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IRRIGATION SCHEDULE OF ACTUAL VERSUS ESTIMATED EVAPOTRANSPIRATION ON VEGETABLE SOYBEAN (*GLYCINE MAX* L.) AGS - 292

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Abstract

Scheduling of irrigation to crops is essential for efficient utilization of available water, saving of input and enhancing yield. The study was aimed to investigate the efficient water use based on soil moisture measuring methods and to evaluate the interactions between actual and estimated water requirement on vegetable soybean field of VFRDC. According to soil analysis, the soil type is sandy loam soil. Soil sample was collected daily for measuring actual water requirement of vegetable soybean by Gravimetric method. The estimated evapotranspiration (ET_0) of Blaney & Criddle was compared to CROPWAT method. The climate data had also recorded such as temperature, humidity, wind and sunshine hours. Crop water requirement was measured by the method of Blaney & Criddle (1950) which is suitable method for the most of crops in Myanmar. A comparison was made between estimated crop water consumption versus actual water consumption. The result of this study showed that in young stage of crop, actual crop water consumption and estimated crop water consumption were almost equal level, but when plants became mature, the actual crop water consumption was higher than the estimated one. Based on this investigation, it must be concluded that the temperature based method for estimated crop water requirement, Blaney and Criddle method, is the most suitable in Myanmar for irrigation schedule.

Introduction

Vegetable soybean belongs to the division Magnoliophyta, Class – magnoliopsida, Order – Rosales and Family Fabaceae, it involved has about 400-500 genera and 10,000 species. Vegetable soybean is botanically called *Glycine max* (L.). Soybean originated from China, and it had been one of the most economically important crops in the world. It was cultivated since 5000 years ago. Recently its cultivation extends from temperate to tropical countries (Xo, 1999). Soybean can be classified into two groups. The first group is grain type which is employed mainly in the bran and oil production, with medium grain size [one hundred seed weight (HSW) varying among 10 to 19 g], however, have undesirable flavor. The second group is denominated

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food type, with flavor taste, constituted by two subgroups, the first with HSW smaller than 10 g, consumed in the sprouts form and natto (fermented) and the second with HSW presenting 20 g or more, being consumed directly by human principally in the immature pod form (Fehr and Caviness, 1977), snack, being denominated vegetable soybean, green soybean or edamame; presenting also the subgroups denominated sweet soybean (Kuromame) and salad soybean. Vegetable soybean requires large amount of water for growth especially during flowering to pod filling stages. Maintaining proper soil moisture throughout the growing season is important for good quality pods. Insufficient water during this period will cause flowers and pods drop developed pods (Nguyen, 1997). However, excessive soil moisture will inhibit root activity resulting of slow growth and delay flower period, so flooding the plants should be avoided. Usually, first irrigation is needed within a week and seeds need moist soil but not wet for their germination, therefore, furrow irrigation up to half or three-quarters of the height is common practice. Depending upon weather and soil moisture conditions, the irrigation is continued at 7-10 day intervals until the pods are well developed. Irrigating the crop is essential at critical periods such as flowering and pod filling stages (Javier, 1991). Maintaining proper soil moisture throughout the growing season is important for good quality pods. The soil must be moist, but not wet, until the pods have matured. Water should be irrigated into 1–2 times/week. Most roots are in the upper 1 ft (30 cm) of soil but root penetration and water extraction take place to 1 to 3 inches (2.54-7.62 cm) depth (Srinives, 1989). Irrigation is one of the most important factors in world agricultural development. Irrigation water requirement using the Cropwat model is a FAO model for irrigation management designed by Smith which integrates data on climate, crop and soil to assess reference evapotranspiration (ETo), crop evapotranspiration (ETc) and irrigation water requirements. Water requirement depend mainly on the nature and stages of growth of the crop (Initial stage, Crop development stage, Mid-season stage and Late-season stage approach) and environmental conditions (Allen *et al.,* 1998). Crop Water Requirement (CWR) is defined as the depth of water needed to meet the water loss through evapotranspiration of a crop (FAO, 1984). Application depth means the amount of water used when irrigating. It is often expressed in millimeters. The control of infiltration and runoff, which is a common problem for farmers, is essential to effectively control the depths of the water to be applied (Pereira, 1996). Irrigation scheduling techniques can be based on soil water measurement, meteorological data or monitoring plant stress. Conventional scheduling methods are to measure soil water content or to calculate or measure evapotranspiration rates. The moisture content of the soil is the most important factor to consider in irrigation scheduling. Soil moisture affects not only plant growth but also the success of seedling, cultivation and harvesting operations (Brady, 1974). There are many methods for measuring soil moisture, including gravimetric, tensiometric, electrical and soil feel methods. A standard method for measuring water content is the gravimetric method. Crop water use or consumptive use, also known as evapotranspiration (ET_c), is the water used by a crop for growth. The method for estimated calculation of crop water requirement has many methods. The most widely and suitable use of method is Blaney and Criddle method (1950).

