Journal of Nature Studies 12 (2): 11-17
ISSN: 2244-5226

Field Monitoring System and Analysis of Rainfall Data for Tomato Cropping Calendar in Batac City, Ilocos Norte, Philippines

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ABSTRACT – Using a Field Monitoring System (FMS), a demonstration study on soil moisture monitoring was conducted in a tomato field in 16N, Quiling Norte, Batac City, Philippines. The FMS consisted of an intelligent sensor node which is capable of automatically measuring rainfall, relative humidity, solar radiation, soil moisture/temperature/electrical conductivity (E C) and wind speed. Additionally, 23 years of rainfall data (1990-2011) from the Mariano Marcos State University Agrometeorological Station were used to determine the start of rain, maximum dry run and end of season/rains. Dynamic changes in soil moisture/temperature/EC were particularly measured and monitored. Based on the findings of the demonstration experiment, the system was effective, reliable, and efficient in monitoring the available moisture in the soil. Irrigation commences when 56-60% of Readily Available Moisture (RAM) has been depleted. Irrigation was done every 11 days at a depth of 50mm to a field capacity of 24%.

Meanwhile, off-season tomato may be best planted on May 11 to May 19 during the rainy season (upland condition) and on the first week of November during the dry season. Better and more detailed understanding of the changes in local environmental and meteorological conditions in 16N Batac City, Ilocos Norte is possible using the FMS data for the next several years. With the noticeable manifestations of climate change, probable modification of the formulated cropping calendar may be done as an adaptation measure in tomato production.

Keywords: Field Monitoring System, Readily Available Moisture, Irrigation, Sensors, Cropping Calendar, Climate Change

INTRODUCTION

Tomato (*Lycopersicum esculentum*) is a bush or vine crop, growing rapidly within 90 to 150 days. It is one leading vegetable in the Philippines based on the value of production. Its fruit contains significant amounts of Vitamin A and C, which can be processed into juice, paste and sauce or sold as fresh tomato for salad and pickle ingredient. This vegetable crop commands high price. It is one of the most profitable crops grown in Ilocos during the rainy months or early part of dry season when supply is scarce (Knott et al 1967).

Tomato is a day length neutral plant. Optimum mean daily temperature for growth is 18 to 25ºC with night temperatures between 10 and 20ºC. Temperatures above 25ºC, when accompanied by high humidity and strong wind, result in reduced yield. Night temperatures above 20ºC accompanied by high humidity and low sunshine lead to excessive vegetative growth and poor fruit production. High humidity leads to a greater incidence of pests and diseases and fruit rotting. Dry climates are therefore preferred for tomato production. Tomato can be grown on a wide range of soils. However, it prefers a well-drained, light loam soil with pH of 5 to 7. Waterlogging increases the incidence of diseases such as bacterial wilt. The crop is moderately sensitive to soil salinity. Yield decrease at various ECe values: 0% at ECe 2.5 mmhos/cm, 10% at 3.5, 25% at 5.0, 50% at 7.6 and 100'/. at ECe 12.5 mmhos/cm. The most sensitive period to salinity occurs during germination and early plant development, and necessary leaching of salts is therefore frequently practiced during pre-irrigation or by over-watering during the initial irrigation application (FAO 2013).

In another study, it was revealed that a slightly higher range of allowable soil moisture depletion was suitable for optimum yield. Economically, a 56-60% of RAM is the most suitable (Manzano et al 2010). It is therefore imperative to keep the right amount of moisture needed by the crop during its entire growth to achieve optimum yield and sustainable farming system through water conservation. On the average, tomato requires 35 mm of water per week for good growth and development. Hence, determination of potential planting date via rainfall analysis is critical for optimum yield and water savings. This may be done using a field monitoring system (FMS).

In general, the study aims to demonstrate soil moisture monitoring in a tomato field and recommend a scientific cropping calendar for tomato. Its specific objectives are:

a) To monitor soil moisture in a tomato field to precisely determine when to irrigate and how much to irrigate using FMS; and
b) To be able to determine the start of rains, maximum dry run, and end of rains for the 23 year rainfall record (1990-2012) at MMSU Agromet Station as basis for tomato cropping calendar.

