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Full Length Article

Assessing the Impact of Thermo-temporal Changes on the Productivity of Spring Maize under Semi-arid Environment

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Abstract

Crop productivity is highly affected by variation in inter-seasonal temperature. Appropriate planting date play key role in crop management to achieve maximum productivity on sustainable basis. To evaluate the effect of planting dates and seasonal variation in temperature on phenology, growth and yield of different maize (*Zea mays* L.) hybrids, an experiment was conducted during spring seasons of 2015 and 2016. Treatments were comprised of four sowing dates (27 January, 16 February, 8 Mach and 28 March) and three maize hybrids (Pioneer-1543, Monsanto DK-6103 and Syngenta NK-8711). The experimental design was randomized complete block design (RCBD) with a split plot arrangement. The effect of variation in temperatures at different stages of crop were evaluated by relationship of mean temperature at different stages during growing season to yield and phenological stages. Results showed that maize hybrids acquired lesser time to emerge with the delay in sowing time from last week of January. Relatively more days to 50% tasseling and silking were recorded in Poineer-1543 by the end week of January sowing. Poineer-1543, Monsanto DK 6103 and Syngenta NK 8711 completed life cycle in 103, 101 and 96 days, respectively. Time series leaf area index (LAI) gradually increased during vegetative stages and reached maximum 65 to 70 days after planting. Maximum and statistically similar time series LAI and total dry matter (TDM) were recorded for January sowing and 2nd week of February sowing. Among maize hybrids, higher biomass and LAI were recorded in Monsanto DK6103 as compared Monsanto DK 6103 and Syngenta NK 8711. Maize hybrids Poineer-1543 produced maximum grain yield of 9291 kg ha^{-1} for January sowing. Relationship of seasonal temperature at different growth stages of maize showed negative correlation with R^2 ranged from 0.92 to 0.99. Therefore, it is concluded that change in temperature at different sowing dates effected the phenology, growth and yield of spring maize. However, maize hybrids Poineer-1543 can sustain the maximum productivity when sown by end of January. © 2018 Friends Science Publishers

Keyword: Maize hybrids; Sowing dates; Phenology; Growth; Thermal changes

Introduction

Environmental factors such as temperatures, radiation and their seasonal trend results in the uncertainty in crop growth, development and yield (Prasad *et al*., 2008). The key challenge is to determine the favorable planting condition for higher production (Harrison *et al*., 2011). The ideal planting time of maize hybrids is different due to differences in maturity and length of growing season as it is temperature dependent (Hammad *et al*., 2017). To maximize the yield, it is essential to select the maize hybrids with right maturity according to planting window (Rehman *et al.*, 2015). Warm growing season affected the crop yield by accelerating the crop growth that shorten the time for grain formation (Funk *et al*., 2008). Future scenarios of climate change shows that maize yield would reduce by 13% in Pakistan over the period 2030-2050 (Ali *et al*., 2017).

Maize is one of the world's principal food crops, feeding both human and livestock (Tah *et al*., 2008). In Pakistan, maize is at third position by area, after wheat and rice (Govt of Pakistan, 2017). Pakistani soils and climatic conditions are suitable for maize production, but yield is less due to inappropriate selection of hybrids and sowing time (Tariq and Iqbal, 2010). Selection of maize hybrids according to the length of season is crucial under semi-arid to arid climate. Sorensen *et al*. (2009) found that when temperature is unsuitable for growth, the early maturing cultivar unable to fully utilize the solar radiation, therefore fail to the explore potential of inputs provided during growing season.

Reduction of yield due to early and late sowing in maize is well documented (Johnson and Mulvaney, 2008). Early sowing reduced the interception of photosynthetically active radiation (PAR) due to late development of leaf area. In late sowing, the high temperature decreases the PAR by reducing

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the thermal time for crop development in two weeks at flowering (Otegui *et al*., 2006; Awais *et al*., 2017). Low temperature in early sowing decreased the plant height by decreasing internodal distance, leaf number and leaf area (Andrade and Vega, 20005). Number of grains per cob are associated with grain yield which are determined by condition during silking time, and variation in temperature at silking stage has large effect on grain yield (Al-Darby and Lowery, 2007). It is reported that two-week delay in sowing time from the recommended, caused the reduction in maize yield by 21% (Khavari *et al*., 2014). The sowing of crop at the optimum time leads to the successful crop production (Azadbakht *et al*., 2012).

