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Optimization of Irrigation and Fertilizer Scheduling Using Cropwat 8.0 under Fully Automated Drip Irrigation for Hybrid Maize

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Abstract: **The experiment was to optimize the requirement of irrigation and fertilizer level for hybrid maize during rabi season based on the climatic data. On this basis irrigation scheduling and fertilizer scheduling is programmed in the fully automated drip irrigation system. Irrigation scheduling was done by calculating the crop water requirement using the climatic data of the cropping period. CWR is calculated by using formula and also by CROPWAT 8.0 produced by FAO. The yield effects under optimized fertilizer level in Hybrid Maize NK6240-Syngenta in fully automated drip irrigation condition was analysed. The crop water requirement was calculated for Hybrid Maize NK6240-Syngenta and scheduled based on the climatic data of the cropping period using CROPWAT8.0. The yield were higher in T5 (125 % RDF) and showed a significant difference in the plant growth .Following this T4 (100%) and T3 (75%) showed similar reading almost revealing that fertilizer applied at root zone is effectively used by the plant in turn resulting in 20-25% saving of fertilizers. The highest water use efficiency of 65.104 kg per ha per mm was recorded in treatment T5.The highest N, P and K fertilizer use efficiency of 81.37kg ha-1 kg of N, 162.74 kg ha-1 kg of P and 162.74 kg ha-1 kg of K were recorded in T3, which is with 75 per cent RDF and the least N, P and K fertilizer use efficiency of 66.68 kg ha-1 kg of N, 133.364 kg ha-1 kg of P and 133.364 kg ha-1 kg of K were recorded in T5 treatment with 125 percent RDF. Leaching effect is reduced in the soil.**

Keywords**: Iirrigation scheduling, Climatological data , CROPWAT8.0**

I. INTRODUCTION

AGRICULTURE provides livelihood to majority of population and thus remains linchpin of Indian economy. WATER is the vital source for crop production and is the most limiting factor in Indian agricultural scenario. Water makes a significant contribution to food security as it directly affects agricultural productivity. Due to the significant growth in agricultural productivity over recent decades, the irrigated areas that comprise 17 per cent of agricultural land produce nearly 40 per cent of food and agricultural commodities. The water used for irrigation in developing countries makes up over 80 percent of fresh water use. The world is facing a threat with a rapid depletion of fresh water resources; the situation is all the more grave in India where the population is increasing at an alarming rate. India possesses 4% of world's fresh water supply. Though India has the largest irrigated area in the world, the coverage is only about 40% of the gross cropped area. One of the reasons for the low coverage of irrigation is the predominant use of flood irrigation, where water use efficiency is very low which is only 35 to 40 per cent because of huge conveyance and distribution losses (Rosegrant,1997). The per capita water availability in terms of average utilizable water resources in the country, has dropped from 6008.0 m3 in 1947 to 1250.0 m3 and is expected to dwindle down to 760.0 m3 (Singh,2006). There are 140.0 m ha of arable land in India in which 41.2 m ha are being irrigated (Ramah, 2008). Maize is one of the important cereal crops in the global agricultural economy both as a food for man and feed for animal and a crop of immense potentiality and therefore called "Queen of cereals" and "kings of fodders". Maize ranks fifth among the cereals in area and production in world and has high nutritive value as compared to rice, wheat and sorghum. Maize grain contains about 66.2 per cent carbohydrate, 11 % protein, 4 % of oil and 2.7 % of crude protein. Besides its use as a food and fodder, Maize is now also gaining increased importance on account of its potential uses in manufacturing of starch, plastic, rayon, textile, adhesive, dyes, resins, boot polish, etc. By 2020, the requirement of maize for various sectors will be round 100 million tones of which the poultry sector alone demand 31 million tonnes (Seshaiah, 2000). Micro irrigation is

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introduced primarily to save water and increase the water use efficiency in agriculture. Reduction in water consumption due to drip method of irrigation over the surface method of irrigation varies from 30 to 70% (Postal et al ., 2001) and yield increase in the yield increase in the range of 20 to 90 % for different crops. By introducing drip irrigation, it is possible to increase the yield potential of crops by three fold with the same quantity of water. All these emphasize the need for water conservation and improvement in water use efficiency to achieve more crops per drop of water. Of the 141.2 M ha of land in India, 62.2 M ha being irrigated. Water and nutrients are important factors for increasing the crop production, but being limited, its efficient use is the key factor for the sustainable agricultural production. Due to water scarcity, the available water resources should be very effectively utilized through water saving irrigation technologies. Studies carried out across different countries including India have confirmed that irrigation plays paramount role in increasing the yield and enhancing crop intensity (Vaidyanathan et al., 1994). The research is conducted to evaluate the yield effects and to optimize the irrigation and fertigation level for Hybrid Maize in fully automated drip irrigation condition and also to find crop water requirement based on the climatic data of the cropping period using CROPWAT8.0.

