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Full Length Article

Evaluating the Impact of Thermal Variations Due to Different Sowing Dates on Yield and Quality of Spring Maize

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Abstract

Climate change is threatening the productivity of cereal crops and creating food insecurity issues worldwide. To assess the impacts of thermal variations on yield and quality of maize, two years field study was conducted during 2014 and 2015. Four maize hybrids were sown in spring season at ten planting dates with fifteen days interval between each planting date. Results revealed that late planted maize in the month of March to onward in spring faced significant decline in yield (10-40%) and quality (10–50%) due to higher temperatures, whereas early sown maize (15^{th} and 30^{th} January) showed better results in terms of grain quality and yield related traits. Yield and quality attributes showed a strong relationship with seasonal thermal variations with reliable R^2 values ranged from 0.80 to 0.95. In conclusion, thermal variations at different sowing dates caused yield decline and quality deterioration in spring maize. However, maize hybrids P-1543 and DK-6103 resulted in higher yield return and better quality when sown earlier at end of January in spring.

Keywords: Maize hybrids; Thermal variations; Planting dates; Yield; Quality

Introduction

Increase in the incidence of abiotic stresses due to climate change will affect both yield and quality of arable crops in semi-arid regions (Yang *et al*., 2015; Farooq *et al*., 2011, 2017). Determining optimum planting window is the key challenge for future maize (*Zea mays* L.) productivity, especially under climate change scenarios (Farooq *et al*., 2009; Abendroth *et al*., 2017).

Maize ranks first among all cereals in terms of production and its multiple uses worldwide. In Pakistan, maize is an important cereal crop and grown on an area of 1.23 M ha and its production was 5.70 M tons in both spring and autumn season (GOP, 2017–2018). However, predicted episodes of heat stress in changing climate scenario can hamper the maize production. Maize productivity will decline up to 13% by the end of 2050 in Pakistan due to climate change (Ali *et al*., 2017). Thermal variations during silking stage have effects on number of grains per cob and grain weight which are associated with grain yield (Al-Darby and Lowery, 2007). Spring sown maize crop often face heat stress at anthesis and post anthesis stage when planted late which results in lesser grains with reduced size and low grain yield (Naveed *et al*., 2014) and grain quality (Yang *et al*., 2015). Maize planting in late April and June will face serious yield decline mainly due higher temperature and more frequent attack of pest and diseases (Wiatrak and Wright, 2004; Bruns and Abbas, 2006). To avoid high temperature stress on reproductive stage, the maize crop can be grown earlier in the month of January during spring season in Pakistan but there can be a risk of suboptimal temperature that may disturbs the normal emergence and early seedling establishment (Naveed *et al*., 2014).

Grain quality is defined as physical and nutritional characteristics as required for human nutrition and these are of prime importance for human and animal feed (Vancetovic *et al*., 2014). Grain quality can be affected by various factors such as climate, genetics and management. Increase in temperature to 32°C or higher during maize growth lead to shortening of grain filling period, shriveled grain, inhibition in starch deposition and reduction in yield (Barnabas *et al*., 2008). High temperature stress reduces the starch, protein and moisture contents enlarges starch granule size and also increases the fraction of long chains in the amylopectin that untimely increases the pasting temperature (Thitisaksakul *et al*., 2012). The flour pasting properties were severely affected by heat stress at grain filling stage. The effects of heat stress on the pasting properties of flour were more severe when they occurred early in the grain filling stage than late (Liu *et al*., 2011; Lu and Lu, 2013). The grain protein contents of various maize hybrids may vary at different planting dates due to thermal fluctuations (Buriro *et al*., 2015). Delayed planting of maize from recommended sowing time, reduce grain protein contents while it may increase when planting

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early (Koca and Canavar, 2014).

Determining the performance of new hybrids yield and quality at series of sowing dates in spring season is needed to monitor the effects of seasonal thermal fluctuations on maize productivity. Moreover, it is very crucial to determine optimum planting window for maintaining the yield and grain quality of maize crop under future climatic scenarios. Therefore, this two-year field study was designed to evaluate the effect of thermal variations at various sowing dates on maize yield and grain quality in semi-arid environment.