The aims and objectives of this research paper are to investigate the efficient water use based on soil moisture measuring methods and to evaluate the interactions between actual and estimated water requirement on vegetable soybean under field cultivation.

Materials and Methods

Experimental Site

The experiments were conducted at the farm of Vegetables and Fruits Research and Development Centre (VFRDC), Hlegu Township, Yangon Region. It is located at 17° 5' North Latitude and 96° 15' East Longitude and its annual average rainfall is 8.95 inches.

Experimental Lay out

There are 20 plots in this experiment. One plot containing 4 rows and each row had 10 plants. The plot size was 360 cm x 180 cm. The spacing between plants and between rows were 30 cm each. Total experimental area was 1772633 cm^2 (Fig. 1).

Cultivation Practices

For vegetable soybean plantation, plough was done one month before planting. Furrow irrigation was done before sowing the seeds at three quarter of the height of experimental plots. Inorganic fertilizer (0:50:0) were applied as basal during land preparation. Side dressing with NPK 50:0:50 were applied at 30 and 40 days after sowing.

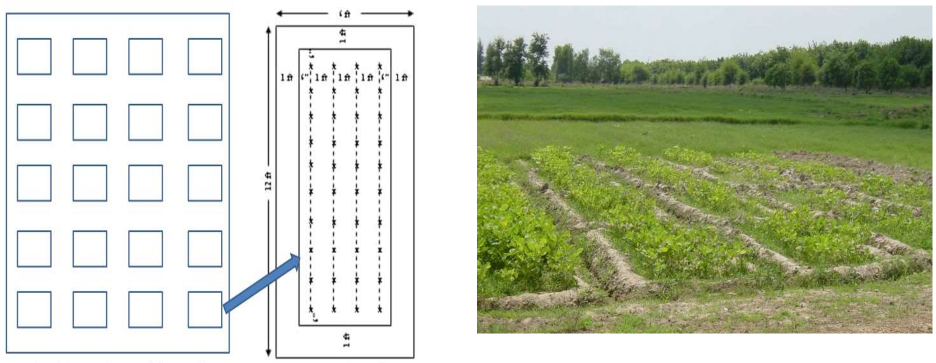

Fig 1. Experimental layout for crop water consumption of vegetable soybean

Culture Condition

The vegetable soybean was first germinated within the(90cm x 120cm) size polyethylene bag in the nursery. After one week, germinated seedlings were transferred to the experimental plot. Before transplanting the seedlings, the soil was irrigated.

Actual Crop Water Requirement

The soil samples were taken in every two days after watering by Gravimetric Sampling Method (Dastane, 1972). For determining bulk density, the soil samples were taken from every corner of each plot. These samples were weighed and placed in the soil sample container, dried in hot air oven at 104°C until the soil samples get constant dried weight and then reweighed.

The bulk density is computed using the following equation.

$$\text{Bulk density, g/cc} = \frac{\text{Dry weight}}{V}$$

where V = soil sample container volume.

For measurement of soil moisture content percent by weight, soil moisture content percent by volume and water depth, the soil samples were taken diagonally three times from each plot with boring stick at a depth of 1 ft (30 cm).These samples were weighed and then dried in hot air oven at 104°C until the soil samples get standard dried weight and then reweighed (Dastane, 1972).

$$\text{Soil moisture content percent by weight} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

Estimated Crop Water Requirement

Blaney and Criddle method is the widely and suitable method for crop water requirement in Myanmar. The following equations are used for estimation.

$$\mathbf{U = K\,f}$$

where, U = monthly evapotranspiration or consumptive use
K = crop coefficient
f = climatic coefficient

$$\mathbf{f = t\,p / 100}$$

where, t = temperature, °F
p = day time hour

$$\mathbf{K = K_t\,K_c}$$

where, K_t = temperature coefficient

$$\mathbf{K_t = 0.0173\,t - 0.314}$$

K_c = standard crop coefficient

CROPWAT method (Version 8.0)

Crop water requirement is also estimated by using CROPWAT computer program for irrigation planning and management. CROPWAT 8.0 for Windows is a decision support tool developed by the Land and Water Development Division of FAO in 2006. It is used for the calculation of crop water requirement and based on soil, climate and crop data.

