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Spatial and Temporal Arrangement of Hybrid Maize for Assesment of Phenology and Agrometeorological Indices

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ABSTRACT

A field trial was conducted during the *Kharif* season of 2020 to assess the effect of spatial and temporal crop geometry on the phenology, yield and agro meteorological indices of hybrid maize at the Agronomy Research Farm, FoA Wadura, Sopore, SKUAST-Kashmir. The experiment was carried out in split- split plot design with dates of sowing (17^{th} SMW; D_1), 19^{th} SMW; D_2 and 21^{st} SMW; D_3) as main plot treatments; varied row spacing (50 cm × 20 cm; S_1, 60 cm× 20 cm; S_2 and 70 cm ×20 cm; S_3) as sub- plot treatments and two maize hybrids (Hytech- 5801;H_1 and YSH- 1; H_2) as sub- sub plot treatments. Results indicated that hybrid Hyteh- 5801 sown on 17^{th} SMW observed highest grain yield and biological yield and took greater days to reach different phenological stages, thereby piled higher heat units, PTUs, HTUs, HyTUs, PTI followed by 19^{th} SMW and 21^{st} SMW. The plant spacing of 70 cm ×20 cm took maximum days for reaching different phenophases and accumulated maximum heat units, PTUs, HTUs, HyTUs, PTI. Thermal use efficiencies were maximum ((HTUE, PTUE, HyTUE and HUE)) when the maize hybrid Hytech-5801was sown on 17^{th} SMW. The biological yield based thermal efficiencies showed the highest response with row-spacing of 50 cm × 20 cm whereas grain yield based thermal efficiencies were maximum under 70 cm×20 cm plant spacing.

Keywords: Agrometeorological indices, Growing degree days, Maize, Phenology, Yield.

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INTRODUCTION

Maize (*Zea mays* L.), the most vibrant food grain crop is grown under distinct soil and climatic conditions. The temperature should be considered as one of the detrimental factors for maize production. Temperature based agro- meteorological indices *viz*, growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU), hydrothermal units (HyTU), phenothermal index (PTI) and heat use efficiency (HUE) as these concepts state a linear relationship between phenophasic development with base and optimum temperature. The optimal average temperatures for the entire crop growing season ranges between 20-22 °C. Different sowing dates with climatic variables (sunshine hours, temperature, rainfall *etc*) have a dynamic effect on the growth and yield of maize plants. It has been found that unfavourable sowing time results in the reduction of grain yield and production of maize. It has been found that delayed sowing of crops decreases the crop duration with a lesser interception of solar radiation (Szeles and Huzsvai, 2020) during the emergence to the silking stage. Delayed planting can produce a lower quantity of dry matter as the crop is exposed to a colder temperature and lower solar radiation (Rehana *et al.*, 2017). Plant spacing is one of the important agronomic attributes as it can have an influence on radiation utilization during carbon dioxide fixation utilizing green plant parts for energy production (Balaji and Joydawson, 2021). Solar radiation received by the leaf surface and effectiveness for producing dry matter and better solar radiations can be intercepted by proper spacing (Jondhale *et al.*, 2018). So, change in sowing time and plant density causes a significant change in the phenophasic development and radiation utilization by maize (Ahmad *et al.*, 2018; Raouf and Sharifi, 2016). The developmental change and biomass accumulation in crops are majorly determined by the climatic variables during the crop growing period which primarily affects the heat unit requirement of the crop from one developmental phase to another (Golla *et al.*, 2018; Xu *et al.*, 2021), however, no significant research was done to find the phenological changes due to varied heat unit requirement under different sowing time and spacing of hybrid maize for efficient utilization of weather parameters. Therefore, the study was conducted to analyze the yield and phasic development of hybrid maize in response to dates of sowing and plant spacing by assessing the agro meteorological indices and thermal efficiencies.

MATERIALS AND METHODS

Location and experiment Details

A field trial was conducted at the research farm of agronomy, Wadura Sopore, Sher-e Kashmir University of Agricultural Sciences and Technology Kashmir in the year 2020 located

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between 34° 21' N latitude and 74° 23' E longitude having an altitude of 1590 m above the mean sea level. The experimental area was having a good drainage facility with unvaried topography. The maximum and minimum temperature (mean) during the crop growing season were 34.5°C and 9.4°C for the first date of sowing, 32.5 °C and 14.1 °C for the second date of sowing and 34.5 °C and 10.1 °C for the third date of sowing (Fig.1, 2&3). The precipitation amounted to 300 mm, 285 mm and 220 mm for different dates of sowing. The mean maximum and minimum relative humidities were 73.7 % and 63.7% for the first date of sowing, 91.4 % and 47.4 % for the second date of sowing and91.9 % and 46.9 % for third date of sowing (Fig.1, 2&3). The experimental plot (Table 1) was

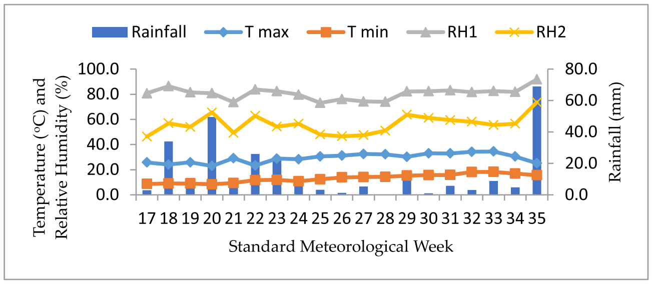


Fig. 1: Weekly meteorological data during the crop growth period for 1st date of sowing (17th SMW(23-29 April)

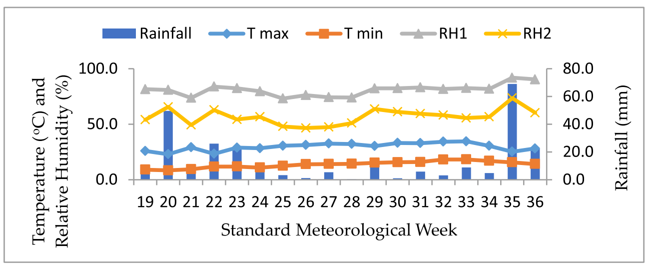


Fig. 2: Weekly meteorological data during the crop growth period for 2nd date of (19th SMW (7-13 May)

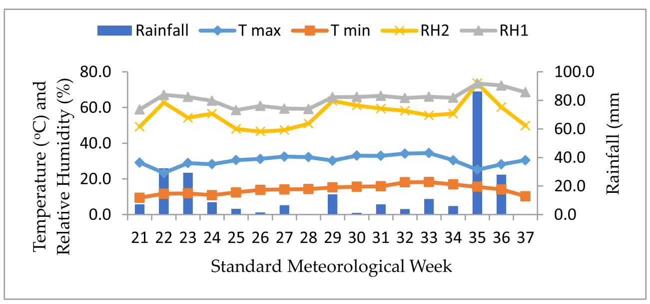


Fig. 3: Weekly meteorological data during the crop growth period for 3rd date of sowing (21st SMW (21-27 May)

having silty clay loam texture with medium availability of nitrogen (306.25kg ha^{-1}), phosphorus (18kg ha^{-1}), potassium (213.80kg ha^{-1}) and neutral in pH (6.8).

