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Influence of Agroclimatic Indices on Yield and Yield Attributes of Maize (*Zea mays* L.)

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ABSTRACT

A field experiment was conducted during kharif season, 2016 at S.V. Agricultural college, Tirupathi to study the Influence of Agroclimatic indices on yield and yield attributes of maize (Zea mays L.). The experiment was laid out in split plot design with twelve treatments. Three maize hybrids D.S 900M, Pinnacle and CP818 with four dates of sowing (June II FN, July I FN, July II FN and August I FN). The results indicated that the number of days to attain different phenological growth stages varied. Among the hybrids Pinnacle recorded numerically higher yield (3006.58 kg ha^{-1}) than D.S 900 M (2748 kg ha^{-1}) but was significantly higher than CP818 (2678.4 kg ha^{-1}) Among the dates of sowing D_1 (June II FN) recorded significantly higher yield (3684.36 kg ha^{-1}) than D_2 (3207.72 kg ha^{-1}), D_3 (2628 kg ha^{-1}) and D_4 (August I FN) recorded significantly lower yields (1724.26 kg ha^{-1}). Pinnacle and June II FN recorded highest accumulated Growing degree days, Heliothermal Units, Photothermal units and Heat Use Efficiency to reach maturity compared to the all other treatments. Buildup of GDD, HTU and PTU are good estimators to study maize phenology and can be used as a reliable tool to optimize the sowing period for different maize cultivars.

Key words: *Grain yield, Growing degree days, Heliothermal units, Photothermal units and Heat use efficiency.*

INTRODUCTION

Maize is the third most important cereal crop species in the world after wheat and rice. Climatic variability has great impact on food production. The variation is especially related to abnormal rainfall, drought, temperature and photoperiodism. Of these changes temperature has great influence on the crop production. Temperature increase can impact crop production in a number of ways, but arguably the most important of these is the impact of temperature on crop phenology. Plant phenology is one of the major factors determining yield of crop. The influence of temperature on phenology and yield of crops are expressed under the accumulated heat units system[13]. Hence, it becomes imperative to have knowledge of the exact duration of phenological growth stages at particular growing environment and their impact on yield of crop.

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Crop model may be developed for large areas to forecast the phenology and crop production attributes. The accuracy of prediction depends on the assessment of plant developmental rate at each growing stage at a growing season. The influence of temperature effect on heat unit requirement of crops should be assessed at different times as temperatures of farm varies considerably. Therefore, an experiment was conducted to determine the phenology and heat unit requirement of maize hybrids under different dates of sowing.

MATERIAL AND METHODS

The experiment was conducted during kharif season, 2016 at S.V. Agricultural college, Tirupati located at 13.65°N and 79.42°E, which is situated in southern agro climatic region of Andhra Pradesh. The experiment was laid out in split plot design with twelve treatments and three replications. The experiment was raised with hybrids as major treatments and dates of sowing as subtreatments. The maize hybrids D.S 900M, Pinnacle and CP818 were sown at four dates of sowing (June II FN, July I FN, July II FN and August I FN). The dates of occurance of different phenological events viz., emergence, six leaf stage, tasselling stage, silking stage, soft dough stage, hard dough stage and physiological maturity stage.

The daily meteorological data from the regional meteorological office situated 1km away from the experimental field, were used. The agro meteorological indices growing degree days (GDD), Photothermal unit (PTU), Heliothermal Unit (HTU) and Heat Use Efficiency (HUE) were calculated using following formulae of Rajput[11].

Growing degree days (°C) = $\sum \frac{Tmin + Tmax}{2} - T_b$

Accumulated PTU (°C day hr) = GDD × Day length (hrs.)

Accumulated HTU (°C day hr) = GDD × Duration of sunshine hours

HUE (kg ha^{-1}°C day $^{-1}$) = $\frac{\text{Dry wt.of grains / unit area}}{\text{GDD}}$

Here,

Tmin= Minimum temperature

Tmax= Maximum temperature

T_b = Base temperature = 8 ^{o}C

RESULTS AND DISCUSSIONS

Phenology

The number of days to attain physiological maturity increased with delay in sowing. Among the hybrids Pinnacle recorded highest number of days taken to physiological maturity (106) followed by D.S900M (104) and CP818 (102). Their was no significant variability among all the growth stages of maize hybrids except at tasseling stage where CP818 recorded more number of days to attain anthesis stage. Among the dates of sowing D_4(August I FN) recorded more number of days to attain anthesis and maturity days (61,113) followed by D_3, D_1 and D_2. Delayed sowings extended life cycle of maize crop under these southern Agroclimatic Zone. Similar variability was also observed by Amgain *et al*.[2] and Majumder *et al*[8].

