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Evaluation of sowing date and fertilization with nitrogen in maize cultivars in rainy conditions in Zambia

Charles Bwalya Chisanga[1,2*], Elijah Phiri[2] and Vernon R. N. Chinene[2]

[1]Ministry of Agriculture, Box 70232, Ndola, Zambia.
[2]Department of Soil Science, School of Agricultural Sciences, University of Zambia, Lusaka, Zambia.

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A study was conducted at the Zambia Agriculture Research Institute (ZARI), Central Research Station, Mount Makulu (latitude: 15.550° S, longitude: 28.250° E, altitude: 1213 m), Zambia to investigate the effects of sowing date (SD), maize (*Zea mays* L.) cultivars and 3 N fertilizer rates on yield and yield components. Maize cultivars were planted on 12th December, 2016 (SD1), 26th December, 2016 (SD2) and 9th January, 2017 (SD3). A split-split plot design was setup with SD, maize cultivars (ZMS 606, PHB 30G19 and PHB 30B50) and nitrogen rate (67.20, 134.40 and 201.60 kg N ha^{-1}) as the main-plot, subplot and sub-subplot, respectively. The rainfall, solar radiation (Srad) and mean temperature at the experimental site during the 2016/2017 season were 930.17 mm, 18.93 MJ m^{-2} day^{-1} and 21.83°C, respectively. Analysis of variance for Split-split plot design was used to analyze maize yield and yield components and means separated at p≤5 using Tukey's Tests. Results showed that the treatment effect of sowing date and cultivar was significant on biomass yield, harvest index, 100-grain weight, seed number m^{-2}, cob length, and width. Seed number m^{-2}, 100-grain weight, grain and biomass yield reduced with delay in sowing date. The reduction in grain yield from SD1-SD2 (1.91 t ha^{-1}), SD1-SD3 (2.90 t ha^{-1}) and SD2-SD3 (0.99 t ha^{-1}) were 21.04, 31.83 and 13.83%, respectively. Therefore, it was concluded that maize grain yield and yield components are affected by SD, cultivar and N. Farmers could enhance maize yield by manipulating sowing date, cultivar selection and N as the most limiting nutrient in agriculture production systems.

Key words: Biomass, corn cultivars, date of sowing, grain yield, leaf area index, nitrogen, total dry matter, yield.

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in the world after wheat and rice and is mainly grown for food, feed and as an industrial raw material (Lukeba et al., 2013). It is grown across a wide range of climate mainly in humid subtropics and warmer temperate regions. Globally, 80% of the cropped land area is under rain-fed agriculture (Turral et al., 2011) limited mainly by water availability and dominated by small-scale farms especially in Africa (Sebastian, 2014; Turral et al., 2011). In Zambia, maize is grown by small-scale (80%) and commercial (20%) farmers (Mulenga and Wineman, 2014). 64% of the people in Zambia live in rural areas

*Corresponding author. E-mail: cbchisanga@gmail.com, Tel.: 260-955-885-667.

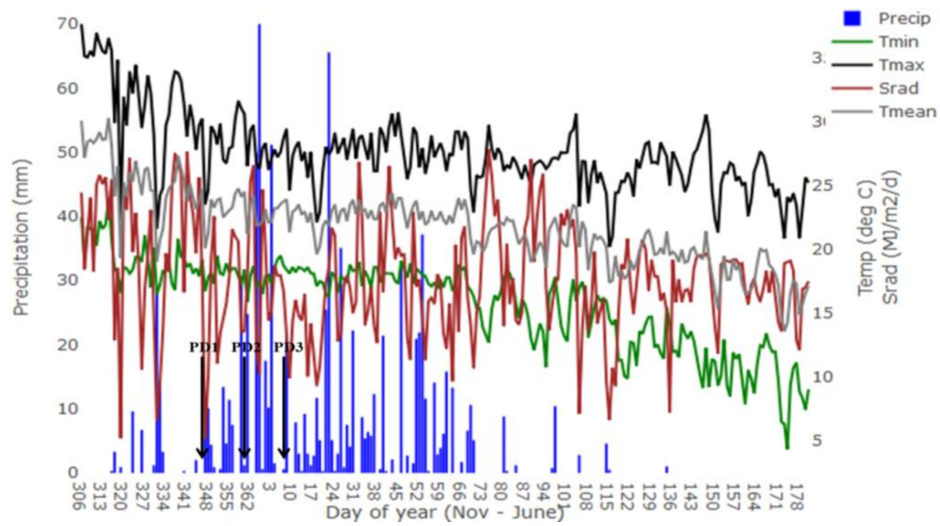

Figure 1. Daily weather data for Mt Makulu during the 2016/2017 season.

and practice rain-fed agriculture which is vulnerable to weather shocks (Arslan et al., 2014; Mulenga and Wineman, 2014). Rainfall is the most important climatic factor that influences rainfed maize growth and yield which is a function of water and nutrient availability.

Fertilizer use on maize in sub-Saharan Africa has increased in the past 30 years (Heisey and Mwangi, 1996). The utilization of inorganic fertilizer is important in soil fertility management; however, fertilizer use in Zambia is very low due to low input and high production costs (Xu et al., 2006) and maize yield varies from 0.7 to 2.5 t ha^{-1} (Burke et al., 2016; Xu et al., 2006). The low maize yield is attributed to use of recycled seeds with low fertilizer application rates (JAICAF, 2008).