Materials and Methods

Experimental Site and Crop Husbandry

The proposed study was performed at Agronomic Research Area, University of Agriculture, Faisalabad; Pakistan (31° 26′ N, 73°04 ′ E) during spring season over a period of two years 2014 and 2015 to analyze the qualitative attributes of spring Maize hybrids under thermo-temporal changes in semi-arid environment. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement followed by three replications. The maize hybrids (H1= DK-6103, H2= NK-8711, H3= P-30-15-43 and H4= YH-1898) were sown at ten sowing dates starting from 15th January and ends up to 1st June with fifteen days interval. Sowing dates were randomized in main plots, while hybrids in subplots. For all sowing date agronomic and plant protection measures were kept uniform. Maize hybrids were sown on ridges using 25 kg ha^{-1} seed rate with dibbling method in 75 cm spaced rows with a plant to plant distance of 20 cm. The soil was supplied with phosphorus (P) @ 115 kg P_2O_5 ha^{-1} in the form of Diamonium Phosphate (DAP) and 92 kg K_2O ha^{-1} in the form of Sulphate of Potash during land preparation; whereas, nitrogen 220 kg ha^{-1} (Urea) was applied in three splits, one third at sowing and rest at 7–8 leaf stage and flowering stages. Recommended irrigation amount according to crop requirements was applied to avoid water stress. The crop was harvested at full physiological maturity. Harvested cobs were sun dried to standardize the moisture contents in grain and then qualitative analysis was done.

Soil and Weather Data

Soil characteristics in terms of soil analysis (mechanical and chemical properties) were determined by standard procedures. A representative soil sample from 0 to 15 cm and 15 to 30 cm was obtained from the experimental area with soil auger before sowing of crop. The samples were thoroughly mixed to make a compound/representative sample before sowing of the crop. The sample was analyzed for its physico-chemical properties. Proportions of sand, silt and clay were obtained with the help of Bouyoucos hydrometer methods. Textural class (percentage of sand, silt and clay) was determined by using international textural triangle (Moodie *et al*., 1959). Soil chemical characters were determined by using methods of Homer and Pratt (1961; Table 1). Daily weather data of maximum and minimum temperature, rainfall and sunshine hours were recorded from the meteorological observatory of University of Agriculture, Faisalabad during both years 2014 and 2015.

Data Collection

Ten cobs were selected randomly from each plot to get yield data and grain samples. Number of grains per cob of ten randomly selected plants from each plot were counted and then averaged. A sample of 1000 grains was taken from each plot, oven-dried and weighed through an electric balance. At maturity, two central rows from each plot were harvested grain yield (kg ha^{-1}) was recorded following Mehboob *et al*. (2018).

Quality Attributes

The maize grain samples were finely ground and grain chemical analysis was done for determining grain protein, ash, moisture and oil content as detailed in AACC (2000). The grain sample was taken and grinded to make flour for determining moisture contents. The flour samples were placed in an air forced draft oven kept with a temperature of 105± 5°C to get constant weights (AACC, 2000). Moisture contents were calculated using following formula:

$$\text{Moisture (\%)} = \frac{\text{Wt. of original sample} - \text{Wt. of dried sample} \times 100}{\text{Wt. of original sample}}$$

The flour sample were taken to determine nitrogen content through Kjeltec System-II, (Tecator AB, Hoganas, Sweden) and based on Kjeldahl method, protein contents were calculated with the method given in AACC (2000). Following formula was used to determine nitrogen content:

$$\text{N (\%)} = \frac{\text{Vol. of } H_2SO_4 \text{ used} \times \text{Vol. of dilution} \times 0.0014 \times 100}{\text{Wt. of sample} \times \text{Vol. of sample taken}}$$

The protein content was further calculated by multiplying the nitrogen content with 6.25.

