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Full Length Research Paper

Correlation and path analysis of yield, yield contributing and malt quality traits of Ethiopian sorghum (*Sorghum bicolor* (L.) Moench) genotypes

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Sorghum is a drought tolerant C_4 tropical crop with wide diversity grown for food, feed and beverages. There is a growing demand for food and malt type sorghum varieties due to the low supply of mat barley, and climate resilient and gluten free nature of the crop. This study was initiated to estimate the associations among traits and the relative importance of traits in influencing grain yield and malting quality of sorghum genotypes. The experiment was conducted at Fachagama in Mhoni ARC, Northern Ethiopia in 2016/2017 using α- lattice design in two replications using supplementary irrigation. Data were collected on agronomic traits, and a selection of 300 g pure seeds were malted (18 hr steeping, 72 hr in 28°C germinated and 24 hr in 50°C dried) for malt quality analysis. Positive and significant correlations with grain yield of TKW (0.766, 0.715), KL (0.671, 0.644), KW (0.524, 0.491) HLW (0.532, 0.504, FHWE (0.257, 0.241) and DP (0.275, 0.271) at both phenotypic and genotypic level was found respectively. TKW exerted high positive genotypic (0.334) and phenotypic (0.287) direct effect and even higher indirect effect on grain yield, which indicated that attention should be given to TKW primarily for direct and indirect selection for yield improvement. Thousand kernel weight and fine grind hot water extract showed a significant positive correlation with diastatic power at genotypic level and increment in these traits results in advancement of diastatic power.

Key words: Diastatic power, direct effect, indirect effect, genotypic and phenotypic association.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is classified under the grass family of Poaceae, genus Sorghum Moench (Poehlman and Sleper, 1995). It originated in Africa, more precisely in Ethiopia, between 5000 and

7000 years ago Vavilov, (1951) and/or centre diversity Harlan, (1992). The crop has spread to other parts of Africa, India, and Southeast Asia, Australia and the United States (Mesfin and Tileye, 2013).

Sorghum is a drought tolerant C_4 tropical crop with wide diversity. It is the fifth most important cereal crop in the world with grain production grown in arid and semi-arid parts of the world (FAO, 2016). It contributes to the protein and energy requirements for millions of people mainly living in Sub-Saharan Africa and Asia (Orr et al., 2016). Sorghum is one of the major staple food crops on which the lives of millions of Ethiopians depend. The majority of grain production goes towards the preparation of diverse food recipes, like porridge,"injera", "Kitta", "Nifro", infant food and syrup (Asfaw, 2007). A small fraction of the grain it is malted for local beverages, such as "Arake", "Tella", and "Borde" (Abegaz et al., 2002).

Barley is the grain of choice for malting in modern brewing (Taylor and Dewar, 2000). Next to barley, of which sorghum malt found the most appropriate alternative for brewing (Agu et al., 2013) and further the brewing qualities are advanced due to gluten-free nature of sorghum protein to substitute the gluten rich cereals in the diet of people suffering from celiac disease (Anheuser, 2010).

Malting is the controlled germination of cereals in moist air, under controlled conditions for mobilizing the endogenous hydrolytic enzymes, especially α-amylase and β-amylase enzymes of the grain. The malting process modifies the grain structure, so that it will be readily solublized during the brewing process to produce fermentable wort (Taylor and Belton, 2002).

In any crop improvement program, the primary (or most essential) characteristic that the breeder looks into is the existence of genetic variability for the characters of interest (Jahufer and Gawler, 2000). Breeders are also interested in the relationship and interdependence that may exist between or among characters for direct and indirect selection (Muhammad et al., 2003).

Grain yield and its quality are the principal characters of a cereal crop (Bello and Olaoye, 2009). They are complex quantitative characters, which are influenced by a number of yield and malt quality contributing factors. Hence, the selection for desirable genotypes should not only be based on yield alone, but also other yield and malt quality components. Direct selection for yield is often misleading in sorghum because yield is polygenically controlled.

For effective utilization of the genetic stock in crop improvement, information of mutual association between yield, malt quality and yield components is necessary. It is therefore, necessary to correlate various characteristics with yield, malt quality and among themselves. The correlation between yield, malt quality and yield components usually show a complex chain of interacting relationship. Path coefficient analysis partitions the components of correlation into direct and indirect effects and highlights the relationship in a more meaningful way (Muhammad et al., 2003). However, no character association studies have been conducted at national level as wel as especially for yield and malt quality.

Although both correlation and path analysis have been extensively studied for agronomic traits in sorghum, such information is unavailable for malting quality traits in Ethiopia. Therefore, such association is essential among traits for further sorghum yield and malt quality improvement, particularly in the region and generally in the country for sorghum malt varieties development. Therefore, the current study was carried out to estimate; the magnitude of genotypic and phenotypic correlation between grain yield, malt quality and yield contributing characters and direct and indirect effects of yield related and malt quality traits for malting (diastatic power) and yield.

MATERIALS AND METHODS

Description of the experimental area

The experiment was carried out at Mehoni Agricultural Research center (MhARC) Fchagama test s tation site in Raya Azebo Woreda using supplementary irrigation in the 2016/2017 cropping season. Fachagama is located at 668 km from the capital Addis Ababa and about 120 km south of Mekelle, capital city of Tigray regional state. Geographically the experimental site is located at 12.70 °N latitude and 39.70 °E longitude with an altitude of 1578 m.a.s.l. The site receives a mean annual rainfall of 539 mm with an average minimum and maximum temperature of 12.8 and 23.2°C, respectively. The soil textural class of the experimental site was clay with pH of 6.89 (Gebremeskel et al., 2017).

Treatments and experimental design

The study genotypes (Table 1) including the two checks (Redswazi and Macia) were kindly availed by the national Sorghum Research Program of Melkasa Agricultural Research Center (MARC). The genotypes are selected based on their dominancy in production and historical usage for local beverage preparation and for some are recently released food varieties to evaluate whether they can be used for both food and malting.

The treatments (genotypes) were grown in (7, 8) α- lattice in two replications, 2 m path width between replications and 0.5 m path between plots found within incomplete blocks. The gross size of experimental plot was 1.5 m x 3 m (4.5 m^2) accommodating two

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Table 1. List of fifty- six Sorghum genotypes including two checks used in the study.

S/N	Genotype	Seed color	Seed Source	G.N.	Genotype	Seed color	Seed source
1	Abamelko	Brown	JARC	29	Degalit Yellow	Yellow	SARC
2	AL-70	White	MARC	30	Demhay	Chalky	TARI
3	Baji	Red	MARC	31	Dima	Red	MARC
4	Birimash	Red	MARC	32	Jamiyu	Red	MARC
5	Osmel	Red	MhARC	33	Jeru	Yellow	MARC
6	Chiro	Red	MARC	34	Jigurti	Red	MARC
7	Dagim	Red	MARC	35	Kodem	Yellow	MARC
8	E36-1	White	MARC	36	Lalo	Brown	TARI
9	Emahoy	Brown	PARC	37	Masugi Red	Red	MARC
10	Merawi	Chalky	MhARC	38	Masugi Yellow	yellow	MARC
11	AbaAre-1	White	MARC	39	Tetron White	Chalky	MARC
12	America-1	Red	MARC	40	Tewzale	Red	TARI
13	Baduqane	Yellow	MARC	41	Tseada Achire	White	TARI
14	Berjokecoll#1	Red	MARC	42	Tseada chimure	White	MARC
15	DagalitYellow-1	Yellow	MARC	43	Wediarse	Chalky	TARI
16	Gorade-2	White	MARC	44	Wegere	Yellow	MARC
17	Hodem-1-3	Yellow	MARC	45	Wetetbegunchie	Red	MARC
18	JimmaLocal-2	Brown	MARC	46	Wode aker	Chalky	MARC
19	Marye#2	Yellow	MARC	47	Yeju	White	SARC
20	Meminay-4	White	MARC	48	ZeriAdis	Yellow	TARI
21	Welenchity Col # 3	Redish	MARC	49	Goronjo	White	MARC
22	Wollo Col#050	Red	MARC	50	Gedo	White	SARC
23	Gano	Yellow	MhARC	51	Melkam	White	MARC
24	Bobe red	Red	MARC	52	Misikir	White	SARC
25	Bobe white	White	MARC	53	Dekeba	White	MARC
26	Dabar	White	MARC	54	Seredo	Buff	MARC
27	Dagnaw	Yellow	TARI	55	Macia (check)	White	MARC
28	Degalit	Yellow	JARC	56	Redswazi (check)	Buff	MARC

Key: TARI = Tigray Agricultural Research Institute, MARC = Melkassa Agricultural Research center, MhARC = Mehoni Agricultural Research center, SARC = Sirinka Agricultural Research center, JARC = Jimma Agricultural Research center and PARC = Pawe Agricultural Research center and G.N= Genotype number.

rows with spacing of 75 cm between rows and 20 cm between plants. The two outer most rows at both ends of first and the last blocks were treated as borders leaving two middle rows of each of the genotypes for sampling.

The experimental field was prepared by using farm tractor plough according to semi conventional farming practice.

It was sown July 11, 2016 at a spacing of 75 x 20 cm.

The full dose of DAP (diaminophosfate) (46% P_2O_5, 18% N) fertilizer at the rate of (100 $kgha^{-1}$) were drilled at planting. Nitrogen fertilizer in the form of urea (46% N at a rate of 100 $kgha^{-1}$) were applied half at sowing by mixing with DAP and the remaining half of urea was top-dressed at knee height. The seeds were sown by hand in the rows as uniformly as possible and covered with soil manually and thinning of seedlings was done two weeks after emergence.