Growing Degree Days

During the crop growing season, GDD accumulated across all the sowing dates ranged from 3170.4 to 2920.8°C and hybrids 2994.1to 3053.3°C from sowing to physiological maturity. The GDD accumulation was higher in case of Pinnacle followed by D.S 900M and CP818 from sowing to physiological maturity. The shifting of sowing dates corresponds to fluctuations in temperatures either lengthing or shortening of the growing periods. D_1 (June II FN) recorded highest GDD followed by D_2 and D_3. GDD varied among all the crop growth stages due to the fluctuated unfavourable conditions high temperatures during the crop growth period. The accumulated heat units decreased for different phenological growth stages as the sowings delayed. Similar variability was also reported by Pandey *et al*.[9], Girijesh *et al*.[3] and Ahmad *et al*[1].

Table 1 Number of days to attain different phenophases of maize as influenced by different dates of sowing

Treatments	Emergence	6 leaf stage	Tasseling stage	Silking stage	Soft dough stage	Hard dough stage	Physiological maturity
Hybrids							
H_1 : D.S 900M	6	24	58	67	77	88	105
H_2 : Pinnacle	7	25	58	67	80	96	106
H_3 : CP818	6	24	61	69	79	90	102
CD (P=0.05)	NS	NS	0.1	NS	NS	NS	NS
Dates of Sowing							
D_1 : June II FN	5	23	57	67	76	92	104
D_2 : July I FN	5	22	56	63	72	84	100
D_3 : July II FN	4	24	60	67	78	88	100
D_4 : August I FN	7	25	61	69	83	94	113
CD (P=0.05)	0.2	0.2	0.1	NS	NS	NS	NS

Table 2 Calendar days and agrometeorological indices at different growth stages of maizehybrids at different dates of sowing

Treatments	Sowing to Physiological maturity				
	Cday	GDD	PTU	HTU	HUE at maturity
Hybrids					
H_1 : D.S 900M	104	3049.1	36101.1	17074	0.9
H_2 : Pinnacle	112	3053.3	36151.1	17098	1.0
H_3 : CP818	102	2994.7	35457.2	16770.3	1.0
Mean	106	3032.3	35903.1	16980.8	1.0
SD	5.3	32.7	387.0	183.1	0.0
CV (%)	5.0	1.1	1.1	6.2	4.8
Dates of sowing					
D_1 : June II FN	104	3170.4	38837.4	20288	1.2
D_2 : July I FN	100	2990	36358.4	19734	1.0
D_3 : July II FN	100	2920.8	34932.8	15501.9	0.9
H_4 : August I FN	112	3079.6	3677.0	14163.4	0.6
Mean	103	3065.2	37023.2	18811.8	1
SD	6.9	129.9	1731.0	2222.3	0.3
CV (%)	6.7	4.2	4.6	11.8	28.4

Photothermal Unit

During the crop growing season, Mean PTU across all the hybrids and sowing dates was 35903.1°C day hour and 37023.2°C day hour respectively. The PTU was higher in case of Pinnacle (36151.1°C day hour) followed by D.S 900M and CP818 from sowing to physiological maturity. D_1 (June II FN) recorded highest PTU (38837.4°C day hour) followed by D_2 and D_3. Due to increased number of calendar days to attain physiological maturity D_4 recorded higher PTU (3677.04°C day hour). Similar variability was also observed by Gowda *et al*[4].

Heliothermal Units (HTU)

During the crop growing season, HTU across all the hybrids and sowing dates was 16980.88°C day hour and 18811.8°C day hour respectively. The HTU was higher in case of Pinnacle (17098°C day hour) followed D.S 900Mand CP818 from sowing to physiological maturity. D_1 (June II FN) recorded highest HTU (20288°C day hour) and D_4 recorded lowest HTU (14163.4°C day hour). Similar variability was also observed by Girijesh *et al*.[3] and Hariram *et al*[5].

