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Seasonal Irrigation Analysis of Maize Using CERES Maize Model in DSSAT under Temperate Kashmir

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ABSTRACT

Seasonal analysis experiments were conducted at Shalimar Campus of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir which is situated 16 Km away from city center that lies between 34.08 ° N latitude and 74.83 ° E longitude at an altitude of 1587 meters above the mean sea level. The experiment was conducted on maize with different levels of irrigation %age. Genetic coefficients of maize variety C_6 were verified/generated for calibration and validation of model CERES-Maize (DSSAT v 4.6). Six treatments were studied using this model comprising i) Unirrigated ii) 90% irrigation iii) 70% irrigation iv)50% irrigation iv) 30% irrigation and 10% irrigation. The model was run using long term weather data of Srinagar (SKUAST-K, Shalimar). To see the impact of irrigation levels on maize behavior with respect to yield and attributes on long term basis. For every treatment in treatment matrix rest of the information was kept same all the input management files. While in simulation we use different treatments by changing the percentage of irrigation applied. The model was run for biophysical analysis with respect to 30 years' weather data for the same location. The CERES-Maize simulation model was calibrated and validated data was used. Simulated studies indicated that Irrigation plays a very important role as far as maize cultivation is concerned. It was observed that irrigated maize with 70 % irrigation provided gives the maximum growth and yield and yield attributes followed by 90 %, 50 %, 30 % and 10 %. However least tops weight was recorded in unirrigated conditions throught out the 30 years' weather data. Harvest and maturity yield in simulation mean 30 years' data showed that the maximum harvest yield of 33.39 qntls ha^{-1} with 70 % automatic irrigated which was closely followed by the treatments 30 %, 10 % and 70 % automatic with mean values of 33.22, 33.20 and 33.20 qtls ha^{-1} respectively. While least value of 2.99 qtls ha^{-1} was recorded under rainfed maize. the magnitude of decrease was around 90 % as compared to all other irrigation levels, thus we can say that water plays a vital role in maize crop production however we can also save it to some extent.

Key words: *CERES maize, DSSAT, Seasonal analysis, Irrigation, Simulation, Yield attributes, Yield. Kg ha^{-1}*

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INTRODUCTION

Maize (*Zea mays* L.) is emerging as an important cereal crop in the world after wheat and rice. It is now an important ingredient in food, feed, fodder and large number of industrial products. It has acquired dominant role in the farming sector and macro-economy of the Asian region. Maize known as the "Queen of Cereals" is the third most important cereal crop in India after rice and wheat and is cultivated on 8.17 million ha with the production of 19.73 million tonnes and productivity of 4.21 tonnes ha^{-1} [1]. Among the major crops of Jammu and Kashmir in terms of acreage maize is grown in area of 315.81 thousand hectares with the production of 0.63 million tonnes and productivity of 2.0 tonnes ha^{-1} [3]. This increase in yield has been mainly achieved by increase in the area under high yielding varieties. Being an important cereal, over 85% of its production in the country is consumed directly as food in various forms, the chapatis is the common 'preparation, whereas, roasted ears, pop corns and porridge are other important forms in which maize is consumed. Besides, it is also used for animal feeding, particularly for poultry and in starch industry. Green maize plants furnish a very succulent fodder during spring and monsoon particularly in North India. Maize is grown under wide range of climatic conditions, mostly in warmer parts of the temperate region and areas of humid sub-tropical climate. It is grown practically at all altitudes except where it is too cold or the growing season is too short. The crop requires considerable moisture and warmth from the time of planting to the termination of flowering period. The amount and distribution of rainfall are important in maize production. Maize cannot tolerate water stagnation. Rainfall of 50-75 cm during the vegetative period is helpful for proper development of maize plant. Moisture stress at the flowering stage drastically lowers the grain yield. Maize is grown in the state during *kharif* season and about 85% of the cropped area is rainfed. Under such considerable rainfed area and there is scope of increasing productivity by using low cost available mulch as under existing agro- climatic condition, the maize crop, is prone to the vagaries of rainfall distribution during crop growth. The process based dynamic simulation crop models based on soil, crop and weather factors could be effective research tools for planning alternative strategies for crop management, land use and water management[5] and also a useful tool for planning and developing technological interventions in diverse areas. The most widely used are the simulation models for maize and wheat, under the common name of CERES (Crop–Environment Resource Synthesis). The CERES models for maize and wheat are some of the most frequently applied crop–weather models in the world, not just in Europe, and this justified its choice in this work. For research planning a validated model with known genetic constants for varieties can be powerful tool for studying the performance of varieties in constrating environments, soil types, diverse cultural practices and management inputs[2]. Technological packages including optimum planting time, irrigation, plant population, suitable varieties and plant geometry can be designed using models. Though this approach has been successfully used in some parts of our country for management decisions and technology evaluation but no efforts have been made in this region. The DSSAT v 4.5 CERES-Maize Crop Simulation Model which was tested over a wide range of environments[4,6] has been used in present investigation.