Data collection and measurements

Agronomic traita

Agronomic data were collected from two rows in each plot on the following parameter; days to flowering (DF), days to maturity (DM), plant height (PH cm), number of productive tillers per plant (NPT), thousand kernel weight (TKW g) and grain yield (GY kg). The moisture level for TKW and GY was adjusted to 12.5% according to (Biru, 1979).

$$Adjusted\ seed\ weight = \text{Intial seed weight}\left(\frac{100-\text{OMC}}{100-\text{DMC}}\right)$$

where, OMC means Original moisture content and DMC means Desired moisture content.

Sorghum grain quality parameters

Hectoliter weight (HLW kg/hL):

Calculated using the instrument which uses hectoliter weight, electronic balance and moisture tester simultaneously according to the American Association of Cereal Chemists (AACC) (2000) method 55 - 10 and obtained values were adjusted to moisture content of 12.5% by the following equation;

$$\text{HLW (12.5\% M basis)} = \text{HLW}\frac{100 - \text{\% moisture measured in the grain}}{100 - 12.5}$$

where, HLW is Hectoliter weight.

Kernel size (KS):

The kernel width (KW), kernel length (KL) and kernel thickness (KT) of ten kernels of each variety of each plot were measured and average value were taken using a digital caliper ($\pm$0.01 mm) according to the modified method of (Schuler et al., 1994).

Germination energy (GE %):

This was done in the Haramaya university food science laboratory. It was done by placing 100 representative grains on damp filter paper with 4 ml water in closed petridshs. The seeds germinated at a temperature of 25°C and 100% relative humidity and counting germinated seeds after 24, 48 and 72 hrs. Germinated seeds were counted and expressed in percentage (Taylor and Taylor, 2008).

Endosperm texture (ET):

The relative proportion of vitreous (corneous) to floury endosperm were determined by cutting 5 kernels in halves longitudinally and evaluated using a rating scale of 1 (corneous), 2 (intermediate to corneous), 3 (intermediate), 4 (intermediate to flowery) and 5 (floury) as described by (Rooney and Millner, 1982).

Grain crude protein content (CP %):

The total protein content was measured by using Near Infrared Reflectance Spectrometry (NIRS), Model EU Perten Machine-IM9500 at Melkassa Agricultural research center food science laboratory. Then the result is converted to dry basis using the formula:

$$\text{Protein (dry basis)} = \frac{(\text{as is})100}{100 - \text{m}}$$

where, as is = the protein taken from the reading and M is % of moisture content of the grain.

Sorghum malt preparation and Sorghum malt quality traits

The malting process was done in the Haramaya university food science laboratory.

Steeping:

Sorghum grain samples of 300 g of each plot were cleaned by a hand picking to remove any defectives and washed three times to remove dirty, dusty and other foreign matters. The samples of the cleaned grains were placed in 300 x 300 mm nylon bags and steeped for 6 hr in steeping vessels (1 kg) containing 0.1% NaOH solution (Taylor and Taylor, 2008). At the end of 6 hr, the vessel was drained off and then refilled with fresh water at 25°C and the water was drained of every 3 hrs after 1 hr of air rest for total of 18 hrs (Dewar et al., 1997a).

Germination:

The steeped samples of each genotype were allowed to germinate in a germination vessel at optimal temperature (28 ^{o}C) for 72 hr germination time and keeping the relative humidity high (95%). Distilled water (20 ml) was sprayed using hand sprayer twice daily to avoid the decrease of relative humidity. The grain was turned to avoid meshing roots and shoots. The germinated samples of the test genotypes were transferred to a temperature controlled drying oven for kilning (Dewar et al., 1997b).

Drying or Kilning: The germinated samples were dried in a temperature controlled drying oven at 50 ^{o}C for 24 hrs according to Dewar et al. (1997a).

Malt quality traits

Malting weight loss (MWL %):

The total malting weight loss was determined by weighing the grains before and after malting by using the following equation (Dewar et al., 1997b).

$$\text{Malting weight loss} = \frac{\text{Initial dry weight of grains} - \text{dry weight of malt}}{\text{Initial dry weight of grains}} \times 100$$

Malt moisture content (MMC %):

The Moisture content of the malt was estimated by gravimetric method of the European brewing convention (EBC) (1997). Malt flour of 5 g was dried in an air forced dry oven for 3 hrs at 103°C. The mass loss on dry mass was determined as % moisture by using the equation:

$$\%\text{MC (Moisture content)} = \frac{(W2-W3)}{(W2-W1)} * 100$$

Where, MC is Moisture content of the malt, W_1 is Weight of container, W_2 is Weight of container and the sample before drying and W_3 is Weight of the container and the sample after 3hr drying.

Diastatic power of malt (DP) (°WK):

The diastatic power of the malt was determined using EBC Method 4.12, 1997 in the Asela malt factory.

Fine grind hot water extract (FHWE %):

It was done in Asela malt factory using the method of American Society of Brewing Chemists (ASBC) (2008).

Data analyses

Correlation analysis

The phenotypic and genotypic correlation between yield components and malting traits of two variables were estimated as described by Singh and Chaudhary in 1985.

$$\text{Phenotypic r} = \frac{\sigma_{p12}}{\sqrt{(\sigma^2_{p1})\,(\sigma^2_{p2})}}$$

$$\text{Genotypic r} = \frac{\sigma_{g12}}{\sqrt{(\sigma^2_{g1})\,(\sigma^2_{g2})}}$$

where, σ_{p12} is the phenotypic covariance between the two traits, σ^2_{p1} is the phenotypic variance of the first trait and σ^2_{p2} is phenotypic variance of the second trait, σ^2_{g12} is the genotypic covariance between the two traits, σ^2_{g1} is the genotypic variance of the first trait and σ^2_{g2} is the genotypic variance of the second traits.

The covariance was computed from the analysis of covariance.

where, r is number of replications:

$$\text{Cov g12} = \frac{MSPg - MSPe}{r}$$

$$\text{Cov p12} = \text{Cov(g12)} + \text{Cov(e12)}$$

where, Cov (g12) is genotypic covariance between traits 1 and y2, Cov p12 is phenotypic covariance between character 1 and 2, Cov (e12) is environmental covariance between character 1 and 2, MSPg is mean sum of cross products of genotype of 1 and 2, MSPe is mean sum of cross products of error of 1 and 2, and r = number of replications.

The phenotypic correlation coefficients were tested for traits significance with 'r' table for sample correlation coefficients at n-2 degree of freedom, as suggested by Gomez and Gomez (1984) or Singh and Chaudhary (1985).

$$t = r_{pxy}\sqrt{\frac{g-2}{(1-rp^{2}_{xy}y)}}$$

t value was tested against the tabulated t-value for (g-2) degree of freedom. Where g is the number of genotypes studied. The genotypic correlation coefficients were tested for their significance using the formula adopted by Robertson (1959).

$$t = \frac{r_{gxy}}{SE_{gxy}}$$

$$SE_{gxy} = \sqrt{\frac{(1-r^2)^2}{2h^2_x h^2_y}}$$

$SErg_{xy}$ is Standard error of genotypic correlation coefficient between character X and Y.

The 't' value, calculated using the above formula, were compared with 't' tabulated at (g-2) degree of freedom at 1 and 5% levels of significance; where r_{gxy} is the genotypic correlation between x and y traits; g = number of genotypes, h^2_x and h^2_y are heritability for traits x and y, respectively.

Path coefficient analysis

Based on genotypic correlation, path coefficient which refers to the direct and indirect effects of the yield attributing traits on grain yield (dependent character) and diastatic power contributing traits were calculated using the method described by Dewey and Lu (1959):

rij = Pij + Σrik pkj

where, rij is mutual association between the independent character (i) and dependent character (j) as measured by the genotypic (phenotypic) correlation coefficients, Pij is direct effects of the independent character (i) on the dependent variable (j) as measured by the genotypic (phenotypic) path coefficients, and Σrikpkj is summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k).

The residual effect, which determines how best the causal factors account for the variability of the dependent factor yield and diastatic power, was computed using the formula:

$1 = p^2R + \Sigma$ p ij rij

where, p^2R= is the residual effect and p ij rij = the product of direct effect of any variable and its correlation coefficient with dependent trait.

Table 2. Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for 14 traits.

