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Water Requirements in Bean Crops Using Cropwat 8.0 in Oenoni Village Kupang District, Indonesia

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ABSTRACT

A study has been carried out to plan the provision of water in the cultivation of green beans based on Cropwat analysis. Climatology data was obtained from BMKG Kupang Class II Climatology Station which included rainfall, minimum temperature, maximum temperature, relative humidity, wind speed, and duration of sun exposure. The data needed is the result of observations for five (5) years, with the period 2014 to 2018 for the Regency of Kupang. Data processing in this study uses 4 main panels in the Cropwat 8.0 program, namely Climate / ETo (climate data) is input data in the form of monthly average maximum air temperature and minimum air temperature, the average month-long sun exposure, and monthly average humidity. The climate data input is used to estimate ETo and the magnitude of the value of solar radiation. Rainfall data to determine effective rainfall with the input of average monthly rainfall over the period 2014-2018. Plant data are plant characteristics and the time of the start of the plant season. Data on plant characteristics referred to are Kc (Plant growth coefficient), length of day for each phase, root depth, plant height, and soil type. The results showed that crop evapotranspiration (ETc) using Cropwat 8.0 software was 270.8. with the highest actual crop evapotranspiration achieved in October of the third period of 4.44 mm and the lowest in October of the second decade of 2.6 mm. The highest irrigation water demand is in the second decade of September at 38.7 mm and the lowest in October the third period at 1.6 mm. These results are quite in accordance with the conditions in the field to plan the start of the growing season. However, daily irrigation operations need to be carried out based on observing actual conditions in the field to maintain groundwater levels in the appropriate range for plant growth.

Key words : *Green beans, Cropwat, Water requirements, Oenoni Village*

Introduction

Green beans (*Phaseolus vulgaris* L.) is one of the important vegetable commodities whose production needs to be improved to improve people's nutrition because it has a high enough nutritional content as a source of vegetable protein with a protein content of approximately 35.1%. Green beans are also useful for expediting the digestive system, stimulating the immune system naturally, neutralizing blood sugar and preventing colon cancer, and being able to reduce the risk of malignant cancer (Cahyono, 2003; Julharfandi, 2011). The part of the bean plant that is utilized is the pod. Young bean pods are usually cooked for "lodeh" or stir-fried vegetables while old pods (seeds) are often used for fried chili sauce (Rukmana, 1998).

From statistical data on vegetables and fruits in Indonesia in 2018, it is known that the harvested area is 25,014 hectares with 304,477 tons of

production, with a production of 12.17 tons / Ha, (BPS, 2018). Increasing bean production can only be done with intensive cultivation, by utilizing the production factors optimally.

Irrigation is one of the most important production factors in the cultivation of annual crops. Green beans can be planted in the rainy season and dry season. In dry weather, water availability is a factor that must be taken into account properly, so that soil moisture reserves are maintained because the lack of soil moisture reserves in the form of water stress affects plant yields and performance in each phase of its growth. Beans have a relatively shallow root structure. Such morphological characteristics cause beans to be sensitive to soil moisture content deficits (Pitono, *et al.,* 2007 Setiawan, *et al.,* 2013)

Irrigation water demand is equivalent to the use of consumptive plants. Consumptive use is the total amount of water consumed by plants for evaporation, transpiration, and metabolic activity of plants, and is often referred to as plant evapotranspiration. The total evapotranspiration of plants during the growing period of plants that must be met by irrigation water supply is influenced by many factors, including the type and age of plants, growth phases, and solar radiation. Cumulative water evapotranspiration of plants depends on the amount of moisture, temperature, humidity, wind speed, radiation intensity, and morphological type of leaves.

CROPWAT 8.0, is a Windows-based computer application program used for the calculation of crop water requirements and irrigation requirements based on soil, climate, and plant data. In addition, the program allows the development of irrigation water scheduling for different management conditions and water delivery schemes for various crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and estimate irrigation performance both for rain conditions and without rain, (FAO, 2020).

Calculation of crop water needs and irrigation water requirements are calculated at 10 daily intervals (ten daily). Irrigation water demand is the difference between plant evapotranspiration (ETc) and effective rainfall (Peff) in each period. Irrigation is basically the addition of water that serves to meet the water needs for plant growth expressed by the amount of plant evapotranspiration (Sapei and Fauzan, 2012). The values of Kc and Peff are different in each period because they have been interpolated automatically by the system contained in the CROPWAT 8.0 software.