Increased in temperature during growing season accelerate the crop growth that reduces the time between planting and grain development limiting the yield (Lobell and Field, 2007). High temperature at flowering (tasseling and silking) inhibited the pollination and grain development. Warmer environmental condition accelerates the pollen shedding and delay in silking (Basra, 2009). Higher temperature above 25 to 28°C increased the plant development and shorten the grain filling duration (Amin *et al*., 2017). Heat stress at silking and tasseling reduced the grain yield by 7% for every day after exposure to stress (Parker, 2004).

Conditions in which new hybrids are sown and untested at different sowing dates, how the maturity of these hybrids interact with environmental variables such as temperatures is a key strategy for maximizing the grain yield and avoid the high temperature effects are lacking. If relationships of temperatures with different stages of crop are identified, then it can be used to develop response function of sowing date and hybrids. This approach will be helpful in seasonal decisions with fluctuation in temperatures. The objectives of this study were to determine the best sowing time for different maize hybrids under semi-arid condition and how thermal changes affect the phenology, growth and yield of maize hybrids.

Materials and Methods

Experimental Site

An experiment was conducted at Water Management Research Center (WMRC), University of Agriculture, Faisalabad Pakistan (31° 22′ N, 73°01 ′ E) during the two spring seasons for the year 2015 and 2016. The seed bed was prepared by ploughing the soil for two times. The experiment was conducted in randomized complete block design (RCBD) with split plot arrangement. The treatments were comprised of four sowing dates (S_1= 27 January, S_2= 16 February, S_3= 08 March, S_4= 28 March) and three maize hybrids (H_1= pioneer-1543, H_2= Mosanto-DK6103, H_3= Syngenta-NK8711). Sowing dates were randomized in main plots, while maize hybrid in subplots. Each treatment was replicated three time. The seed rate was applied at 25 kg ha^{-1}. The row to row distance of 20 cm and plant to plant distance of 75 cm were maintained. Based on soil analysis, recommended dose of 200 kg ha^{-1} nitrogen (N) in the form of urea, 125 kg ha^{-1} phosphorus (P) in the form of ammonium phosphate and 125 kg ha^{-1} potassium (k) in the form of sulfate of potash were used. All P, K and one third dose of N were applied at sowing, while remaining doses of N were applied in two splits. First dose was applied at six leaves stage (V6) and second at vegetative tasseling (VT) stage. All other agronomic practices such as weeds, and pest control were kept same for all treatments.

Soil and Weather Data

Soil physical, chemical and hydraulic analysis were conducted prior to the sowing of crop as shown in Table 1. Representative ten soil samples were taken using soil augur from depth of 0-15 cm and 15-30 cm. The samples of different depths were thoroughly mixed to obtain composite samples, then air dried, crushed and sieved using 2 mm stainless steel sieve and were subjected to analyzed. Percentage of silt and clay were determined by Bouyoucos Hydrometer Method using 1% Sodium Hexametaphosphate as a dispersing agent. The texture class of soil was determined using the international texture triangle (Moodie *et al*., 1959). Available phosphorus was measured by spectrophotometer using the Olson method (Homer and Prueger, 1961). Potassium was determined by flame photometer (Mehlich, 1953). Total N was measured by using the kjeldahl method (Bremne, 1960). Electrical conductivity of soil was determined by Field Scout EC 110 Meter following the protocol by Mehlich (1953). Saturation percentage was determined from a paste which brought to saturation by adding water while stirring (Johnson, 1962). Field capacity of the soil was determine by fallowing the protocol describe by Karkanis (1983). Daily weather data of maximum and minimum temperature, rainfall and sunshine hours were recorded from the observatory at WMRC during the growing season in 2015 and 2016 (Fig. 1)