The management decisions that affect maize yield and yield components are sowing date (SD), nitrogen fertilizer application rate (Abedinpour and Sarangi, 2018; Bejigo, 2018) and cultivar selection (Norton and Silvertooth, 1998). Additionally, the selection of specific maize cultivars has implication on the management of the SD. Maize growth and yield is influenced by changes in temperature (10 - 30°C) and rainfall, and this is associated with sowing date (Ali et al., 2018; NSW, 2009). It requires 450 - 600 mm of water per season and this is acquired from the root soil water reserves (du Plessis, 2003). Small scale farmers use multiple sowing dates to ensure successful crop growth and yield as it influences the duration of the vegetative and reproductive phases.

The maize plant produces high dry matter and requires nutrients such as nitrogen (N), phosphorus (P) and potassium (K) (Gul et al., 2015). Nitrogen (N) is the most limiting nutrient controlling the primary production of agricultural systems and its deficiency reduces maize yield (Bejigo, 2018; Valadabadi and Farahani, 2010). Nitrogen deficiency is the second biggest limiting parameter after drought in maize production (Lafitte et al., 1997). The amount of available soil nitrogen determines yield potential and additions of inorganic nitrogen fertilizers can considerably increase maize yield and yield components (Valadabadi and Farahani, 2010). Nitrogen fertilization rates affects the accumulation of maize dry matter production by influencing leaf area development (Fetahu et al., 2014).

The rate of crop growth through the vegetative and reproductive phases is a function of its response to temperature, (Srad) and precipitation (Kamal et al., 2017). The rate of plant growth indicates the partitioning of dry matter in plants and is analyzed by measuring leaf area and biomass accumulation. The yield potential for different maize cultivars varies seasonally. There is insufficient research on the effect of sowing date, cultivar and nitrogen fertilizer rate on maize growth and yield. Therefore, the study objective was to investigate the effect of sowing date, maize cultivar and nitrogen fertilizer rates on yield and yield components.

MATERIALS AND METHODS

Description of study area

A study was conducted at the Zambia Agricultural Research Institute (ZARI) Central Research Station at Mount Makulu (latitude: 15.550° S, longitude: 28.250° E, altitude: 1213 m), Zambia. The daily weather data (latitude and longitude of the weather station, rainfall, maximum, and minimum temperature, Srad) was obtained from the Zambia Meteorological Department. The rainfall, Srad, mean, maximum and minimum temperature at the field experimental site during the 2016/2017 season were 930.17 mm, 18.93 MJ m^{-2} day^{-1}, 21.83, 15.36 and 28.29°C, respectively as indicated in

Figure1). The soil at the study site was classified in USDA Soil Taxonomy (Soil Survey Staff, 2014) as clayey, mixed, hyperthermic, typic Paleustalf in soil taxonomy. It is well drained, yellowish red to red (2.55 YR), deep to very deep, clayey soil with

Table 1. Soil physical characteristics at experimental sites.

Depth (cm)	0-20	20-40	40-60	60-80	80-100	Analysis method
Soil texture	clay	clay	clay	clay	clay	SPAW
Silt (%)	12.80	16.80	12.80	18.80	2.80	Hydrometer method
Sand (%)	39.60	35.60	37.60	41.60	37.60	
Clay (%)	47.60	47.60	49.60	39.60	59.60	
Bulk density (g cm^{-3})	1.43	1.41	1.41	1.46	1.36	SPAW
LL (cm^3 cm^{-3})	0.287	0.287	0.299	0.244	0.350	
DUL (cm^3 cm^{-3})	0.407	0.409	0.419	0.363	0.470	
SAT (cm^3 cm^{-3})	0.459	0.467	0.468	0.447	0.487	
SHC (mm h^{-1})	0.350	0.500	0.290	1.480	0.010	

LL = lower limit (Wilting point); DUL = drained upper limit (Field Capacity); SAT = saturation; SHC = saturated hydraulic conductivity; SPAW = soil-plant-air-water.

Table 2. Soil chemical characteristics at experimental sites.

Depth (cm)	0-20	20-40	40-60	60-80	80-100	Analysis method
Total N (%)	0.031	0.042	0.054	0.061	0.036	Modified Kjeldahl
NO_3N (ppm)	29.90	48.70	56.40	70.10	42.80	
NH_4N (ppm)	18.00	29.20	33.90	42.10	25.70	
P (mg kg^{-1})	10.00	11.00	10.00	18.00	12.00	Bray 1
K (mg kg^{-1})	1.05	0.99	1.12	0.59	0.89	Ammonium acetate
Ca (cmol(+) kg^{-1})	11.00	9.30	3.40	2.90	3.20	Ammonium acetate
Mg (cmol(+) kg^{-1})	3.50	2.70	2.30	1.00	1.30	Ammonium acetate
OC (%)	0.35	0.57	0.66	0.82	0.50	Walkley and black
CEC (cmol(+) kg^{-1})	15.57	13.02	6.85	4.52	5.42	Ammonium acetate

P = phosphorus; K = potassium; Mg = magnesium; OC = organic carbon.

high activity clayey, medium base saturation and clayey topsoil.