METHODOLOGY

Locale and Description of the Study Area

The demonstration study was carried out under natural paddy-tomato-corn-finger pepper field. A 600 m^2 Farmers' field in 16N Quiling Norte, Batac City, Ilocos Norte was selected for experimentation. The source of irrigation water was from a shallow tubewell which was delivered to the field via PVC pipes. The average monthly precipitation, solar radiation, air temperature, wind speed, and relative humidity were 3.0 mm, 69.09 W/m^2, 25.37^{o}C, 0.52 m/s, and 88.65%, respectively during the study period.

Batac City, in Ilocos Norte, has distinct rainy and dry seasons. The rainy season or wet season occurs from the later part of May to September. The dry season is from October to early part of May. Mean total rainfall from October to May (dry season) ranged from 1.92mm to 169.45mm.

Land Preparation

The experimental area was plowed and harrowed twice. This was to pulverize the soil and make the soil surface more uniform and level prior to planting. Soil samples were collected at the experimental area before the establishment of tomato crop. Spacing between plants was 35 cm and between rows, 90 cm.

Irrigation

Furrow irrigation method using irrigation pipes was used in this study. The equivalent depth of irrigation for every treatment was computed by the equation:

$$d = \frac{(FC - AWD)}{100}(A_s)(d_{rz})$$

Where:

d = equivalent depth of water to be applied, mm or cm;
FC = field capacity, %;
AWD = allowable moisture depletion
Pre-determined value = 56-60% of Readily Available Moisture (RAM).
RAM = 75% of Available Moisture (AM);
A_s = apparent specific gravity;
d_{rz} = effective depth of root zone, mm or cm.

The soil moisture content at field capacity was determined 2-3 days after irrigation at saturation, where drainage had ceased. The apparent specific gravity of the soil was determined through oven drying method. On the other hand, the effective root zone of each crop was taken from published tables.

The available moisture of the soil is computed using the formula:

$$AM = FC - PWP$$

Where:
A = Available moisture, %;
FC = Field capacity, %;
PWP = Permanent wilting point, %

The permanent wilting point was determined using sunflower plants. The moisture content of the soil was determined when the test plants showed signs of permanent wilting and was considered its PWP.

Moisture Content Determination

The daily content of the soil was monitored using the calibrated soils sensor of the Field Monitoring System. Data was periodically and manually downloaded. Irrigation water was then applied when the pre-determined allowable depletion was reached.

Other cultural management practices used, such as fertilizer application, seeding, transplanting, weeding, pesticide application and harvesting, g were based on the package of technology for tomato.

Field Monitoring System Set-up

A Vantage Pro2 Weather Station- Field Server with 5-port Em50 data logger connection was installed in the study site (Fig. 1). In the absence of field router, data such as solar radiation, air temperature, humidity, wind direction, wind speed, precipitation, soil moisture content, soil temperature, and electrical conductivity of soil were downloaded manually. The downloaded data were then processed, analyzed, and interpreted. Soil moisture sensors (5TE: soil moisture, temperature, EC), developed by Decagon Devices, Inc., USA, were installed at 15 cm below the soil surface which were connected to the 5-port Em50 Data Logger.

Fig. 1. The FMS Set-up

Twenty three years of rainfall data (1990-2011), which were solely gathered from Mariano Marcos State University (MMSU) Agrometeorological Station were analyzed using the INSTAT program. INSTAT is a statistical package with special facilities for handling and processing climatic data (particularly rainfall) and providing useful statistics necessary for precision farming. Meanwhile, the rainfall data recorded by the FMS were used for the water balance in the soil root zone. This is necessary in validating the soil moisture data of the FMS. Long term rainfall data of the FMS could later be used for a downscaled and field-specific determination of cropping calendar for tomato production. The present study generally sought to determine a tomato cropping calendar across tomato fields of Batac City, Ilocos Norte based from MMSU Agromet data.