The experiment consisted of three factors with three sowing dates as main plot treatments *viz*.(17th SMW(23-29 April) (D_1), 19th SMW (7-13 May) (D_2) and 21st SMW (21-27 May) (D_3), three spacings as sub-plot treatments *viz*. 50 cm × 20 cm (S_1), 60 cm × 20 cm(S_2), 70 cm × 20 cm (S_3) and two hybrids as sub-sub-plot treatments *viz.* Hytech- 5801 (H_1), YSH- 1(H_2) laid out in split-split plot design with three replications. The days taken for reaching different phenophases (Knee high stage, Tasseling stage, Silking stage and Maturity) were recorded from the time of sowing. Observations for grain and biological yield were recorded at harvest.

Table 1: Physical and chemical characteristics of experimental plot.

Particulars	Value
Mechanical analysis	
Bulk density (g cm^{-3})	1.13
Fine sand (%)	10.46
Silt (%)	54.21
Clay (%)	35.33
Texture class	Silty clay loam
Chemical analysis	
Soil pH	6.8
Electrical conductivity (dSm^{-1}) at 25°C	0.27
Organic Carbon (%)	0.74
Available Nitrogen (kg ha^{-1})	306.25
Available Phosphorous (kg ha^{-1})	18.80
Available Potassium (kg ha^{-1})	213.80

Computation of agrometeorological indices and Thermal use efficiencies

The weather parameters *viz*. daily max. and min. temperature, sunshine hours, day length and average relative humidity was assessed and used for calculation of agrometeorological indices *viz*. growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU), hydrothermal unit (HyTU) and phenothermal index (PTI) at different growth stages using the formulas given below. GDD, HTU, PTU and HyTU were measured from the date of sowing to each phenophase with a base temperature 10 °C.

$$GDD = [(T_{Max}+T_{Min})/2] - T_b$$

Where:

T_{max} = Daily max. temperature

T_{min} = Daily min. temperature

Tb = base temperature (a temperature below which no development occurs for a given plant species).

$$HTU = (GDD \times SSH)$$

Where, SSH (hour) is the daily sunshine hours

$$PTU = (GDD \times DL)$$

Where, DL (hour) is the day length

$$HyTU = (GDD \times RH)$$

Where, RH (%) is the daily mean relative humidity.

$$PTI = \frac{\text{Heat units consumed between two phenophases}}{\text{Duration between two phenophases}}$$

For obtaining HUE, HTUE, PTUE and HyTUE, grain and biological biomass was divided by the respective agrometeorological indices.

Statistical Analysis

Crop phenology and grain yield data were analyzed as per the analysis of variance (ANOVA) using the statistical procedure of split split plot design. The extent of the relationship between yield (Grain/biological) with different indices was computed using correlation. Regression of yield with respective indices was worked out in the form of a regression equation to find the response of yield (Grain/biological) determined by various indices. The statistical procedure was performed using SPSS software.

RESULTS AND DISCUSSION

Phenology

Results of the experiment showed significant variation in maize hybrids with varying sowing dates and crop geometry for the completion of different growth stages (Table 2). The developmental rate of plant growth quantitatively depends on the prevailing temperature. The sowing of maize hybrids on 17th SMW (D_1) took maximum days to maturity followed by sowing on 19th SMW (D_2) and 21st SMW (D_3). The prevalence of cooler temperature in the first sowing date increased the number of calendar days during crop growth and hence took a greater number of days to attain maturity as also observed by Shrestha *et al.* (2016) and Maurya *et al.* (2016). Wider spacing of 70 x 20 cm took a maximum number of days (119.95) for completion of different phenophases whereas closer spacing significantly reduced the crop duration vis a vis phenophases. Due to significant competition for growth factors like light, nutrients, carbon dioxide *etc*, in closely spaced crops, the transition period between vegetative and reproductive phases gets accelerated resulting in a shorter growth duration. Among the hybrids, Hytech-5801 took higher days to complete maturity (122.74) and YSH-1 reached maturity in 108.97 days only probably due to the different genetic make-up of these varieties. The variation in crop phenology among the hybrid maize cultivars was also recorded by Majumder *et al*. (2016).

Agrometeorological indices

Growing degree days

Growing degree day concept which assesses the relationship between growth and temperature by accounting for the heat unit requirement for completion of different development stages of crop. Varying sowing dates and crop geometry showed significant variation in heat unit accumulation among the maize hybrids at different phonological stages (Table 3). Maximum heat units (1345.33 ^{0}C day) were accumulated by sowing the hybrid on 17th SMW (D_1) followed 19th SMW (D_2) and 21st SMW (D_3) which accumulated 1319.85 ^{0}C and 1257.46 ^{0}C day, heat units for crop maturity, respectively. The favourable weather conditions and lengthier crop duration in early sowing led to maximum heat unit accumulation, conversely, reproductive growth and crop duration were drastically reduced with delayed sowing as reported by Kaur *et al.* (2019) and Thimme *et al.* (2013). Wider spacing of 70 cm × 20 cm accumulated higher heat units (1337.06 ^{0}C day) in contrast to the narrow spacing of 60 cm × 20 cm and 50 cm × 20 cm. The highly amplified competition for resource factors such as light, nutrients, carbon dioxide *etc*, in closely planted crops quickens the transition from vegetative to reproductive phase, hence decreasing the duration and heat unit requirement of the crop. Similar results were observed by Peng *et al.* (2014). The hybrids showed difference for heat unit requirement with Hytech-5801 accumulating more heat units (1373.33 ^{0}C day) as compared to YSH-1 (1241.76 ^{0}C day) probably due to the differential crop duration and genetic makeup of hybrids (Majumder *et al*., 2016;Deshmukh *et al*., 2021).

