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Full Length Research Paper

Irrigation water scheduling for tomato under soilless planting and greenhouse conditions

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Accurate determination of irrigation schedule is a very difficult and time consuming process. Most advanced countries with advanced agricultural systems have developed data bank from which irrigation schedules for various field crops at various vegetative stages and soil types are provided. In Nigeria, irrigation schedule has always being left at the mercies of estimation from various known methods of determining water demand or water use of a crop from various climatological and hydrological data around the production area. This is a different ball game all together when planting on soilless media like sawdust, coconut fiber, peat moss, sand and others as recently practiced in many advanced countries like Japan instead of planting directly on the soil which in turns communicates directly with the earth mass. Since irrigation schedule depends majorly on type of crop, soil or soilless medium and climate, it is reasonable to provide data and other means of determining the irrigation of some crops grown on some locally available soilless media from the existing methods of irrigation scheduling. In this study, the information adapted from FAO (1998) was modified to obtain a set of steps used to determine the irrigation schedule for tomato grown on some soilless media in Owo, Ondo state, south west of Nigeria. Tomato was irrigated with sprinkler and drip irrigation systems and water use by tomato was monitored at the various growth stages. The irrigation water need of tomato was 715mm/month while irrigation interval and numbers of application were 5days and 24 respectively for the peak season of water demand. As the soilless media will often drain away, several numbers of application of water at very small quantities were administered per day based on the calculated irrigation schedule. Volume of water/plant/day was 0.44l/plant/day. This value was adjusted for the early season and late season of tomato based on type of soilless media and daily water consumptive use. The irrigation schedule resulted in optimum performance of tomato with good quality yield and marketable tomato fruits under both irrigation systems.

Keywords: Irrigation schedule, soilless media, sprinkler and drip irrigation, tomato, yield.

INTRODUCTION

Irrigation scheduling is the decision of when and how much water is to be applied to a field (Broner, 2005). Its purpose is to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level. Irrigation scheduling saves water and energy. All irrigation scheduling procedures consist of monitoring indicators that determine the need for irrigation. Uniform water distribution across the field is important to derive maximum benefits from irrigation scheduling and management. Azah (2009) defined irrigation scheduling as the use of water management strategies to prevent over application of water while minimizing yield loss due to water shortage or drought stress. Accurate water application prevents over- or under-irrigation. Over-irrigation wastes water, energy and labour. It leaches expensive nutrients below the root zone and out of reach of plants, reduces soil aeration and thus crop yields. Under irrigation stresses the plant and causes yield reduction. Without scheduling, there is no means of determining when irrigation is required. Deciding when to irrigate is based on knowing to what level soil moisture can be allowed to deplete without causing undue water stress to the plant. This soil moisture level varies with soil type and water demand of the crop (Burt et al, 2008). When sprinkler and drip irrigation methods are used, it may be possible and

Table 1. Procedure for estimating Irrigation Schedule for major crops for different soils and climates

Soil Type/ Climate	Comments
Shallow and/or sandy soil	In a sandy soil or a shallow soil (with a hard pan or impermeable layer close to the soil surface), little water can be stored; irrigation will thus have to take place frequently but little water is given per application.
Loamy soil	In a loamy soil more water can be stored than in a sandy or shallow soil. Irrigation water is applied less frequently and more water is given per application.
Clayey soil	In a clayey soil even more water can be stored than in a medium soil. Irrigation water is applied even less frequently and again more water is given per application.
Climate 1	Represents a situation where the reference crop evapotranspiration ETo = 4 - 5 mm/day.
Climate 2	Represents an ETo = 6 – 7 mm/day.
Climate 3	Represents an ETo = 8 – 9 mm/day.