Primary focus of the analysis was on the determination of start of rains, maximum dry run and end of rains (end of season) on a daily basis per year. These were summarized using the statistics minimum, maximum, mean, median, and standard deviation. Further analysis was done using percentile points at 10, 20 50, 80 and 90 percentage points.

Limitation of the Study

The study was limited only to the demonstration of the functionality of the FMS. Hence, yield data and other more detailed agronomic characterization were not gathered. Gathering of yield data and production results of the trials were scheduled for the Phase 2 of the study when a Field Router is already available.

Moreover, the 8-month rainfall data and other agrometeorological data recorded by the FMS in this study are not yet adequate for reliable weather forecasting analysis particularly rainfall. .

RESULTS AND DISCUSSION

Soil Moisture Monitoring

The soil moisture sensor of the FMS was laid out at a depth of 15 cm in a loam field. The field capacity and allowable depletion of readily available moisture was calibrated for the FMS using gravimetric method. The field capacity and wilting point were found to be 24% and 12%, respectively. The allowable moisture depletion of 56-60% of RAM was translated into volumetric water content. An hourly data recording was set at the ECH2O software of the FMS which was manually monitored and downloaded. The FMS was found effective in precisely monitoring the periodic depletion of soil moisture. Results of the study revealed that the actual irrigation interval is 11 days with 50mm depth of application. The result is very important in guiding the farmer or the irrigator in determining how much water should be applied to his field.

Unsuitable irrigation interval and improper amount may be enough to cause water to be a limiting factor for yield of tomato. Several researchers have reported that frequency of irrigation and quantity of nutrient in solution provided to plants affect yield (Byari and Al-Sayed, 1999; May and Gonzales 1994; Peet and Willits 1995; Singandhupe et al 2002). Therefore, the result pointed out by the FMS is very useful.

Start of Rains

Start of rains may be defined in different ways for different purposes. A definition may be based solely on rainfall amount. In this study, two definitions were considered:

(i) The first occasion after first April or May that there is more than 20mm either on a single day, or within 2 days. 15^{th} April was considered as a third alternative earliest date.
(ii) The first occasion after the same dates in (i) that the (running) 10 day total is greater than half the evapotranspiration assumed as 5mm/day.

As reflected in Table 1, the mean start of rains ranged from 133-140 days of year (May 12 – May 19). This implies that in Batac City, the start of rainy season is May. The 80 percent is the value that is exceeded once in 5 years ((1/0.2) = 5) 14 that point, the mean start of rains ranged from 132-140 days of year (May 11 – May 19).

In tropical countries tomatoes do not grow well during the rainy season. They are often affected by insects and diseases that thrive during the rainy months (Café. 2013). However, tomato hybrid varieties that are resistant to rainy condition may be planted. To save irrigation cost, considering local condition, the tomato seedlings maybe planted on the onset of rainy season (May) in an upland condition. The plants will be ready for harvest before the start of typhoon season which is usually August to September. This finding generally agrees with the article of PCARRD (2007) that tomato is generally best grown from November to February in the lowlands and May to October for the off season type.

Table 1. Start of rains, maximum dry run, end of rains, and recommended cropping calendar for tomato in Batac City, Ilocos Norte, Philippines.

Parameter	Estimated Mean Value	Estimated Value (80% Probability)	Recommended Transplanting Date
Start of rains	133th - 140th day of year or May 12 – May 19	132th - 140th day of year or May 11 – May 19	May 11 – May 19 (rainy season)
Maximum dry run	May = 22 days June = 9.22 days July = 6.70days	May = 34 days June = 12 days July = 11days	
End of rains	297th day of the year October 23	310th day of the year or November 5	1st week of November (dry season)

Maximum Dry Run

Spell lengths each year was examined with the SPELL command of the INSTAT. Dry days were days defined as less than 0.85mm of rainfall. This threshold value of rainfall was considered but other values can be used.