Traits	DF	PH	NPT	GY	TKW	HLW	KL	Kw	KT	GE	CP	MWL	FHWE	MMC	DP
DF	1	0.679**	-0.234	0.173	0.284*	-0.395**	0.099	0.223	0.479**	-0.362**	-0.218	-0.019	0.378**	-0.093	-0.071
PH	0.624**	1	-0.06	0.453**	0.406**	-0.12	0.379**	0.23	0.338*	-0.217	-0.08	0.184	0.303*	-0.257	0.153
NPT	-0.234-	-0.045	1	0.166	-0.109	0.046	0.071	-0.118	0.011	-0.181	0.047	-0.054	-0.079	-0.099	0.096
GY	0.17	0.428**	0.16	1	0.766**	0.532**	0.671**	0.524**	0.445**	0.216	-0.099	0.182	0.257*	-0.344**	0.275*
TKW	0.270**	0.367**	-0.104	0.715**	1	0.502**	0.596**	0.61**	0.513**	0.223	-0.081	0.329*	0.369**	-0.334*	0.363**
HLW	-0.379**	-0.11	0.041	0.504**	0.467**	1	0.364**	0.326*	0.032	0.327*	-0.036	0.321*	0.04	-0.163	0.108
KL	0.094	0.347**	0.073	0.644**	0.581**	0.339**	1	0.603**	0.454**	0.308*	0.101	0.221	0.134	-0.241	0.177
Kw	0.208*	0.216*	-0.107	0.491**	0.588**	0.30**	0.584**	1	0.684**	0.256	0.055	0.242	0.288*	-0.308*	0.138
KT	0.470**	0.328**	0.012	0.425**	0.493**	0.021	0.451**	0.651**	1	0.055	-0.081	0.058	0.378**	-0.228	0.028
GE	-0.349**	-0.195*	-0.177	0.207*	0.221*	0.301**	0.300**	0.237*	0.057	1	0.201	0.176	-0.074	-0.088	0.151
CP	-0.194*	-0.045	0.05	-0.084	-0.06	-0.059	0.13	0.088	-0.016	0.177	1	-0.003	-0.275*	-0.064	-0.026
MWL	-0.024	0.183	-0.049	0.175	0.301**	0.287**	0.210*	0.221*	0.058	0.181	0.001	1	0.113	-0.15	0.454**
FHWE	0.363**	0.303**	-0.073	0.241*	0.348**	0.043	0.14	0.286**	0.377**	-0.068	-0.183	0.12	1	-0.176	0.276*
MMC	-0.093	-0.241*	-0.095	-0.329**	-0.322**	-0.162	-0.225*	-0.294**	-0.217*	-0.083	-0.044	-0.134	-0.168	1	-0.093
DP	-0.071	0.196*	0.096	0.271**	0.349**	0.101	0.179	0.138	0.032	0.082	-0.003	0.442**	0.275**	-0.09	1

* and ** are significant at P≤0.05 and P≦0.01.

The residual effect (p^2R) was estimated using the formula:

$$\sqrt{1-R^2}$$

where, $R^2 = \Sigma \text{pij rij}$

$$p^2R = \sqrt{1-\sum \text{pij rij}}$$

RESULTS AND DISCUSSIONS

Correlation of grain yield with agronomic and malt quality traits

Estimates of phenotypic (r_p) and genotypic (r_g) correlation coefficients between each pair of the traits are presented in Table 2. Grain yield (kg ha^{-1}) showed positive and highly significant (P $\leq$0.01) genotypic correlation with plant height (r_g=0.453), thousand kernel weight (r_g=0.766), hectoliter weight (r_g=0.532), kernel length (r_g=0.671), kernel width (r_g=0.524) and kernel thickness (r_g=0.445) at (P $\leq$0.05), for fine grind hot water extract (r_g=0.257) diastatic power (r_g=0.275) (Table 2), which indicates that improving these chaaracters may result in the improvement of yield due to high positive correlation. Selecting sorghum genotypes with late maturing and higher plant height might lead to larger grain size, seed weight, increased grain yield and fermentable extract. The findings of the present study are in agreement with the results obtained for plant height and days to flowering by Kalpande et al. (2014) and plant height and thousand kernel weights by (Ezeaku and Mohammed, 2006). Therefore, any improvement of these traits would result in a substantial increment on grain yield.

Grain yield (kg ha^{-1}) showed positive and highly significant (P $\leq$0.01) phenotypic correlation with plant height (r_p=0.428) thousand kernel weight (r_p=0.715), hectoliter weight (r_p=0.504), kernel length (r_p=0.644), kernel width (r_p=0.491) kernel thickness (r_p=0.425) and diastatic power (r_p=0.271) and positive significant (P $\leq$0.05) correlation with germination energy (r_p=0.207). This assures that as vigorousity increases high dry matter acumulation and possibility of grain yield improvement by phenotypic selection of these traits. Khandelwal et al. (2015) reported similar result for thousand kernel weights but negative significant correlation for plant height.

Grain yield had significant negative correlation with malt moisture content (r_g=-0.344) and

(r_p=-0.329) at genotypic and phenotypic level, respectively. This is in accordance with Laidig et al. (2017) for thusand seed weight, grain size, malt extract and protein content and in contrary for hectoliter weight and malting weight loss. Similar results were also found by Alhassan et al. (2008) for germination energy and malting weight loss. The traits such as plant height, thousand kernel weight, hectoliter weight, kernel length, kernel width and kernel thickness showed positive and highly significant correlation (P≤0.01) at both genotypic and phenotypic levels, while DP showed significant correlation (P≤0.05) at phenotypic level with grain yield. This indicated that selection for PH, TKW, HLW, KL, KW, KT, FHWE and DP would improve grain yield.

Grain yield had shown highly significant negative genotypic and phenotypic correlation with malt moisture content and non significant negative correlation at both genotypic and phenotypic level for protein content. This could be due to nutrient and others competition between the traits that arise from their inherent nature of the linkage or pleiotropy. The negative correlation impedes the improvement of grain yield.

Phenotypic correlation among agronomic and malt quality traits

This study indicated that days to flowering showed positive and significant correlation at (P≤0.01) with plant height (r_p=0.624) and kernel thickness (r_p=0.47), whereas at (P≤0.05) with kernel width (r_p=0.208) (Table 2) which sugests that selection for those traits improves grain yield simultaneously. Alam et al. (2014) reported positive and non significant phenotypic association to plant height and days to flowering. Days to flowering revealed highly significant negative correlation with hectoliter weight (r_p= -0.379) and germination energy (r_p = -0.349). Alhassan et al. (2008) found negative correlation of days to flowering with α- and β- amylase enzymes, whereas, positive correlation to germination energy and malting weight loss.

Plant height showed significant (P≤0.01) positive correlation with kernel length ($r_{p\,=}$ 0.347), kernel thickness (r_p=0.328), hot water extract (r_p=0.303) and diastatic power whereas, negatively and significantly correlated with germination energy (r_p=- 0.195). Plant height showed significant positive association to germination energy and negative to association to α- and β- amylase enzymes were reported by Alhassan et al. (2008). The negative correlation between those traits makes it impossible to achieve the simultaneous improvement of those traits along with each other. Kernel length showed positive significant (P≤0.01) association with kernel thickness (r_p=0.451) and germination energy (r_p=0.3).

Thousand kernel weight revealed significant positive association (P≤0.01) for days to flowering (r_p=0.27), plant height (r_p=0.367), grain yield (r_p=0.715), hectoliter weight (0.467), kernel length (r_p=0.581), kernel width (r_p=0.491) and kernel thickness (r_p=0.493) and at (P≤0.05) for germination energy (r_p=0.221). This indicates that simultaneously improvement of these traits. Amsalu and Endashaw (2012), found similar result with plant height and thousand kernel weight with days to flowering. The positive correlation of thousand kernel weight with germination energy, malting weight loss and diastatic power is similar with the finding of Beta et al. (1995). Positive correlation of thousand kernel weight with grain size and test weight were reported by Adetunji (2011). Hectoliter weight showed highly significant positive association (P≤0.01) with kernel length (r_p=0.339), kernel width (r_p=0.300) and malting weight loss (r_p=0.287) while negative association with plant height.

Protein content revealed negative significant correlation (P≤0.05) to days to flowering and also non significant negative correlation to plant height, grain yield, thousand kernel weight, hectoliter weight, kernel thickness, fine grind hot water extract and malt moisture content. This negative correlation between two desirable traits may impede to achieve the simultaneous improvement of those traits along with each other. Similar results were reported by Kassahun et al. (2011) for days to flowering, maturity, plant height, thousand kernel weight and grain yield. Alhassan et al. (2008) also reported similar finding for germination energy, malting weight loss and malt moisture content.

Fine grind hot water extract showed positive association (P≤0.01) for days to flowering, (0.363), plant height, (0.303), kernel width (0.286) and kernel thickness (0.377) also positive association for hectoliter weight, kernel length and malting weight loss. However, negative association to germination energy. Non significant positive association of fine grind hot water extract with medium size seed, hectoliter weight and thousand kernel weights was found by Adetunji (2011). Malt moisture content showed significant negative association at (P≤0.01) with grain yield (r_p=-0.329) and plant height (rp=-0.322) and kernel width (r_p=-0.294), at (P≤0.05) to plant height (r_p=-0.241), kernel thickness (rp=-0.217) and kernel length (rp=-0.225). This is in harmony with Beta et al. (1995) and Alhassan and Adedayo (2011).

A positive significant correlation was shown for diastatic power at (P <0.01) with thousand kernel weight (rp = 0.246) and at (P <0.05) for grain yield (rp = 0.21) however, non significant negative correlation with days to flowering, protein content. According to Alhassan et al. (2008) Alfa- and β-amylase were positively correlated with thousand kernel weight, and negatively to days to flowering. Generally, positive phenotypic correlation of any pairs of traits of the present sorghum population indicated the possibility of correlated response to selection. In contrary to this, the negative correlation prevents the simultaneous improvement of those traits along with each other.

Genotypic correlation among the component traits

Days to flowering showed positive and highly significant correlation with kernel thickness (r_g=0.479) and plant height (r_g=0.679), while non significant positive correlation with kernel length (Table 2). In contrary, it shown highly significant negative association with hectoliter weight (rg=-0.395) and germination energy (rg=-0.362). Alhassan and Adedayo (2011), reported significant positive association of germination energy with days to flowering which is contrary to the current finding.

Plant height showed significant positive association ($P≤0.01$) with kernel length, (r_g=0.379), ($P≤0.05$) kernel thickness (r_g=0.338) whereas, negative association with germination energy. The positive correlation of GY, DF and PH suggests selecting sorghum genotypes with higher plant height might lead to reduced earliness and increased grain yield. This in agreement with Amsalu and Endashaw (2012) and in contrary to Alam et al. (2014) reported positive and non significant genotypic association to plant height and days to anthesis.