Source: FAO (1998)

Table 2. Reference crop evapotranspiration (mm/day) for different climatic zones

Climatic zone	Mean daily temperature		
	Low (<15°C)	Medium (15-25ºC)	High (>25ºC)
Desert/arid	4 – 6	7 – 8	9 – 10
Semi-arid	4 – 5	6 – 7	8 – 9
Sub-humid	3 – 4	5 – 6	7 – 8
Humid	1 – 2	3 – 4	5 – 6

Source: FAO (1998)

practical to vary both the irrigation depth and interval during the growing season. With these methods it is just a matter of turning on the tap longer/shorter or less/more frequently. The methods used to determine the irrigation schedule are: plant observation, estimation and simple calculation. Theplant observation method is normally used by farmers in the field to estimate when to irrigate. The method is based on observing changes in plant characteristics, such as changes in colour, curling of the leaves and ultimately plant wilting. For theestimation method, a table is provided with irrigation schedules for the major field crops grown under various climatic conditions. Thesimple calculation method is based on the estimated depth (mm) of the irrigation application, and the calculated irrigation water need of the crop during the growing season. In Table 1 is detailed information on how to estimate irrigation schedule for major field crops during the period of peak water demand. The schedules are given for different crops in three different soil types and three different climates. The information adapted from FAO (1998) is based on calculated crop water needs and an estimated root depth for each of the crops under consideration. The calculation assumes that with the irrigation method used, the maximum possible net application depth is 70 mm.

With respect tosoil types, a distinction is made between sand, loam, and clay, which have, respectively, low, medium and high available water content. An overview indicating the climatic zones where ETo values can be found is given in Table 2. Irrigation schedules based on the crop water needs in peak period are given in Table 3

The irrigation schedule, which is obtained using Table 3, is valid for the peak period that is the mid-season stage of the crop. In order to save water, it may be feasible to irrigate, during the early stages of the crop development, with smaller irrigation applications than during the peak period. During the late season stage it

Table 3. Estimated irrigation schedules for major crops based on the crop water needs in the peak period

	Shallow and/or sandy soil				loamy soil				clayey soil			
	Interval (days)			Net irr. depth (mm)	Interval (days)			Net irr. depth (mm)	Interval (days)			Net irr. depth (mm)
Climate	1	2	3		1	2	3		1	2	3	
Alfalfa	9	6	5	40	13	9	7	60	16	11	8	70
Banana	5	3	2	25	7	5	4	40	10	7	5	55
Barley/Oats	8	6	4	40	11	8	6	55	14	10	7	70
Beans	6	4	3	30	8	6	4	40	10	7	5	50
Cacao	9	6	5	40	13	9	7	60	16	11	8	70
Carrot	6	4	3	25	7	5	4	35	11	8	6	50
Citrus	8	6	4	30	11	8	6	40	15	10	8	55
Coffee	9	6	5	40	13	9	7	60	16	11	8	70
Cotton	8	6	4	40	11	8	6	55	14	10	7	70
Cucumber	10	7	5	40	15	10	8	60	17	12	9	70
Crucifera*	3	2	2	15	4	3	2	20	7	5	4	30
Eggplant	6	4	3	30	8	6	4	40	10	7	5	50
Flax	8	6	4	40	11	8	6	55	14	10	7	70
Fruit trees	9	6	5	40	13	9	7	60	16	11	8	70
Grains, small	8	6	4	40	11	8	6	55	14	10	7	70
Grapes	11	8	6	40	15	11	8	55	19	13	10	70
Grass	9	6	5	40	13	9	7	60	16	11	8	70
Groundnuts	6	4	3	25	7	5	4	35	11	8	6	50
Lentils	6	4	3	30	8	6	4	40	10	7	5	50
Lettuce	3	2	2	15	4	3	2	20	7	5	4	30
Maize	8	6	4	40	11	8	6	55	14	10	7	70
Melons	9	6	5	40	13	9	7	60	16	11	8	70
Millet	8	6	4	40	11	8	6	55	14	10	7	70
Olives	11	8	6	40	15	11	8	55	19	13	10	70
Onions	3	2	2	15	4	3	2	20	7	5	4	30
Peas	6	4	3	30	8	6	4	40	10	7	5	50
Peppers	6	4	3	25	7	5	4	35	11	8	6	50
Potatoes	6	4	3	30	8	6	4	40	10	7	5	50
Radish	4	3	2	15	5	4	3	20	7	5	4	30
Safflower	8	6	4	40	11	8	6	55	14	10	7	70
Sorghum	8	6	4	40	11	8	6	55	14	10	7	70
Soybeans	8	6	4	40	11	8	6	55	14	10	7	70
Spinach	3	2	2	15	4	3	2	20	7	5	4	30
Squash	10	7	5	40	15	10	8	60	17	12	9	70
Sugarbeet	8	6	4	40	11	8	6	55	14	10	7	70
Sugarcane	7	5	4	40	10	7	5	55	13	9	7	70
Sunflower	8	6	4	40	11	8	6	55	14	10	7	70
Tea	9	6	5	40	13	9	7	60	16	11	8	70
Tobacco	6	4	3	30	8	6	4	40	10	7	5	50
Tomatoes	6	4	3	30	8	6	4	40	10	7	5	50
Wheat	8	6	4	40	11	8	6	55	14	10	7	70