Soil characterization

Soil samples were collected before land preparation and planting. Ten auger soil samples were collected from five depths (0-20, 20-40, 40-60, 60-80 and 80-100 cm) before planting at the rainfed field experimental site. The soil samples were thoroughly mixed, and a composite sample was put in one bag for each layer. A duplicate set of sub-samples from the composite were collected for soil chemical analysis as shown in Tables 1 and 2. Field moist soil samples for NO3-N and NH4-N determinations were stored in a cooler box, refrigerated and analyzed within a week. To determine gravimetric and volumetric soil water, the sub-samples were weighed and oven dried at 105°C for 24 h as presented in Tables 1 and 2. The remaining sub-samples were air-dried and passed through a 2 mm sieve and used for physical properties analysis.

The soil samples were analyzed for texture, pH, exchange potassium (K), extractable phosphorus (P), organic carbon, ammonium (NH4+) and nitrate (NO3-) at Zambia Agriculture Research Station (ZARI) using standard methods as shown in Tables 1 and 2 (Hoogenboom et al., 1999; Saxton and Rawls, 2006; Soil Survey Staff, 2014). The SPAW (soil-plant-air-water) model (Saxton and Rawls, 2006; Saxton and Willey, 2006) was used to determine the values for bulk density, wilting point or lower limit of soil water content (LL15), drained upper limit of soil water content (DUL), saturated soil water content (SAT) and hydraulic conductivity.

Field experiment

A split-split plot experimental design was setup with 3 sowing dates (SDs; 12th December, 2016, 26th December, 2016 and 9th January, 2017), maize cultivars (ZMS 606 [V1], PHB 30G19 [V2] and PHB 30B50 [V3]) and 3 nitrogen fertilizer levels (N1, N2 and N3) with 3 replications as indicated in Table 4. 120 (N1), 240 (N2) and 360 (N3) kg/ha NPK 10-20-10 (N, P_2O_5, K_2O) was applied as basal dressing at each sowing date. 120 (N1), 240 (N2) and 360 (N3) kg urea (46% N) were applied as top dressing as shown in Table 4. The main plot, subplots and sub-sub plots were the sowing date, maize cultivars and nitrogen fertilizer rate, respectively. Two days before planting, the site was disced to a depth of about 30 cm and harrowed. Individual plot sizes were 6 m (7 rows) by 5 m. The plots were separated from each other by a 2 m distance to prevent cross contamination of treatments. Three seeds were sown by hand per station at 5 cm depth in a flat seedbed in 0.75 m between row spacing and 0.50 m within row spacing. Plants per station were later thinned to 2. Weeds were controlled using herbicides and hand hoes during the growing period.

Plant materials

Medium maturing maize cultivars (PHB 30G19, PHB 30B50 and ZMS 606) were selected. The PHB 30G19 and PHB 30B50 are white and yellow varieties produced by pioneer and matures from 120-130 days. The ZMS 606 is a medium maturing three-way white maize hybrid with maturity ranging from 125 - 130 days. It has an

Table 3. Growth and development stages.

Vegetative stage	Reproductive stage
Emergence (VE)	silking (R1)
first leaf collar (V1)	blister (R2)
second leaf collar (V2)	milk (R3)
third leaf collar (V3)	dough (R4)
nth leaf collar (V(n))	dent (R5)
tasseling (VT)	maturity (R6)

Source: NSW (2009) and Hoogenboom et al. (1999).

exceptionally good drought tolerance and all diseases such as leaf bright and cob rot. PHB 30B50, and PHB 30G19 and ZMS 606 are recommended to be grown under irrigated and rainfed conditions. The selected cultivars have a long commercial life and are planted by the small scale farmers locally.

Maize growth stages and analysis

The maize growth stages are divided into vegetative (V) and reproductive (R) stage as shown in Table 3. The first and last V stages are emergence (VE) and tasseling (VT). The number of leaves (n) on maize varies depending on the cultivar, maturity and environment. The leaf stage is identified by the top leaf with a visible full collar, and they are described using the leaf collar method (Hoogenboom et al., 1999; NSW, 2009).

Phenological stages and physiological maturity were recorded when 50 and 75 % of the plants reached the stage, respectively as described by Asseng et al. (1998) and Hoogenboom et al. (1999). Biomass harvest was done at recommended growth stages V6 (50% of plants with collar of 6th leaf visible), R1 (50% of plants with some silks visible outside husks), R4 (50% of plants in *dough* stage-endosperm with pasty consistency-often 24-28 days after silking) and R6 (75% of plants with black layer at the base of the seed) as shown in Table 4. The appearance of a black layer on maize seeds was used as a criterion for determining maturity (Sharifi and Namvar, 2016). The maize leaf area was calculated by multiplying the manually measured length, maximum width and 0.75 reported as the maize calibration factor (Karuma et al., 2016). The dry plant matter at vegetative and reproductive stages (V6, R1, R4 and R6) was determined using destructive sampling and oven dried at 70°C for 72 h. The following parameters were measured: cob length, and width, leaf area index (LAI), harvest index (HI), 100-grain weight, seed number m^{-2}, biomass, leaf blade, leaf sheath, stem, husk, stover and grain yield. The vernier caliper and measuring ruler were used to measure cob width and length, respectively.