Thousand kernel weight showed positive significant correlation at ($P≤0.01$) with hectoliter weight (rg=0.502). Kernel length (rg=0.596), Kernel width (rg=0.603), kernel thickness (r_g=0.513) and at ($P≤0.05$) with MWL (r_g=0.3290). This probably indicated that longer phenological period of tall genotypes could result in large assimilate accumulation with the maximum contribution to thousand kernel weight and grain yield. This is partially agreed with the result of Amsalu and Endashaw (2012) for plant height and days to flowering. Non significant positive correlation of thousand kernel weight with test weight (Kg/hl) and positive significant for large side size and significant negative with small seed size association with grain size was found by Chiremba et al. (2011).

Protein content showed significant negative correlation with fine grind hot water extract (r_g=-0.275) and non significant negative correlation with days to flowering, plant height, grain yield, thousand kernel weight, hectoliter weight, kernel thickness, malt weight loss and diastatic power. For both genotypic and phenotypic associations this is in agreement with Adetunji (2011) for hectoliter weight, thousand kernel weight, seed size and fine grind hot water extract, and Alhassan et al. (2011) for plant height, days to flowering, malting weight loss and germination energy. The negative correlation of the desirable trait protein content to those traits may impede or makes it impossible to achieve the simultaneous improvement of those traits along with each other.

Fine grind hot water extract revealed positive correlation at ($P≤0.01$) with days to flowering (r_g=0.378), thousand kernel weight (r_g=0.369), and kernel thickness (r_g=0.378) at ($P≤0.05$) with plant height (r_g=0.303), kernel width (r_g=0.288) and grain yield (r_g=0.257) suggesting that longer phenological period of genotypes could result in large seed size with the maximum contribution to thousand kernel weight, grain yield and fermentable extract. Similarly, Adetunji (2011) reported positive correlation of total fermentable sugars to TKW and HLW.

Diastatic power revealed positive significant ($P≤0.01$) correlation with malt weight loss (r_g= 0.454) and thousand kernel weight (r_g=0.363); and at ($P≤0.05$) fine grind hot water extract (rg=0.276) and grain yield (rg=0.275). The significant positive correlation is in conformity with Edney et al. (2007). This indicates metabolic reaction created due to high disatatic power and germination energy resulted in respiration loss, rapid germination in short period of time and malting loss. The negative genetic correlation for some of the malting and agronomic traits indicated that improvement of malting quality traits will require more than just selection. According to Alhassan et al. (2008) α- and β-amylase were positively correlated with thousand kernel weight, and negatively to days to flowering were reported. Malt moisture content correlated negatively for all of the traits at both genotypic and phenotypic level. This is in accordance with Alhassan et al. (2008).

Generally, genotypic correlation coefficients were relatively higher in magnitude than that of phenotypic correlation coefficients, which indicated the presence of inherent association among various traits that could be mainly due to the presence of linkage and of the pleiotropic effects of different genes. However, in some cases the phenotypic correlation values were higher than the genotypic correlation values suggesting the importance of environmental effects. This finding is in agreement with previous findings of Khandelwal et al, (2015) in sorghum. The positive association between all possible pair of traits suggested that the possibility of correlated response to selection so that with the improvement of one trait, there will be an improvement in the other positively correlated trait. This is because a positive genetic correlation between two desirable traits makes the job of plant breeder easy for improving both traits simultaneously. Unlike positive correlation, negative correlation between two desirable traits may impede to achieve the simultaneous improvement of those traits along with each other.

Phenotypic direct and indirect effects of various traits on grain yield

Partitioning of phenotypic correlations into direct and indirect effects on grain yield (Table 2) revealed that the trait hectoliter weight showed the highest positive direct effect with value (0.307) on grain yield followed by thousand kernel weight (0.287), kernel length (0.258), plant height (0.227) while, diastatic power showed

Table 3. Estimates of direct (bold diagonal) and indirect effect (off diagonal) at phenotypic level of nine traits on grain yield.

Traits	PH	TKW	HLW	KL	KW	KT	FHWE	MMC	DP	r_p
PH	0.227	0.106	-0.034	0.090	-0.016	0.040	-0.008	0.016	0.009	0.428**
TKW	0.083	0.287	0.143	0.150	-0.042	0.060	-0.009	0.022	0.017	0.715**
HLW	-0.025	0.134	0.307	0.088	-0.022	0.002	-0.001	0.011	0.005	0.504**
KL	0.079	0.167	0.104	0.258	-0.042	0.055	-0.004	0.015	0.007	0.644**
KW	0.049	0.169	0.092	0.151	-0.072	0.079	-0.007	0.020	0.007	0.491**
KT	0.074	0.142	0.006	0.117	-0.047	0.121	-0.010	0.015	0.006	0.425**
FHWE	0.069	0.100	0.013	0.036	-0.020	0.046	-0.025	0.011	0.013	0.241*
MMC	-0.055	-0.092	-0.050	-0.058	0.021	-0.026	0.004	-0.068	-0.004	-0.329**
DP	0.044	0.100	0.034	0.039	-0.010	0.014	-0.007	0.006	0.048	0.271**

Residual = 0.24, $r_{p\,=}$ phenotypic correlation with grain yield.

negligible positive direct effect on grain yield. However, kernel width (-0.072), malt moisture content (-0.068) and fine grind hot water extract (-0.025) had negative phenotypic direct effect on grain yield. So, the improvement of grain yield is as the expense of KW, MMC and FHE directly. Similar result was reported by Chittapur and Biradar (2015) for direct positive correlation of plant height, thusand kernel weight and seed size with grain yield.

Thousand kernel weights, both the direct and indirect positive effects largely via hectoliter weight and kernel length outweighed for the positive correlation with grain yield (r_p = 0.715**). So, both direct positive and indirect positive effects were the causes of the significant correlation. Therefore, such considerable indirect effects should be considered for selection. Considerable direct effect and positive significant correlation of thousand kernel weight with grain yield was reported by Khandelwal et al.(2015).

Plant height had positive direct effect and the phenotypic correlation with grain yield was significant positive. Its indirect effect via thousand kernel weight and other traits were mostly positive therefore, the positive correlation coefficient with grain yield was due to its direct and indirect effect. This is agreed with the finding of Kassahun et al. (2011).

Kernel length was another trait which had positive direct effect which is small as compared to its correlation coefficient. But it also contributed considerable positive indirect effect to grain yield via thousand kernel weight and hectoliter weight. Therefore, high positive correlation of kernel length with grain yield was due to both its positive direct effect and indirect effect via thousand kernel weight and hectoliter weight. The high positive correlation of KW with GY was mainly due to the indirect effects of Kernel length and thousand kernel length, so, KL and TKW should considered for grain yield improvement.

Diastatic power and kernel thickness showed positive direct effect (Table 3). The indirect effect of diastatic power via other characters was positive and negligible except TKW; therefore, its significant positive correlation coefficient with grain yield was mainly due to the indirect effect of thousand kernel weight.

Fine grind hot water extract, kernel width and Malt moisture content exerted directly negative effect on and negative correlation to grain yield. The positive association of FHWE with grain yield is mainly due to indirect effect of TKW. However, the negative association malt moisture with grain yield is due to both negative direct and indirectly effects of most of the traits. Negative direct effect of FHWE to grain yield was reported in barley by Pržulj et al. (2013).

The traits that exerted positive direct effect (thousand kernel weight, hectoliter weight, plant height and kernel length, kernel thickness, and diastatic) and their positive significant correlation coefficient with grain yield were known to affect grain yield in the favorable direction and needs much attention during the process of selection. Moreover the small indirect effects of TKW (0.169), HLW (0.143), PH (0.083) and KL (0.151) through other traits should be simultaneously considered. The phenotypic residual value (0.24) indicated that the traits which were included in the phenotypic path analysis explained 75.66% of the variation in grain yield.

Genotypic direct and indirect effects of various traits on grain yield

Estimates of genotypic direct and indirect effects of the selected traits on grain yield are presented in (Table 4). Genotypic path analysis showed that thousand kernel weight (0.334), exerted the highest positive direct effect to grain yield followed by hectoliter weight (0.309), kernel length (0.256) plant height (0.219). Diastatic power and

Table 4. Estimates of direct (bold diagonal) and indirect effect (off diagonal) at genotypic level of nine traits on grain yield**.**

Traits	PH	TKW	HLW	KL	KW	KT	FHWE	MMC	DP	r_g
PH	0.219	0.136	-0.037	0.097	-0.020	0.042	-0.006	0.017	0.007	0.453*
TKW	0.089	0.334	0.155	0.152	-0.054	0.063	-0.008	0.021	0.012	0.766**
HLW	-0.026	0.167	0.309	0.093	-0.029	0.004	-0.001	0.010	0.004	0.532**
KL	0.083	0.199	0.113	0.256	-0.054	0.056	-0.003	0.015	0.005	0.671**
KW	0.051	0.204	0.101	0.154	-0.089	0.085	-0.006	0.020	0.005	0.524**
KT	0.074	0.171	0.010	0.116	-0.061	0.123	-0.008	0.015	0.004	0.445**
FHWE	0.066	0.123	0.012	0.034	-0.026	0.047	0.021	0.011	0.009	0.257*
MMC	-0.056	-0.112	-0.050	-0.061	0.027	-0.028	0.004	-0.064	-0.003	-0.344*
DP	0.044	0.121	0.036	0.038	-0.012	0.014	-0.006	0.006	0.034	0.275*

Residual = 0.17, rg = genotypic correlation with grain yield.

fine grind hot water extract exerted negligible positive direct effect to grain yield. Similar result was reported by Chittapur and Biradar (2015) for direct positive correlation of plant height and thousand kernel weight.

