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Effect of Irrigation Interval on Chlorophyll Fluorescence of Tomatoes under Sprinkler

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ABSTRACT

The aim of the research was to determine the effect of irrigation interval on chlorophyll fluorescence of tomato (*Lycopersicon esculentum* Mill) under sprinkler irrigation using Compact Violet Laser-Induced Fluorosensor (CVLIF) to measure leaf photosynthetic performance. Four irrigation intervals; one day (T_1), three days (T_2), five days (T_3) and seven days (T_4) were used. Parameters measured were: Soil moisture content before and after irrigation, T_1 (4.7), T_2 (4.5), T_3 (5.4), T_4 (4.2) and T_1 (15.1), T_2 (15.1), T_3 (13.6) and T_4 (11.7), respectively; Fluorescence decrease ratio (Rfd) at F690 and F740, T_1(2.465), T_2(1.690), T_3(1.998), T_4(1.702) and T_1 (1.929), T_2 (1.205), T_3 (1.241), T_4 (1.101), respectively and adaptability (AP), T_1 (0.155), T_2 (0.180), T_3 (0.253), T_4 (0.222). Irrigation interval of five days, using the same amount of irrigation water was physiologically (in terms of adaptability) better than 1, 3 and 7 and adaptability could be used as an effective parameter to estimate the water status of tomatoes under various environmental stress conditions.

Key words: Environmental stress, evapotranspiration, fluorescence decrease ratio, adaptability, irrigation schedule

INTRODUCTION

The increasing worldwide shortages of water and cost of irrigation are leading to an emphasis on developing methods of irrigation that minimize water use (maximize the water use efficiency). This has lead to irrigation scheduling which is conventionally aimed to achieve an optimum water supply for productivity, with soil water content being maintained close to field capacity. In many ways irrigation scheduling can be regarded as a mature research field which has moved from innovative science into the realms of use, or at most the refinement, of existing practical application. (Jones, 2004).

Nevertheless, in recent years there has been a wide range of proposed novel approaches to irrigation scheduling which has not yet been widely adopted; many of these are based on sensing the soil moisture status directly (Jones, 1990). Regardless of irrigation scheduling plant still regulates their diurnal water status at a favourable level by the control of stomatal aperture. Stomatal closure helps to maintain a high leaf water potential, which leads to a reduction in photosynthetic activity. Stomatal closure reduces CO_2 entry into leaves which reduces the intercellular CO_2 concentration and lowers C fixation. This causes an imbalance between photochemical activity at photosystem II (PS II) and electron requirement for photosynthesis and leads to increased susceptibility to photo-damage (Jones, 2004).

Plant use the sunlight in any growth stage and after using the light energy for living activities, unused energy in that stage is re-emitted as fluorescence (Saito *et al.*, 2003).

Chlorophyll fluorescence is a very sensitive probe of the physiological status of leaves; it provides very rapid assessment of plant performance in a wide range of situations. Chlorophyll fluorescence parameters such as PS II photochemical efficiency (F_V/F_M), chlorophyll Fluorescence decrease ratio (Rfd) and size of the acceptor pools available to PSII (S_m) indicates seasonal changes in the activity of photosynthetic apparatus (Krause and Wies, 1991).

However under stress, the photosynthetic quantum conversion declines and correspondingly heat emission and chlorophyll fluorescence increases considerably.

Krause and Wies (1991) reported that chlorophyll fluorescence indirectly measures photosynthesis efficiency. If a leave is placed in a dark for a couple of minutes and then is returned to the light, fluorescence quickly rises to an initial level (F_O). Fluorescence increases from F_O to its maximum (F_M) due to the rapid decrease of electron accepting QA (quinone-type acceptor) molecules. The variable fluorescence (F_V) is the difference between F_M and F_O and is extremely sensitive to changes in the ultrastructure of membranes and rates of electron transfer. Hence F_V/F_M can be presented as the yield of photochemical reaction (Krause and Wies, 1991).

The study was undertaken to identify ways in which chlorophyll fluorescence may be used effectively to select the best irrigation interval for tomato plants performance.

MATERIALS AND METHODS

The study area: The study was carried out at the University of Cape Coast (UCC) Teaching and Research Farm from 2006-2007. It falls within the coastal savanna zone of Ghana between latitude 05° 03'N and 05° 15'N, longitude 01° 13W and 01° 13'W. The area is characterized by a mean annual rainfall, which varies from about 750 to 1200 mm. The area has two seasons that is dry season and wet season. The wet season can also be divided into two, the minor one and the major one. The major season is from May to July with a peak in June and the minor season is from September to November with a peak in October. The main dry season is from December to February (Ayittah, 1996).

Temperatures are uniformly high throughout the year with an annual average minimum of 30°C. Diurnal variations in temperature are greatest in February and March.

Determination of Etc: The mean daily Eto for the study area was computed using Modified Penman method (Sam-Amoah, 1996). The Etc was then derived from the formulae below:

$$\text{Etc} = \text{KcETo (Doorenbos and Pruitt, 1977)}$$

Where:
ETc = Crop Evapotranspiration
Eto = Reference Evapotranspiration (Modified Penman Method)
Kc = Crop Coefficient

Total volume of water for the growing period was 31.48 m^3. The same amount was used for each of the treatments.