Data Collection

Crop phenology data were recorded at different stages. Days to emergence were recorded by selecting the central row as observation after second day of sowing. Days to 50% tasseling, 50% silking and maturity were recorded by tagging 10 plants randomly. Plant samples were taken fortnightly for the estimation of leaf area index (LAI) and total dry matter (TDM). Three plants were harvested from each plot leaving the appropriate boarder. Fresh weight of stem and leaf were recorded, and then sub sample of 10 g used to obtain leaf area using leaf area meter (LI-3100 area meter, Lincoln, Nebraska USA). For TDM, leaf, stem, tassel and cob when developed, were oven dried at 70°C for 48 h for dry weight. The method of LAI and TDM calculation was used as by Nasim *et al*. (2011). LAI was determined as a ratio of leaf area to ground area (Watson, 1947). At maturity, half of plants were harvested, and cob were separated, sun dried for 5 days and threshed to record the grain yield. Five cobs were selected randomly from each plot to record the number of grains per cob and 1000 grain weight.

Statistical Analysis

Combined year analysis was done with all data including growing seasons, the significance of different sowing dates and maize hybrids using Fisher's analysis of variance technique (ANOVA). The differences among treatments means of each observed variable were compared using the honest significant difference (HSD) test at 0.05 probability. Proc glm under SAS V9.4 software was used to perform statistical analysis (O'Rourke *et al*., 2013). Pearson product moment correlation analysis (Equation 1) were conducted to correlate the temperatures at different phenological stages of the crop. Nasim *et al*. (2016) used the correlation approach for assessment of agroclimate variability. In current study, mean temperature of both years of 2015 and 2016 were calculated at different critical stages.

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x^2)][n\sum y^2 - (\sum y)^2]}} \qquad \text{(Equation 1)}$$

Where "r" is the Pearson product moment correlation coefficient, "n" is the number of paired, "x" is the temperature and "y" is specific stage of crop.

Results

Weather Conditions

Weather data of growing seasons during 2015 and 2016 showed that year 2016 was slightly warmer than 2015 with 25 mm less rainfall and higher maximum and minimum temperatures by about 1.74°C and 0.52°C, respectively (Fig. 1). Overall maximum and minimum temperature were 2°C higher in each sowing date during growing seasons.

Effect of Sowing Time on Phenology of Maize Hybrids

The results showed various trends for year response. The interactive effect of sowing time and maize hybrids for days to emergence, days to 50% tasseling and silking was found highly significant (Table 2). More days to emergence (14.66) were taken by Sengenta-NK8711by January sowing. The days taken to emergence gradually decreased by sowing from end January to end March sowing. While, minimum days to emergence were observed for sowing by end of March, in case of Poineer-1543 and Mosanto-DK6103 (Table 5).

Relatively more days to 50% tasseling (74.16) and silking (82.66) were recorded for Pioneer-1543 for January sowing. Whereas, lesser days to 50% tasseling and silking were taken by Syngenta-NK8711 for 28th March sowing (Table 5). Results showed that days to 50% tasseling and silking decreased by 24 days as planting was delayed from end January to end March.

Days to maturity were significantly affected by sowing dates and hybrids. The year affect was also found significant. All three maize hybrids acquired three days more to mature in 2015 as compared to 2016 (Table 3). Earlier maturity in 2016 might be due to higher temperature of 2°C in year 2016 (Fig. 1). Crop matured in 109 days for January sowing. Among maize hybrids, Pioneer-1543 and Monsanto-DK6103 completed maturity in 101 and 103 days respectively. However, Syngenta-NK8711 took 96 days for maturity.

Effect of Sowing Time on Growth of Various Maize Hybrids

Leaf area index (LAI) was significantly affected by growing season. While, interactive effect of sowing dates and hybrids were found non-significant (Table 3). Higher LAI values were recorded during 2015 as compared to 2016 (Table 4).

Time series LAI showed almost similar pattern for each sowing time and maize hybrids during crop season 2015 and 2016. The LAI gradually increased until flowering stage and then decreased up to physiological maturity. Among maize hybrids, higher LAI was found in Monsanto-DK6103, followed by Pioneer-1543 and Syngenta NK8711 in both growing seasons (Fig. 2).