Data Collection

Monthly data on temperature, humidity and average rainfall were collected. Soil sample was also collected 2 days after irrigation until the next irrigation (wilting point). Dry and wet weight of soil sample was measured and the moisture content and water depth was calculated in every sample collection time.

Results

The growing period can be divided into four distinct growth stages

(Fig. 2): initial, crop development, mid-season and late season.

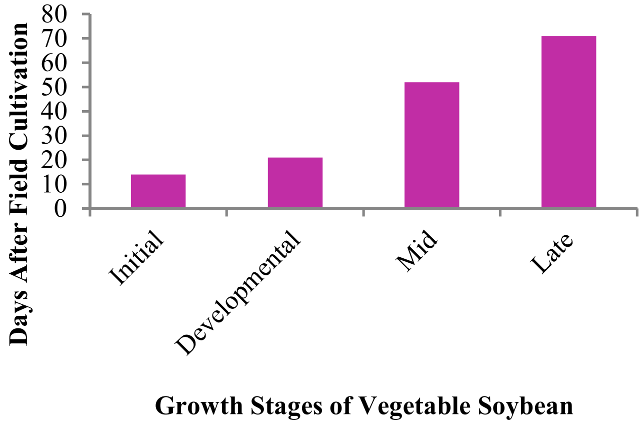

Fig 2. Growth stages of vegetable soybean

Crop water requirement at growth stages of vegetable soybean

Two days after irrigation, wet weight, dry weight, moisture content and water depth in the soil sample of the five plots were recorded until next irrigation time. The required data and the result of ET_c (actual crop water consumption) at initial, developmental, mid and late stages were shown in Tables (1, 2, 3 and 4).

Table 1. Soil sample collection for actual crop water consumption at initial stage (14-21 DAFC (Days after field cultivation)

Plot	Initial Stage (Mean)			
	Wet	Dry	MO	WD
1	48.25	44.45	12.24	1.47
2	50.03	46.10	12.21	1.42
3	49.00	45.05	12.56	1.51
4	49.58	46.08	10.88	1.31
5	50.03	46.28	11.60	1.39
Total	246.89	227.96	59.49	7.10
Mean	49.38	45.59	11.90	1.42

Wet = Wet Weight in Soil Sample MO = Soil Moisture Percent by VolumeDry = Dry Weight in Soil Sample WD = Water Depth, (inch)

Table 2. Soil sample collection for actual crop water consumption at developmental stage (21-50 DAFC)

Plot	Developmental Stage (Mean)			
	Wet	Dry	MO	WD
1	45.10	42.48	8.83	1.06
2	50.75	47.75	9.00	1.08
3	49.55	39.53	36.30	4.36
4	47.35	38.08	34.86	4.18
5	49.45	40.70	30.79	3.69
Total	242.20	208.54	119.78	14.37
Mean	48.44	41.71	23.96	2.87

Table 3. Soil sample collection for actual crop water consumption at mid stage (51-70 DAFC)

Plot	Mid Stage (Mean)			
	Wet	Dry	MO	WD
1	53.73	48.60	15.12	1.81
2	48.43	43.98	14.49	1.74
3	54.83	49.28	16.13	1.94
4	46.38	42.25	14.00	1.68
5	45.70	38.38	27.31	3.28
Total	249.07	222.49	87.05	10.45
Mean	49.81	44.50	17.41	2.09

Table 4. Soil sample collection for actual crop water consumption at late stage (71-90 DAFC)

Plot	Late Stage (Mean)			
	Wet	Dry	MO	WD
1	48.98	36.23	50.39	6.05
2	48.48	45.73	8.61	1.03
3	45.85	36.15	38.42	4.61
4	42.03	35.38	26.92	3.23
5	46.10	43.48	8.63	1.04
Total	231.44	196.97	132.97	15.96
Mean	46.29	39.39	26.59	3.19

Comparison of Actual water use and Estimated water use

Based upon the daily temperature, the estimated daily crop water consumption was calculated by Blaney and Criddle method. Actual crop water consumption or ET_c and estimated crop water requirement were also calculated by gravimetric method and Blandey and Criddle method (Table 5, Fig. 3 and 4).