Thousand kernel weight and Hectoliter weight which had significant high positive correlation (0.766**) and (0.532**), respectively with grain yield exerted positive direct effect (0.334) and (0.309). This indicated that the correlations of these traits with grain yield were found to be partly due to their direct effects. Therefore, simultaneous selection through these traits will be effective for grain yield improvement. Considerable direct effect and positive significant correlation of thousand kernel weight with grain yield was reported by (Khandelwal et al., 2015; Silva et al., 2017).

Plant height had positive direct effect and the genotypic correlation with grain yield was significant and positive. Its indirect effect via thousand kernel weight was positive therefore, the positive correlation coefficient with grain yield was mainly due to its direct and indirect effect. The direct positive effect of plant height to grain yield is in accordance with Kalpande et al. (2014) and Silva et al. (2017)

Kernel length revealed small positive direct effect to grain yield and also showed positive indirect effect through thousand kernel weight and hectoliter weight to grain yield. The causes of the positive association of kernel length with yield were mainly due to its positive direct effect and indirect effects through thousand kernel weight and hectoliter weight. Kernel width exerted direct negative effect on grain yield. The positive correlation with GY was due to the counter balance of the positive indirect effects of TKW, HLW and KL. So, the TKW, HLW and KL should be considered for the increment of grain yield.

Fine grind hot water extract has negligible positive direct effect and positive genotypic correlation with grain yield. This indicated that the positive correlation was mainly through in direct effect of thousand kernel weight. Diastatic power showed negligible positive direct effect to grain yield. The positive significant correlation of diastatic power with grain yield is due to the positive direct effect and positive indirect effects of thousand kernel weight.

Malt moisture content exerted directly negative effect on and negative correlation to grain yield. The negative association with grain yield is mainly due to the equivalent indirect effect of thousand kernel weight. The negative direct effect and correlation of MMC to grain yield was favorable, as malt moisture does not need to increase.

Generally, the positive significant correlation and positive direct effect of PH, TKW, HLW, KL, KT and FHWE, synchronization with considerable indirect effects of thousand kernel weight (0.204), hectoliter weight (0.155) plant height (0.084) and kernel length (0.154) will be most effective in improving grain yield of these genotypes. For all the traits taken to path analysis the direct effects are not equivalent to their correlation coefficients, so this allows for simultaneous selection at phenotypic level. The genotypic residual value (0.17) indicated that the traits used in the genotypic path analysis explained 82.06 % of the variation for grain yield.

Genotypic direct and indirect effects of various traits on diastatic power

Estimates of genotypic direct and indirect effects of the selected traits on diastatic power are presented in (Table 5). Genotypic path analysis showed that malt weight loss (r_g=0.382) had the greatest unfavorable positive direct effect. So, selection could be effective for genotypes having high diastatic power with low to medium malt weight loss. The positive direct effect of malting weight loss on diastatic power is indicative of the respiratory loss during seedling growth. The current study is in conformity

Table 5. Estimates of direct (bold diagonal) and indirect effect (off diagonal) at genotypic level of four traits on diastatic power.

Traits	GY	TKW	MWL	FHWE	r_g
GY	**0.068**	0.093	0.070	0.044	0.275*
TKW	0.052	**0.122**	0.126	0.063	0.363**
MWL	0.012	0.040	**0.382**	0.019	0.454**
FHWE	0.018	0.045	0.043	**0.171**	0.277*

Residual factor = 0.66

with Wenzel and Pretorius (1995) in sorghum. Alhassan et al. (2008) reported direct effect of (0.16) MWL to alpha amylase.

Thousand kernel weight (r_g=0.122), FHWE (r_g=0.171) exerted considerable direct effect and positive correlation to DP and showing the direct effects were higher than indirect effects. The considerable direct effect and positive correlation of FHWE to DP and the DP value of the genotypes above specification (28 SDU/g) indicates the availability of enough diastase enzymes to digest the starch to get fermentable sugars. This is in agreement with Kumar et al. (2014) for both timely and late sown barley and in contrary to Bichoński and Śmiałowski (2004) in Bbarley of DP and FHWE. Kumar et al. (2014) also reported that TKW (0.222) direct effect to malt extract in late sown barley. Grain yield exerted negligible positive direct effect to DP and its significant correlation with DP was due its both direct effect and indirect positive effects of TKW, MWL and FHWE. Therefore, Selection through direct positive effect of TKW, FHWE and low to medium malt weight loss content (higher dry malt mass) genotypes will be effective in improving sorghum diastatic power.

Path coefficient analysis in this study did not account for all variation in diastatic activity as indicated by the magnitude of the residual effects (0.66) of the nine agronomic and malting quality traits which pointed out that there are other traits in addition to the four traits to be included in the path analysis that contribute to diastatic activity. This is agreed with the high residual effect (0.97) for sorghum diastatic power as reported by Wenzel and Pretorius (1995), (0.4) for sorghum α-amylase activity (Alhassan et al., 2008) and for finger millet agronomic traits to grain yield (0.89) (Abuali et al., 2012).

SUMMARY AND CONCLUSIONS

Grain yield (kg ha$^{-1)}$ was found to be positively and significantly correlated with PH, TKW, HLW, KL, KW, KT, FHWE and DP both at phenotypic and genotypic level and significant positive correlation with GE at phenotypic level. So, the significant genotypic correlations of PH, TKW, HLW, KL, KT and higher r_g than r_p can be concluded that the association was inherent and selection would be effective to improve GY of the genotypes.

Focus on the direct and indirect favorable effect and significant positive correlation of TKW, HLW, KL, KT, and PH at both Phenotypic and genotypic level needs much attention and implies that selection on these traits would have a tremendous value for yield improvement of these sorghum genotypes. The considerable direct effect of TKW (0.122), FHWE (0.171) and their positive correlation with DP at genotypic level and increment in these traits would results in advancement of DP. However, unfavorable positive direct effect and significant correlation of MWL with DP genotypic level impedes DP improvement.

So, in order to bring an effective improvement of grain yield and malt quality traits, more attention should be given for traits such as PH, TKW, kernel size which showed high positive phenotypic and genotypic correlation coefficients with a considerable direct and indirect effect on grain yield and the positive correlation of the most limiting malt quality traits of DP and FHWE with grain yield of sorghum genotypes in the present study.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

American Association of Cereal Chemists (AACC) (2000). Approved Methods of the American Association of Cereal Chemists. 10th Edition, American Association of Cereal Chemists Inc., St. Paul.

Abegaz K, Fekadu B, Langsrud T, Judith AN (2002). Indigenous processing methods and raw materials of borde, an Ethiopian traditional fermented beverage. Food Technology Africa 7:59-64.

Abuali AI, Abdelmulla AA, Idris AE (2012). Character Association and Path Analysis in Pearl Millet (*Pennisetum glaucum* L.). American Journal of Experimental Agriculture 2(3):370-381.

Adetunji A (2011). Development of a database of sorghum cultivars in southern Africa, with emphasis on end-use quality, particularly brewing quality. MSc Thesis. University of Pretoria, Pretoria, South Africa.

Agu R, Palmer C, Geoff H (2013). Evaluation of the potentials of millet, sorghum and barley with similar nitrogen contents malted at their optimum germination temperatures for use in brewing. Journal of

Insitute of Brewing 119:258-264.

Alam MM, Hammer GL, Van Oosterom EJ, Cruickshank AW, Colleen H, Jordan DR (2014). A physiological framework to explain genetic and environmental regulation of tillering in sorghum. Australia. New Phytologist 203:155-167.

Alhassan U, Adedayo A (2011). Genetic Diversity in Malting Quality of some Sorghum Genotypes [*Sorghum bicolor* (L.) Moench]. PAT 6(2):51-60.

Alhassan U, Yeye MY, Aba DA, Alabi SO (2008). Correlation and path coefficient analyses for agronomic and malting quality traits in some sorghum [*Sorghum bicolor* (L.) Moench] genotypes. Journal of Food, Agriculture and Environment 6(3-4):285288.

Amsalu A, Endashaw B (2012). Geographical patterns of morphological variation in sorghum [*Sorghum bicolor* (L.) Moench] germplasm from Ethiopia and Eritrea: Quantitative characters. Euphytica 115: 91–104.

Anheuser B (2010). Red bridge Beer Made with you in Mind. Availbale at: http://www.redbridgebeer.com/homePage.aspx.

American Society of Brewing Chemists (ASBC) (2008). Method: malt analysis, in Methods of Analysis of the American Society of Brewing Chemists. American Society of Brewing Chemists: St Paul, MN.

Asfaw A (2007). The role of introduced sorghum and millets in Ethiopian agriculture. Journal I CRISAT 3(1):1-4.

Bello OB, Olaoye G (2009). Combining ability for maize grain yield and other agronomic characters in a typical southern guinea savanna ecology of Nigeria. African Journal of Biotechnology 8(11):2518-2522.

Beta T, Rooney LW, Waniska RD (1995). Malting characteristics of sorghum varieties. Cereal Chemistry 72(6):533-538.

Bichoński A, Śmiałowski T (2004). Relationships and correlations between brewery traits of the spring barley varieties 7(2).

Biru A (1979). Agricultural field experiment management manual part II. AIR (Institute of Agricultural Research), Addis Ababa, Ethiopia.

Chiremba C, Rooney LW, Taylor JRN (2011). Relationship between simple grain quality parameters for the estimation of sorghum and maize hardness in commercial hybrid cultivars. Journal of Cereal Chemistry 88:570-575.