II. MATERIALS AND METHODS

The field experiments were conducted in the Irrigation Cafeteria of Water Technology Centre of Tamil Nadu Agricultural University (TNAU) farm situated at eastern block. The field is located at 11^{0} N latitude and 77^{0} E longitudes with mean altitude of 426.7 m above the mean sea level. The total annual rainfall of the region is 720 mm per year. The mean annual maximum and minimum temperature is 32^{0} C and 22^{0} C respectively. Average relative humidity, sunshine hour and evaporation are 66 percent, 6.9 hour and 5.4 mm/day respectively. The soil of the experimental area belongs to sandy clay loam texture and assumed to be homogenous in nature. Irrigation source was from bore well from which irrigating water was pumped using a 5 hp motar and stored in a surface level storage tank. The water is conveyed through the filters provided to the PVC main pipe line of 75 mm diameter. PVC submain of 63 mm diameter was connected to the main line to which, LLDPE laterals of 16mm diameter were connected. Along the laterals inline drippers of 4 LPH were fixed at a spacing of 60 cm. Sub mains and the laterals were provided at the end with end caps. The quality of the irrigated water is analyzed. The pH of the irrigated water was 7.4 and EC was 0.29(dSm-1). The experiment was conducted during 2013 to 2014 (December to April, Rabi season). A field crop of Hybrid maize (NK 6240 – Syngenta) was grown in experimental site. The duration of the crop is 120 days. The field was first ploughed with a disc plough followed by passing a cultivator twice and then leveled. In the leveled field, bed preparation is done. Each bed is of 4 feet in which laterals is provided at the center of each bed. The experiment was carried out in irrigation cafeteria, Water Technology Centre, TNAU, Coimbatore. Total experimental area is 1375m2. The length and width of the field is 55m length and 25m breadth. The total area is divided into five equal strips of 5m x 55m according to the treatments. Field experiment was laid out in Randomized Block design with five treatments, three replications. The experimental design carried out was randomized block design with five treatments and three replications.

The treatment details of the experiment are as follows.

T1- absolute control

T2 -50% - Required Dosage of Fertilizer
T3-75% - Required Dosage of Fertilizer
T4-100%- Required Dosage of Fertilizer
T5-125% -Required Dosage of Fertilizer

The seeds were sown at a seed rate of 20kg per ha. The seeds were dibbled into the soil at 1-2 seeds per hole. Paired row planting is adopted. Thinning and gap filling operations were carried out on 12th DAS thus left only one healthy and vigorous seedling per hill. Hand weeding was done on 25 DAS and 45 DAS to all treatments.

Irrigation and Fertigation

The experiment was carried out with fully automated drip irrigation and fertigation. The automation setup was provided by NETAFIM. The model installed was NMC-JUNIOR. Its process controller manages irrigation, fertigation, misting, and cooling systems. The main features of NMC-JUNIOR are 15 irrigation programs, Flow control (high and low flow, uncontrolled water flow), Up to 8 dosing channels, optionally with dosing meters, Fertigation by quantity, time, ratio (L/m3) and EC/pH, History of water and fertigation quantities and PC communication. The irrigation and fertigation schedule are calculated and the programs were set according to the experimental setup (for 5 sub-mains and 15 laterals).

Irrigation Scheduling

Irrigation scheduling is the decision of when and how much water to be applied for an crop to maximize net returns. The maximization of net returns requires a high level of irrigation efficiency. This requires the accurate

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measurement of the volume of water applied or the depth of application. It is also important to achieve a uniform water distribution across the field to maximize the benefits of irrigation scheduling. Accurate water application prevents over- or under-irrigation. Over-irrigation wastes water, energy and labor, leaches nutrients below the root zone and leads to water logging which reduces crop yields. Under-irrigation stresses the plant, resulting in yield reductions and decreased returns. (FDRP, KGVDP, Annex F, 1999). Irrigations were scheduled on the basis of climatological approach. Irrigation scheduling was calculated both manually and also by using CROPWAT 8.0. Lifesaving irrigation was given immediately after the dibbling and again the field was irrigated on 4th day and 8th day. After the 12th day, subsequent irrigations were scheduled once in two days based on the following formula and applied each time as per the treatment schedule.

The K_c values for Maize for different stages are given in the Table below.