Heliothermal units (HTU)

Differential sowing dates and crop geometry of maize hybrids recorded significant differences in heliothermal units at various phenophases (Table 4). The maximum heliothermal units (10892.71 ^{0}C day) were accumulated in the early sown crop on 17th SMW followed by sowing on 19th SMW (10681.40 ^{0}C day) and 21st SMW (10164.92 ^{0}C day). The variation in temperature and bright sunshine hours coupled with longer duration in early sowing accumulated higher heliothermal units (Shingne *et al*., 2020). Planting geometry which caused the difference in crop duration and growing degree days reported significant variation in heliothermal unit accumulation. The geometry of 70 cm×20 cm recorded maximum helio-thermal units (10786.79 ^{0}C day) followed by crop geometry of 60 cm × 20 cm and 50 cm × 20 cm, respectively. Reduced crop duration and heat units in narrow planting geometry result in lower accumulation of heliothermal units compared to wider planting (Singh and Singh, 2015). Maize hybrid Hytech-5801 recorded maximum

Table 2: Effect of dates of sowing dates and plant spacing on phenological stages (Days) of hybrids.

Treatments	Knee high	Tasseling	Silking	Maturity
Time of sowing				
17th SMW (D_1)	37.8	78.95	83.91	118.81
19th SMW (D_2)	35.78	76.93	81.1	116.09
21st SMW (D_3)	34.23	73.92	78.82	112.66
SE(m)±	0.65	0.92	0.77	0.87
CD (p=0.05)	1.95	2.78	2.31	2.63
Row spacing				
50 cm × 20 cm (S_1)	33.36	74.56	78.72	111.76
60 cm × 20 cm (S_2)	36.07	76.5	81.41	115.84
70 cm × 20 cm (S_3)	38.39	78.75	83.71	119.95
SE(m)±	0.92	1.31	1.09	1.24
CD (p=0.05)	2.76	3.94	3.27	3.72
Varieties				
Hytech- 5801 (H_1)	39.85	80.91	85.25	122.74
YSH- 1 (H_2)	32.03	72.3	77.31	108.97
SE(m)±	0.46	0.74	2.62	3.56
CD (p=0.05)	1.38	2.24	7.85	10.69

Table 3: Growing degree days (GDD) of maize hybrids under different dates of sowing and plant spacing.

Treatments	knee high	Tasseling	Silking	Maturity
Time of sowing				
17th SMW (D_1)	348.54	895.74	972.72	1345.33
19th SMW (D_2)	305.14	832.92	894.56	1319.85
21st SMW (D_3)	287.26	772.12	837.92	1257.46
SE(m)±	7.63	16.74	8.53	14.54
CD (p=0.05)	22.90	50.22	25.59	43.64
Row spacing				
50 cm × 20 cm (S_1)	285.58	803.33	863.95	1297.32
60 cm × 20 cm (S_2)	315.54	833.50	903.68	1306.26
70 cm × 20 cm (S_3)	339.81	863.94	937.58	1337.06
SE(m)±	10.79	23.66	12.06	8.33
CD (p=0.05)	32.38	71.00	36.19	25.00
Varieties				
Hytech- 5801 (H_1)	356.33	894.70	959.21	1373.33
YSH- 1 (H_2)	270.96	772.49	844.26	1241.76
SE(m)±	2.73	10.98	36.66	42.33
CD (p=0.05)	8.20	32.95	110.00	127.00

Table 4: Heliothermal units (HTU) of different maize hybrids under different dates of sowing and plant spacing.

Treatments	knee high	Tasseling	Silking	Maturity
Time of sowing				
17th SMW (D_1)	2703.4	7472.64	8134.77	10892.71
19th SMW (D_2)	2380.57	6956.8	7471.03	10681.4
21st SMW (D_3)	2261.61	6446.03	6978.27	10164.92
SE(m)±	67.10	142.39	64.40	99.60
CD (p=0.05)	201.34	427.17	193.3	298.99
Row spacing				
50 cm × 20 cm (S_1)	2023.22	6586.40	7099.00	10448.42
60 cm × 20 cm (S_2)	2419.32	6946.39	7528.23	10503.82
70 cm × 20 cm (S_3)	2902.99	7342.69	7956.82	10786.79
SE(m)±	94.91	201.30	91.12	18.25
CD (p=0.05)	284.746	604.12	273.36	54.75
Varieties				
Hytech- 5801 (H_1)	2796.18	7481.06	7998.59	11063.13
YSH- 1 (H_2)	2100.86	6435.90	7057.45	10096.22
SE(m)±	23.84	98.54	49.93	275.13
CD (p=0.05)	71.46	295.62	149.87	825.32

heliothermal units (11063.13 ^{0}C day) as compared to YSH-1 (10096.22 ^{0}C day). It has been also suggested significant differences in crop duration among the hybrids could be ascribed to the varied heliothermal unit accumulation.

Photothermal units (PTU)

The results of the experiment showed significant variation at different growth stages in photothermal units accumulation among hybrids under varied dates of sowing and planting geometry (Table 5). Sowing of maize hybrids on 17th SMW accumulated maximum photothermal units (17906.99 ^{0}C day) followed by 19th SMW and 21st SMW sown crop. The prevalence of maximum air temperature and favourable temperature during the entire crop duration of early sown crop resulted in the accumulation of higher photothermal units. The findings of Shingne *et al.* (2020) and Harleen *et al.* (2019) also reported higher PTU accumulation in the early sown crop. The hybrid maize was sown at wider geometry of 70 cm × 20 cm registered the highest photothermal units (17892.16 ^{0}C day) compared to crop geometry of 60 cm × 20 and 50 cm × 20 cm, respectively. Sumeriya (2006) also found higher PTU under wider planted crops which was due to better availability of resource inputs *viz.* sunlight, moisture, nutrients resulting in increased crop duration and heat unit requirement in contrast to narrower planting creating stiff competition for growth resources. Among the hybrids, Hytech-5801 recorded higher photothermal units (18354.69 ^{0}C day) as compared to YSH-1 (16703.03 ^{0}C day). The differential behaviour to accumulation of photothermal units was due to variation in crop duration between two maize hybrids (Majumder *et al.*, 2016).

Table 5: Photothermal units (PTU) of different maize hybrids under different dates of sowing and plant spacing.