MATERIALS AND METHODS

Observed weather and soil data of Shalimar main campus of University for was used for. The statistical analysis of 30 years' weather data was done using SPSS 17.0. Already calibrated coefficients of maize cultivar (Table 1) were used in the CERS maize model. The coefficients for cultivar were estimated from field experiment by adjusting coefficients until close match were achieved between simulated and observed phenology and yield.

Table 1: Genetic coefficients of maize cultivar C6

Cultivar	Parameters					
	P-1	P-2	P-5	G-2	G-3	PHINT
C6	230	0.0	450	600	9.9	66

P-1: Thermal time from seedling emergence to the end of the juvenile phase (expressed in growing degree days above a base temperature of 8 ^{0}C) during which plant is not responsive to changes in photoperiod.

P-2: Extent to which development (expressed as days) is delayed for each hour increase in photoperiod at which development proceeds at a maximum rate (which is considered to be 12.5 hours).

P-5: Thermal time from silking to physiological maturity (expressed in degree days above a base temperature of 8 ^{0}C).

G-2: Maximum possible number of kernels plant^{-1}.

G-3: Kernel filling rate during the linear grain filling stage under optimum condition (mg day^{-1}).

PHINT: Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances.

RESULTS AND DISCUSSION

The monthly average of 30 years' weather data of Shalimar Srinagar reveals that maximum temperatures ranges between 9.8 ^{0}C to 30.6 ^{0}C and minimum ranges between -3.9-17.7 ^{0}C. As far as rainfall is concerned the maximum number of rainy day occurs in April I,e 12 which was followed by the month of July with 10 rainy days. Thus assuming that the growing period of maize receives a good amount of rainfall but only in once during the entire growing season (Table 2 Fig 1). The soil was low in available nitrogen and high in available P and K, with neutral pH.The Simulation studies using DSSAT 4.6 predicted that, from the 1985-2014 meteorological data and among all the six treatments it was observed that the lowest growth yield and yield attributing characters were recorded in rainfed maize as compared to irrigated levels. The highest growth parameters LAI, Tops weight. Maturity / harvest yield was recorded at automatic 50 % followed by automatic 30 %. However, the further increase from 50% to 70 % and 90 % failed to show any significant impact on the increase in growth and yield attributing characters. The highest tops weight of 11941 Kg ha^{-1} was recorded with automatic 50 % which was closely followed by automatic 30% with 11851 kgha^{-1}. The least tops weight was recorded with rainfed maize with 2334 Kg ha^{-1} only. As far as anthesis date is concerned which ranges between 182 in rainfed maize and 184 days in highest level of irrigation which is automatic 90%. This may be due to fact that two days gap i,e early maturity in rainfed maize because of the non availability of the moisture and plants comes under stress earlier thus shifting from vegetative to reproductive phase is earlier in rainfed maize as compared to irrigated ones although the difference was of two days only. Dry matter – Et production was maximum at 70 % automatic irrigation followed by 90 % and 50 % and least in rainfed maize thus revealing that the more evapotranspiration was at 70 % automatic irrigation followed by 90 % and 50 % and least in rainfed maize. While on the other hand Dry matter – irrigation production with maximum values of 43.44 at 90 % followed by 70 % automatic irrigation, 50 %, 30 % and 10 % and least in rainfed maize with 5.47. Dry matter –rain production was highest at 50 % automatic irrigation followed by 30 % automatic irrigation, 10 % automatic irrigation and followed by 70 % automatic irrigation. The dry matter - transpitaion production also followed the same trend which are in conformity with results of Zaho *et al*[8].As far as maturity is concerned there was only two days' difference the rainfed maize got earlier maturity as compared to irrigated levels because of the fact that presence of more moisture delays the maturity or shifting of vegetative phase to reproductive phase as the anthseis date was also enhanced by two days in case of irrigated. Mean evaporation total was higher in 50 % automatic irrigation followed by 50 % and 70 % with 245.40 mm,245.33 mm and 242.43 mm respectively. Least evaporation of 129.67 mm was recorded at rainfed maize because of the fact that presence of less moisture on the surface to evaporate (fig: k and l) same results were also reported by Zeleke and Wade[7]. Highest evapotranspiration 2299 mm was observed at 10 % automatic irrigated followed by 30 % automatic and 90 % automatic assuming the fact that at 10 % automatic more moisture is taken up by the plants because of competition and presence of less moisture which gets rapidly evaporated at surface of the soil (fig: a and b). Harvest and maturity yield in simulation mean 30 years' data showed that the maximum harvest yield of 33.39 qtls ha^{-1} with 70 % automatic irrigated which was closely followed by the treatments 30 %, 10 % and 70 % automatic with mean values of 33.22, 33.20 and 33.20 qtls ha^{-1} respectively. While least value of 2.99 qtls ha^{-1} was recorded under rainfed maize with the magnitude of decrease around 90 percent when compared to 30 %, 50 % and 70 % automatic, however there was not too much differences in the harvest yield within these levels (Fig: g, h, I and J). But 90 % automatic irrigation gives lesser harvest / maturity yield 28.80 qtls ha^{-1}as compared to the other irrigated levels. Thus we can assume that maize is a tricky crop and requires moisture for its growth and development however we can save the water by reducing the water level from 90 % of threshold to 30 % of thresh hold level by not sacrificing yield of maize to a significant extent. However, the harvest of maize not only depends on weather conditions, but also on human decisions.

