important in prediction of yield.

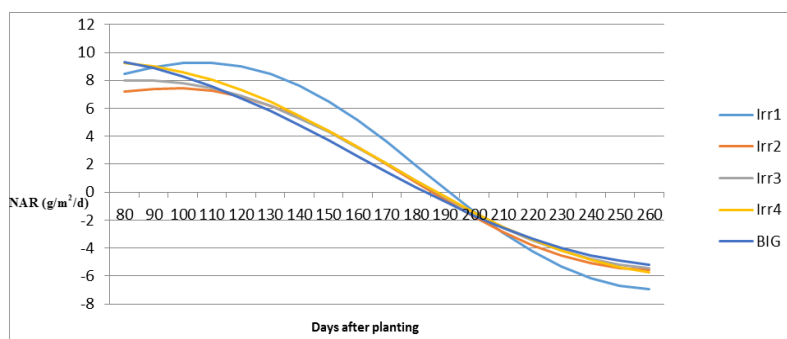


Figure 6.

CONCLUSION

Drought, one of the environmental stresses, is a worldwide problem that constraining plant growth and limiting the global crop production seriously, in majority of agriculture fields of world and recent global climate change has made this situation more adverse (Liu et al., 2013). Growth analysis is still the most simple and precise method to

evaluate the contribution of different physiological processes in plant development (Seyed Sharifi and Raei, 2011). (Hokmalipour and Hamele Darbandi, 2011) indicated that physiological growth analysis is the important in prediction of yield. Understanding physiological basis of winter wheat in different irrigation treatments is critical for the rationale design of agricultural practices. The highest total dry matter after big lysimeter, was obtained for irrigation number four. The maximum and the minimum CGR was related to irrigation one and irrigation four, respectively. RGR decrease during plant growth and reached to a zero at 185-195 days after planting, and it reached into negative after these days until harvesting time. Moreover, the highest LAI was related to irrigation treatment number 2, and the lowest one was obtained for treatment number one. The NAR was low in the beginning of sampling, thereafter increased considerably up to 105 days after planting which was 8.6 g/m²/day. Then showed a declining trend after that toward zero (192 days after planting), then it has negative trend.

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