Treatments	knee high	Tasseling	Silking	Maturity
Time of sowing				
17th SMW (D_1)	4782.81	12180.061	13197.13	17906.99
19th SMW (D_2)	4150.53	11338.74	12172.84	17742.32
21st SMW (D_3)	3861.72	10472.08	11306.54	16937.26
SE(m)±	104.12	223.81	122.82	189.63
CD (p=0.05)	312.59	671.40	368.49	568.99
Row spacing				
50 cm × 20 cm(S_1)	3879.46	10925.03	11683.99	17180.08
60 cm × 20 cm(S_2)	4294.16	11334.12	12270.90	17514.34
70 cm × 20 cm(S_3)	4621.43	11731.72	12721.608	17892.16
SE(m)±	147.31	316.50	173.71	110.04
CD (p=0.05)	442.07	949.50	521.13	330.12
Varieties				
Hytech- 5801(H_1)	4848.14	12156.00	13011.60	18354.69
YSH- 1 (H_2)	3681.90	10504.57	11439.40	16703.03
SE(m)±	35.91	147.71	231.92	531.19
CD (p=0.05)	107.86	443.35	695.54	1593.59

Hydrothermal units (HyTU)

The hydrothermal unit calculation of hybrid maize revealed significant variation under varying sowing dates and planting geometry for reaching different growth stages (Table 6). Maximum hydrothermal units (92139.60 ^{0}C day %) were accumulated by sowing on 17th SMW followed by sowing on 19th SMW and 21st SMW. Favourable weather, longer crop duration and greater heat unit aggregation resulted in maximum accumulation of hydrothermal units in the early sown crop. The findings of Kaur *et al.* (2019) and Kadam (2021) also favour similar results. Crops sown at plant spacing of 70 cm × 20 cm recorded the highest hydrothermal units (91719.46 ^{0}C day %) compared to crop geometry of 60 cm × 20 cm and 50

Table 6: Hydrothermal units (HyTU) of different maize hybrids under different dates of sowing and plant spacing

Treatments	knee high	Tasseling	Silking	Maturity
Time of sowing				
17th SMW (D_1)	23125.78	60084.70	65423.40	92139.60
19th SMW (D_2)	20849.95	55508.20	59806.70	90884.10
21st SMW (D_3)	19893.27	51401.00	55883.50	85901.24
SE(m)±	487.84	1163.26	591.70	984.21
CD (p=0.05)	1463.52	3489.79	1775.11	2952.60
Row spacing				
50 cm × 20 cm (S_1)	19427.97	53538.09	57745.7	87595.08
60 cm × 20 cm (S_2)	21386.80	55683.44	60513.79	89610.40
70 cm × 20 cm (S_3)	23054.17	57772.42	62854.25	91719.46
SE(m)±	689.90	1645.10	836.71	1391.80
CD (p=0.05)	2069.72	4935.31	2510.39	4175.67
Varieties				
Hytech- 5801 (H_1)	24077.19	59890.16	64411.50	94245.10
YSH- 1 (H_2)	18502.15	51439.19	56331.00	85038.20
SE(m)±	239.43	662.21	2718.71	2962.81
CD (p=0.05)	718.30	1986.64	8156.23	8888.40

cm × 20 cm. Availability of higher growth inputs viz., sunlight, moisture, nutrients under wider spacing led to more accumulation of hydrothermal units in contrast to narrowly spaced geometry. The hybrid Hytech-5801 required more hydrothermal units to reach different phenophases compared to YSH-1. The variation could probably be due to different genetic makeup causing significant distinction in the maturity of hybrids.

Phenothermal index (PTI)

Degree days per growth day generally expressed as phenothermal index showed an increasing trend from knee-high to flowering stage and thereafter decreased till maturity suggesting a decline in daily thermal consumption towards senescence. The phenothermal index for consecutive phenophases of maize hybrids varied significantly under different dates of sowing and crop geometry (Table 7). The sowing of maize hybrids on 17th SMW (D_1) recorded maximum values of phenothermal index (12.25) in contrast to 19th SMW and 21st SMW sown crop. Higher phenothermal index value recorded in early sowing could probably be due to the longer duration of the early sown crop. The results are also supported by the findings of Shingne *et al.* (2020). It was observed that the phenothermal index gradually decreased from emergence to maturity with the decrease in plant spacing with 70 cm x 20 cm recorded highest value (12.64) compared to crop geometry of 60 cm x 20 and 50 cm x 20 cm where PTI values of 11.68 and 11.06 were recorded. The increased crop duration under wider spacing due to optimal utilization of resources resulted in higher PTI values. Further, among the hybrids, Hytech-5801 attained higher values of phenothermal index in contrast to YSH-1 across all phenological stages.

Yield

Data in Table 8 indicated that the yield of maize hybrids was governed significantly by dates of sowing and crop geometry. Sowing on 17th SMW (D1) observed higher grain and biological yield (70.15 and 202.96 q/ha) as compared to the sowing of hybrids on 19th SMW and 21st SMW. The lower yield in delayed sowing could be due to the prevalence of high temperature leading to increased respiration rate and reduced net photosynthesis and hereafter less translocation of assimilates as also reported by Najmah *et al.* (2020). The results showed that crop geometry of 70 × 20 cm recorded higher grain and biological yield in contrast to narrower geometry of 60 x 20 and 50 x 20 cm, respectively. Efficient absorption of nutrients and solar radiations for improved photosynthesis resulted in the highest grain yield in wider spaced crops. However, in the case of narrowly spaced crops, more number of plants per unit area resulted in the highest biological yield in case of which led to more biomass production. Kebede (2019); Shafi *et al.* (2012) and Hugar *et al.* (2015) reported similar findings. Moreover, the hybrid Hytech-5801 registered higher grain and biological yield (71.04 and 203.83 q/ha) than YSH-1 (60.87 and 179.26 q/ha) which could

Table 7: Pheno- thermal index (PTI) of maize hybrids under different dates of sowing and plant spacing.

Treatments	Knee high to Tasseling	Tasseling to Silking	Silking to Maturity
Time of sowing			
17th SMW (D_1)	13.75	16.18	12.25
19th SMW (D_2)	12.82	13.89	12.00
21st SMW (D_3)	11.79	13.37	11.13
SE(m)±	0.075	0.33	0.15
CD (p=0.05)	0.225	1.01	0.454
Row spacing			
50 cm × 20 cm (S_1)	12.57	14.12	11.06
60 cm × 20 cm (S_2)	12.80	14.21	11.68
70 cm × 20 cm (S_3)	12.98	15.11	12.64
SE(m)±	0.106	0.28	0.1
CD (p=0.05)	0.318	0.852	0.32
Varieties			
Hytech- 5801 (H_1)	13.112	14.97	12.56
YSH- 1 (H_2)	12.47	14.92	11.56
SE(m)±	0.06	0.26	0.43
CD (p=0.05)	0.183	0.783	1.311

Table 8: Yield and thermal use efficiencies of different maize hybrids under different dates of sowing and plant spacing.