Table 2: Mean monthly average meteorological data observed at Shalimar from 1985-2014

Month	T max ^{0C}	T min. ^{0C}	Total Rainfall mm	No. of Rainy days
January	11	-3.9	38.2	1
Feberuary	12.8	-0.9	47.4	7
March	16.8	2	45.9	7
April	20.8	7.1	73.8	12
May	28.4	11.2	43.7	7
June	29.3	15.5	63.9	5
July	30.4	17.7	50.6	10
August	30.6	16.2	21.9	7
September	26.9	10.2	34.1	5
October	23.7	5.4	9.6	2
November	14.8	0.6	44.8	4
December	9.8	-0.6	19.2	5

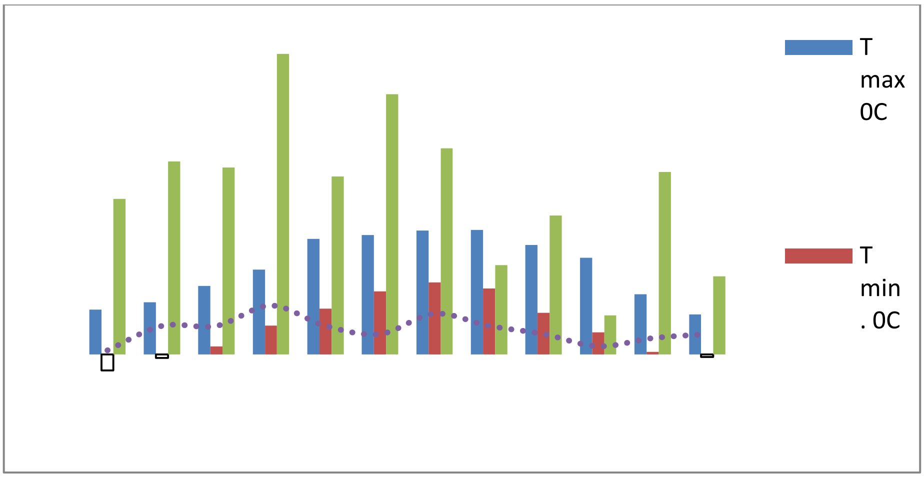
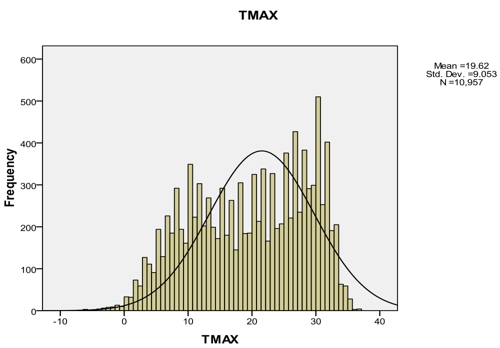
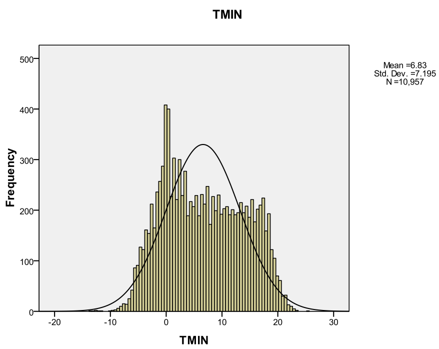
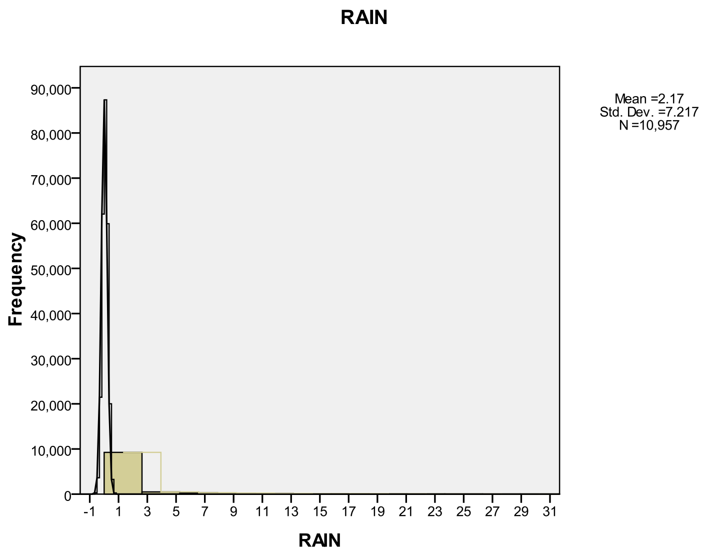
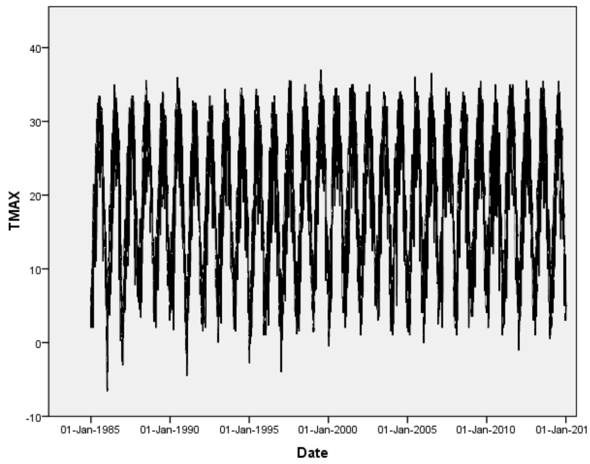