WR_c Where,

WR_c - Computed water requirement (lit plant-1)

CPE - Cumulative pan evaporation for two days (mm)

KP - Pan factor (0.8)
KC - Crop factor
WP - Wetted fraction (0.8)
A - Area per plant, m2

Time of operation of drip system to deliver the required volume of water per plot was computed based on the formula

Table 1: Crop factor (Kc) values for Maize

Crop	Days	Kc
Initial stage	6-25	0.4
Flowering stage	26-60	0.75
Grain formation stage	61-75	1.05

CROPWAT 8.0
CROPWAT is a DOS or Windows based decision support system designed as a tool to help agro-meteorologists, agronomists, and irrigation engineers carry out standard calculations for and crop water use studies, CROPWAT 8.0 is a decision support system developed by FAO, having as main functions to calculate reference evapotranspiration, crop water requirements, crop irrigation requirements and also to develop irrigation schedules under various management conditions, Scheme water supply. It is tool for testing the efficiency of different irrigation strategies (e.g., irrigation scheduling, improved irrigation efficiency) under climate change. The climatic data is obtained from Department of Meteorology, TNAU. The data obtained are provided as input. The input modules are Climate/ETo, Rain, Crop, Soil, Crop pattern and the calculation modules are Crop Water Requirement, Schedule and Scheme. The input data required and their respective output data is listed in table below .

Biometric observations
Within the net plot area, five plants in each plot were selected at random, tagged and subsequently used for recording all biometric observations. Growth parameters were recorded at 30, 60 and 90 DAS of crop growth.

Fig:1 Comparison of cobs of T3, T5 and T4

Water Use Efficiency
Water Use Efficiency (WUE) was calculated for each treatment, which is the ratio of yield of the crop in kg ha-1 and total water used in mm.
Where,

WUE - Water Use Efficiency, kg per ha per mm of water used.

Y - Yield of the crops, kg ha-1.
W.A - Total water utilized, mm.

Fertilizer Use Efficiency
Fertilizer Use Efficiency (FUE) was calculated separately for N. P and K for each treatment, which is the ratio of yield of the crop in kg ha-1 and total nitrogen, potassium and phosphorus applied in kg ha-1.

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FUE = (Y/F*A)

Where,
FUE - Fertilizer Use Efficiency
Y - Yield of the crops, kg ha-1
F.A - Total fertilizer applied

Moisture distribution Pattern:

The wetting pattern of soil under different treatments was analyzed by taking moisture content at different horizontal distances and depths. In order to study the soil moisture distribution in soil, samples were collected at a distance at 0, 15, 30, and 45 cm from emitter along the horizontal direction and at surface and at a depth of 0, 10, 20, and 30 cm. The samples were collected before irrigation, immediately after irrigation, one day after irrigation and two day after irrigation.

Determination of soil moisture by gravimetric method

Using gravimetric method the soil moisture measurements were calculated. Soil samples were taken using tube type soil augers and were kept in moisture boxes and covered immediately with lids. The samples were weighed along with the moisture box (W2) and then placed in an oven at 105o C for 24 hrs until all moisture was driven out. It was weighed again and the weight (W3) was noted. The soil moisture content is expressed as per cent by weight on dry basis.

The percentage of moisture content = (W2-W1) / (W3-W1)*100

Where,
W1-Weight of empty container with lid (g)
W2- Weight of container with lid and moist soil (g)
W3- Weight of container with lid and dry soil (g)

III. RESULT AND DISCUSSION

The present study was undertaken to evaluate the yield effects in Hybrid Maize in fully automated condition and also to optimize the fertilizer level required. This experiment is being carried out to increase the yield of maize with optimized fertilizer level in automated drip irrigation and fertigation. The texture was sandy clay loam in the surface with clay in the subsurface and the soil remains dry during the growth period unless irrigated. The soil had a bulk density of 1.53 g per cc, particle density of 2.62 g per cc and pore space of 42 per cent. The studies revealed that there is notable increase in the bulk density, particle density, porosity and pH, electrical conductivity (EC) and available NPK. The pH values were found to be different for different treatments. EC also have the same effect as that of pH, but it showed higher values in 100 per cent and 125 per cent treatments due to the increased in nutrients application in the respective treatments. The Coefficient of Variation (CV) for drip irrigation system is calculated as 0.041 per cent. Statistical Uniformity of the system was calculated as 95.9 per cent. The Uniformity Coefficient of the drip irrigation system was found to be 94.38 per cent. The high value of Uniformity Coefficient indicated the excellent performance of fully automated drip irrigation and fertigation system in supplying water and fertilizer uniformly throughout the laterals. From the biometric observation discussed in the previous chapter the results revels that T5 with 125 % RDF showed greater significant followed by T4 with 100%RDF and T3 with 75 % RDF and then T2 with 50% RDF and T1 with absolute control. The results show that the irrigation and fertilizer given is used efficiently. Irrigation is done based on the climatic data, showed an water saving of nearly 20%. At 30th day after showing, plants under all the five treatment do not show much variation among themselves. At 60th day after sowing plants showed significant variation in their biometric characters in all the five treatments, while T5 showing significant growth. T3and T4 showing less variation in them. i.e similar biometric characters were found. The grain formation were found first in T5 and followed by T4 and T3. T2 and T1 showed late flowering stage and poor grain formation with irregular cobs size and weight. Comparing the biometric characters and the yield obtained showed in the result and discussion shows that T5 is significant from all other treatment with showing highest yield of 343 kg, WUE of 65.10 kg per ha per litre of water used. Though T5 showed greater yield and significant growth, T3 and T4 showed efficient utilization of the irrigation and fertigation provided. The treatment T4 and T3 gave almost same result which with further minute treatment variation can bring nearly 20 -25% of fertilizer saving.