Treatments	Grain yield (q ha^{-1})	Biological yield (q ha^{-1})	HTU GYB	HTU BYB	HTUE GYB	HTUE on BYB	PTUE GYB	PTUE BYB	HyTU GYB	HyTU BYB
Dates of sowing										
17th SMW (D_1)	70.15	202.96	5.37	15.46	0.66	1.91	0.39	1.14	0.07	0.22
19th SMW (D_2)	65.81	193.04	4.83	14.31	0.59	1.76	0.36	1.06	0.07	0.20
21st SMW (D_3)	61.89	178.64	4.51	12.70	0.55	1.57	0.33	0.95	0.06	0.18
SE(m)±	1.26	3.03	0.11	0.42	0.01	0.05	0.008	0.03	0.001	0.01
CD (p=0.05)	3.77	9.09	0.33	1.26	0.03	0.15	0.024	0.09	0.005	0.03
Row spacing										
50 cm × 20 cm (S_1)	56.97	193.43	4.31	15.34	0.52	1.87	0.32	1.14	0.06	0.22
60 cm × 20 cm (S_2)	65.49	190.95	4.87	14.14	0.60	1.75	0.36	1.05	0.07	0.20
70 cm × 20 cm (S_3)	75.40	190.27	5.53	12.99	0.68	1.61	0.41	0.96	0.08	0.19
SE(m)±	1.30	3.16	0.15	0.59	0.01	0.07	0.01	0.04	0.002	0.008
CD (p=0.05)	3.90	9.48	0.47	1.78	0.05	0.21	0.03	0.13	0.007	0.02
Varieties										
Hytech- 5801 (H_1)	71.04	203.83	5.34	15.26	0.664	1.89	0.40	1.14	0.078	0.22
YSH- 1 (H_2)	60.87	179.26	4.46	13.05	0.55	1.60	0.33	0.97	0.065	0.19
SE(m)±	0.67	4.47	0.10	0.66	0.008	0.07	0.007	0.04	0.0016	0.01
CD (p=0.05)	2.01	13.41	0.30	1.99	0.02	0.21	0.02	0.14	0.005	0.03

GYB means grain yield basis and BYB means biological yield basis

Table 9: Correlation studies of yield and yield parameters with various weather parameters

	Grain yield	Grains per cob	Cob weight	Seed index	T Max.	T Min.	Rainfall	SSH	RH1	RH2
Grain yield	1									
Grains per cob	0.715**	1								
Cob weight	0.918**	0.800**	1							
Seed index	0.657**	0.972**	0.787**	1						
T Max.	-0.471*	-0.608**	-0.646**	-0.683**	1					
T Min.	-0.222	-0.665**	-0.427	-0.707**	0.728**	1				
Rainfall	0.484*	0.637**	0.613**	0.580*	-0.276	-0.144	1			
SSH	-0.457	-0.240	-0.383	-0.149	-0.226	-0.425	-0.726**	1		
RH1	0.424	-0.204	0.206	-0.271	0.356	0.626**	0.051	-0.619**	1	
RH2	0.057	0.078	0.036	0.000	0.407	0.473*	0.662**	-0.820**	0.311	1

** means significance at 0.00;, T Max. is maximum Temperature; T Min. is Minimum Temperature; SSH are sunshine hours; RH1 and RH2 are morning and evening Relative humidity

probably be due to the different genetic makeup of hybrids as reported by Majumder *et al.* (2016).

Thermal use efficiencies

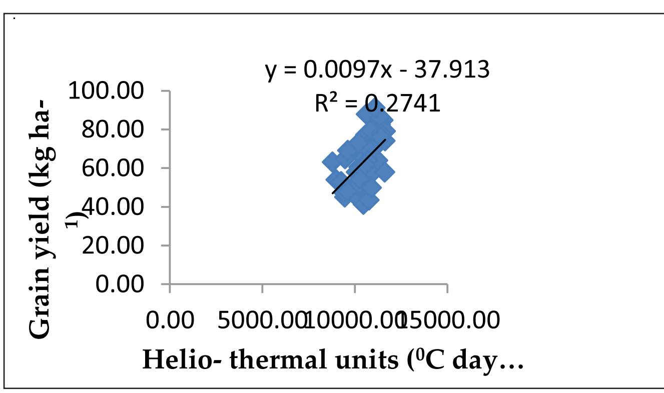
The crops do not use the heat energy fully for producing dry matter, but genetic makeup and crop management factors *etc.* which govern the potential yield of the crop can be measured in terms of thermal efficiencies as shown in Table 8. Among the dates of sowing, significantly highest values of thermal use efficiencies *viz.* HTU (5.37 and 15.46 kg/ha/°C day), HTUE (0.665 and 1.911 kg/ha/°C day hour), PTUE (0.399 and 1.147 kg/ha/°C day hour) and HyTUE (0.079 and 0.226 kg/ha/°C day hour %) on grain and biological yield basis were recorded in the crop sown on 17th SMW as compared to crop sown on 19th SMW and 21st SMW. This could be attributed to lengthier crop duration and higher grain yield and biological yield which resulted in higher values of thermal use efficiencies in early sowing as compared to delayed sowing. Geometry of 70 cm × 20 cm resulted in higher values of all thermal use efficiencies on a grain yield basis, however, spacing of 50 cm × 20 cm recorded higher thermal use efficiencies on a biological yield basis. The findings of Kebede (2019) also support these results and found that higher values of thermal use efficiencies in wider spaced crops could be ascribed to more interception of solar radiations for improved photosynthesis hence increased grain yield whereas, higher values of thermal use efficiencies in the narrow spaced crop for biological yield could be due to more plant population which increased the increased biological yield significantly. Moreover, hybrid Hytech-5801 showed higher values of all thermal use efficiencies as compared to YSH-1 which greatly could be due to the greater crop duration and yield of the former hybrid.