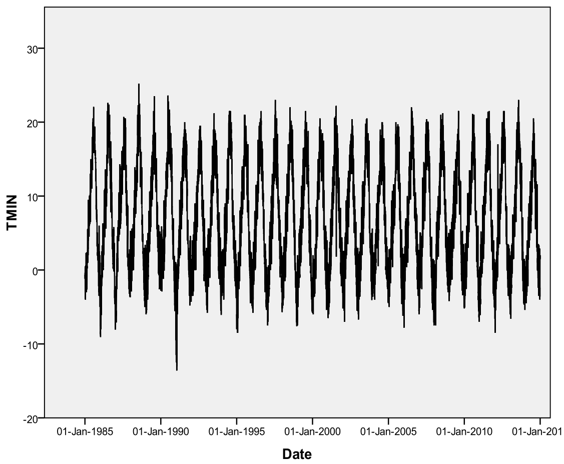
Fig. 1: Mean monthly average meteorological parameters observed at Shalimar from 1985-2014

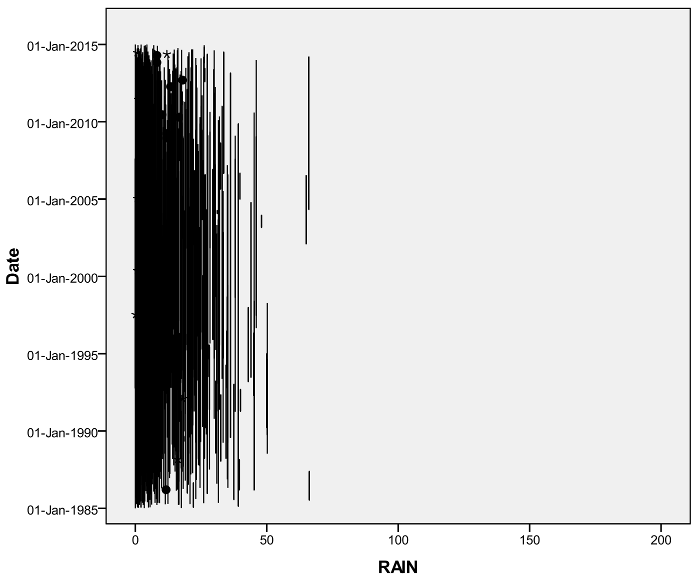


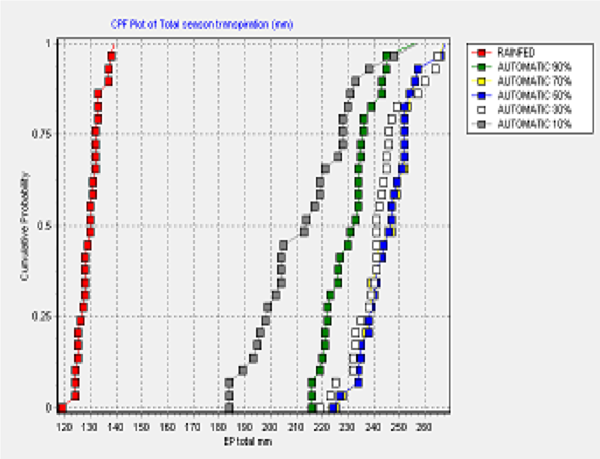


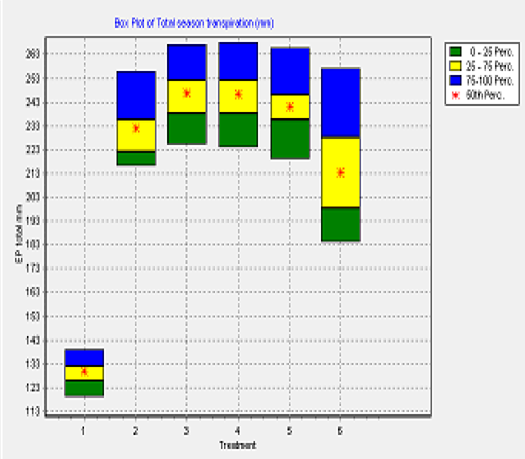

RAIN
Mean =2.17
Std. Dev. =7.217
N =10,957
Frequency
RAIN


TMAX
Date

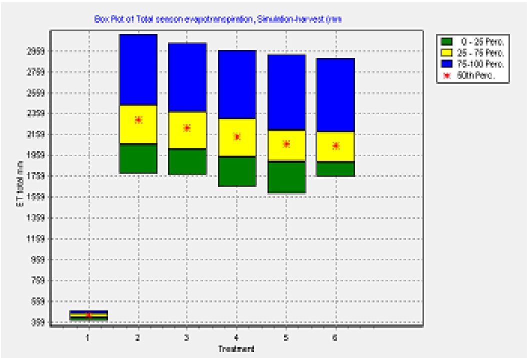

TMIN
Date

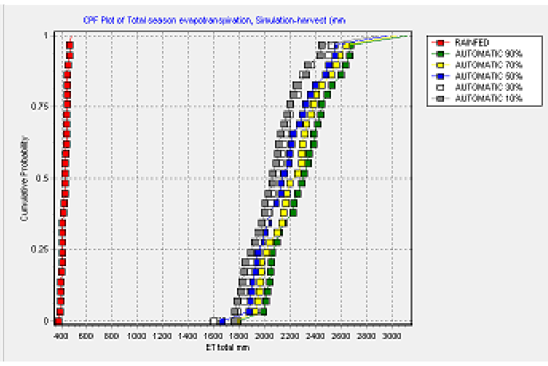

Date
RAIN


CPF Plot of Total season transpiration (mm)