Oenoni Village, is an area of vegetable production centers, including beans. Cultivation activities were carried out at the beginning of the dry season, with irrigation practices that do not save water. Irrigation practices that do not save water are indicated by the excessive water supply, even though water is a very limited resource in the East Nusa Tenggara region which is generally a semi-arid area.

Based on the problems above, the application of water for beans is examined by referring to the schedule/amount of irrigation water from the calculation of the COROPWAT 8.0 application program, based on the growth phase of beans.

Materials and Methods

This research was conducted in 2 stages, namely: Phase 1 study, making a schedule of water supply based on the results of the analysis of the CROPWAT 8.0 application program, and stage 2, which was field trial testing.

First Stage of Study

In the first study, we need climate data in the form of rainfall data, minimum temperature, maximum temperature, relative humidity, wind speed, and sun exposure time. The data needed is daily data for 5 years, from 2014 to 2018. The data source was obtained from BMKG Class II Climatology Station, Lasiana Kupang.

Data processing techniques in the Phase 1 study, used 4 main panels in the CROPWAT 8.0 program, namely Climate / ETo (weather data), Rain (rain data), Crop (crop data), and Soil (soil data). Climate factor data which is still in the form of daily data is made into daily baseline data, so the input data on the panel is daily basic data (10 daily data).

The results of the application process are obtained by analyzing crop water requirements in the last panel CWR (Crop Water Requirements) and Schedule. Analysis of the first phase of the study, conducted in May 2019.

Phase Two Study

The second phase of the study was field testing with 76 bean plants. This stage, begins with land preparation, making beds as many as 2 beds with a size of 1.2 mx 8.5 m, height of beds 0.30 m, the distance between beds 0.3 m, spacing of planting holes in beds 0.7 mx 0.4 m, with 1 seed per hole.

Ingredients used var bean seeds. lux 3 of the Chia Tai Seed trademark, irrigation water according to the reference of water supply, fertilizer, and medicine. The equipment used includes cultivation equipment and analytical scales. Phase 2 of the field experiment was conducted in Oenoni 1 Village, Amarasi District, Kupang Regency. The implementation will take place from the beginning of June 2019 until the end of October 2019.

The data needed in the second phase of the study is data on crop production from each individual plant, so that production data from 76 plants are obtained during 6 harvests. The results of data collection were analyzed with a simple statistic in the form of production standard deviation to determine the productivity bias of each plant.

Results and Discussion

Analysis of Potential Evapotranspiration, Effective Rain and Plant Characteristics

The results of the potential evapotranspiration analysis from the input of climate factors (air humidity, exposure time, minimum-maximum temperature, and wind speed) are known in Table 1.

From the results of calculations with the CROPWAT 8.0 application program, it is known that the highest evapotranspiration potential occurred in May, amounting to 4.84 mm/day. The lowest was in October at 2.63 mm/day. This is odd, but the average irradiation length in October is only 2.4 hours, the possibility of many clouds forming which prevents solar radiation, and also relatively low wind speeds.

Rainfall plays an important role in plant growth and production. Photosynthesis will decrease if 30% of water content in leaves is lost, then the process of photosynthesis will be stopped if water loss reaches 60% (Tjasyono, 2004). Sahirudin, *et al.* (2014), an assessment of the efficiency of water needs must analyze effective rainfall, irrigation water requirements, and irrigation water availability.

Based on Table 1, it is also known that the average annual effective rainfall is 928.6 mm. The highest average effective rain occurred in January at 176.8 mm and the lowest in August at 6.1 mm.

Based on the analysis using CROPWAT 8.0 software, it shows that the bean plants have the following plant coefficients (*Kc*) as follows: initial and development stages 0.50, mid-season 1.05, and late season 0.90. The initial period is 20 days, 30 days of development, 30 days mid-season, and 10 days a late season. Plant age up to 90 days or 14 weeks of production.

Crop Water Needs and Actual Irrigation in Bean Plants

Based on the application output Cropwat 8.0 plants begin to require irrigation in the second decade from May to the end of October. Soil with a deficit of moisture that exceeds the allowable limit will inhibit plant growth and reduce the quality of the beans produced. Calculation of water needs and scheduling according to daily time can be presented in Table 2.