Chittapur R, Biradar BD (2015). Association studies between quantitative and qualitative traits in rabi sorghum. Indian Journal Agricutural Science 49(5):468-471.

Dewar J, Taylor JRN, Berjak P (1997a). Determination of improved steeping conditions for sorghum malting. Journal of Cereal Science 26:129-136.

Dewar J, Taylor JRN, Berjak P (1997b). Effect of germination conditions, with optimised steeping on sorghum malt quality with particular reference to free amino nitrogen. Journal of the Institute of Brewing 103:171-175.

Dewey DR, Lu KH (1959). A correlation and path coefficient analysis of components of crested wheat grass kernel production. Journal of Agronomy 51:515-518.

Edney MJ, Eglinton JK, Collins HM, Barr AR, Legge WG, Rossnagel BG, Brew JI (2007). Importance of Endosperm Modification for Malt Wort Fermentability. Journal of Institute of Brewing 113(2):228-238.

European Brewery Convention (1997). EBC-Analytica, 5th ed., Hans Carl Fachverlag, Nurnberg.

Ezeaku IE, Mohammed SG (2006). Character association and path analysis in grain sorghum. African Journal Biotechnology 5(14):1337-1340.

Food and agriculture organization (FAO) (2016). Cereals production and utilization. Biannual report, 2016.

Gebremeskel G, Yemane G, Solomon H (2017). Response of Sorghum (*Sorghum bicolor* (L.) Moench) varieties to blended fertilizer on yield, yield component and nutritional content in irrigation in Northern Ethiopia. International Journal of Agricultural Bioscience 6(3):153-162.

Gomez AK, Gomez AA (1984). Statistical Procedures for Agricultural Research. John Willey and Sons Inc., New York. 657 p.

Harlan JR (1992). Crops and Man. 2nd Edition, American Society of Agronomy and Crop Socence. America, Madison, WI.

Jahufer MZZ, Gawler FI (2000). Genotypic variation for seed yield components in white clover (*Trifoliumrepens* L.). Australian Journal of Agricultural Research 51:657-663.

Kalpande HV, Chavan SK, More AW, Patil VS, Unche PB (92014). Character association, genetic variability and component analysis in sweet sorghum [*Sorghum bicolor* (L. Moench]. Journal Crop and Weed 10(2):108-110.

Kassahun A, Habtamu Z, Geremew B (2011). Variability for yield, yield related traits, protein Content and association among traits of sorghum [*Sorghum bicolor* (L) Moench] Varieties in Wollo, Ethiopia. Journal Plant Breeding and Crop Science pp. 125-133.

Khandelwal V, Shukla M, Jodha BS, Nathawat VS, Dashora SK (2015). Genetic Parameters and Character Association in Sorghum [*Sorghum bicolor* (L.) Moenc]). Indian Journal of Science and Technology 8(22).

Kumar V, Pal R, Verma S, Kumar D, Kharub AS, Sharma I (2014). Association of malting quality attributes under timely and late sown conditions in barley (*Hordeum vulgare* L .). Jurnalof Wheat Research 6(2):167-170.

Laidig F, Peter H, Dirk P, Thomas R (2017). Breeding progress, genotypic and environmental variation and correlation of quality traits in malting barley in German official variety trials between 1983 and 2015. Journal of Theoretical and Appllied Genetics 130(11):2411-2429.

Mesfin T, Tileye F (2013). Genetic Diversity of Wild Sorghum (*Sorghum bicolor* ssp. *verticilliflorum* (L.) Moench) Germplasm from Ethiopia as Revealed by ISSR Markers. Asian Journal of Plant Science 12(3):137-144.

Muhammad A, Muhammad R, Muhammad ST, Amer H, Tariq M, Muhammad SA (2003). Character association and path coefficient analysis of grain yield and yield components in maize. Pakistan Journal of Biological Science 6(2):136-138.

Orr A, Mwema C, Gierend A, Nedumaran S (2016). Sorghum and Millets in Eastern and Southern Africa. Facts, Trends and Outlook. Working Paper Series No. 62. ICRISAT Research Program, Markets, Institutions and Policies. Patancheru 502 324, Telangana, India: International Crops Research Institute for the Semi-Arid Tropics 76 p.

Poehlman JM, Sleper DA (1995). Breeding Field Crops 4th ed. Iowa State University Press, Ames. Iowa.USA. 494 p.

Pržulj N, Momcilovic V, Crnobarac J (2013). Path Coefficient Analysis of Quality of Two-Row Spring Barley. Genetika 1(45):121-30.

Robertson GE (1959). The sampling variance of the genetic correlation coefficient. Biometric 15:469-485.

Rooney LW, Milner FR (1982). Variation in the structure and kernel characteristics of sorghum. Processing international symposium on sorghum grain quality, ICRISAT: Patancheru, A., India pp. 143-162.

Schuler SF, Bacon RK, Gbur EE (1994). Kernel and spike character influence on test weight of soft red winter wheat. Journal of Cereal Science 34:1309-1313.

Silva KJ, Teodoro PE, Menezes CB, De Júlio MP (2017). Contribution of morphoagronomic traits to grain yield and earliness in grain sorghum. Journal Genetics and Molecular Research 16(2).

Singh RK, Chaudhary BD 91985). Biometrical Methods in Quantitative Genetics 3rd Editition. Kaliyani Publishers, New Delhi-Ludhiana.

Taylor JRN, Belton PS (2002). Sorghum. In: Belton PS, Taylor JRN (eds.), Pseudo cereals and Less Common Cereals pp. 55-59.

Taylor JRN, Dewar J (2000). Fermented products: Beverage and porriges, pp.751-795. In Smith CW, Frederiksen RA (eds.), Sorghum: origin, history, technology, and production, Wiley, New York.

Taylor JRN, Taylor J (2008). Five Simple Methods for the Determination of Sorghum Grain End-Use Quality. Department of Food Science, University of Pretoria, South Africa. INTSORMIL Scientific Publications. Available at: http://digitalcommons.unl.edu/intsormilpubs/17.

Vavilov NI (1951). The origin, variation, immunity and breeding of cultivated plants. Chronica Botanica 13:1-366.

Wenzel WG, Pretorius AJ (1995). The genetic variability of malt quality and related characteristics in grain sorghum. South African Journal of Plant and Soil 12(1):38-41.

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Evaluation of sowing date and fertilization with nitrogen in maize cultivars in rainy conditions in 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 $p \leq 5$ 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

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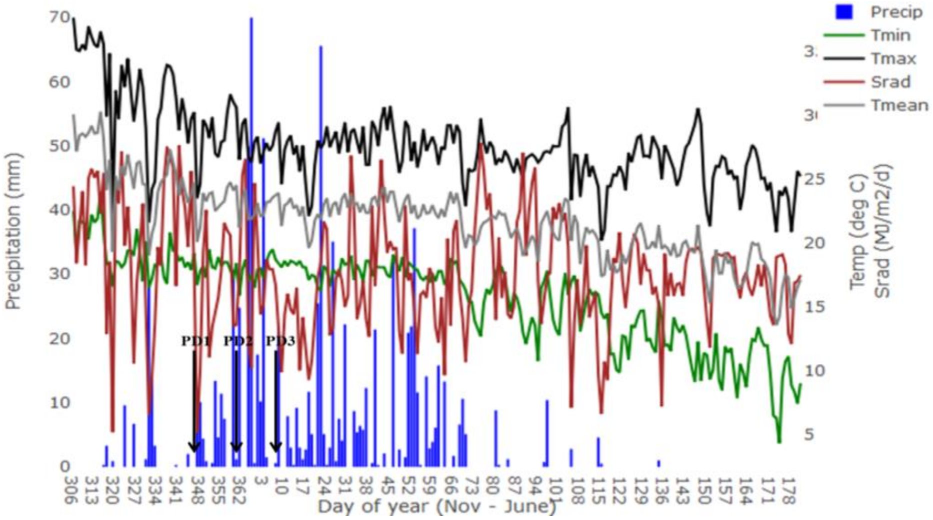

Figure 1. Daily weather data for Mt Makulu during the 2016/2017 season.

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 ($p \leq 0.05$) 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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REFERENCES

Abduselam F, Lagese Z, Tegene S, Tadesse F, Biri A, Siraj N (2017). Performance Evaluation and Adaptability of Improved Released Maize (*Zea mays* L.) Varieties in the Midlands of Fedis District of Eastern Hararghe. Pelagia Research Library Asian Journal of Plant Science and Research 7:10-14.

Abedinpour M, Sarangi A (2018). Evaluation of DSSAT-CERES Model for Maize under Different Water and Nitrogen Levels. Pertanika Journal of Science and Technology 26:1605-1618.

Ali W, Ali M, Ahmad Z, Igbal J, Anwar S (2018). Influence of Sowing Dates on Varying Maize (*Zea mays* L.) Varieties Grown Under Agro-Climatic Condition of Peshawar. European Journal of Experimental Biology 8:36.

Amjadian M, Farshadfar M, Gholipoor M, Shirvani H (2015). The effects of planting date on the yield and yield components of corn (*Zea mays* L.) cultivar, single cross 704. Agriculture Science Developments 4:1-3.

Arslan A, McCarthy N, Lipper L, Asfaw S, Cattaneo A, Kokwe M (2014). Food security and adaptation impacts of potential climate smart agricultural practices in Zambia (No. 14-13), ESA Working Paper.

Asseng S, Keating BA, Fillery IRP, Gregory PJ, Bowden JW, Turner NC, Palta JA, Abrecht DG (1998). Performance of the APSIM-wheat model in Western Australia. Field Crops Research 57:163-179.