Heat Use Efficiency

During the crop growing season, Mean HUE across all the hybrids and sowing dates was 1.0and 1.0. The HUE was higher in case of Pinnacle and CP818 was 1 kg ha^{-1} ^oC day^{-1} and D.S 900M (0.91 kg ha^{-1} ^oC day^{-1}) from sowing to physiological maturity. Among the dates of sowing D_1 (June II FN) recorded highest HUE (1.2 kg ha^{-1} ^oC day^{-1}) and lowest by D_4 (August

I FN, 0.6 kg ha^{-1} ^oC day^{-1}). Higher HUE represents that plant utilized the heat more efficiently by increasing biological activity and higher grain yield. Similar variability was also observed by Thavaprakash *et al*.[15], Girijesh *et al*.[3] and Rajesh *et al*.[10] in wheat.

Yield and Yield components

Number of Cobs per m^{-2}

Among the hybrids Pinnacle recorded numerically higher number of cobs m^{-2} compared to D.S 900 M and CP818. D_1 (June II FN) recorded numerically higher number of cobs m^{-2} compared to other dates of sowing. This can be ascertained due to D_1 sowing accumulated high GDD and PTU. It denotes that maize crop yield is influenced by temperature, daylength as well as sunshine hours. Similar variability was also reported by Rajesh *et al.*[10] in wheat.

Number of seed rows per cob (number)

Among the hybrids Pinnacle recorded significantly higher number of rows per cob (20.80) than D.S 900 M and CP818. Increased GDD, HTU and PTU accumulation in case of Pinnacle resulted in increased cob filling. Similar variability was observed in the findings of Shrestha *et al*[12].

Among the dates of sowing D_1 (June II FN) recorded significantly higher number of rows per cob (24.47) compared to D_2, D_3 and D4. The date of sowing showed variation among the accumulated GDD, HTU and PTU. June II FN sown crop took maximum GDD from sowing to maturity resulting in higher number of rows per cob compared to other dates of sowings. The results are in conformity with the findings of Yusafzai *et al.*[16] and Jaliya *et al*[7].

Number of Seeds per Row (number)

Similar to number f rows per cob, number of seeds per row also influenced by temperature and sunshine hours were Pinnacle recorded significantly higher number of seeds per row (11.7) than D.S 900 M and D_1 (June II FN) recorded numerically higher number of seeds per row (13.3) and lower number of seeds per row was recorded in D_4 (August I FN, 8.9). The results are in conformity with the findings of Hossein *et al*[6].

100 Grain Weight (g)

Among the hybrids Pinnacle recorded significantly higher 100 grain weight(26.4 g) compared to D.S 900 M (25.7 g) and CP 818(24.5 g).The results are in conformity with the Yusafzai *et al*.[16]. Among the dates of sowing D_1 (June II FN) recorded significantly higher 100 grain weight (31.5) compared to other dates of sowing. The increased test weight (g) in early sowing (June II FN) is highest due to accumulated GDD, PTU and HTU especially at soft dough stage compared to other delayed sowings. It denotes that temperature, daylength and sunshine hours prevailing at grain filling stage is important. Similar variability among the dates of sowing and genotypic interactions was also reported by Yusafzai *et al.*[16] and Hossein *et al*[6].

Cob Yield kg ha^{-1}

Cob yield (kg ha^{-1}) was on par among all the three hybrids. CP818 recorded 4486.2 kg ha^{-1}, Pinnacle of 4442.1 kg $ha^{-1}$and D.S 900 M of about 3801.1kg ha^{-1}. Among the dates of sowing D_1(June II FN) recorded numerically higher cob yield (6716.4 kg ha^{-1}) compared to D_2 (July I FN, 4551.1 kg ha^{-1}), D_3 (July II FN, 3194 kg ha^{-1}) and D_4 (August I FN) recorded lower cob yield (2522.3 kg ha^{-1}). The results are in confirmity with findings of Jaliya *et al*[7]. Such increased yield under first date of sowing (June II FN) is because the crop accumulated higher GDD, PTU and HTU from emergence to physiological maturity compared to delayed sowings.

Cob length (cm)

Among the hybrids there was significant difference and Pinnacle recorded numerically higher cob length (13.2 cm) compared to D.S 900 M(12.7 cm) and CP818 (11.7 cm). Among the dates of sowing D_1 (June II FN) recorded numerically higher cob length (15.7 cm) compared to D_2 (14.1 cm), D_3 (12.1 cm) and D_4 (8.5 cm).