Time series total dry matter (TDM) was significantly affected by sowing time and maize hybrids. Among sowing times, the dry matter accumulation gradually decreased by delay in sowing during both years (Fig. 3a and b). Comparatively higher dry matter was accumulated by sowing of maize hybrids at 27 January and 16 February. However, sowing of maize during last week of March produced minimum dry matter. Among maize hybrids, Pioneer-1543 and Monsanto-DK6103 produced higher TDM (Fig. 3c and d).

Effect of Sowing Time on Maize Grain Yield and its Yield Components for Different Hybrids

Interactive effect of maize hybrids and sowing dates was found significant for number of grains per cobs, 1000 grain weight and grain yield (Table 3). Higher number of grains per cob (453.3), 1000 grain weight (299.72 g) and grain yield (9291.7 kg ha^{-1}) were recorded for Pioneer-1543, planted at 27 January. While, minimum grains per cob, grain weight and yield were recorded in Syngenta NK8711 for sowing at 28 March. Grain yield, number of grains and weight gradually decreased by delay in sowing from January to end march (Table 5). Results also indicated that grain yield was decreased by 35% when sowing delayed from 27 January to 28 March.

Plant height, plant population, biological yield and harvest index were significantly affected by sowing dates and maize hybrids (Table 3). Maximum plant height was recorded for January sowing, while minimum for 28 March sowing date. Plant height decreased by 13% by delayed in planting from January to March.

Table 1: Soil physical, chemical and hydraulic properties during the year 2015 and 2016

a) Soil physical properties				
Depth	Sand (%)	Silt (%)	Clay (%)	
0-15 cm	63.7	21.2	17.4	
15-30 cm	62.1	21.7	17.7	
b) Chemical properties				
Year	2015		2016	
Depth	0-15	15-30	0-15	15-30
Nitrogen (%)	0.045	0.043	0.044	0.046
Available Phosphorus (ppm)	7.13	7.19	6.83	7.09
Available Potassium (ppm)	61.7	63.11	67.6	68.9
EC (dS m^{-1})	1.75	1.77	1.79	1.78
Soil PH	8.10	8.05	8.13	8.09
OM (%)	0.44	0.43	0.41	0.42
c) Hydraulic properties				
Saturation (%)	35	37	36	38
Field Capacity (%)	21.5	21.9	20	20.7

Table 2: Analysis of variance for different sowing dates on phenology of maize hybrids 2015-16

Source of Variance	DF	Days to Emergence	Days to 50% Tasseling	Days to 50% Sillking	Days to Maturity
Year (Y)	1	0.0001^{**}	0.116^{NS}	0.107^{NS}	0.006^{**}
Block (Year)	4	0.735^{NS}	0.014^{*}	0.176^{NS}	0.356^{NS}
Sowing dates (A)	3	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.0001^{**}
YA	3	0.7981^{NS}	0.943^{NS}	0.962^{NS}	0.803^{NS}
Hybrids (B)	2	0.013^{*}	0.020^{*}	0.0001^{**}	0.0001^{**}
AB	6	0.049^{*}	0.021^{*}	0.0071^{**}	0.999^{NS}
YB	2	0.597^{NS}	0.998^{NS}	1.000^{NS}	0.993^{NS}
YAB	6	0.992^{NS}	1.000^{NS}	1.000^{NS}	0.995^{NS}
R^2		0.88	0.94	0.96	0.95
RMSE		1.33	3.077	2.75	2.43

Note: Number represents the probability levels, * and ** are significant at 0.05 and 0.01 probability level, respectively; NS = Non-significant; DF = Degree of freedom; # = Number

Table 3: Analysis of variance for different sowing dates on yield attributes of maize hybrids 2015-16