Bejigo G (2018). Growth and Yield Response of Maize (*Zea mays* L.) Varieties with Varying Rates of Nitrogen Supply in Halalaba District. American Journal of Agriculture and Forestry 6:237-245.

Burke WJ, Jayne TS, Black JR (2016). Factors explaining the low and variable profitability of fertilizer application to maize in Zambia. Agricultural Economics 48:115-126.

Chisanga CB, Phiri E, Chizumba S, Sichingabula H (2015). Evaluating CERES-Maize Model Using Planting Dates and Nitrogen Fertilizer in Zambia. The Journal of Agricultural Science 7:1-20.

Dahmardeh M (2012). Effects of sowing date on the growth and yield of maize cultivars (*Zea mays* L.) and the growth temperature requirements. African Journal of Biotechnology 11:12450-12453.

de Mendiburu F (2016). Agricolae: Statistical Procedures for Agricultural Research. R package version 1.2-4.

du Plessis J (2003). Maize production. Agricultural Information Resource Centre pp. 1-38.

Fetahu S, Aliu S, Rusinovci I, Elezi F, Bislimi K, Behiluli A, Shabani Q (2014). Variation of physiological growth indices, biomass and dry matter yield in some maize hybrids. Albanian Journal of Agricultural Sciences pp. 69-73.

Gul S, Khan MH, Khanday BA, Nabi S (2015). Effect of sowing methods and NPK levels on growth and yield of rainfed maize (*Zea mays* L.). Scientifica 6 p.

Heisey PW, Mwangi W (1996). Fertilizer Use and Maize Production in Sub-Saharan Africa (No. 96-01), CIMMYT Economics Working Paper. Mexico, D.F.

Hoogenboom G, Wilkens PW, Tsuji GY (1999). DSSAT v3, volume 4. University of Hawaii, Honolulu, Hawaii.

Japan Association for International Collaboration of Agriculture and Forestry (JAICAF) (2008). Agriculture and forestry in Zambia: present situation and issues for development. Lusaka.

Kamal K, Telker SG, Gogoi M, Kumar D (2017). Crop simulation models. Biomolecular Reports pp. 225-229.

Karuma AN, Gachene CKK, Gicheru PT, Mtakwa PW, Amuri N (2016). Effects of tillage and cropping systems on maize and beans yield and selected yield components in a semi-arid area of Kenya. Tropical and Subtropical Agroecosystems 19:167-179.

Lafitte HR, Edmeades GO, Johnson EC (1997). Temperature responses of tropical maize cultivars selected for broad adaptation. Field Crops Research 49:215-229.

Li Y, Tao H, Zhang B, Huang S, Wang P (2018). Timing of Water Deficit Limits Maize Kernel Setting in Association With Changes in the Source-Flow-Sink Relationship. Frontiers in Plant Science 9:1326.

Lukeba JCL, Vumilia RK, Nkongolo KCK, Mwabila ML, Tsumbu M (2013). Growth and Leaf Area Index Simulation in Maize (*Zea mays* L.) under Small-Scale Farm Conditions in a Sub-Saharan African Region. American Journal of Plant Sciences 4:575-583.

Malekabadi SR, Pazoki A, Mehrvar MR (2014). Evaluating the effects Planting date on some Quantitative and Qualitative Characteristics of new Maize Varieties in the Region. Bulletin of Environment, Pharmacology and Life Sciences 3:189-192.

Mousavi R, Aboutalebian MA, Sepehri A (2012). The effects of on-farm seed priming and planting date on emergence characteristics, yield and yield components of a corn cultivar (SC 260) in Hamedan. Annals of Biological Research 3:4427-4434.

Mulenga BP, Wineman A (2014). Climate Trends and Farmers' Perceptions of Climate Change in Zambia.

Norton ER, Silvertooth JC (1998). Evaluation of Planting Date Effects on Crop Growth and Yield for Upland Cotton, Arizona.

NSW (2009). Maize growth and development. NSW Department of Primary Industries, State of New South Wales.

Peykarestan B, Seify M (2012). Impact of sowing date on growth and yield attributes of Pop Corn grown under different densities 3:85-91.

Saxton KE, Rawls WJ (2006). Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Science Society of America Journal 70:1569-1578.

Saxton KE, Willey PHP (2006). The SPAW model for agricultural field and pond hydrologic simulation, in: SPAW Model pp. 1-37.

Sebastian K (2014). Atlas of African agriculture research and development: Revealing agriculture's place in Africa. International Food Policy Research Institute, Washington, DC.

Sharifi RS, Namvar A (2016). Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (*Zea mays* L.). Biologija 62:35-45.

Singh J, Hadda MS (2014). Phenology and thermal indices of maize (*Zea mays* L.) influenced by subsoil compaction and nitrogen fertilization under semi-arid irrigated conditions. Journal of Applied and Natural Science 6:349-355.

Soil Survey Staff (2014). Keys to Soil Taxonomy, Tenth Edition, 12th Edition, Natural Resources Conservation Service. Washington, DC.

Tsimba R, Edmeades GO, Millner JP, Kemp PD (2013). The effect of planting date on maize grain yields and yield components. Field Crops Research 150:145-155.

Turral H, Burke J, Faurès JM (2011). Climate change, water and food security. Rome, Italy.

Valadabadi SA, Farahani HA (2010). Effects of planting density and pattern on physiological growth indices in maize (Zea mays L.) under nitrogenous fertilizer application. Journal of Agricultural Extension and Rural Development 2:40-47.

Xu Z, Govereh J, Black JR, Jayne TS (2006). Maize yield response to fertilizer and profitability of fertilizer use among small-scale maize producers in Zambia, in: International Association of Agricultural Economists Conference, Gold Coast, Australia, 12-18 August. Gold Coast, Australia P 14.

Zeidan MS, Amany A, Bahr El-Kramany MF (2006). Effect of N fertilizer and plant density on yield and quality of maize in sandy soil. Research Journal of Agriculture and Biological Sciences 2:156-161.

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Response of chickpea varieties and sowing dates for the management of chickpea ascochyta blight (*Ascochyta rabiei* (Pass.) Disease at West Belesa District, Ethiopia

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A two year experiment was conducted at Ascochyta rabiei sick plot infested West Belesa District to evaluate potential chickpea varieties and sowing date for the management of Ascochyta blight. Five varieties namely, Dhera, Habru, Ejeri, Chefe, Teje; and three sowing dates at 10-day intervals (15th July (early), 25th July (optimum) and 5th August (late) were used as treatments. Treatments were arranged in split plot design with three replications. Varieties were assigned on main plot and sowing date to sub-plot. Results indicated that the maximum incidence and severity of 44.65 and 30.06% respectively were recorded from Teje variety in early sowing while the minimum incidence and severity of 28.1 and 15.45%, respectively were recorded from Dhera variety in optimum sowing. The maximum grain yield of 33.49 q/ha and insignificance yield loss were recorded from Dhera variety in optimum sowing while the minimum grain yield and maximum yield loss of 18.41 q/ha and 44.97% respectively were recorded from Teje variety in early sowing. Based on mean value of two years experiment result suggested that Dhera variety applied at optimum sowing caused significant reduction in ascochyta blight incidence leading to a corresponding increase in grain yield of chickpea.

Key words: Chickpea, ascochyta blight, didymellarabiei, disease incidence, percentage severity index, area under disease progress curve, relative yield loss.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the second most important cool season food legume crop after common bean (*Phaseolus vulgaris* L.) followed by field pea (*Pisum sativum*) and third in production among the food legumes grown worldwide (Diapari et al., 2014; Benzohra et al., 2014). The average chickpea yield in Ethiopia on farmers' field is usually below 20 q/ha although its potential yield is more than 50 q/ha (Ejeta and Hussein, 2015; Melese,

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2005; Zewdie, 2018b). A number of biotic and abiotic factors are responsible for high yield gaps. This resulted from susceptibility of chickpea landraces to frost, drought, water-logging, poor cultural practices and low or no protection against weeds, diseases and insect pests (Iqbal et al., 2003).Although more than 70 pathogens have been reported on chickpea from different parts of world so far (Iqbal et al., 2003; Zewdie, 2018b), only a few of them are currently recognized as significantly important pathogens to chickpea production (Pande et al., 2011). One of the greatest biotic stress reducing potential yields in chickpea is Ascochyta blight caused by Ascochyta rabiei (Pass) Labr. (Teleomorph: Didymell arabiei (Kovacheski) von Ayx). It is the most destructive foliar fungal disease of chickpea in the world, where the chickpea growing season is cool and humid (Benzohra et al., 2012; Iqbal et al., 2003).

The occurrence of chickpea Ascochyta blight has been reported from across six continents, including Asia; Africa; Europe; North America; South America and Australia (Nene et al., 2012). Ascochyta blight has been reported to cause up to 100 percentage crop loss under favorable environmental conditions where the relative humidity is greater than 60% and temperature range of 10-20°C (Aslam et al., 2014). Sometimes it may cause total failure of the whole chickpea crop. At present in Ethiopia, production of the Kabuli type of chickpea is being commercialized and seed exchange is widely adapted. Commercial cultivars only possess partial resistance and resistance can breakdown easily by the pathogen, and this is because of the pathogen is highly sexual recombination (Kanouni et al., 2011). However, ascochyta blight is effectively managed with the integration of different strategies. Several cultural practices, such as rotation with non-host crops, use of host resistance, sowing dates and destruction of diseased plant debris, will all help to reduce inoculum level and inhibit severe epidemics (Ejeta and Hussein, 2015). Therefore, the objectives of this study were (i) to evaluate potential chickpea varieties and sowing date against chickpea ascochyta blight disease; and (ii) to determine association of ascochyta blight incidence and severity on yield and yield component of chickpea.