Cumulative Probability
EP total mm
RAINFED
AUTOMATIC 90%
AUTOMATIC 70%
AUTOMATIC 50%
AUTOMATIC 30%
AUTOMATIC 10%

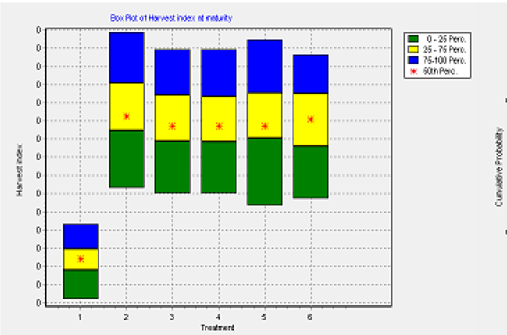

Box Plot of Total season transpiration (mm)
EP total mm
Treatment
0 - 25 Perc.
25 - 75 Perc.
75-100 Perc.
50th Perc.

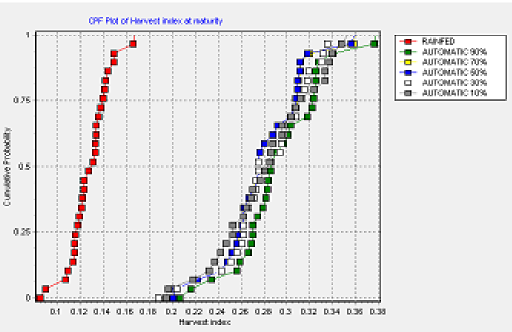
(a) (b)


Box Plot of Total season evapotranspiration, Simulation-harvest (mm
ET total mm
Treatment
0 - 25 Perc.
25 - 75 Perc.
75-100 Perc.
50th Perc.