Source of Variance	DF	Maximum LAI	Plant Height (cm)	Plant Population (m^{-2})	Grain per Cob (#)	1000 Grain Weight (g)	Grain Yield (kgha^{-1})	Bilogical Yield (kgha^{-1})	Harvest Index (%)
Year (Y)	1	0.047^{*}	0.574^{NS}	0.611^{NS}	0.957^{NS}	0.808^{NS}	0.597^{NS}	0.290^{NS}	0.722^{NS}
Block (Year)	4	0.033^{*}	0.049^{NS}	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.464^{NS}	0.0001^{**}
Sowing dates (A)	3	0.038^{*}	0.035^{*}	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.0001^{**}
YA	3	0.980^{NS}	0.999^{NS}	0.633^{NS}	0.739^{NS}	0.988^{NS}	0.862^{NS}	0.866^{NS}	0.664^{NS}
Hybrids (B)	2	0.0001^{**}	0.326^{NS}	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.007^{**}
AB	6	0.462^{NS}	0.999^{NS}	0.532^{NS}	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.193^{NS}	0.500^{NS}
YB	2	0.677^{NS}	0.934^{NS}	0.208^{NS}	0.707^{NS}	0.012^{*}	0.759^{NS}	0.913^{NS}	0.987^{NS}
YAB	6	0.730^{NS}	0.999^{NS}	0.647^{NS}	0.703^{NS}	0.028^{*}	0.312^{NS}	0.986^{NS}	0.998^{NS}
R^2		0.90	0.75	0.91	0.98	0.97	0.99	0.80	0.84
RMSE		0.33	16.18	0.48	9.34	6.41	177.23	1394.5	2.94

Note: Number represents the probability levels * and ** are significant at 0.05 and 0.01 probability level, respectively; NS = Non-significant; DF = Degree of freedom; # = Number

Table 4: Effect of sowing dates on phenology, growth and yield component of maize hybrids

Treatments		Days to Maturity (Days)	Maximum LAI	Plant Height (cm)	Plant Population (m^{-2})	Bilogical Yield (kg ha^{-1})	Harvest Index (%)
Year	2015	101.61 A	5.60 A	224.9	6.36	19442.7	37.65
	2016	98.44 B	5.22 B	221.1	6.08	19059.0	36.63
Sowing Dates	SD1= 27 January	109.16 a	5.86 a	236 a	7.11 a	20815.3 a	41.7 a
	SD2= 16 February	102.61 b	5.66 ab	230.0 ab	6.50 b	20078.4 a	41.78 b
	SD3= 08 March	95.22 c	5.25 ab	222.5 ab	6.05 b	19023.5 b	35.88 c
	SD4= 28 March	93.11 c	4.85 b	203.5 b	5.22 c	17086.3 c	33.30 c
Maize Hybrids	Pioneer-1543	103.04 a	5.41 b	222.8 a	6.75 a	19659.3 a	10.83 b
	Monsanto-DK6103	101.33 a	5.74 a	226.7 a	6.41 a	20220.8 a	12.04 a
	Syngenta-NK8711	95.70 b	5.07 c	219.6 a	5.50 b	17872.6 b	11.41 ab

Table 5: Interactive effect of sowing dates and hybrids on phenology, growth and yield attribute of maize hybrids for the year 2015-16

Sowing Dates (SD)	Maize Hybrids	Days to Emergence	Days to 50% Tasseling	Days to 50% Sillking	Grain per Cob (#)	1000 Grain Weight (g)	Grain Yield (kgha^{-1})
Year	2015	13 A	61 A	67 A	380 A	276 A	7344 A
	2016	9 B	58 A	65 A	378 A	271 A	7011 A
SD1= 27 January	Pioneer-1543	12.16 abc	74.16 a	82.66 a	453.3 a	299.72 a	9291.7 a
	Monsanto-DK6103	13.16 ab	72.16 a	81.00 ab	433.5 b	299.33 a	8885.0 b
	Syngenta-NK8711	14.66 a	69.16 ab	75.66 bc	379.5 cd	273.55 c	7780.9 c
SD2= 16 February	Pioneer-1543	11.50 bc	59.50 dc	67.00 de	434.8 ab	291.08 a	8113.0 c
	Monsanto-DK6103	12.16 abc	64.16 bc	71.00 dc	427.5 b	287.59 ab	7959.9 c
	Syngenta-NK8711	13.33 ab	62.83 c	67.33 de	362.1 d	256.77 d	6626.9 e
SD3= 08 March	Pioneer-1543	11.16 bcd	55.83 de	63.66 e	390.6 c	275.06 b	7271.9 d
	Monsanto-DK6103	11.83 bc	58.83 dc	66.33 de	384.3 c	273.74 c	7083.1 d
	Syngenta-NK8711	10.33 dc	54.50 def	57.33 f	336.8 e	265.99 dc	6104.3 f
SD4= 28 March	Pioneer-1543	8.50 d	51.16 gef	57.50 f	329.5 e	266.42 dc	5960.4 f
	Monsanto-DK6103	8.50 d	49.00 gf	55.16 gf	321.8 e	263.08 dc	5793.8 f
	Syngenta-NK8711	9.83 dc	47.33 g	51.50 g	295.8 f	231.34 e	5265.1 g