Table 5. Comparison of Actual water use and Estimated water use of Gravimetric Method and Blaney & Criddle method

Growth Stage	Actual (mm)	Estimated (mm) (Blaney & Criddle)
Initial Stage	36.04	36.58
Developmental Stage	26.50	26.42
Mid Stage	43.65	36.58
Late Stage	28.83	20.24

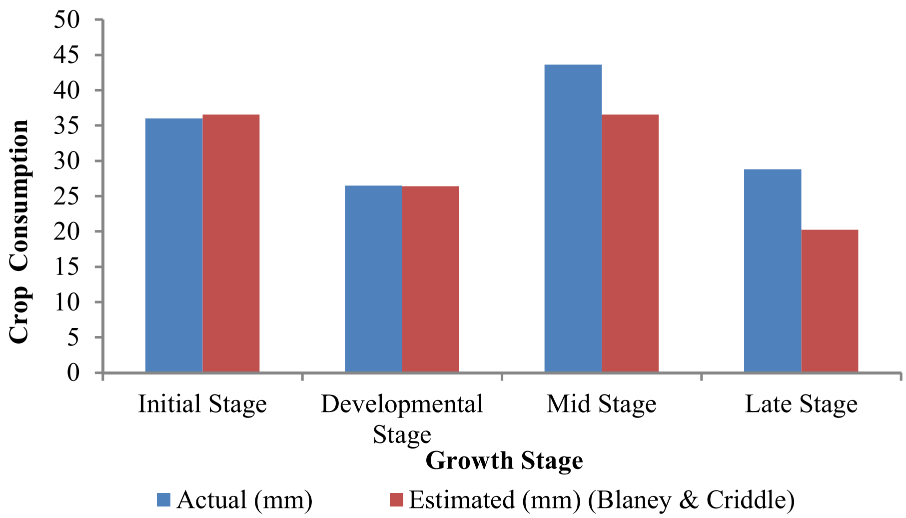

Fig 3. Comparison of crop water consumption of vegetable soybean at different growth stages by actual and Blandy and Criddle methods

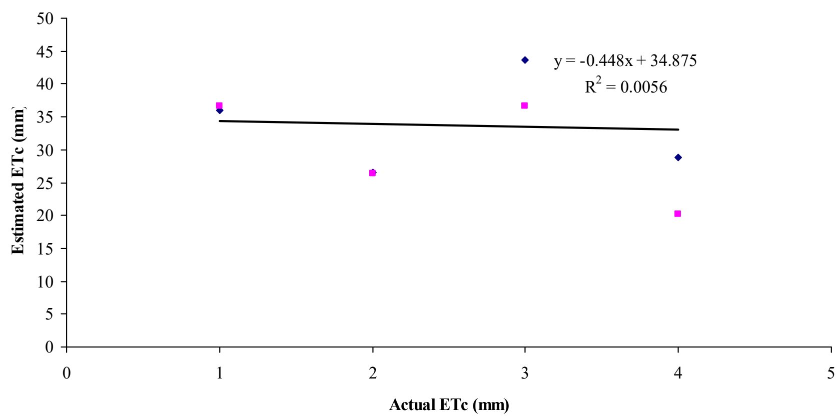

Fig 4. Linear regression graph showing the comparison of actual and estimated (Blaney & Criddle) ET_c (mm)

Comparison of CROPWAT and Blaney and Criddle for ET_c

Another methods used in this experiment are CROPWAT and Blaney and Criddle. These methods are used to measure for evapotranspiration rate of crop. When measure at the initial growth stage of crop, the Blaney and Criddle had crop water consumption of 36.58 mm and the CROPWAT had 30.25 mm. In developmental stage, Blaney and Criddle had 26.42 mm while in CROPWAT had 57.33 mm. Blaney and Criddle and CROPWAT had 36.58 mm and 50.50 mm at mid stage. At the late stage, Blaney and Criddle had higher ET_c (20.24 mm) than CROPWAT (17.60 mm). The difference was also presented in (Table 6 and Fig. 5).