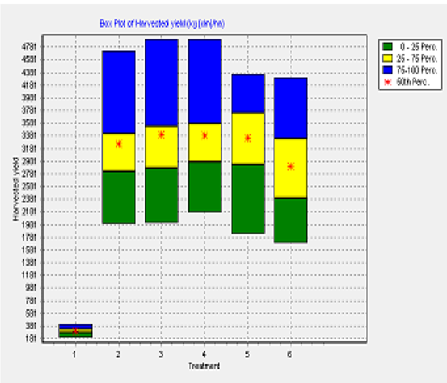

CPF Plot of Total season evapotranspiration, Simulation-harvest (mm
Cumulative Probability
ET total mm
RAINFED
AUTOMATIC 90%
AUTOMATIC 70%
AUTOMATIC 50%
AUTOMATIC 30%
AUTOMATIC 10%

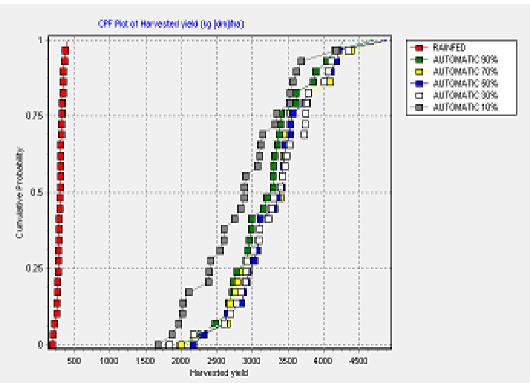
(c) (d)


Box Plot of Harvest index at maturity
Harvest index
Treatment
0 - 25 Perc.
25 - 75 Perc.
75-100 Perc.
50th Perc.

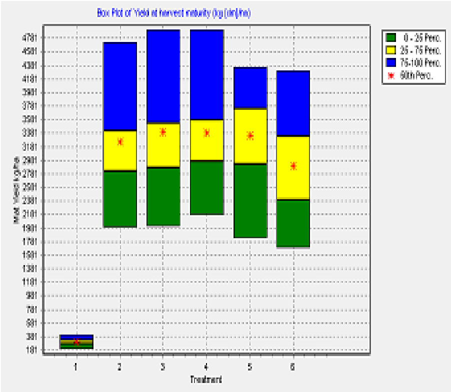

CPF Plot of Harvest index at maturity
Cumulative Probability
Harvest index
RAINFED
AUTOMATIC 90%
AUTOMATIC 70%
AUTOMATIC 50%
AUTOMATIC 30%
AUTOMATIC 10%

(e) (f)

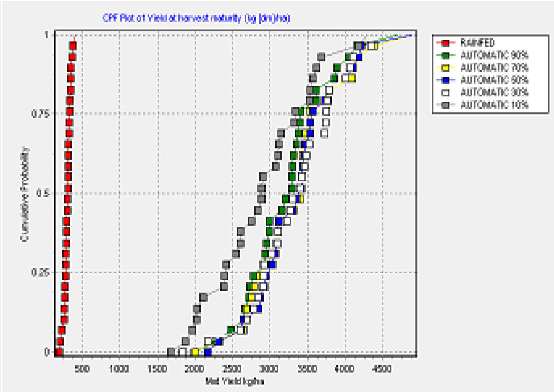

Box Plot of Harvested yield (kg [dm]/ha)
Harvested yield
Treatment
0 - 25 Perc.
25 - 75 Perc.
75-100 Perc.
50th Perc.


CPF Plot of Harvested yield (kg [dm]/ha)
Cumulative Probability
Harvested yield
RAINFED
AUTOMATIC 90%
AUTOMATIC 70%
AUTOMATIC 50%
AUTOMATIC 30%
AUTOMATIC 10%

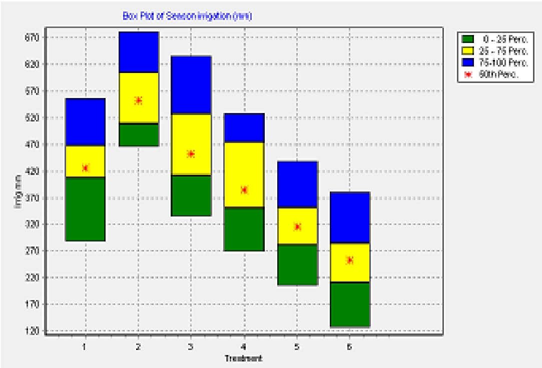
(g) (h)


Box Plot of Yield at harvest maturity (kg [dm]/ha)
0 - 25 Perc.
25 - 75 Perc.
75-100 Perc.
50th Perc.
Treatment

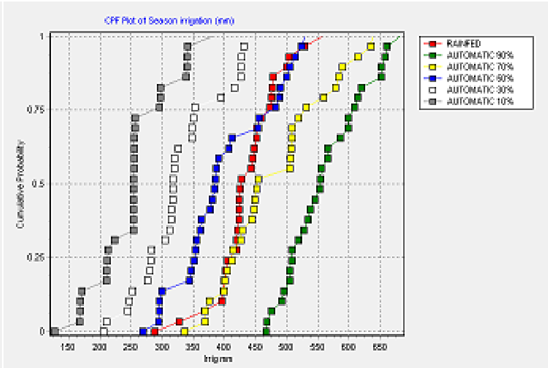
(i)