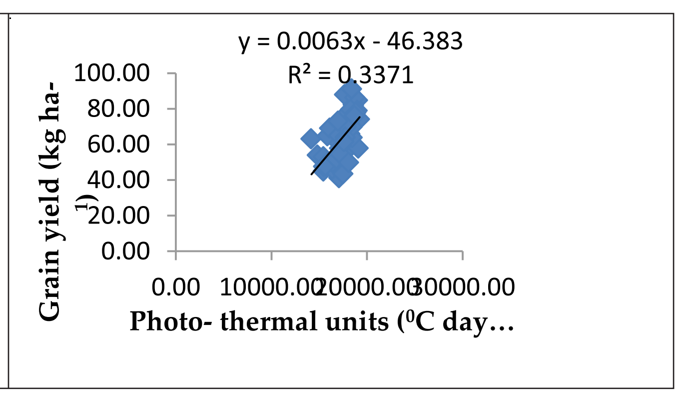
Correlation studies

A highly positive and significant correlation was noted between grain yields with grains per cob, between grains per cob with cob weight between cob weight and seed index (Table 9), these findings corroborate those of Kumar *et al.* (2006). Similarly, the correlation between temperature (Maximum and minimum) with yield and yield attributing factors were found to be negative and significant. The correlation between rainfall with yield and yield attributing factors was positive and significant while maximum temperature and minimum temperature was negative and non-significant. The correlation between sunshine hours were negative and non-significant with yield, yield attributing factors maximum temperature and minimum temperature but had negative and significant correlation with rainfall. The correlation between RH_1 was found non-significant