Statistical analysis

The analysis of variance (ANOVA) of a split-split plot design was used to analyze the data and means separated at 5% probability level (p≤0.05) using the agricolae package. The treatment means with the same letter were not significantly different as shown in Table 7 and 8; however, specific pairs of group means that showed significance were further tested using Tukey's HSD Test. The analytical procedure was performed by post-hoc multiple comparison procedures. The split-split plot design analysis was divided into three parts: the main-plot, subplot and sub-subplot analysis. Leaf area index, yield and yield components were analyzed using the ssp. plot() function in agricolae package in R Programming software (de Mendiburu, 2016). Equations 1, 2, 3 and 4 below were used to compute growing degree days (GDDs), crop heat units (CHUs), phenothermal (PTI) and heat use efficiency (HUE), respectively.

$$GDD = \sum\left(\left(\frac{T_{max} + T_{min}}{2}\right) - T_{base}\right) \quad (1)$$

$$Daily\ CHU = \frac{1.8(T_{min} - 4.4) + 3.33(T_{max} - 10) - 0.084(T_{max} - 10)^2}{2} \quad (2)$$

$$Phenothermal\ (PTI) = \frac{GDD}{Growth\ duration} \quad (3)$$

$$Heat\ use\ efficiency\ (HUE) = \frac{Grain\ yield\ (kg/ha)}{GDD} \quad (4)$$

Where; GDD is the growing degree-days, Tmax and Tmin are the daily maximum and minimum temperatures, respectively, and T_{base} is the minimum temperature threshold.

RESULTS AND DISCUSSION

Effect of sowing date on growing degree days, crop heat units, phenothermal index and heat use efficiency

Computed cumulative GDD, CHU, Srad, and precipitation at vegetative and reproductive stages, grain yield, growth duration, PTI and HUE are shown in Table 5 and Table 66. Sowing date 1 (SD1) had more GDD, CHU, cumulative Srad and cumulative precipitation compared to SD2. The SD3 had higher cumulative Srad and CHU compared to SD1 and SD2; however, the cumulative precipitation amount received during SD3 was lower compared to SD1 and SD2 and this could have contributed to lower grain yield. The GDDs decreased with delay in SD and this study agrees with the findings of Dahmardeh (2012).

Precipitation, Srad, maximum and minimum temperature were different during the duration of each SD as the season progressed as shown in Table 5 and 6. SD1 (precip: 850.37 mm, tmax: 27.47°C, tmin: 17.14°C, Srad: 17.38 MJ m^{-1} d^{-1}) recorded higher meteorological parameters compared to SD2 (precip:

Table 4. Summary of data collected from the rainfed experiment site.

		SD1			SD2			SD3		
	Variety	ZMS 606	30G19	30B50	ZMS 606	30G19	30B50	ZMS 606	30G19	30B50
		1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
N rate	Land preparation						29-Nov-16			
	Basal dressing and planting		12-Dec-16			26-Dec-16			09-Jan-17	
	Top dressing		30-Jan-17			17-Feb-17			03-Mar-17	
	Herbicides						14-Dec-16			
	Herbicides						23-Dec-2016 and 18-Jan-2017			
	Weeding						17-Jan-17			
	Pesticides					29-Dec-16				
Phenological stages	Emergence	21-Dec-16	21-Dec-16	20-Dec-16	04-Jan-17	04-Jan-17	03-Jan-17	17-Jan-17	16-Jan-17	17-Jan-17
	V6	06-Jan-17	06-Jan-17	06-Jan-17	20-Jan-17	20-Jan-17	19-Jan-17	06-Feb-17	06-Feb-17	05-Feb-17
	R1	15-Feb-17	15-Feb-17	13-Feb-17	04-Mar-17	2-Mar-17	04-Mar-17	19-Mar-17	19-Mar-17	17-Mar-17
	R4	14-Mar-17	14-Mar-17	12-Mar-17	28-Mar-17	28-Mar-17	26-Mar-17	12-Apr-17	12-Apr-17	10-Apr-17
	R6	14-Apr-17	15-Apr-17	13-Apr-17	26-Apr-17	22-Apr-17	25-Apr-17	18-May-17	19-May-17	18-May-17
Biomass sampling	V6	06-Jan-17	06-Jan-17	06-Jan-17	20-Jan-17	20-Jan-17	20-Jan-17	06-Feb-17	06-Feb-17	06-Feb-17
	R1	15-Feb-17	15-Feb-17	13-Feb-17	04-Mar-17	04-Mar-17	2-Mar-17	21-Mar-17	21-Mar-17	21-Mar-17
	R4	16-Mar-17	16-Mar-17	16-Mar-17	30-Mar-17	30-Mar-17	28-Mar-17	13-Apr-17	13-Apr-17	13-Apr-17
	Final harvest		03-May-17			15-May-17			01-Jun-17	

N1 (1): 67.20 kg N ha^{-1}; N2 (2): 134.40 kg N ha^{-1}; N3 (3): 201.60 kg N ha^{-1}; pesticide: Monocrotophos, fustac; herbicide: Nicosulfuron; termites: Terminator (Imidacloprid 30.5% SC) 350 g of Imidacloprid $litre^{-1}$.

763.27 mm, tmax: 27.02°C, tmin: 16.32°C, Srad: 17.22 MJ m^{-1} d^{-1}) and SD3 (precip: 515.27 mm, tmax: 26.88°C, tmin: 17.16°C, Srad: 17.38 MJ m^{-1} d^{-1}). Maize planted at SD2 had less cumulative GDDs compared to SD1 and SD3 during the grain filling period. SD1 experienced higher seasonal temperatures which increased biomass and grain yield. Conversely, SD3 experienced lower temperatures that reduced biomass and grain yield. Consequently, phenothermal index (PTI) and heat use efficiency (HUE) reduced with delay in SD.