Soxhelt System was used to obtain oil content in the samples through the standard method detailed in AACC (2000) by using formula:

$$\text{Oil content (\%)} = \frac{\text{Wt. of fat/oil in sample} \times 100}{\text{Wt. of sample}}$$

To determine ash content, flour samples were kept in muffle furnace (MF-1/02, PCSIR, Pakistan) at a temperature of 550°C to burn and get stable weight of grey ash (AACC, 2000). Following formula was used to get ash contents:

$$\text{Ash (\%)} = \frac{\text{Wt. of ash} \times 100}{\text{Wt. of sample}}$$

Statistical Analysis

The statistical analysis was done by using Fisher's analysis of variance technique (ANOVA) to check significance of treatments. The significant differences among treatment means was determined by using honest significant difference (HSD) test at 5% probability level. Statistix V9.0 software was used for performing statistical analysis. Regression analysis was done to model covariance between yield and quality attributes for rise in temperature at 10 planting dates throughout the spring season.

Results

Weather Conditions

Experimental site experienced a huge variation in maximum and minimum temperature during crop season. In 2014 maximum and minimum temperature was 41.8ºC and 4.5ºC whereas in 2015 it was 38.7ºC and 6.9ºC, respectively. The temperature was lower in early months of sowing, rising up to maximum in June and then declines to the end of the year. Rainfall variability exists as during the year 2015 there were plenty of rainfalls with more intensity as compared to year 2014. The monthly mean values of minimum (Tmin), maximum (Tmax) temperatures, precipitation and solar radiations for the period of study are shown in Fig. 1.

Effects of Sowing Date and Hybrids on Yield and Yield Attributes of Spring maize

The results showed significant differences ($P < 0.01$) among all sowing dates and hybrids and interaction was found non-significant for number of grains per cob, 1000 grain weight (g) and grain yield (kg ha^{-1}) (Table 2). Number of grains per cob, 1000 grain weight (g) and grain yield (kg ha^{-1}) gradually increased from early to optimum sowing time and then decreased when crop sowing was delayed from recommended sowing time (Table 2). Maximum number of grains per cob (504 and 498) was recorded for maize sown on 30th January which was statistically at par with 15th February sown crop during both years respectively, whereas minimum number of grains per cob (107) was recorded at 1st June which was statistically at par with crop sown on 1st and 16th May. Among hybrids FH-1898 gave lesser number of grains per cob (305) and maximum number of grains per cob was obtained from hybrid (P-1543) (Table 2). Maximum 1000 grain weight (299) was recorded for 30th January sown crop which was statistically at par for 15th February and 1st January sown crop during both years. Lowest value of grain weight (g) was recorded for maize sown on 1st June which was statistically at par with crop sown on 1st and 16th May. Hybrid FH-1898 had smaller grains while DK-6103 had the bolder grain followed by P-1543 (Table 2). Thousand grain weight (g) differed significantly during both crop years as higher 1000 grain weight of maize was recorded in 2015 than 2014 (Table 2). Grain yield (kg ha^{-1}) increased from early to optimum sowing time (15th February) and decreased at late sowing dates (Table 2). Maximum grain yield (kg ha^{-1}) (9366) was recorded for 30th January sown crop which was statistically at par with 15th February planted maize during both years.

Table 1: Summary of soil analysis for experimental site during both years (2014 and 2015)

Parameter	Spring	Status
PH	8.2	Alkaline
EC (dSm^{-1})	4.4	Saline
N (%)	0.062	Medium
P_2O_5 (ppm)	18.5	High
K_2O (ppm)	260	High
Organic Matter	1.26	Medium
Sand (%)	20	
Silt (%)	17	
Clay (%)	63	