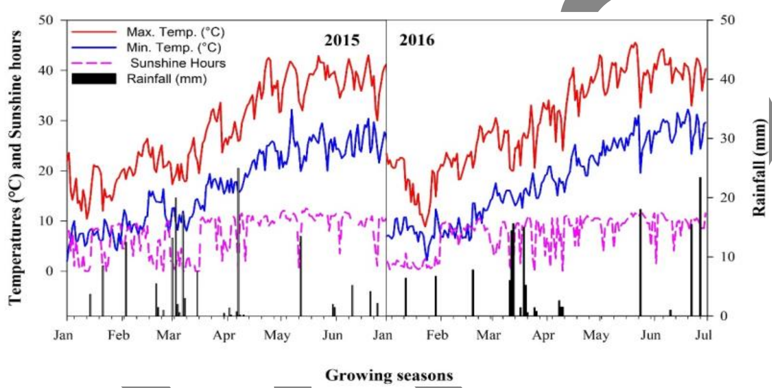

Fig. 1: Average monthly seasonal weather conditions for spring maize during 2015 and 2016

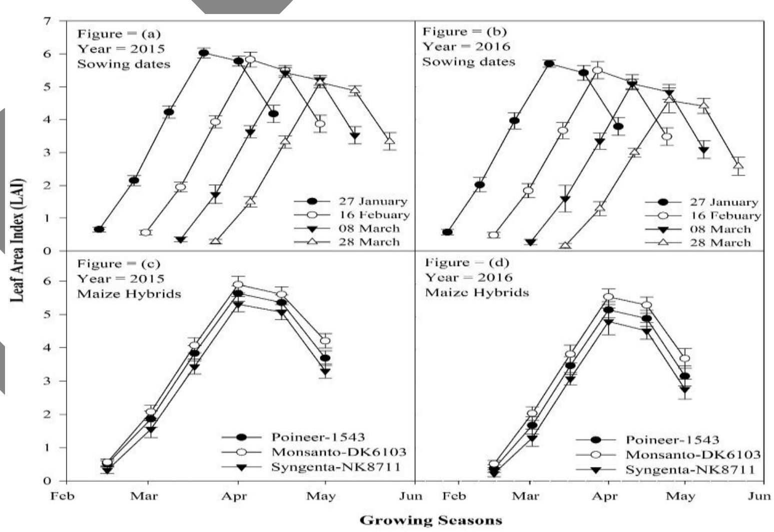

Fig. 2: Time series leaf area index (LAI) of maize hybrids at different sowing dates

Plant height was statistically similar in maize hybrids. Similar trend was found for plant population and harvest index.

Higher biological yield was found for January and second week of February sowing. Biological yield also decreased by 17% by delayed in planting from January to end March. In case of hybrids, Monsanto-DK6103 and Pioneer-1543 produced maximum biological yield as compared to Syngenta NK8711 (Table 4).