HUE and this was associated with higher grain yield at all treatment levels as shown in Table 6 SD1.

The variation in maize SD determined the amount of Srad intercepted by the crop during its growth period. The amount of incident Srad and the proportion that is intercepted directly by the crop determines crop growth rate and its yield and yield components. The number of days during grain filling period reduced with delay in SD. SD1 with longer grain filling period, had higher PTI and experienced a longer period from silking to physiological maturity compared to SD2 and SD3. Delayed sowing date reduced maize yield and yield components due to changes in temperature and soil moisture (Abduselam et al., 2017; Li et al., 2018).

Treatment effect of sowing date on 100 grain weight, grain, biomass, stover, harvest index, cob length and width

The treatment effects of sowing date was very highly significant on cob length, cob width, 100

Table 5. Computed cumulative GDD, CHU, Srad and precip at vegetative and reproductive stages of maize.

Growth stage		ZMS 606				PHB 30G19				PHB 30B50			
		Precip	**Srad**	**GDDs**	**CHUs**	**Precip**	**Srad**	**GDDs**	**CHUs**	**Precip**	**Srad**	**GDDs**	**CHUs**
Sowing date 1	Emergency	61.30	151.32	147.85	569.00	61.30	151.32	569.00	569.00	53.80	129.77	132.60	510.90
	V6	318.90	441.06	389.80	1,478.13	318.90	441.06	389.80	1,478.13	318.90	441.06	389.80	1,478.13
	Silking (R1)	649.90	1,105.69	982.25	3,749.83	649.90	1,105.69	982.25	3,749.83	617.90	1,066.07	950.25	3,632.28
	Dough stage (R4)	826.10	1,537.91	1,367.60	5,246.80	826.10	1,537.91	1,367.60	5,246.80	826.10	1,500.74	1,343.30	5,146.80
	Maturity (R6)	847.58	2,169.10	1,776.88	6,852.76	850.37	2,176.23	1,789.03	6,904.86	847.58	2,149.40	1,761.62	6,799.04
Sowing date 2	Emergency	225.70	185.17	145.50	560.80	225.70	185.17	145.50	560.80	224.20	166.44	130.30	502.89
	V6	292.40	406.95	376.25	1,469.43	292.40	406.95	376.25	1,469.43	292.10	393.09	362.50	1,414.19
	Silking (R1)	708.90	1,148.00	1,015.85	3,906.82	695.60	1,122.56	985.15	3,795.36	708.90	1,148.00	1,015.85	3,906.82
	Dough stage (R4)	743.20	1,594.73	1,343.25	5,192.30	743.20	1,594.73	1,343.25	5,192.30	743.20	1,558.06	1,317.30	5,087.33
	Maturity (R6)	762.25	2,108.68	1,708.39	6,659.43	757.17	2,065.51	1,664.64	6,468.36	762.25	2,097.97	1,698.85	6,615.54
Sowing date 3	Emergency	27.30	121.75	130.85	514.32	24.60	110.23	117.50	458.95	27.30	121.75	130.85	514.32
	V6	252.30	453.14	421.25	1,636.73	252.30	453.14	421.25	1,636.73	240.00	439.09	406.90	1,579.33
	Silking (R1)	484.90	1,190.58	1,012.85	3,907.97	484.90	1,190.58	1,012.85	3,907.97	484.90	1,144.12	985.20	3,800.46
	Dough stage (R4)	506.37	1,655.87	1,324.74	5,147.29	506.37	1,655.87	1,324.74	5,147.29	506.38	1,611.09	1,298.04	5,045.86
	Maturity (R6)	515.27	2,228.83	1,754.32	6,890.01	515.27	2,244.70	1,766.29	6,939.26	515.27	2,228.83	1,754.32	6,890.01

Note: Precip in mm; srad in Mj m^{-2} d^{-1}; GDD in ^{o}Cd; CHU in ^{o}Cd.

grain weight, HI, grain, stover and biomass yield at maturity, highly significant on biomass (R1), and leaf-blade (R6) and significant on LAI (R1) and husk (R6) as shown in Tables 7 and 8. SD effect on grain yield at SD1, SD2 and SD3 were 9.08, 7.16 and 6.18 t ha-1, respectively. Delay in SD led to reduction in 100-grain weight, cob length, grain and biomass yield due to decreasing cumulative rainfall and lowering of air temperatures and Srad. Peykarestan and Seify (2012) reported that the SD treatment effect was significant on 100 grain weight and grain yield. Studies undertaken by Abduselam et al. (2017), Amjadian et al. (2015) and Chisanga et al. (2015) showed that delay in sowing date reduced maize grain number, biomass and grain yield. Similarly, Malekabadi et al. (2014) noted that delay in SD reduced total grain yield and yield components. In cases where planting is delayed, knowledge on planting is delayed, knowledge on how the maize cultivar maturity interacts with the environmental components is key to developing mitigating strategies that leads to optimizing and stabilizing grain yield (Tsimba et al., 2013). Results indicated that the SD treatment effect influenced biomass and grain yield. In spite of the N rate effect being statistically non-significant, N2 affected grain yields compared to N1. Maize grain yield increased by increasing the rate of applied nitrogen. Similar results have been reported by Bejigo (2018). Mousavi et al. (2012) has also reported significant effect of SD on HI of maize.