* cabbage, cauliflower, etc.

Source. FAO (1998)

may be feasible to irrigate less frequently, in particular if the crop is harvested dry.

When planting on the soilless media, it is a different ball game as the media do not communicate with the entire soil mass and the irrigated water soon drains away such that irrigation frequency has to be increased but with less quantity of applied water. This study attempts to find a solution to the problems of irrigation schedule for some crops grown on soilless media which texture are close to sandy soil in greenhouse in Nigeria by modifying and using information adopted from FAO (1998). Tomato plantis used for this study due to its great importance and general consumption by majority of the citizens of the country.

Table 4. Steps taken in calculating the irrigation schedule

Step 1:	Estimate the net and gross irrigation depth (d) in mm.
Step 2:	Calculate the irrigation water need (IN) in mm, over the total growing season.
Step 3:	Calculate the number of irrigation applications over the total growing season.
Step 4:	Calculate the irrigation interval in days.

Source: FAO (1998)

Table 5. Approximate root depth of the major field crops

Shallow rooting crops (30-60 cm):	Crucifers (cabbage, cauliflower, etc.), celery, lettuce, onions, pineapple, potatoes, spinach, other vegetables except beets, carrots, cucumber.
Medium rooting crops (50-100 cm):	Bananas, beans, beets, carrots, clover, cacao, cucumber, groundnuts, palm trees, peas, pepper, sisal, soybeans, sugarbeet, sunflower, tobacco, tomatoes.
Deep rooting crops (90-150 cm):	Alfalfa, barley, citrus, cotton, dates, deciduous orchards, flax, grapes, maize, melons, oats, olives, safflower, sorghum, sugarcane, sweet potatoes, wheat.

Source: FAO (1998)

Table 6.Approximate net irrigation depths (mm)

Soil Type	Shallow rooting crops	Medium rooting crops	Deep rooting crops
Shallow and/or sandy soil	15	30	40
Loamy soil	20	40	60
Clayey soil	30	50	70

Source: FAO (1998)

MATERIALS AND METHODOLOGY

Tomato was grownon February 8, 2009 and seedlings were transplanted at an average height of about 12cm on February 20, 2009 inside a self-constructed home type greenhouse in six different soilless media inside polythene bags. The media were sterilized sawdust, washed sand, grinded coconut fibers and combinations of the three media in 1:1 ratio by volume. The volume of the medium in each bag was approximately 13 liters. The water holding capacity and air porosity of the growing media are detailed in Table 3.7. These parameters were determined volumetrically in the laboratory. The tomato was then irrigated by both sprinkler and drip irrigation systems. Water use at various growth stages was monitored. The experiment was repeated in June, 2009 when sowing was done on June 12 and transplanting was carried out on June 25, following the same method.

As there are few known standard research with data for estimating irrigation water scheduling for the numerous field crops grown in Nigeria as at present, the information adapted from FAO (1998) was modified and used for estimating irrigation water need and hence irrigation water scheduling in this study. Irrigation schedule was determined by the simple calculation method based on the total growing period as provided by FAO (1998). This was done by taking the steps given in Table 4.

From Table 5, the root depth or the gross irrigation depth (d) of tomato was chosen to be 50cm and the approximate net irrigation depth (dnet) from Table 6 is 30mm. The irrigation water need (in mm/month) for tomatoes, planted 20 February and harvested 30 June, as estimated for a similar climate with shallow and/ or sandy soil is as presented in Table 7, which sums up to 715mm/month.