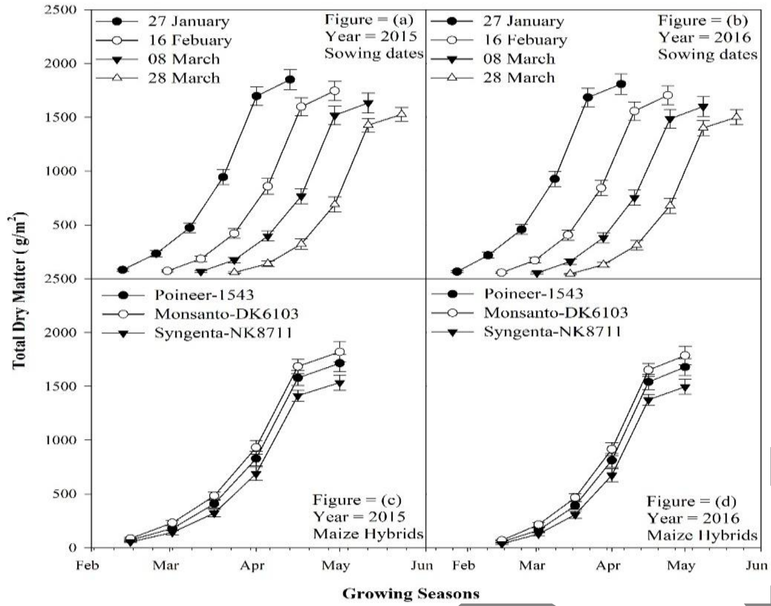

Fig. 3: Time series total dry matter (TDM) of maize hybrids at different sowing dates

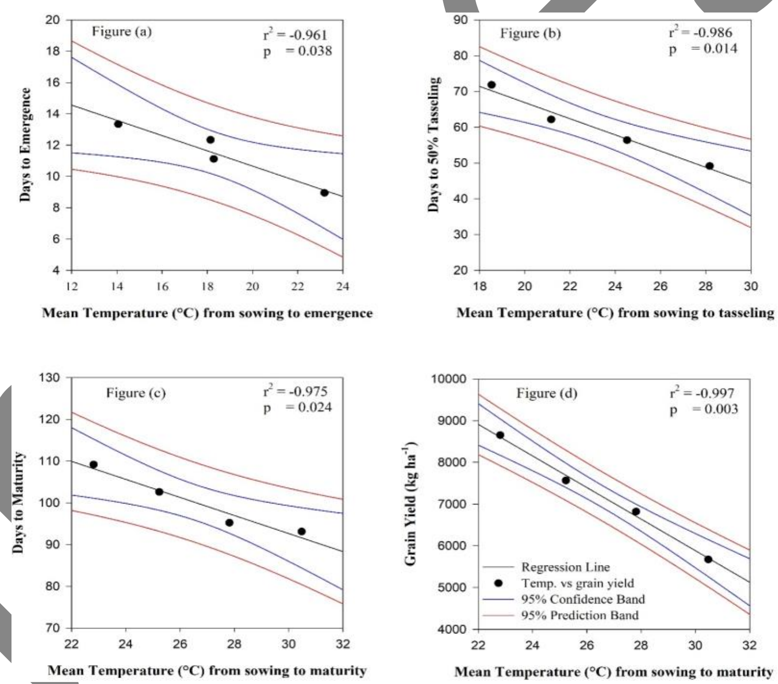

Fig. 4: Effect of mean temperature from sowing to (a) emergence on days to emergence (b) tasseling on days to tasseling (c) maturity on days to maturity (d) maturity on grain yield (kg ha^{-1})

Association of Thermal Changes with Phenology and Yield of Hybrid Maize

Productivity of maize was affected by environmental conditions such as maximum and minimum temperature. Strong negative correlation (-0.961; *p* =0.038) of mean temperature for days to emergence (Fig. 4a) revealed that with increase in temperature, the time to emergence decreased. Mean temperature from sowing to tasseling on days to tasseling had a negative correlation (-0.986; *p*= 0.014) (Fig. 4b). Average temperature of about 2°C was higher in the sowing dates of 8 and 28 March from the 27 January. Increase in 2°C temperature decreased the days to 50% silking. Mean temperature from sowing to maturity with days to maturity also showed negative correlation (-0.975; *p* = 0.024) (Fig. 4c). The average temperature of about 6-7°C was higher in 28 march sowing date as compared to 27 January, which took lesser number of days to mature. Strong negative correlation (-0.997; p = 0.003) was observed between mean temperature from sowing to maturity and grain yield (Fig. 4d). It showed that as temperature is increased the grain yield is also linearly decreased.