The mean difference in grain and biomass yield was significantly different due to SD treatment effects from SD1-SD2, SD1-SD3 and SD2-SD3 being 1.91 and 2.11, 2.90 and 2.52, and 0.99 and 0.42 t ha^{-1}, respectively. The means for the 100 grain weight was statistically significant from SD1-SD2 (8.07 g), SD1-SD3 (10.49 g) and SD2-SD3 (2.42 g). The effect of sowing date on maize yield has been studied in Pakistan and results showed that early sowing of maize cultivars gave higher grain yield (Ali et al., 2018). The cob length mean difference between SD1-SD2, SD1-SD3 and SD2-SD3 were 0.21, 0.45 and 0.25 cm, respectively.

Table 6. Computed grain yield, growth duration, NUE, PTI and HUE.

Growth stage		ZMS 606			PHB 30G19			PHB 30B50		
	N rate	N1	N2	N3	N1	N2	N3	N1	N2	N3
Sowing date 1	Grain yield kg ha^{-1}	9,182.80	8,731.40	7,896.10	8,369.40	7,931.60	9,733.60	9,489.80	9,560.90	10,791.70
	Growth duration (days)	123.00	123.00	123.00	124.00	124.00	124.00	122.00	122.00	122.00
	PTI	14.45	14.45	14.45	14.43	14.43	14.43	14.44	14.44	14.44
	HUE (^{o}Cd)	5.17	4.91	4.44	4.68	4.43	5.44	5.39	5.43	6.13
Sowing date 2	Grain yield kg ha^{-1}	6,854.00	8,174.00	6,536.20	7,336.90	6,496.80	7,909.50	7,901.70	5,273.70	7,987.40
	Growth duration (days)	121.00	121.00	121.00	117.00	117.00	117.00	120.00	120.00	120.00
	PTI	14.12	14.12	14.12	14.23	14.23	14.23	14.16	14.16	14.16
	HUE (^{o}Cd)	4.01	4.78	3.83	4.41	3.90	4.75	4.65	3.10	4.70
Sowing date 3	Grain yield kg ha^{-1}	5,962.40	6,511.80	6,083.10	6,142.60	6,061.80	6,065.80	5,567.30	6,883.90	6,315.40
	Growth duration (days)	129.00	129.00	129.00	130.00	130.00	130.00	129.00	129.00	129.00
	PTI	13.60	13.60	13.60	13.59	13.59	13.59	13.60	13.60	13.60
	HUE (^{o}Cd)	3.40	3.71	3.47	3.48	3.43	3.43	3.17	3.92	3.60

SD = sowing date.

The mean differences of LAI between SD1-SD2, SD1-SD3 and SD2-SD3 were 0.33, 0.53 and 0.17 m^2 m^{-2}, respectively. LAI decreased with delay in sowing date.

Treatment effect of maize cultivar on stover, grain, 100 grain weight and seed number m^{-2}

The treatment effect of cultivar was very highly significant on stover, 100 grain weight, seed number m-2, cob width, harvest index and leaf-blade at R1 and R4 as shown in Tables 7 and 8. PHB 30B50 cultivar had the highest 100 grain weight of 40.34 g followed by PHB 30G19 and ZMS 606 as shown in Table 8. ZMS 606 had the highest number of seed number m-2 compare to PHB 30G19 and PHB 30B50. The results show that the cultivars were statistically different and each performed differently as influenced by the cultivar treatment effect. The cultivars varied significantly in grain yield and such finding are comparable to those reported by Abduselam et al. (2017) who observed that cultivar significantly influenced total grain yield and yield components.

The mean differences in stover yield due to cultivar treatment effect between PHB 30G19-PHB 30B50, PHB 30B50- ZMS 606 and PHB 30G19- ZMS 606 were 0.21, 0.63 and 0.84 ton ha- PHB 30B50, PHB 30B50- ZMS 606 and PHB 30G19- ZMS 606 were 0.21, 0.63 and 0.84 ton ha^{-1}, respectively. The differences in 100 grain weight and seed number m^{-2} due to cultivar treatment effect between PHB 30B50- PHB 30G19, PHB30B50- ZMS 606 and PHB 30G19-ZMS 606 were 5.82 g and 447 seeds m^{-2}, 6.72 g and 495 seeds m^{-2}, and 0.89 g and 48 seeds m^{-2}, respectively.

Treatment effect of nitrogen fertilizer rate on leaf area index, maize yield and yield components

The treatment effect of N was very highly significant with leaf area index at V6. The mean differences between N2-N1, N3-N1 and N3-N2 were 0.03, 0.11 and 0.08 m^2 m^{-2}, respectively. Higher N fertilizer application rate increased LAI.

Application of N2 had higher biomass followed by N1 and N3. PHB 30G19 cultivar had the highest mean biomass (9.45 g m^{-2}) followed by PHB 30B50 (9.37 g m^{-2}) and ZMS 606 (9.36 g m^{-2}). Maize grain yield and yield component were increased with higher nitrogen fertilizer rate (Bejigo, 2018; Sharifi and Namvar, 2016; Singh and Hadda, 2014) even though the study results were statistically non-significant. Pooled data showed an increase in seed number m^{-2} at higher

Table 7. Treatment effect of SD, cultivar, and N on yield and yield parameters.