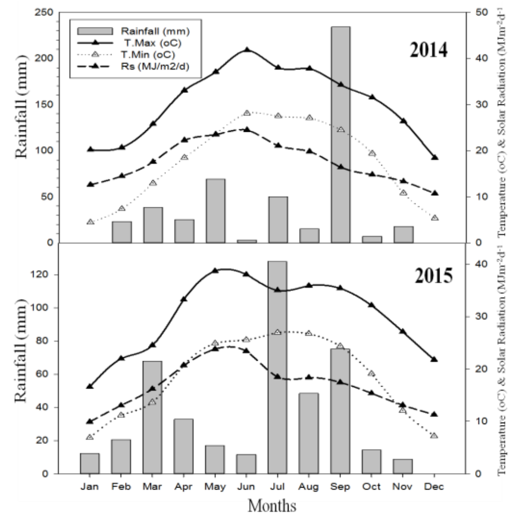

Fig. 1: Climatic data for the spring maize growing experimental years (2014 and 2015), monthly minimum (ºC), maximum (ºC), mean temperature (ºC), monthly rainfall (mm) and cumulative monthly solar radiations (MJ m^{-2})

However, minimum grain yield (kg ha^{-1}) (1382) was recorded for maize planted on 1st June which was statistically at par with crop sown on 1st and 16th May. Among maize hybrids, FH-1898 produced less grain yield (kg ha^{-1}); whereas maximum grain yield (kg ha^{-1}) was obtained from DK-6103 followed by P-1543 and NK-8711 (Table 2). In case of years, a non-significant effect was found for number of grains per cob and grain yield (kg ha^{-1}) (Table 2).

Yield attributes with corresponding to thermal variation at 10 planting dates computed with linear regression model indicating that number of grains per cob, 1000 grain weight (g) and grain yield (kg ha^{-1}) tend to be associated with thermal variations showing reliable R^2 values of 0.82, 0.88 and 0.78 respectively (Fig. 2).

Effects of Sowing Dates and Hybrids on Grain Quality Attribute

The results showed significant differences ($P < 0.01$) among all sowing dates for quality attributes of maize, however, maize hybrids significantly differed only for moisture and oil content during both years and ash content during

Table 2: Effect of sowing date and hybrids on yield and yield attributes of spring hybrid maize

Treatments	Number of grains per Cob		1000 Grain weight (g)		Grain yield (kg ha^{-1})	
	2014	2015	2014	2015	2014	2015
(A) Sowing Date						
S_1 = 15th Jan	467.25 AB	467.9 B	289.8 AB	284.3 ABC	6902.0 BC	6263.0 C
S_2 = 30th Jan	504.33 A	498.0 A	298.2 A	300.5 A	9365.5 A	9201.5 A
S_3 = 15th Feb	487.70 A	488.1 A	296.8 AB	296.1 AB	9141.7 A	9268.9 A
S_4 = 2nd Mar	437.31 BC	442.4 C	283.7 B	284.8 ABC	7383.2 B	8313.6 B
S_5 = 17th Mar	422.59 C	419.4 D	268.2 C	274.8 ABCD	5811.8 CD	5635.9 C
S_6 = 1st Apr	356.53 D	327.2 E	251.3 D	266.8 BCDE	4709.5 D	4635.6 D
S_7 = 16th Apr	226.68 E	209.6 F	240.0 DE	260.3 CDEF	2880.1 E	3681.0 E
S_8 = 1st May	141.68 F	135.5 G	236.8 E	252.2 DEF	1959.6 EF	2094.9 F
S_9 = 16th May	109.63 F	108.6 H	232.2 E	241.6 EF	1571.5 F	1547.0 F
S_{10} = 1st June	107.88 F	101.5 H	227.3 E	234.3 F	1382.2 F	1422.9 F
HSD (0.05)	43.41	16.83	13.26	30.57	1247.2	719.19
Significance	**	**	**	**	**	**
(B) Hybrids						
H_1 = DK-6103	332.9 A	325.0 AB	265.8 A	282.9 A	5297.3 A	5394.1 A
H_2 = NK-8711	325.1 AB	319.9 B	264.0 A	265.4 B	5140.1 A	5227.6 A
H_3 = P-1543	337.5 A	329.8 A	268.2 A	280.2 A	5417.6 A	5387.1 A
H_4 = FH-1898	308.9 B	304.6 C	251.7 B	249.8 C	4588.0 B	4816.9 B
HSD (0.05)	21.49	7.54	5.94	14.30	519.29	235.38
Significance	**	**	**	**	**	**
Interaction	NS		NS		NS	
Year Mean	326.1	319.8	262.48 B	269.62 A	5110.8	5206.5
HSD (0.05)	10.54		6.59		122.44	
Significance	NS		*		NS	