Based on the results, the mean maximum dry run for the 23 year record in May, June, and July were 22, 9.22 and 6.70 days, respectively. The values are actually dry spells that have been considered to continue over the end of the month (i.e. a dry spell in April when it continues in May will be recorded and covered in May). Maximum dry runs at 80-percentage point chance of dry spells in those same months were 34, 12 and 11 days. The recommended transplanting date of tomato for the rainy season is from May 11 to 19. During transplanting, the field is irrigated up to field capacity. The transplanted plants are insured against water stress since the estimated irrigation interval of 11 days can cover the maximum possible dry run of 11 days for the month of May.

End of Season/Rains

The Water balance command of the INSTAT program was used to determine the end of rains. The end of the rains was defined as the first occasion after 1st September that the water balance dropped to zero. 5mm evaporation value was based on the dry season evapotranspiration in Batac City, Ilocos Norte which was computed using the FAO-Penman Monteith Method. The maximum soil capacity was taken as 100mm.

Table 1 reveals that the mean end of the season was approximately 297 day of the year (October 23) which was based on rainfall and the water storage. In the daily water balance analysis, water starts to diminish in October and zeroing in January, February and March. The soil water reservoir is rain recharge in May.

At 80 percentage point, the end of rains was 310th day of the year (November 5).

In tomato production, frequent rains are undesirable because they make cultural operations difficult. Excessive rainfall drowns the plants and leaches the nutrients especially on light soils.

Considering the above conditions, transplanting date of tomato on October 23 onwards is justified for Batac City, Ilocos Norte conditions. In a previous study (Acosta et al 2000), September is the recommended transplanting date of tomato in Ilocos Norte. The discrepancy maybe attributed to area of coverage. In this present study, location specific data were used. Weather patterns in many areas of Ilocos Norte are different due to its geographical setting.

Climate Change and Adaptation Measure

Better and more detailed understanding of the changes in local environmental and meteorological conditions in 16N Batac City, Ilocos Norte is possible using the FMS data for next several years. With the noticeable manifestations of climate change, probable modification of the formulated cropping calendar may be done as an adaptation measure in tomato production.

SUMMARY AND CONCLUSION

The study was conducted to monitor the soil moisture regime of a tomato field using a Field Monitoring System (FMS) in 16N, Quiling Norte, Batac City, Philippines. Rainfall data from the MMSU Agromet Station was analyzed to determine the best possible cropping calendar of tomato for the wet and dry seasons.

Dynamic changes in soil moisture content were particularly measured and monitored. Based on the findings of the demonstration experiment, the FMS was effective, reliable, and efficient in monitoring the available moisture in the soil. Results revealed that for optimum overall development of the plants, irrigation should commence when 56-60% of Readily Available Moisture (RAM) has been depleted. With this, the actual irrigation interval is 11 days with 50mm depth of application. The result is very important in guiding the farmer or the irrigator in determining when to irrigate and how much water should be applied to his field.

Meanwhile, off-season tomato may be best planted on May 11 to May 19 during the rainy season (upland condition) and on the first week of November during the dry season.

STATEMENT OF AUTHORSHIP

Dr. Virgilio Julius P. Manzano Jr is the lead author of this article which is a part of the research project entitled “Climatic changes and evaluation of their effects on agriculture in Asian monsoon region (CAAM)” under the research framework of the Green Network of Excellence (GRENE) for the Japanese fiscal years from 2011 to 2015 (by the end of March 2016) supported by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT). He was responsible in conceptualizing the study, setting up the study area, data gathering and analysis. Most importantly, he prepared the draft and finalized the writing of this article for publication.

Dr. Masaru Mizoguchi is the co-author of this article and the project leader of GRENE-CAAM. He led the design and set-up of the FMS. He also provided critical suggestions in the methodology

and helped in preparing the final draft of this article.

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JOURNAL OF NATURE STUDIES
(formerly Nature's Bulletin)
Print ISSN: 1655-3179
Online ISSN: 2244-5226