CPF Plot of Yield at harvest maturity (kg [dm]/ha)
RAINFED
AUTOMATIC 90%
AUTOMATIC 70%
AUTOMATIC 50%
AUTOMATIC 30%
AUTOMATIC 10%
Cumulative Probability

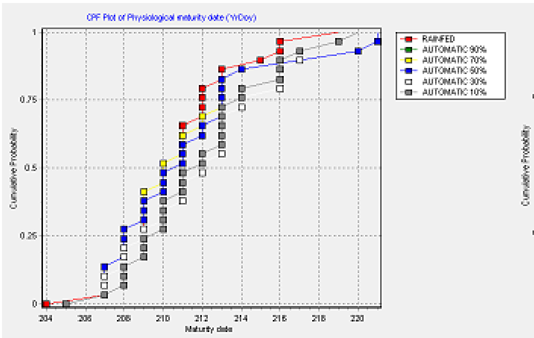
(j)


Box Plot of Season irrigation (mm)
0 - 25 Perc.
25 - 75 Perc.
75-100 Perc.
50th Perc.
Treatment

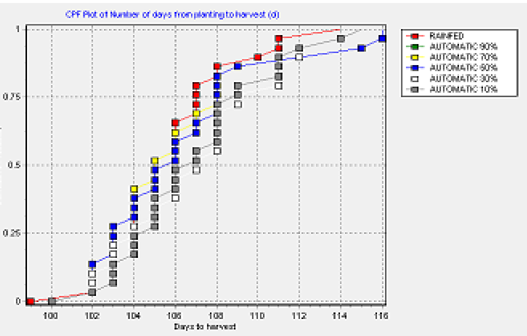
(k)


CPF Plot of Season irrigation (mm)
RAINFED
AUTOMATIC 90%
AUTOMATIC 70%
AUTOMATIC 50%
AUTOMATIC 30%
AUTOMATIC 10%
Cumulative Probability

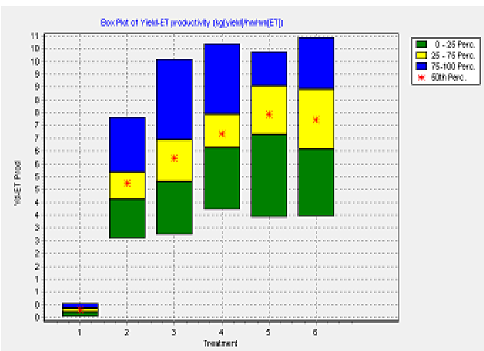
(l)


CPF Plot of Physiological maturity date (YrDoy)
RAINFED
AUTOMATIC 90%
AUTOMATIC 70%
AUTOMATIC 50%
AUTOMATIC 30%
AUTOMATIC 10%
Cumulative Probability
Maturity date

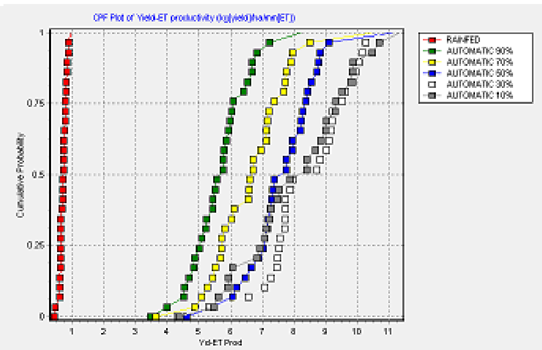
(m)


CPF Plot of Number of days from planting to harvest (d)
RAINFED
AUTOMATIC 90%
AUTOMATIC 70%
AUTOMATIC 50%
AUTOMATIC 30%
AUTOMATIC 10%
Cumulative Probability
Days to harvest

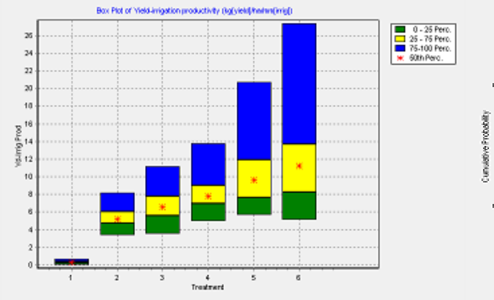
(n)


Box Plot of Yield-ET productivity (kg[yield]/ha/mm[ET])
0 - 25 Perc.
25 - 75 Perc.
75-100 Perc.
50th Perc.
Treatment

(o)


CPF Plot of Yield-ET productivity (kg[yield]/ha/mm[ET])
RAINFED
AUTOMATIC 90%
AUTOMATIC 70%
AUTOMATIC 50%
AUTOMATIC 30%
AUTOMATIC 10%
Cumulative Probability
Yid-ET Prod