Table 1. Results of ETo and Effective Rainfall Based on Meteorological Data

Month	Rainfall (mm)	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	Eto mm/day	Effective Rainfall (mm)
Jan	518.4	25.0	31.0	84	7	5.2	15.2	3.18	176.8
Feb	343.8	24.3	30.3	84	5	6.6	18.3	3.74	159.4
Mar	283.6	24.4	30.4	85	5	7.8	21.2	4.34	153.4
April	73.6	24.8	30.8	78	6	8.2	22.2	4.51	64.9
May	38.2	23.9	31.9	73	9	9.8	24.1	4.84	35.9
June	8.0	23.1	31.6	70	9	8.2	21.3	4.26	7.9
July	24.0	22.6	30.6	70	10	9.6	23.5	4.55	23.1
Augt	6.2	22.5	30.5	67	9	9.6	24.0	4.56	6.1
Sept	17.6	24.0	30.0	69	7	9.4	23.6	4.51	17.1
Oct	31.8	25.6	31.6	69	7	2.4	12.3	2.63	30.2
Novr	113.8	25.9	31.9	75	5	8.8	20.4	4.06	93.1
Dec	357.9	25.5	31.5	83	5	5.6	15.4	3.19	160.8
Total	1816.9	24.3	31.0	76	7	7.6	20.1	4.03	928.6

Source: CROPWAT 8.0 application analysis *results*

Table 2. Irrigation in Green Beans at CROPWAT 8.0

Month	Dec	Stage	Kc Coeff	Etc mm/day	Etc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec	Act Irg. ml/day
Jul	3	Initial	0.50	2.28	11.4	3.1	8.0	32
Aug	1	Initial	0.50	2.28	22.8	3.1	19.7	79
Aug	2	Development	0.52	2.39	23.9	0.7	23.1	92
Aug	3	Development	0.67	3.03	33.3	2.4	30.9	124
Sep	1	Development	0.82	3.84	38.4	4.4	34.0	136
Sep	2	Mid-season	0.94	4.44	44.4	5.7	38.7	155
Sep	3	Mid-season	0.95	3.82	38.2	7.1	31.1	124
Oct	1	Mid-season	0.95	2.85	28.5	7.0	21.4	86
Oct	2	Late season	0.92	2.06	20.6	7.7	12.9	52
Oct	3	Late season	0.82	2.34	9.4	5.6	1.6	6,0

Source: Results of CROPWAT 8.0 application analysis and analysis of actual needs.

The magnitude of the reference for water supply in July 3rd decade was 8.0 mm/decade/plant which tended to increase until the middle period, namely in September 3rd decade, 38.7 mm/decade/plant. The medieval period is the formation of fruit so beans need a lot of water. At the end of the middle period, it declines to the end of October 3rd decade, where plants show signs of being framed.

Based on data obtained from Table 2, an experiment was carried out on plants to determine the production produced by referring to the actual irrigation of individual plants per day starting with 32 ml/day in the initial phase in July 3rd decade, and increasing at its peak in the mid-season in September 2nd decade was 155 ml/day and again decreased to. 6.0 ml/day in the late season phase in October 3rd decade.

Fluctuating bean crop production every harvest, the harvest is carried out 6 times, which starts at the mid-2nd stage (September 3rd decade) until the first final stage (October 2nd decade), with a time interval of harvest 3 days. At the final stage, there was still the production of beans but not calculated in this study, because the performance of the fruit produced was not uniform, many were small. Production of beans for 6 harvest periods, presented in Table 3.

Land productivity with water treatment that refers to the water needs of plants provides bean production that varies at each time of harvest. The lowest production in the sixth harvest, with an average production of 105 g/plant. The highest production occurred at the 4th harvest with an average production of 329 g/plant. The standard deviation of the products for each harvest is different, but at the peak of production in the 3rd and 4th harvest, the standard deviation of production is getting smaller, which indicates that the diversity of production bias is getting smaller.

The results obtained are relatively greater than those produced by farmers in Oenoni, because the yields of farmers are an average of 200 kg, whereas in this study yielded 351 kg, or equivalent to 35 tons/ha.

Conclusion

From the results and discussion, it can be concluded that:

1. Reference for giving irrigation water to beans in Oenoni Village in ml / day / plants as follows: July 3 = 32, August 1 = 79, August 2 = 92, August 3 = 124, September 1 = 136, Sep-

Table 3. Production of beans for 6 harvest periods

Production	The Harvest Period						Total
	1	2	3	4	5	6	
gram / plant	197	263	316	329	197	105	1.048 gram
kg / 76 plants	15	20	24	25	15	8	170 kg
Sx	20,76	7,85	5,79	5,38	21,08	9,71	Sx rerata=11,60

Source: Primary data processed.

tember 2 = 155, September 1 = 124, October 1 = 86 October 2 = 52, October 1 = 6

2. Total plant production per plant individual is 1,048 g, with a standard deviation of 6 harvests of 11.60.

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