Mean sharing different letters in a column differ significantly at $p \leq 0.05$
*, ** = significant (5%) and highly significant (1%), respectively
NS = Non-Significant,
HSD =Honest Significant Difference Test

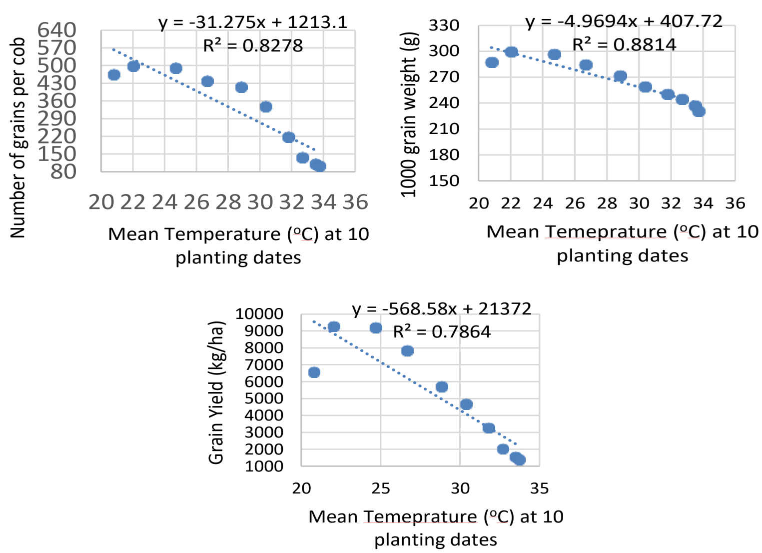

Fig. 2: Relationship between number of grains per cob, 1000-grain weight (g) and grain yield (kg ha^{-1}) with mean temperature

2015 while, interaction of maize hybrids and sowing dates remained non-significant for grain quality traits (Table 3). High protein contents, ash and moisture contents was found when maize crop sown from 15th Jan to 15th February during both years and protein contents start to decline when sowing of crop was delayed from 1st April to 1st June (Table 3). Maximum ash contents (%) were obtained for 15th Jan sown crop during both years. Ash contents were recorded minimum on 1st June sown crop which was statistically at par with 1st and 16th May (Table 3). Maximum ash and moisture contents were found in P-1543 while other three hybrids (DK-6103, NK-8711, FH-1898) were found statistically at par with each other (Table 3). Maximum oil contents (%) were obtained from 15th February sown crop during both years. Oil content substantially reduced when sowing of crop was delayed form 1st April to1st June (Table 3). Hybrid showed significant effect among each other in case of oil

Table 3: Effect of sowing dates and hybrids on grain quality attributes of spring hybrid maize