for every parameter except minimum temperature and sunshine hours. The correlation between RH_2 was found to be non-significant with every parameter except rainfall, sunshine hours, RH_1 and RH_2.

Regression analysis

According to the regression coefficient grain yield was influenced by agro meteorological indices and thermal use efficiencies in the range of 0.06 to 0.88 and 0.041 to 0.88 respectively (Fig. 4&5). Further, the coefficient of determination for biological yield ranged from 0.125 to 0.146 and 0.142 to 0.831 with agro meteorological indices and thermal use efficiencies respectively (Fig. 6). GDD accounted for 32.3 % variability for grain yield and 13.1 % for biological yield. Agrometeorological indices i.e., HTU, PTU and HyTU recorded variability of 27.4%, 33.7 % and 32.2 % with grain





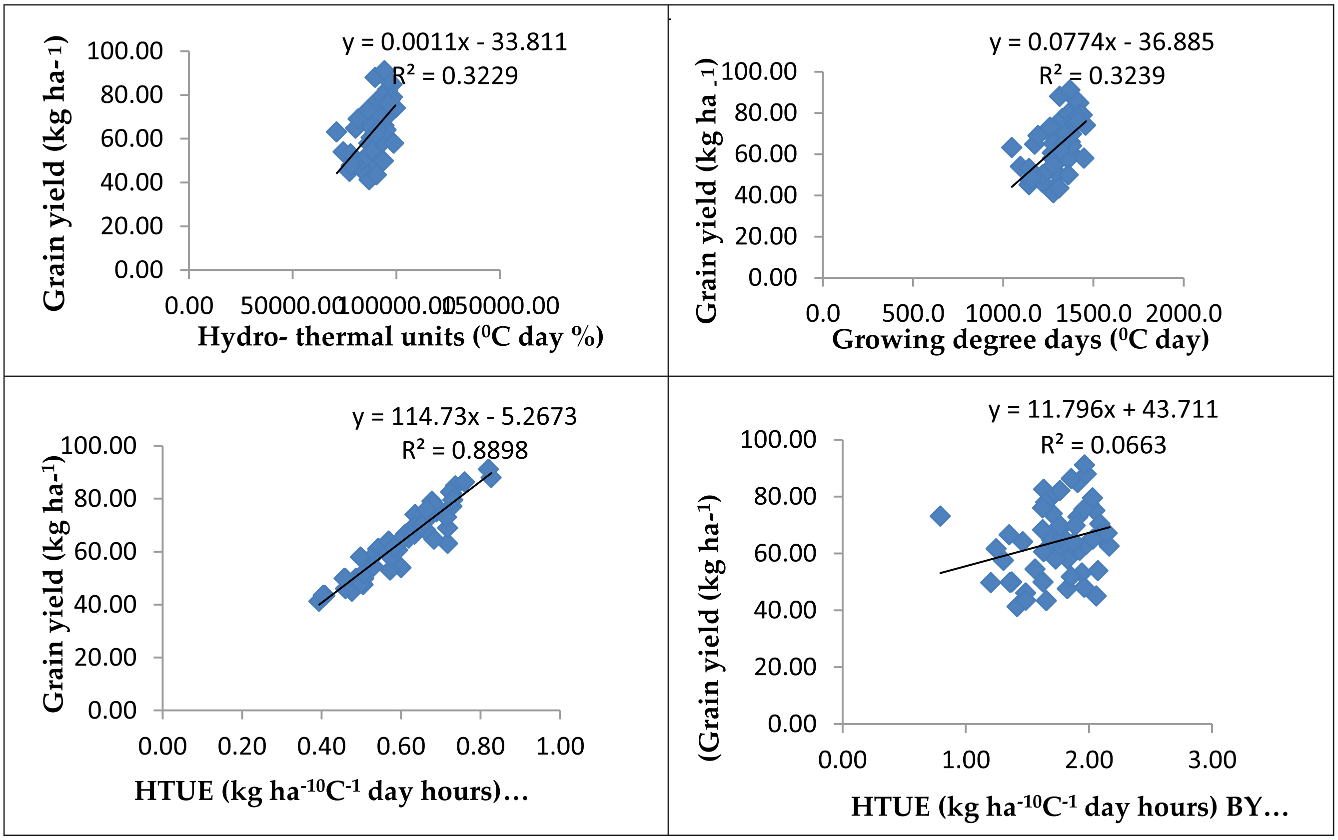
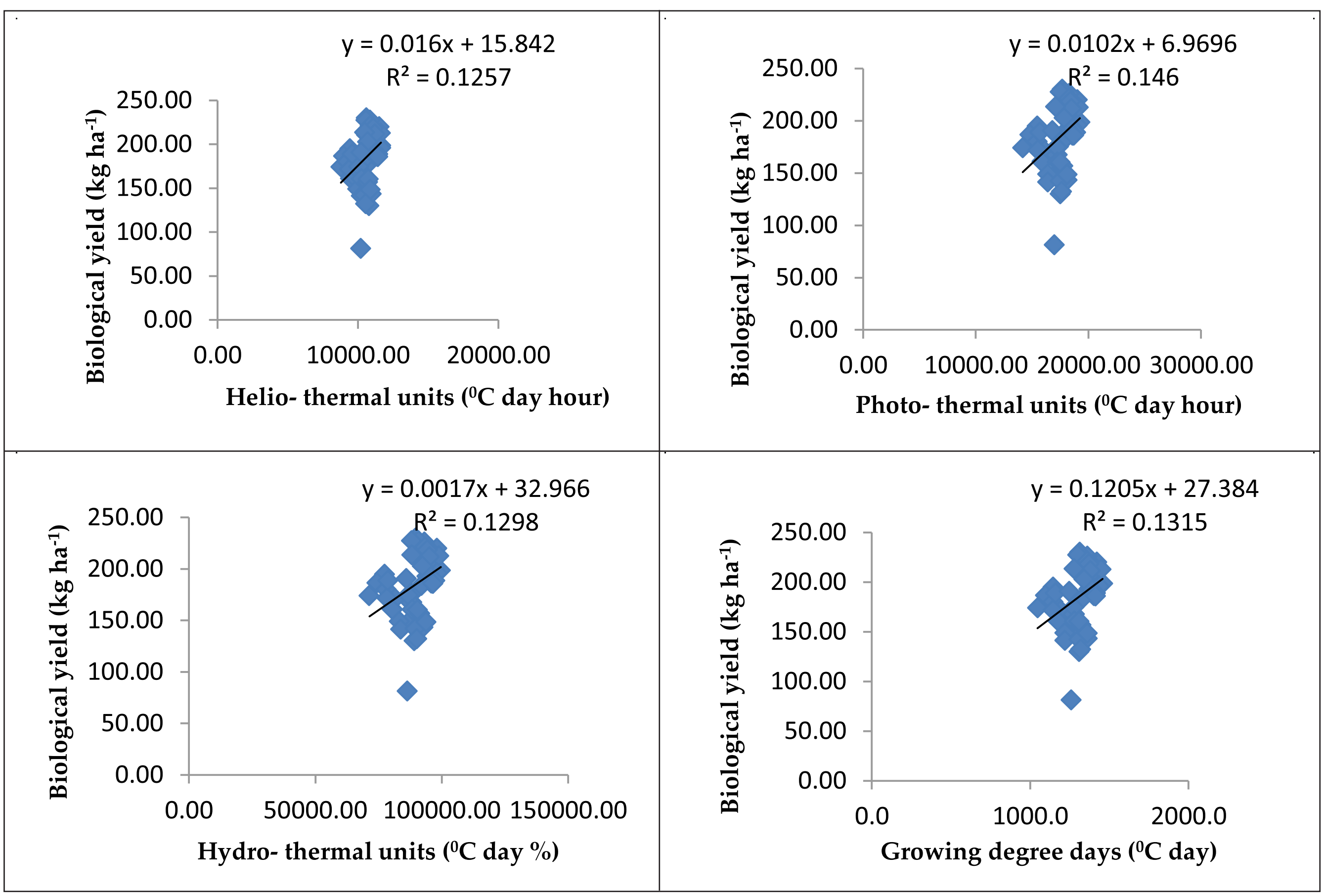