Chlorophyll fluorescence determination: In order to determine the effect of irrigation interval on the chlorophyll fluorescence parameters of tomato plant, only the leaves that had most recently matured. i.e., third leaves from the apex were used for measuring the leaf photosynthetic performance using Compact Continuous Violet Laser-Induced Fluorosensor (CVLIF) (Anderson *et al.*, 2004). The photosynthetic apparatus was used to register and determine the continuous chlorophyll fluorescence spectra and induction kinetics in the 685 and 740 nm as well as the ratio F685/F740. Radiations from a continuous-wave violet laser diode emitting at 396 nm through a fibre was closely incident on the detached leaves of tomato to excite chlorophyll pigments, which was detected by an integrated spectrometer with CCD readout. The chlorophyll fluorescence spectra with peaks at 685 and 740 nm were monitored for 180 s for each of the tomato leaves giving fluorescence kinetics curve or Kautsky curve (Anderson *et al.*, 2004). The Kautsky's curves were monitored from a maximum intensity level (Fmax) followed by a fluorescence decay until a steady state (Fs) was achieved. From the slow fluorescence decrease (Fd = Fmax-Fs), the fluorescence decrease ratio (Rfd = Fd/Fs) of the leaf was calculated. Stress adaptation index (Ap) was then computed from the formulae

$$\text{Ap} = \frac{1\text{-Rfd (FRB)} + 1}{\text{Rfd (RB)} + 1}$$

Where:

Ap : Stress adaptation index

Rfd (FRB) : Fluorescence decrease ratio for far red band

Rfd (FRB) : Fluorescence decrease ratio for red band

Experimental design for irrigation interval on tomato growth: A randomized complete block design (RCBD) was used. There were 16 plots and each plot size was 8×8 m. There were eight rows with plant spacing of 1×l m and plant population per plot was 64.

Seed: The Wosowoso variety of tomato was used. It was obtained from a certified seed company in Cape Coast.

Nursing and planting: The seeds were nursed and planting was done a month after nursing. Growing period was 90 days.

Irrigation: There were four treatments with four replications. The treatments were: daily application of water (T_1), every third day (T_2), every fifth day (T_3) and every seventh day (T_4). The treatments were imposed two weeks after transplanting.

Moisture determination: Soil water contents were measured before and after irrigation in the laboratory by the gravimetric method.

Crop measurement: Data collected on plant growth included: Chlorophyll fluorescence and adaptability. There were five sampling times and measurements were taken on five plants on each.

Cultural practices: The plants were staked and fertilizer application to all treatment was done. Plants were kept free of weed by repeated hand weeding and insects, pest and diseases were controlled with fungicide and insecticide.

RESULTS AND DISCUSSION

Soil moisture content: From Table 1, T_1 (15.1) and T_2 (15.1) had the highest mean soil moisture content after irrigation. T_3 (5.4) had the highest mean soil moisture content before irrigation but T_4 (4.2 and 11.7) had the lowest mean soil moisture content before and after irrigation, respectively.

From Table 2, the soil water depth increased as the amount applied increased. During the growing stage, more water was required at the development stage and mid-season and then it declined during the late-season.

Fluorescence decrease ratio (Rfd at F 690) and Irrigation interval: From Fig. 1, T1 had the highest fluorescence decrease ratio (Rfd) at F690 of 2.465 but T2 recorded the lowest fluorescence decrease ratio (Rfd) at F 690 of 1.690.

From Fig. 2, T_1 had the highest fluorescence decrease ratio (Rfd) at F740 of 1.929 but T_4 recorded the lowest fluorescence decrease ratio at F740 of 1.101.

Table 1: Soil moisture content before and after irrigation for the four treatments

	Soil moisture content	
Treatment	Before irrigation (%)	After irrigation (%)
T_1	4.7	15.1
T_2	4.5	15.1
T_3	5.4	13.6
T_4	4.2	11.7

Table 2: Soil water depth at different growth stages

Growth stages	Treatment	Depth (cm)
Initial (10 days)	T_1	1.0
	T_2	4.8
	T_3	6.1
	T_4	10.0
Development (20 days)	T_1	1.6
	T_2	7.7
	T_3	9.8
	T_4	16.0
Mid-season (30 days)	T_1	2.5
	T_2	10.5
	T_3	14.5
	T_4	18.7
Late-season(30 days)	T_1	2.0
	T_2	7.6
	T_3	11.8
	T_4	15.0

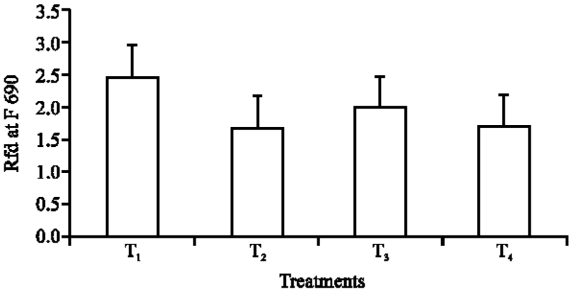

Fig. 1: Fluorescence decrease ratio (Rfd) and irrigation interval fluorescence decrease ratio (Rfd at F 740) and irrigation interval