Treatment/cultivar	V6 (g m^{-2})	R1 biomass (g m^{-2})	R4 biomass (g m^{-2})	R1 leaf blade (g m^{-2})	R4 leaf blade (g m^{-2})	R6 leaf blade (g m^{-2})	R6 stem (g m^{-2})	R6 cob (g m^{-2})	R6 leaf sheath (g m^{-2})
SD1	11.38[a]	256.7[b]	449.40[a]	100.36[a]	93.67[a]	20.78[b]	47.77[b]	158.0[a]	17.69[b]
SD2	8.49[b]	212.6[a]	501.67[a]	80.77[b]	97.91[a]	25.20[b]	47.59[b]	140.8[ab]	16.31[b]
SD3	8.31[b]	263.2[b]	534.41a	91.17[ab]	89.00[a]	35.03[a]	68.17[a]	128.4[b]	27.85[a]
Significance	***	**	ns	ns	ns	***	***	***	***
Tukey HSD 5%	1.64	40.10	130.69	10.58	24.14	6.45	39.78	24.95	2.77
CV %	26.65	25.04	34.9	17.77	34.2	31.60	12.62	5.1	20.49
ZMS 606	9.36[a]	229.9[b]	461.04[a]	77.56[b]	80.98[b]	19.89[b]	51.23[b]	109.10[b]	17.65[b]
P30B19	9.45[a]	270.0[a]	504.88[a]	104.46[a]	105.7[a]	31.59[a]	62.15[a]	157.8[a]	21.82[a]
P30G50	9.37[a]	232.7[ab]	519.56[a]	90.27[ab]	93.90[ab]	29.53[a]	50.15[b]	160.3[a]	22.38[b]
Significance	ns	*	ns	***	***	***	**	***	***
Tukey HSD 5%	1.14	33.23	62.74	13.47	13.47	5.77	31.56	11.43	2.53
CV %	19.5	24.7	19.5	21.96	21.96	36.00	13.72	3.3	20.7
Nitrogen (N) rate (N1)	9.28[a]	246.2[a]	506.10[a]	88.66[a]	94.33[a]	271.2[a]	54.88[a]	137.37[a]	21.83[a]
Nitrogen (N) rate (N2)	9.66[a]	248.9[a]	461.42[a]	88.67[a]	91.77[a]	279.1[a]	51.56[a]	137.74[a]	19.53[a]
Nitrogen (N) rate (N3)	9.24[a]	237.7[a]	517.96[a]	94.96[a]	94.48[a]	310.3[a]	57.08[a]	152.07[a]	20.49[a]
Significance	ns	ns	ns	ns	ns	ns	Ns	ns	ns
Tukey HSD 5%	1.09	59.1	57.18	10.53	10.94	54.34	37.93	16.18	2.34
CV %	21.9	24.9	23.0	19.6	19.7	27.60	15.32	5.6	20.60
Interaction (SD* V) significance	*	ns	ns	**	ns	ns	ns	ns	ns
Interaction (V*N) significance	ns	ns	ns	ns	ns	ns	*	ns	ns
Interaction (V*SD*N) significance	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means sharing the same letter in the table do not differ statistically at $p < 0.05$; N1=52 kg N ha-1; N2 = 134.40 kg N ha-1; N3 = 201.60 kg N ha-1; LSD = least mean differences; * = significant at 5% level; ** = highly significant at 5% level; *** = very highly significant at 5% level; ns = non-significant; At R6 weight = g m^{-2}square meter (g m^{-2} * 10 = t ha^{-1}); wt = weight; two plants were analyzed at V6, R1 and R4.

N fertilizer rate. In similar studies undertaken by Sharifi and Namvar (2016), it was observed that seed number m^{-2} increased with increasing nitrogen rates. Increase in grains per ear at higher nitrogen rates is due to the lower competition for nutrient and this allows the plants to accumulate more total dry matter with higher capacity to convert more photosynthesis into sink resulting in more grains per ear (Bejigo, 2018). In a study by Zeidan et al. (2006), it was observed that seed number m^{-2} was maximum at the highest nitrogen fertilizer application rate.

Treatment effect on interaction between sowing date and cultivar

The interaction effect between sowing date and cultivar was very highly significant on cob length, highly significant on leaf-blade (R1), stover, and 100-grain weight and significant on V6 as shown in Table 7 and 8. The interaction effect of SD and cultivar was very highly significant on cob length and this has also been reported by Mousavi et al. (2012). The mean differences between SD1:V3-SD2:V3, SD1:V3-SD3:V3, SD1:V3-SD1:V2, SD1:V3-SD2:V2, SD1:V3-SD3:V2, SD1:V3-SD1:V1, SD1:V3-SD2:V1 and SD1:V3-SD3:V1 were 12.81, 18.66, 12.04, 18.05, 18.85, 13.40, 18.81 and 19.41, respectively. Cultivar V3 (PHB

Table 8. Treatment effect of SD, cultivar, and N on yield and yield parameters.