Treatments	Protein contents (%)		Moisture (%)		Oil Content (%)		Ash (%)	
	2014	2015	2014	2015	2014	2015	2014	2015
(A) Sowing Date								
S_1 = 15th Jan	12.08 A	12.02 A	12.89 A	12.84 A	3.00 AB	2.99 B	1.87 A	1.85 A
S_2 = 30th Jan	11.39 A	11.38 B	12.82 A	12.95 A	2.74 BC	2.79 BC	1.75 B	1.75 B
S_3 = 15th Feb	11.25 A	11.28 B	12.62 A	12.57 A	3.80 A	3.77 A	1.77 AB	1.74 B
S_4 = 2nd Mar	9.30 B	9.34 C	12.58 A	12.58 A	2.69 BC	2.74 BC	1.53 C	1.51 C
S_5 = 17th Mar	9.04 B	9.06 D	12.58 A	12.36 A	2.50 BC	2.34 CD	1.20 D	1.19 D
S_6 = 1st Apr	6.13 C	6.18 E	11.24 B	11.29 B	2.07 C	2.07 D	0.81 E	0.78 E
S_7 = 16th Apr	6.07 C	6.07 E	10.64 BC	10.79 BC	2.18 BC	2.21 D	0.64 F	0.62 F
S_8 = 1st May	6.06 C	6.02 E	10.20 C	10.24 C	2.15 BC	2.14 D	0.42 G	0.41 G
S_9 = 16th May	6.01 C	6.03 E	10.12 C	10.02 C	2.17 BC	2.15 D	0.45 G	0.43 G
S_{10} = 1st June	6.05 C	6.09 E	8.95 D	8.83 D	2.23 BC	2.24 D	0.45 G	0.43 G
HSD (0.05)	0.96	0.18	0.89	0.80	0.89	0.43	0.10	0.09
Significance	**	**	**	**	**	**	**	**
(B) Hybrids								
H_1 = DK-6103	8.44	8.46	11.16 B	11.06 B	2.72 A	2.72 A	1.07 A	1.05 AB
H_2 = NK-8711	8.32	8.34	11.53 AB	11.49 B	2.73 A	2.74 A	1.06 A	1.04 B
H_3 = P-1543	8.42	8.36	11.88 A	11.95 A	2.43 B	2.42 B	1.14 A	1.13 A
H_4 = FH-1898	8.18	8.24	11.29 B	11.29 B	2.34 B	2.30 C	1.08 A	1.06 AB
HSD (0.05)	0.46	0.49	0.52	0.44	0.23	0.02	0.07	0.07
Significance	NS	NS	**	**	**	**	NS	**
Interaction	NS		NS		NS		NS	
Year Mean	8.34	8.35	11.46	11.44	2.54	2.54	1.08	1.06
HSD (0.05)	0.28		0.32		0.18		0.26	
Significance	NS		NS		NS		NS	

Mean sharing different letters in a column differ significantly at $p \leq 0.05$
*, ** = significant (5%) and highly significant (1%), respectively
NS = Non-Significant,
HSD =Honest Significant Difference Test

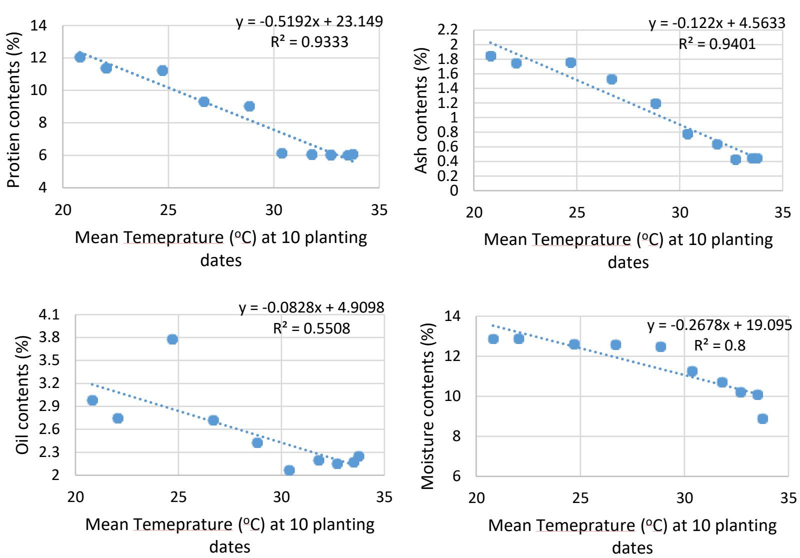

Fig. 3: Relationship between grain protein (%), ash (%), oil (%) and moisture contents (%) with mean temperature

contents during both years. Maximum oil contents (2.72, 2.73) were found in DK-6103 and NK-8711; while, other two (P-1543, FH-1898) were found statistically at par with each other for oil contents (Table 3).