(p)



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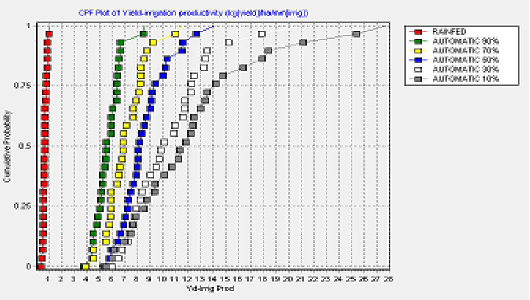

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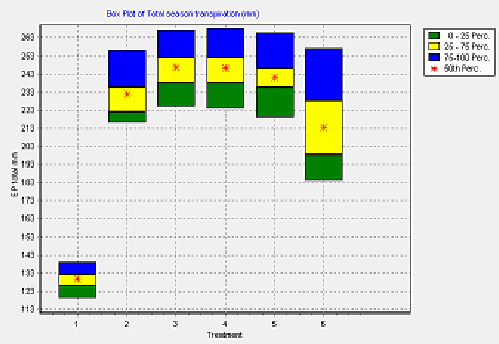

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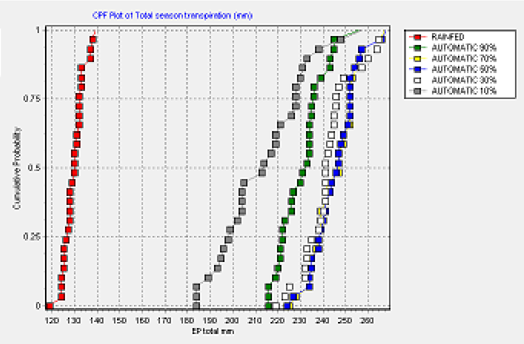

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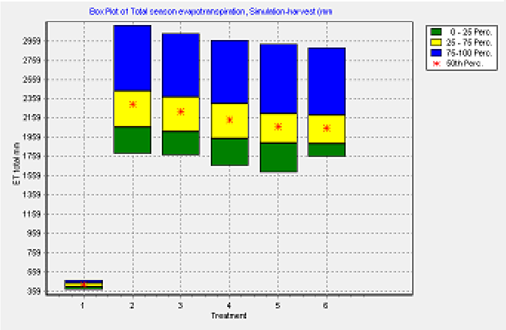

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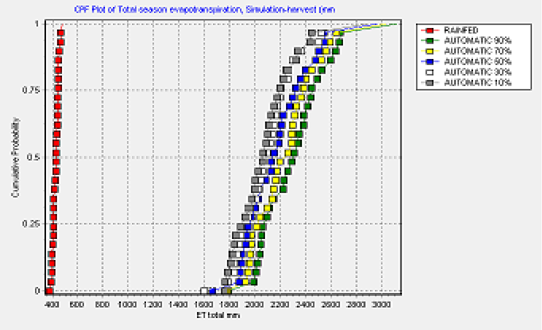

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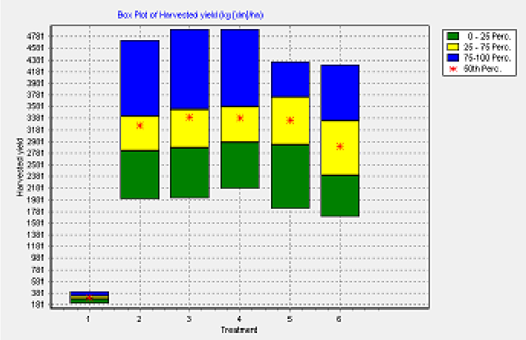
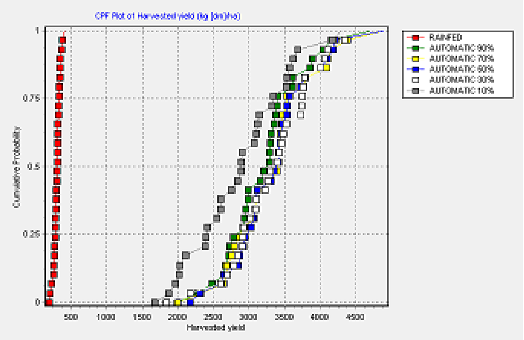


(w)



(x)

SUMMARY AND CONCLUSION

Using DSSAT for decision making with respect to crop is beneficial not only for the crop, but also we can save our resource too. Maize as a tricky crop requires moistures for its growth and development, however we can reduce the water quantity by providing only 30 % automatic irrigation (when required) and thus are able to save the water by 70 % of thresh hold level and getting the maximum benefits with least inputs.

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