Treatment/cultivar	R6 husk (g m^{-2})	R6 stover (g m^{-2})	R6 grain (g m^{-2})	100 grain wt (g)	Seed no m^{-2}	Cob width	Cob length	HI	V6 lai	R1 lai	R4 lai	R6 biomass (g m^{-2})
SD1	33.30^{b}	277.5^{a}	907.6^{a}	42.35^{a}	2153a	5.49^{a}	21.43^{a}	0.77^{a}	0.34^{a}	3.81^{a}	3.39^{a}	1185.0^{a}
SD2	28.06^{b}	258.0^{b}	716.3^{b}	34.27^{b}	2064a	5.29^{b}	21.3^{a}	0.73^{b}	0.34^{a}	3.48^{ab}	3.34^{a}	974.3^{b}
SD3	55.06^{a}	314.5^{b}	617.7^{c}	31.86^{b}	2014a	5.04^{c}	18.43^{b}	0.66^{c}	0.32^{a}	3.31^{ab}	2.94^{a}	932.2^{b}
Significance	*	***	***	***	ns	***	***	***	ns	*ns	ns	***
Tukey HSD 5%	13.40	31.30	90.78	1.25	17.90	0.1720	1.9370	0.02	0.04	0.4584	0.89	115.26
CV %	45.70	16.84	18.52	4.6	57.8	5.10	11.41	4.64	22.3	19.49	22.85	17.05
ZMS 606	37.73^{ab}	234.5^{b}	732.6^{a}	33.62^{b}	2258^{a}	5.17^{b}	19.48^{a}	0.75^{a}	0.34^{a}	3.15^{b}	2.79^{b}	967.1^{a}
PHB 30G19	44.72^{a}	318.0^{a}	733.9^{a}	34.52^{b}	2210^{a}	5.51^{a}	20.78^{a}	0.69^{c}	0.32^{a}	3.61^{a}	3.49^{a}	1052.0^{a}
PHB 30B50	33.97^{b}	297.4^{a}	775.2^{a}	40.34^{a}	1763^{b}	5.14^{b}	20.91^{a}	0.72^{b}	0.34^{a}	3.85^{a}	3.38^{a}	1073.0^{a}
Significance	*	***	ns	***	***	***	ns*	***	ns	***	***	ns
Tukey HSD 5%	2.18	24.20	61.78	2.803.35	211.38	0.16	1.85	0.02	0.04	0.30	0.37	80.01
CV %	32.00	15.5	15	14.12	15.52	3.30	7.8	3.8	20.5	15.5	20.8	14.1
Nitrogen (N) rate (N1)	21.83^{a}	278.2a	742.3^{a}	36.70^{a}	2061^{a}	5.27^{a}	20.33^{a}	0.72^{a}	0.29^{b}	3.44^{a}	3.23^{a}	1020.0^{a}
Nitrogen (N) rate (N2)	19.53^{a}	272.6a	729.2^{a}	35.91^{a}	2054^{a}	5.24^{a}	20.33^{a}	0.73^{a}	0.32^{b}	3.51^{a}	3.12^{a}	1002.0^{a}
Nitrogen (N) rate (N3)	20.49^{a}	299.2a	770.2^{a}	35.87^{a}	2116^{a}	5.31^{a}	20.51^{a}	0.72^{a}	0.40^{a}	3.65^{a}	3.31^{a}	1069.0^{a}
Significance	ns	ns	ns	ns	ns	ns	ns	ns	***	ns	ns	ns
Tukey HSD 5%	2.34	31.88	90.79	3.43	13.74	0.10	0.94	0.02	0.04	0.48	0.39	124.6
CV %	26.20	18.52	18.5	16	44.2	5.60	16.5	4.1	18.3	23.1	20.5	20.4
Interaction (SD*V) significance	ns	**	ns	**	ns	ns	***	ns	ns	ns	ns	ns
Interaction (V*N) significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Interaction (V*SD*N) significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means sharing the same letter in the table do not differ statistically at $p < 0.05$; N1=52 kg N ha^{-1}; N2 = 134.40 kg N ha^{-1}; N3 = 201.60 kg N ha^{-1}; LSD = least mean differences; * = significant at 5% level; ** = highly significant at 5% level; *** = very highly significant at 5% level; ns = non-significant; At R6 weight=g m^{-2}square meter (g m^{-2} * 10 = t ha^{-1}); wt = weight; two plants were analyzed at V6, R1 and R4.

30B50) performed better compared to V2 (PHB 30G19) and V1 (ZMS 606).

Treatment effect on interaction between nitrogen fertilizer rate and cultivar

The interaction effect between cultivar and N was significant on stem weight as shown in Table 7 and 8. The mean difference between P30G19:N3-P30B50:N1, P30G19:N3-P30B50:N2, P30G19: N3-ZMS606:N2 and ZMS606:N3-P30G19:N3 were 0.22, 0.21, 0.20 and-0.26 ton ha^{-1}, respectively. PHB 30G19 yielded more leaf-blade weight compared to the ZMS 606 and PHB 30B50.

Conclusion

This study has demonstrated that maize yield is influenced by SD, N and cultivar. SD is a critical factor for capturing higher Srad without nutrient and soil moisture deficiency. Biomass and grain yield reduces with delay in SD and low soil fertility (N). SD, cultivar and N treatment effect significantly influenced maize yield and yield components. Delay in SD lead to reduction in grain and biomass yield due to lowering of temperature, phenothermal index (PTI) and reduction in cumulative rainfall during the plant growth duration. Farmers could enhance maize yield by manipulating sowing date, cultivar selection, N fertilizer rate and tillage. Crop yield parameters are useful in cultivar selection.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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