Grain yield

Among the hybrids Pinnacle recorded numerically higher yield (3006.58 kg ha^{-1}) than D.S 900 M (2748 kg ha^{-1}) but was significantly higher than CP818 (2678.4 kg $ha^{-`1}$). Due to increased heat use efficiency in

case of Pinnacle total kernel yield increased since the grain yield is linearly related to heat use efficiency.

Among the dates of sowing D_1 (June II FN) recorded significantly higher yield (3684.36 kg ha^{-1}) than D_2 (3207.72 kg ha^{-1}), D_3 (2628 kg ha^{-1}) andD_4 (August I FN) recorded significantly lower yields (1724.26 kg ha^{-1}). The higher yields attributed to the favorable agro-climatic conditions particularly temperature, day length and sunshine hours interms of higher accumulated GDD, PTU and HTU from sowing to physiological maturity compared to other dates of sowing. The early planting dates resulted in higher yields compared to delay in sowing dates because of high heat use efficiency of 1.2 compared to other sowings.

These results indicated that build up of GDD, PTU, HTU and HUE are good estimators to study phenology and can be used as a reliable tool to optimize the sowing period for different cultivars. Similar results were obtained by Shrestha *et al*[12].

Stover Weight (Kg ha^{-1})

Similar to yield components Pinnacle recorded significantly higher Stover weight (5509.1 kg ha^{-1}) compared to D.S 900 M (5252.6 kg ha^{-1}) and CP818 (5314.3 kg ha^{-1}). Among the dates of sowing D_1 (June II FN) also recorded significantly higher stover weight (7523.2 kg ha^{-1}) compared to all other dates of sowing. First date of sowing (June II FN) crop exposed to favorable weather interms of temperature, day length, sunshine hours caused higher stover yield along with grain yield. Similar results were obtained by Sreenivasulu *et al*[14].

Harvest Index (%)

Among the hybrids there Pinnacle recorded higher harvest index (37.5%) compared to D. S 900 M (35.6%) and CP818 (34.3%). Similarly D_1 (June II FN) recorded significantly higher harvest index (39.8%) compared to D_2 (38.3%), D_3 (36.1%) and D4 (29.1%) due to higher accumulation of GDD, PTU and HTU. Similar results were obtained by Shrestha *et al*[12].

Table 3: Yield attributes of maize hybrids as influenced by different dates of sowing

Treatments	No. of cobs m^{-2}	No. of rows cob^{-1}	No. of seeds row^{-1}	100 grain weight (g)	Cob yield (kg ha^{-1})	Cob length (cm)
Hybrids						
H_1 : D.S 900M	7	18.6	10.9	25.7	3801.1	12.7
H_2 : Pinnacle	7.4	20.8	11.7	26.4	4442.1	13.2
H_3 : CP818	7.1	17.1	11.2	24.5	4486.2	11.7
CD (P=0.05)	NS	1.4	0.7	0.4	692.6	2.2
Dates of Sowing						
D_1 : June II FN	7.9	24.5	13.3	31.5	6716.4	15.6
D_2 : July I FN	7.3	22.1	11.9	26.3	4551.1	14.1
D_3 : July II FN	6.9	17.7	10.9	22.4	3194.1	12.1
D_4 : August I FN	6.6	10.9	8.8	21.8	2522.9	8.5
CD (P=0.05)	NS	1.12	NS	0.8	NS	1.1

Table 4 Grain yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) of maize hybrids as influenced by different dates of sowing

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
Hybrids			
H_1 : D.S 900M	2748.9	4854.3	35.6
H_2 : Pinnacle	3006.6	4867.3	37.5
H_3 : CP818	2678.4	4947.5	34.3
CD (P=0.05)	304.7	NS	2.37
Dates of Sowing			
D_1 : June II FN	3684.4	5580.9	39.8
D_2 : July I FN	3207.7	5192.3	38.3
D_3 : July II FN	2628.8	4593.3	36.1
D_4 : August I FN	1724.3	4192.4	29.1
CD (P=0.05)	238.8	367.1	4.2

CONCLUSION

Pinnacle proved to be superior and better adapted to southern Agro Climatic conditions compared to D.S 900M and CP818. Sowing of maize hybrids in June II FN is appropriate interms higher physiological maturity efficiency and yield in sothern agro climatic zone. Buildup of GDD, HTU and PTU are good estimators to study maize phenology and can be used as a reliable tool to optimize the sowing period for different maize cultivars. Estimation of heat use efficiency is also useful for the appraisal of yield potential of maize in different dates of sowing.

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