Discussion

Warmer temperatures increases the rate of phenological development (Hatfield and Prueger, 2015; Jan *et al*., 2017). The present study results showed that days to emergence consistently decreased from January to end March sowing (Table 5). Early sowing had more days to emergence might be due to lower soil temperature (Johnson and Mulvaney, 2008). Edalat and Kazemeini (2014); Butler and Huybers (2015) reported that high soil temperature, reduced the time to emergence and caused poor germination. In current study, higher days to 50% tasseling and silking were recorded in Poineer-1543 for end January sowing and gradually decreased at end March sowing (Table 5). The possible reason might be that high temperature in late sowing, affected the pollination and silk viability. Exposed silks are killed prematurely due to high temperature. Ekeleme *et al.* (2009) reported that photoperiods influenced the crop development. Difference in photoperiods are associated with the early and late sowing periods.

In present study, number of days to maturity decreased with delayed in planting (Table 5). Early maturity in late planting might be due to shorter vegetative and reproductive period. Nielsen *et al*. (2009) reported that delay in sowing decreases the growing degree days which lead to early maturity.

Time series LAI linearly increased up to flowering stage and then decreased (Fig. 2). The reason might be due to inhabitation of leaf area development and acceleration of leaf senescence (Dahmardeh, 2010). Time series TDM also linearly increased and sustain at maturity, while in case of maize hybrids maximum biomass accumulation was observed in Monsanto-DK6103 (Fig. 3). Increased in dry matter accumulation may be due to higher light interception, photosynthesis and transpiration (Law-Ogbomo and Remison, 2009). Another possibility may be the stay green character of this hybrid (Cunningham, 2014).

Maximum plant height recorded in hybrids Pioneer-1543 and Monsanto-DK6103 in early sowing of present study (Table 5) might be genetic character of this hybrid. Ali *et al*. (2015) Buriro *et al*. (2015) also reported that plant height is genetically and environmental controlled factor as temperature is increased in late sowing decreased the plant height.

In current study, higher number of grains per cob was recorded in early sowing and lesser in late sowing (Table 5). The reason could be that prolonged growing and grain filling period in early sowing induced the proper seed setting. These results are in agreement with Tsimba *et al*. (2013) who reported that high temperature in late sowing reduced the pollen viability and seed setting due to disruption of source sink relationship. Similar finding was found by Jabran *et al.* (2017), that high temperature at flowering during late sowing reduced the PAR by reducing the degree days, which decreases the efficiency of the size sink through abortion of grain and ear.

Higher grain yield was recorded for end January sowing and decreased in late sowing for early maturating hybrids (Table 5). Ali *et al.* (2015) Nasim *et al.* (2017) reported that grain yield reduced with delay in planting. Higher yield in early sowing might be due to longer growth cycle and favorable temperature during grain filling stage. Bhusal *et al.* (2016) showed that in late sowing, crop had shorter period to produce grains that limit the yield.

Favorable seasonal temperature is also important for successful crop production, gradual increased temperature substantially decreased the yield. Correlation of seasonal mean temperature at different stages negatively affected the phenology and grain yield (Fig. 4). The reason could be that higher temperature increased the development and reduced the growing length (Harrison *et al*., 2011; Nasim *et al*., 2016a). Schlenker and Roberts, (2006) found growth rate is increased as temperature is increased from 25°C and reduction in grain yield occur when temperature greater than 30°C

Conclusion

Delay in sowing from 27 January to 28 march gradually decreased growth, grain yield of maize and yield component. Higher temperature enhanced the growth rate, reduced days to maturity and caused the pollen sterility that lead to decrease the attainable yield. Among maize hybrids Poineer-1543 produced significantly higher grain yield fallowed by Monsanto-DK6103 and Syngenta NK-8711. Similarly, higher grains and biological yields were achieved when maize crop was planted during 27 January. Among hybrids, Poiner- 1543 performed best in spring season at 27 January sowing date.

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