Maize quality attributes with respect to thermal variation at 10 planting dates computed with linear regression model indicating that grain protein (%), ash (%) and moisture contents (%) tend to be associated with thermal variations showing reliable R^2 values (0.93, 0.94 and 0.80) respectively whereas grain oil contents (%) showed weak relationship (R^2=0.55) with thermal variations (Fig. 3).

Discussion

Every hybrid has its specific characters as it requires an optimum sowing time and any deviation from the optimal time (early or late sowing); will cause a huge decline in yield due to variation in temperature. Crop planted at optimum sowing date produced more grain yield, while delay in sowing substantially decreases the grain yield of maize (Buriro *et al*., 2015) as was observed in this study. In the present study, late sowing dates reduce the number of grains per cob, 1000 grain weight, and grain yield of maize hybrids (Table 2), possibly due to high temperature at reproductive stage as heat stresses during grain filling period reduce grain weight and starch accumulation. These effects were severe during early grain development stage than the later. Starch and grain filling process decreased when temperature exceed above 32°C (Ahmed *et al*., 2015), which reduces the grain size and ultimately grain yield as was observed in the current study. Increase in day temperature up to 38°C at reproductive stages directly influence the pollination and grain formation resulting in reduced grain yield of maize crop (Wahid *et al.,* 2007) as was observed in current study. Temperature rises from 25°C to 40°C in the months of April to June (Fig. 1), this increase in temperature at grain-filling stage decreases the grain-filling duration and lower the grain weight (Mayer *et al*., 2014). Maximum 1000 grain weight, grains per cob and grain yield were obtained at early and optimum sowing date provided with ideal agronomic practices and environment conditions (Table 2), these results are consistent with Ullah *et al.* (2010), Beiragi *et al.* (2011) and Long *et al.* (2017), who reported that at early and late sowing dates, all yield contributing components decreased which ultimately resulted in lower grain yield. These authors also suggested that optimum planting window is more relevant factor for getting higher yield and better quality of maize grains.

Grain quality is affected by genetics, management and environmental factors. Nutritional composition of maize and maize products was reported in the range of 11.6–20.0% (moisture), 1.10–2.95% (Ash), 4.50–9.87% (protein), 2.17–4.43 (oil) under ideal conditions (Enyisi *et al*., 2014). In the present study it was observed that at early to optimum sowing dates (30th Jan to 17th March), there was high protein contents, ash, moisture and oil contents found in grain (Table 3) due to favorable temperature during growth and grain formation period. Grain protein, ash and moisture contents were starts to decrease when maize planting was delayed from 17th March (Table 3). These results are consistent with the findings of Koca and Canavar (2014). The variation in protein, ash and moisture contents is accredited to the maize hybrid used, temperature fluctuation and agronomic practices like sowing time (Buriro *et al*., 2015).

The percentage ash and protein content was recorded within the range of (1.53–1.87) and (9.30–12.08), when maize crop was sown early then the recommended sowing time and optimum sowing period (Table 3) that showed an agreement with the results reported by the Ijabadeniyi and Adebolu (2005) and Ikram *et al.* (2010). Protein contents gradually decreased when maize planting was delayed from April to June (Table 3) due to high temperature that ultimately affect the fertilization process and grain formation due to distraction in source sink relationship which ultimately results in reduced sink size and lower grain components (Tsimba *et al*., 2013). The percentage oil contents obtained for maize hybrids in current study was consistent (Table 3) and in agreement with (Ikenie *et al*., 2002) but slightly differs from the findings of Ijabadeniyi and Adebolu (2005) that found higher oil content in the range 4.17 – 5.0%. The observed differences in oil content were possibly due to thermal variations.

Conclusion

With the delay in sowing from end of March to onward in spring season, yield and quality of maize is affected negatively. To maintain grain quality and getting higher yield, early maize plantation in January is beneficial in future. Among hybrids P-1543, DK-6103 produced high yield and better quality when sown earlier at end of January in spring. Last week of January to 1st week of March is the optimum duration for spring maize plantation to get maximum return when provided with optimum environment and agronomic conditions.

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