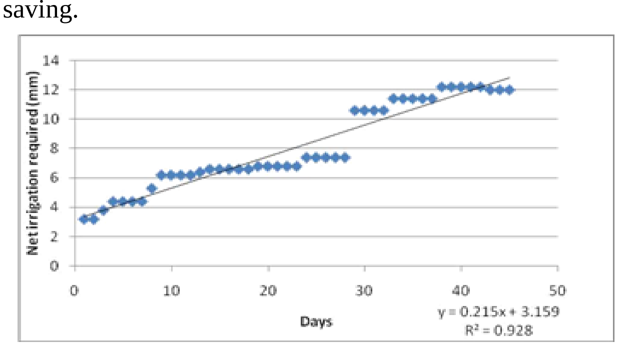

Fig 2: Irrigation requirement calculated for Hybrid maize by CROPWAT8.0(based on climatic data obtained)

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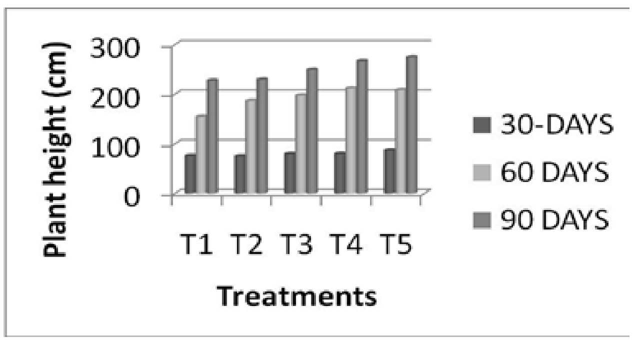
Moreover, the experimental plot showed only about 2-3 kg of weeds completely during the cropping period .Weeding was done two times during cropping period. This shows that water applied is being efficiently used by plant. The emitters in the experimental plot showed an mean minimum discharge of 3.2 lph and mean maximum discharge of 3.6 lph after harvest (after fertigation). This shows the clogging effect in the inline emitters of the experimental plot. It is recommended to give acid treatment after every cropping season and also replacement of old emitters by new emitters in order to get uniform distribution in head, middle and tail.

Comparison of irrigation scheduling

Irrigation water requirement for the maize plant to grow was calculated based on the climatic data available. The regression model reveled that the R2 value is high in the first graph, which shows the goodness of fit, reveling nearly 20% water saving. Though it gives efficient and accurate calculation, it requires lot of data such as climatic data and crop data. The usage of CROPWAT 8.0 was easy and effective. Usage of this package does not require any training, its user friendly. One can use CROPWAT 8.0 for storing the data and for calculating the crop water requirement. The output data obtained from this can be used for reference for further study for fully automated drip irrigation and Fertigation. It can also be easily retrieved.



The graph for the input data is readily available in CROPWAT8.0. Usage of fully automated drip irrigation and fertigation can completely minimize the loss of water that is irrigated excessively which in turn saves water to nearly 30-40% generally when compared to conventional methods. CROPWAT8.0 gives the accurate calculation of the irrigation water requirement. So Automation of drip irrigation and Fertigation along with the Irrigation Scheduling obtained for the particular crop can minimize water loss highly. Irrigation scheduling was done based on the climatological data obtained for 25 years and the forecasted data obtained for the cropping period . WUE and FUE was found to be high when compared to the practice followed by the farmers usually and irrigation scheduling done based the climatogical data. Using of CROPWAT8.0 gives accurate CWR, which is useful for programming in fully automated condition . Hence fertilizer is applied at correct time at the root zone results in effective utilization of the fertilizers. The result revealed that irrigation scheduling done using CROPWAT 8.0 using climatogical data was effective and the forecasted data helped us to manage the irrigation frequency, volume of irrigation and application of time of fertilizer. Leaching of soil was very much reduced. Hence only required volume of water is alone given to the plant, effective utilization of water and fertilizer was found. Wastage of water and fertilizer was much reduced resulting in saving of 20- 30%. Hence water is applied in the required quantity for the crop reduced emergence of weeds. Irrigation scheduling based on climatological data reduced the utilization of labour unwantedly and also provided an good economic return (increased yield with minimal input). The usage of fully automated drip irrigation and fertigation will definitely take agriculture to next level in future which will make a remarkable change in FARM MECHANIZATION.

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