Number of irrigation application over the growing season was calculated as

No. of application = Irrigation water needed over growing season/ 30(dnet) = 715/30
= 24

Irrigation Interval = Total growing season (days)/ No. of Application = 120/24 = 5 days

Volume of water required per plant per day was estimated from the following relationship:

Table 7. Monthly irrigation water need by tomato

Month	Water need (mm)
Feb.	40
March	120
April	170
May	200
June	185

Table 8. Volume of water used by each soilless treatment at various vegetative stages (liters)

	Sprinkler Irrigation			Drip Irrigation		
Treatment	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
	SM I	SM II	SM III	DM I	DM II	DM III
T1	12	48	25	7.9	14.4	6.4
T2	11	35	22	6.2	12.5	5.6
T3	13	41	20	6.8	12.2	6.2
T4	15	38	27	7.1	12.6	6.9
T5	12	36	18	5.6	12.2	6.0
T6	12	32	26	7.1	13.5	6.6
T1	12	46	24	6.9	15.1	7.2
T2	11	36	20	6.3	13.3	5.8
T3	14	37	25	7.0	13.3	5.9
T4	15	38	22	7.2	12.7	7.0
T5	11	36	21	5.8	12.5	6.3
T6	13	36	23	7.3	13.2	6.4
T1	12	46	20	7.2	13.9	6.8
T2	12	33	22	6.9	12.0	6.7
T3	11	35	27	6.7	13.4	6.1
T4	12	35	28	7.3	13.3	7.5
T5	11	29	26	6.5	12.6	6.1
T6	13	38	27	7.1	13.2	6.4

T1-T6 – Soilless media (3 replicates)
Stage 1 – Planting to the beginning of flowering
Stage 2 – Flowering to fruiting
Stage 3 – Fruiting to maturation and harvest

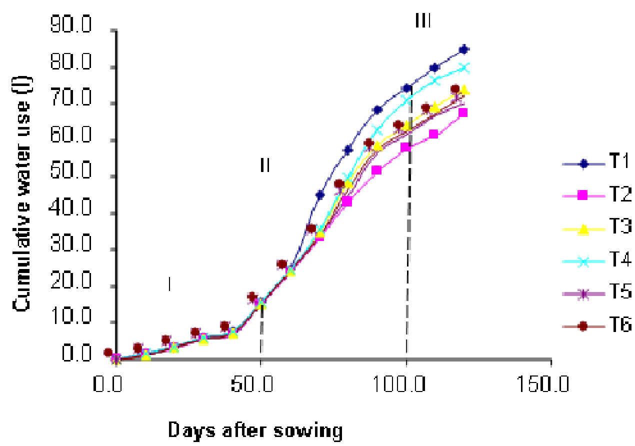

Figure 1.Water used by treatments at various growth stages of tomato under sprinkler irrigation.

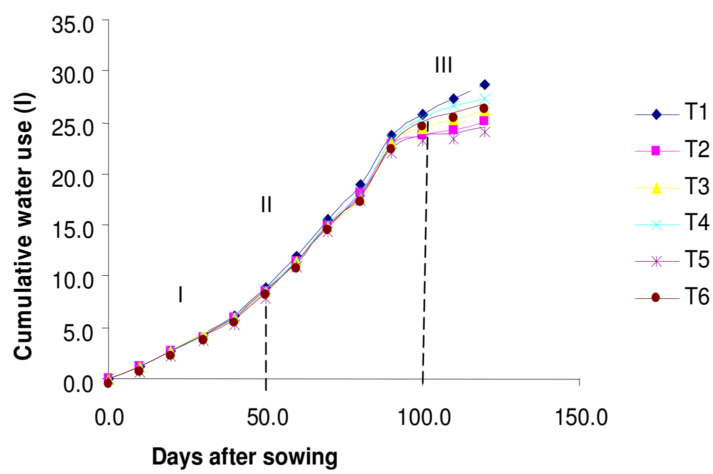

Figure 2. Water used by treatments at various growth stages of tomato under drip irrigation.