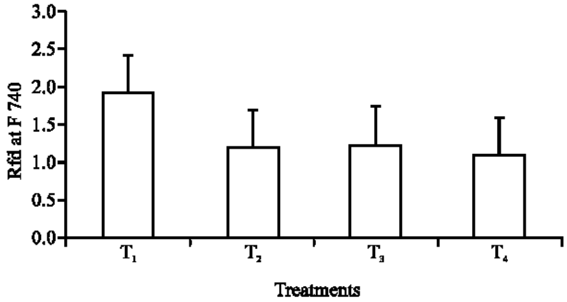

Fig. 2: Fluorescence decrease ratio (Rfd) and irrigation interval

Adaptability and irrigation interval: T1 had the lowest adaptability of 0.155. The highest adaptability value of 0.253 was recorded by T3.

There were significant differences among the treatments for adaptability.

Effect of soil moisture content on chlorophyll fluorescence: In this experiment after irrigation, one day irrigation interval had the highest moisture content which resulted in higher plant growth which was in agreement with Wang *et al.* (2003). They indicated that drought stress is one of the major causes for crop loss worldwide, reducing average yields with 50% and over. Maxwell and Johnson (2000) also indicated that plant growth depends on cell division, enlargement and differentiation and all these are influenced by other physiological processes and it was in agreement with the present study.

From the present study, it was observed that increase in chlorophyll fluorescence and adaptability had effect on the growth of the tomato plant which was in agreement with Krause and Wei (1991). They reported that chlorophyll fluorescence indirectly measures photosynthesis efficiency.

Hetherington *et al.* (1998) also assessed the photosynthetic activities of different chlorophyll containing part of tomato plants. They concluded that the non-leaf green tissues of tomato are quite active photosynthetically and therefore potentially contribute significantly to plant growth which was in agreement with the present study.

Fluorescence decrease ratio (Rfd), adaptability and irrigation interval: Chlorophyll fluorescence parameters such as adaptability and fluorescence decrease ratio were affected by

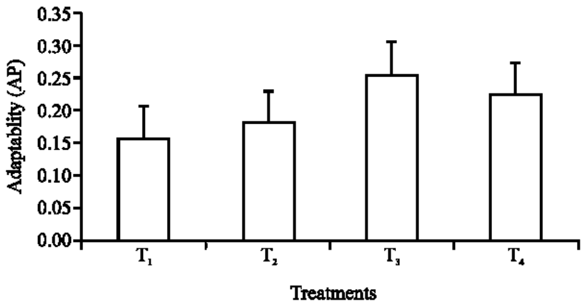

Fig. 3: Adaptability and irrigation interval

change in irrigation interval. The decrease of fluorescence decrease ratio (Rfd) in tomatoes under the sprinkler irrigation could be explained as photoinhibitory effect on the Calvin cycle by changes in the environmental conditions such as temperature, oxygen, light etc and physiological status of plants (Krupa *et al.*, 1993). T4 had the lowest fluorescence decrease ratio of 1.702 and this could be due to decrease in the rate of utilization of Adenosine Triphosphate (ATP) and Nicotinamide Adenine Dinucleotide Phosphate (NADP) in photosynthetic metabolism which could not be compensated for the next time of application of water. Increase in irrigation interval could cause inhibition of photosynthetic metabolism and can result in the decline in photosynthetic potential which when sufficiently large to overcome stomatal limitation will result in a further decrease in CO_2 assimilation rate (Lawlor and Cornic, 2002).

From Fig. 2, T_2, T_3 and T_4 had Rfd values less than 2.0 but T_1 had Rfd values greater than 2.3. This can be speculated that the lower fluorescence is due to increase in the nonradioactive energy dissipation. It is also known that drought may lead to an increase in nonphotochemical quenching (Sheuermann *et al.*, 1991).

From Fig. 3, it can be seen that as irrigation interval increases then adaptability also increases and the higher the Rfd value the higher the adaptability. T_3 recorded the highest adaptability (Vitality) Value of 0.253 and was well adapted with other environmental stress conditions present. Pukacki (1991) indicated that for well-stressed adapted plants the Rfd value is less than 2.3 and plant of lower vitality indicate Rfd Value less than 2.0 and it was in conformity with the present study.

CONCLUSION

Irrigation interval of five days, using the same amount of irrigation water was physiologically (in terms of adaptability) better than 1, 3 and 5 and adaptability could be used as an effective parameter to estimate the water status of tomatoes under various environmental stress conditions. Tomato plant under T_1 resulted in higher fluorescence decrease ratio (Rfd) than those under the other treatments.

T_3 (0.22) should be practiced so that a higher fluorescence decrease ratio and adaptability can be achieved for tomato production during the dry season

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