Fig. 4: Regression equation of agro-meteorological indices with grain yield of hybrid maize



yield and 12.5 %, 14.6 % and 12.9 % with biological yield respectively. Thermal use efficiencies accounted for maximum variability for grain yield and biological yield (Fig. 5&6). The maximum variability of thermal use efficiencies on a grain yield basis was shown by HTUE (88.9%) and the maximum variability of thermal use efficiencies on basis of biological yield was shown by HUE (79.4 %). The PTUE, HyTUE and HUE on a grain yield basis accounted for the

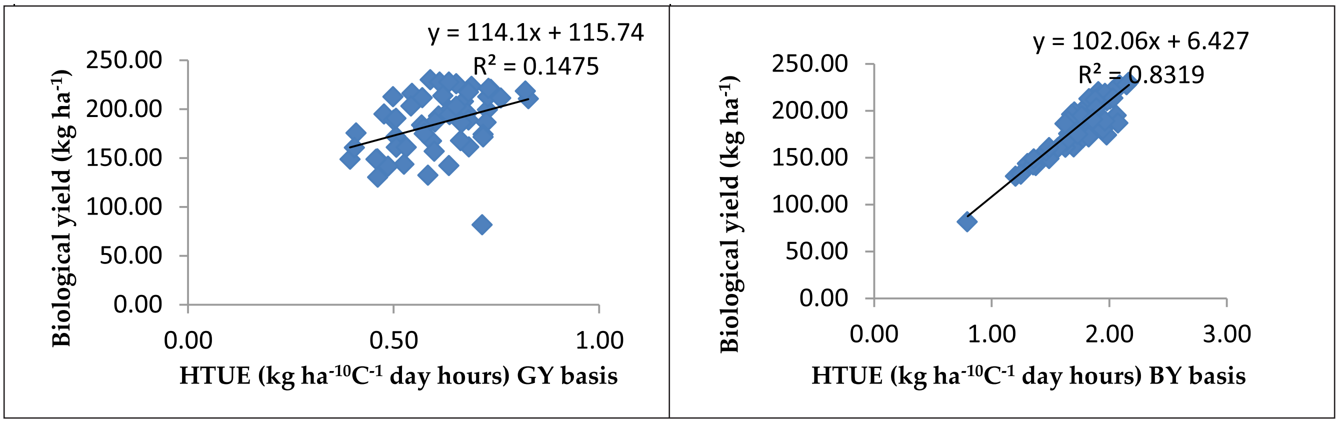
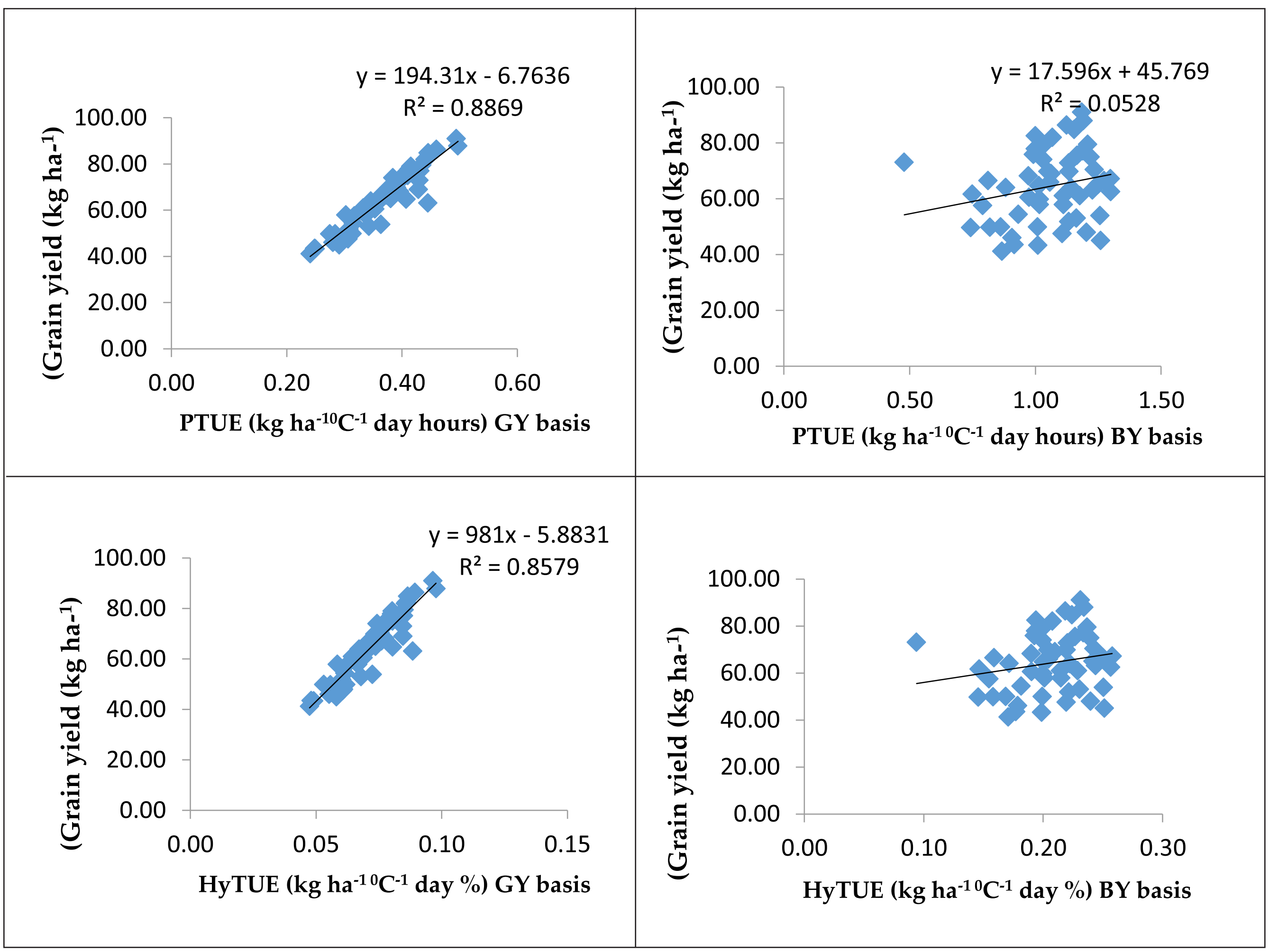


Fig. 5: Regression equation of thermal use efficiencies with grain yield of hybrid maize

variability of 88.6%, 85.7 % and 86.7 % while as on biological yield basis accounted for 5.2%, 4.1 % and 4.5 % with grain yield respectively. Thermal use efficiencies *viz*. HTUE, PTUE, HyTUE and HUE on grain yield basis showed variability of 14.7 %, 14.4 %, 14 % and 79.4 % with biological yield and same thermal use efficiencies on biological yield basis showed 83.1 %, 81.8%, 78% and 14.2 % with biological yield.



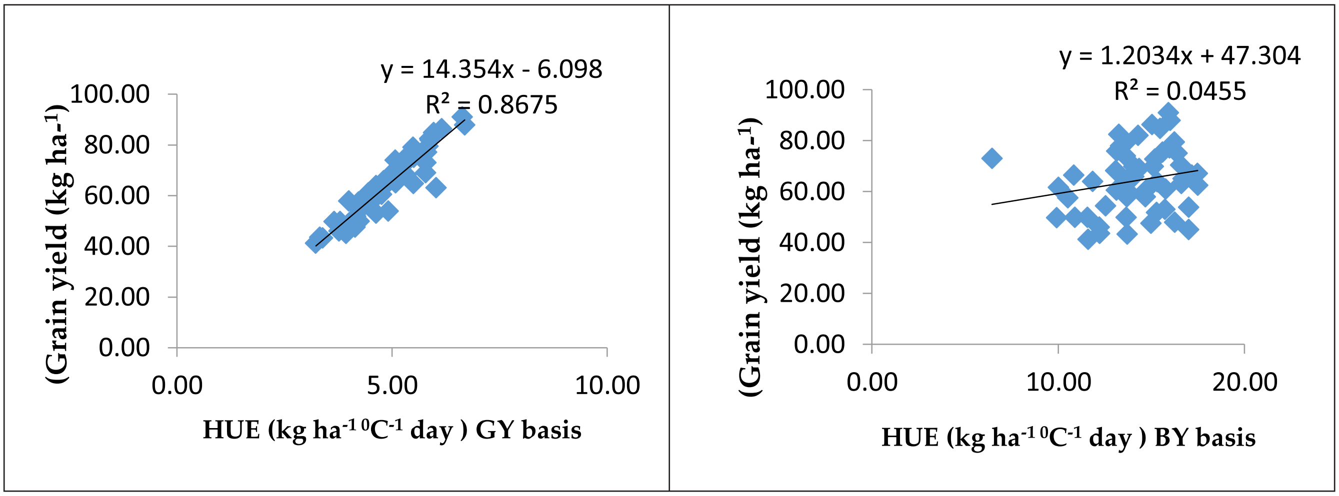


Fig. 6: Regression equation of agrometeorological indices with a biological yield of hybrid maize

CONCLUSIONS

The study was concluded with the observation that the arrangement of hybrid maize under spatial and temporal crop geometry had a profound impact on the phenophasic development, thermal use efficiencies and productivity. The study conclusively indicated that hybrid Hytech-5801 should be sown in 17th SMW at plant spacing of 70 cm × 20 cm for proper phonological development to efficiently accumulate maximum heat units with increased thermal use efficiencies for higher grain yield.

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