Volume of water required/plat/day = (ET_p * area/crop)/E_n …………… (4)

Similarly , $ET_p = ET_0 * P/85$ …….. (5)

where ET_p= Peak evapotranspiration rate for the month under consideration (February)

ET_o = Reference evapotranspiration rate for the month = 8 mm/day (estimated, Table 2.3)

P = percentage of total area shaded by crop which is close to 80% based on Ewemoje et al. (2004) studies.

With all the values inputted into equation 5,

ET_p = 7.53 mm/day.

Area/crop = surface area of bag = 0. 0283m^2

Volume of water/ plant/day = 7.53 x 0.0283/0.95 = 0. 22l/plant/day. Because the media do not communicate with soil mass and water soon drain out of the drainage holes at the bottom of each bag, this value was increased by a factor of safety which was chosen to be 2.

Therefore, volume of water/plant/day during the peak period was 0.44l/plant/day which was adjusted for early and late season of tomato and type of soilless medium.

RESULTS AND DISCUSSIONS

The irrigation water need of tomato was 715mm/month while irrigation interval and numbers of application were 5days and 24 respectively. Since the media were not soil mass but rather isolated from the ground water, the applied water soon drain away because of the drainage holes at the bottom of the bags containing the media, number of application was therefore increased for different growth periods with the same number of irrigation water to have different number of fertigations per day under both irrigation systems with respect to the different growth stages and efficiencies of the two irrigation systems. These values were also used for estimating the irrigation scheduling for tomato during the second planting in June. A summary of the volume of water used by each soilless medium under each irrigation system at various growth stages for the two growing periods is presented in Table 8. Water used in stage II which is the period between the start of flowering and fruiting is significantly higher (at 0.05 LS) than the one used in stages I& III under both sprinkler and drip irrigation systems. Under the sprinkler irrigation, water used in stage III is higher than that of stage I whereas under drip irrigation this trend was reversed. This could be attributed to wastage of water in stage III under sprinkler due to interception by leaves and shoots of tomato before getting to the soilless medium. This trend could also be due to lower Coefficient of Uniformity of the sprinkler. These arguments are probably responsible for the general increase in total water applied under sprinkler as compared to the drip for all the growth stages. The daily usage of water at various growth stages were added together every 10 days over the growing period to yield a curve of cumulative water use versus days after sowing (DAS) for the sprinkler and drip systems as depicted by Figures.1 and 2 respectively. Both curves are sigmoidal and bear close resemblance to the one reported in FAO (2010) paper which was presented with sharp lines instead of smooth curves. It could be deduced that the sprinkler irrigation used 3 times the amount of water used by the drip irrigation. The quality of fruit reduced under the sprinkler system but the total yield was not affected.

CONCLUSIONS AND RECOMMENDATIONS

The FAO (1998) information on water scheduling for some major crops under different soil types and climates was able to provide adequate, relevant and necessary data for estimating the irrigation water scheduling for tomato grown on soilless media inside a greenhouse after some careful modifications. It is hoped that information provided by this study will be well useful for similar future works.

REFERENCES

Azah CH (2009). Design of a geograghic information supported plantation. Thesis presented for IngenieurAgronome Diploma. Dept. of Agricultural Engineering, Plantation du Haut Penja, Cameroon+xii.

Broner I (2005). Irrigation Schelduling.*Colorado State University Extension – Agriculture Bulletin*. 4.709: 344-432.

Burt C, Canessa P, Schwankl L , Zoldoske D (2008). Water Conservation report Drew in Correct Conclusions. Commentary on Farm Bareau Federation.Issued on Jan. 28, 2009.

Ewemoje TA, Adewole OA. , Enujowo OO (2004).Design, construction and performance evaluation of a drip irrigation system.*Proceeding of the 5th International Conference of Nigerian Institution of Agricultural Engineers*. 26: 184-188.

FAO (1998). Irrigation Water Management: irrigation scheduling. Natural Resources Management and Environment Department.

FAO (2010). Water Development and Management unit retrieved 15 Aug. 2010 from http:/www.fao.org/nr/water/cropinfo_tomato.html

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