Table 6. Comparison of Actual and Estimated (CROPWAT and Blaney and Criddle) Methods for water consumptive use (mm)

Growth Stage	Actual	CROPWAT	Blaney and Criddle
Initial stage	36.04	30.25	36.58
Developmental stage	26.50	57.33	26.42
Mid stage	43.65	50.50	36.58
Late stage	28.83	17.60	20.24

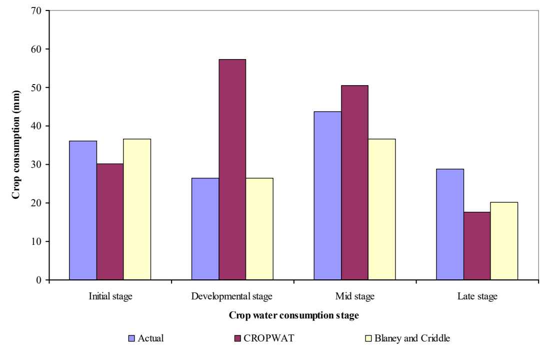

Fig 5. Comparison of crop water consumption of vegetable soybean at different growth stages by actual, CROPWAT and Blandy and Criddle methods

Discussion and Conclusion

The results showed that between two methods, the estimated water consumption of Blaney and Criddle method was more closed to the actual water consumption of vegetable soybean at any growth stage. These were 36.04 and 36.58 at initial stage; 26.50 and 26.42 at developmental stage; 43.65 and 36.58 at mid stage and 28.83 and 20.24 at the late stage while the value of CROPWAT was not associated with the actual water consumption of crop (30.25 at initial stage, 57.33 at developmental stage, 50.50 at mid stage and 17.60 at late stage). According to results of these measurements, CROPWAT had higher evapotranspiration rate than Blaney and Criddle method. The correlation of actual water consumption and estimated consumption of Blaney and Criddle was 0.005. Linear regression is correlated between -1 and 1 (http//brohrer.github.io). Therefore actual water consumption and estimated consumption of Blaney and Criddle was correlated. It is therefore suggested that the Blaney and Criddle method could substitute for actual water consumption of crop. The calculation of actual water consumption requires daily soil sample collection, drying of collected soil in an oven. If the consideration intended to the cultivators or to the arid areas which had scarcity of water, or to the required materials and so on, the Blaney and Criddle method was the most suitable and reliable method. Blaney and Criddle method is simple, using measured data on temperature only (www.fao.org). In CROPWAT, input data used are climatic data (temperature, humidity, sunshine duration, wind speed and rainfall, crop data and soil categories (www.thematrixit irrigationit lessons). The CROPWAT had higher

ET_c values when compared to Blaney and Criddle, there might be due to the climatic factor requirements. CROPWAT had higher climatic factor requirements but modified Blaney and Criddle is only T°-based method. Therefore, there has a suggested that if all the climatic data is available, CROPWAT formula can be used to measure ET_c. If temperature (T°) data is only available, the Blaney and Criddle formula is suitable to use to estimate ET_c. Crops are different in their response to water stress at a given growth stage. Crops summarized according to their sensitivity to water stress at various growth stages reveal the importance of these stages in making the irrigation decision (Karam *et al*., 2004). It can also express that if the mean temperature know, percent of annual day time hours can be calculated based on latitude data that is easily available for users. Mean temperature can be obtained easily at anywhere, therefore, temperature based modified Blaney and Criddle method can be used throughout the country. The user should be checked up with actual and estimates according to their location and eliminate condition. According to the observation, Blaney and Criddle method is well suited for vegetable soybean. It can be concluded that the irrigation schedule uses daily meteorological data as inputs to calculate evapotranspiration. It also contains a water balance ledger to keep track of water removed from the soil and water added to the soil. Irrigation is predicted according to how long it would take, to deplete the moisture remaining in the soil. The model will either save the farmer on water resources, energy and labour, or will increase his yield and income on less irrigated land. Vegetable soybean production in Myanmar is still low compare to other countries due to the lack of the applied methods. If the estimated methods can be used properly, the yield will be increased. Among methods, the Blaney and Criddle method is suitable for Myanmar because it is temperature based method and low equipment of other factors. It is therefore hoping to help the yield and income of cultivators which will also provide the national economy.

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Websites (1) www.fao.org

(2) www.thematrixit irrigationit lessons)

(3) http//brohrer.github.io