MATERIALS AND METHODS

Description of the study area

The field experiments were conducted during 2017 and 2018 cropping season on ascochyta blight sick plot at West Belesa District, which are demonstration site of College of Agriculture and Environmental Sciences. The study area was located in North Gondar Zone, Amhara Regional State, Ethiopia. The study area has latitude, longitude and altitude of 16°49″44′N, 43°27″47′E and 950 m above sea level, respectively and receives average annual rainfall of about 1050 mm; it has maximum and minimum temperatures of 31.0 and 17.5.0°C, respectively, whereas the soil type is light silty-loam and 85 km away from East south of Gondar (Ebissa, 2017).

Treatments and experimental design

There are a total of 15 treatment combinations, five Kabuli chickpea varieties namely, Dhera, Ejeri, Habru, Chefe, Teje; and three sowing date at 10-day intervals (15th July, (early), 25th July (optimum) and 5th August (late). Treatments were laid out in Split Plot Design with three replications. Chickpea varieties were assigned on main plot and sowing date as subplot. Spacing between subplots and replications were 0.5 and 1 m, respectively. Each experimental plot size was $4.8m^2$ (1.2 m × 4 m). The seeds were planted at spacing of 10 cm between plant and 30 cm between rows and were covered with fine layer of soil. Plots were prepared and fertilized with 100 kg/ha DAP at planting and all other management practices were performed as per the general recommendations for chickpea.

Data collection

In field experiment, observation of ascochyta blight incidence was done at 10 days interval based on the percent of wilt incidence in each experimental unit. Initial scoring for ascochyta blight incidence was done when lesions were visible on the three to five basal leaves of the plants. Numbers of plants infected in the middle rows were recorded and their means were converted into percentage as the total plant observation.

Disease incidence on each plot was calculated on the following way:

$$\text{DI (\%)} = \frac{\text{Number of plant that appear symptoms}}{\text{Both number of disease infected and healthy plants}} \times 100 \quad (1)$$

Ascochyta blight disease assessment was started immediately after disease onset was visible as lesion on upper leaf and wilting of leaf tips were observed. Severity was recorded on ten randomly tagged plants per plot and assessed seven times every ten days interval using 1-9 rating scale (Millan et al., 2006). Disease severity was calculated from the estimated size of the lesions. Lesion sizes were scored on a 1- 9 scale as follows: 1No lesions; 2 Lesions on some plants, usually not visible; 3 A few scattered lesions, usually seen only after careful examination; 4 Lesions and defoliation on some plants, not damaging; 5 Lesions common and easily observed on all plants but defoliation/damage not great; 6 Lesions and defoliation common, few plants killed; 7 Lesions very common and damaging; 8 All plants with extensive lesions causing defoliation and the drying of branches, 50% of the plants killed; 9 Lesions extensive on all plants, defoliation and drying of branches; more than 75% of the plants killed. The severity grades were converted into percentage severity index (PSI) for the analysis (Campbell and Madden, 1990; Fininsa, 2003)..

$$\text{PSI} = \frac{\text{Sum of numerical ratings}}{\text{Number of plants scored} \times \text{maximum score on scale}} \times 100 \quad (2)$$

The disease progress rate for each treatment was estimated as the slope of the regression line of the disease progress data. Area under progress curve (AUDPC) was calculated for each treatment from the assessment of disease incidence using the formula:

$$\text{AUDPC} = \sum 0.5(X_{i+1}+xi)\,(t_{i+1}-ti) \quad (3)$$

Where, x**i** is the cumulative disease severity expressed as a proportion at the ith observation, ti is the time (days after sowing) at the observation and n is total number of observations. Since

Table 1. Significances of mean square values for different traits affected by chickpea varieties and sowing date at West Belesa district during 2017 and 2018 cropping season.

SV	DF	DI (%)	PSI	AUDPC	DPR	NPPP	HSW	Yield
Replication	(r-1) = 2	7.99^{ns}	9.39^{ns}	219.5^{ns}	0.79^{ns}	219.5^{ns}	0.18^{ns}	207.23^{ns}
Main plot (A)	(m-1) =4	3.58*	66.13*	36.45*	21.13	45.03*	11.98*	67.45*
Error (a)	(r-1) (m-1)= 8	14.05*	27.18*	337.89*	10.13	337.89*	7.15*	158.34*
Sub plot (B)	(s-1) = 2	91.13*	91.13*	191.65*	40.53	191.65*	29.47*	175,89*
AXB	(m-1)(s-1) = 8	12.79*	0.79*	44.82^{ns}	21.13^{ns}	44.82^{ns}	1.58^{ns}	628.36*
Error(b)	m(r-1)(s-1) = 20	2.14	0.38	23.52	1.08	23.52	3.71	56.36
CV (%)		10.98	12.74	11.23	12.56	14.43	10.23	7.44

ns non-significant at $P < 0.05$, * Significant at $P<0.05$, SV source of variation, DF degree of freedom, CV coefficient of variation, DI % disease incidence percentage, PSI percentage severity index, AUDPC area under disease progress curve, DPR disease progress rate, NPPP number of pod per plant, HSW hundred seed weight.

Ascochyta blight severity was expressed in percent and time (t) in days, AUDPC values were expressed in %-days (Campbell and Madden, 1990). AUDPC values were used in analysis of variance to compare amount of disease among plots with different treatments. Relative yield loss (RYL) was calculated using the formula of Madden et al. (2007).

$$RYL = \frac{Y1-Y2}{Y2}\times 100 \qquad (4)$$

Where, RYL Relative yield loss (reduction of the yield and yield component), Y1yields which was obtained from plots with maximum protection) and Y2 yields which was obtained from plots with minimum protection).

Statistical data analysis

Data on chickpea Ascochyta blight incidence, percentage severity index, AUDPC%-day, yield and yield component various agronomic data were subjected to analysis of variance (ANOVA) according to the Duncan Multiple Range Test (DMRT) as suggested by Gomez and Gomez (1984) using statistical package SAS, version 9 (SAS institute Inc, 2002); least significance difference (LSD) was used for the mean comparison at 5% probability level.

RESULTS AND DISCUSSION

Incidence of Ascochyta blight

Analysis of variance showed that disease incidence (DI) was significantly affected by chickpea varieties, sowing dates, and their interaction at $p < 0.05$(Table 1). Among the interaction effects, the minimum disease incidence of 27.34 and 28.85% respectively was recorded from Dhera variety in optimum sowing date during 2017 and 2018 cropping season respectively, followed by Habru variety in optimum sowing date with result of 28.45 and 29.03%. On the contrary, the maximum disease incidence of 43.34 and 45.95% respectively was recorded from Teje variety in early sowing date during 2017 and 2018 cropping season respectively, followed by Chefe variety in early sowing date with results of 42.62 and 43.07% respectively (Table 2).This indicates that varieties of Dehra and Habru have potential resistance against blight incidence than other varieties under different sowing dates; this agrees with the observation made by Jirata (2016) on the same crop.

According to the mean value of two years; the minimum disease incidence of 28.10 and 28.74% was recorded from Dhera and Habru variety in optimum sowing date, respectively while the maximum disease incidence of 44.65 and 42.83% was recorded from Teje and Chefe varieties in early sowing dates, respectively (Table 2). Variety resistant had less disease incidence than that of the susceptible variety (Kanouni et al., 2011). Incidence of Ascochyta blight was reduced and greater influence was recorded in optimum sowing date than early and late sowing date, which is in agreement with findings of Ejeta and Hussein (2015).. During 2017 cropping season, all treatments showed better resistance against Ascochyta blight incidence than 2018. As mentioned previously, this could be due to high rainfall, high soil water holding capacity and lower daily maximum temperature conditions during 2018 which are conducive for the growth and development of disease.

Ascochyta blight percentage severity index

The results found that chickpea varieties, sowing date and their interaction revealed that significant differences at $P<0.05$ on Ascochyta blight percentage severity index (Table 1). Among interaction effects, the minimum percentage severity index was recorded from Dhera variety (13.84% and 17.05%) in optimum sowing date, followed by Habru variety (15.04 and 18.53%) in optimum sowing date during 2017 and 2018 cropping season respectively (Table 2). On the other hand, the maximum percentage severity index was recorded from Teje variety (31.67 and 34.45%) in early sowing date, followed by Teje variety (28.97 and 30.07%) in late sowing date and

Table 2. Two way interaction effects of chickpea varieties and sowing date on incidence and PSI of chickpea Ascochyta blight at West Belesa district during 2017 and 2018 cropping season.

Variety	Sowing date	DI (%)		Mean of two years (%)	PSI (%)		Mean of two years (%)
		2017	2018		2017	2018	
Dhera	Early	33.08^{c}	35.04^{c}	34.06^{c}	18.18^{c}	22.34^{c}	20.26^{de}
	Optimum	27.34^{a}	28.85^{a}	28.10^{a}	13.84^{a}	17.05^{a}	15.45^{a}
	Late	30.56^{b}	32.19^{b}	31.38^{b}	15.36^{ab}	20.47^{b}	17.92^{bc}
Habru	Early	35.05^{d}	37.56^{d}	36.31^{d}	21.55^{de}	25.55^{d}	23.55^{fg}
	Optimum	28.45^{a}	29.03^{a}	28.74^{a}	15.04^{ab}	18.53^{a}	16.79^{ab}
	Late	32.95^{c}	35.08^{c}	34.02^{c}	18.09^{c}	23.48^{c}	20.79^{de}
Ejeri	Early	38.33^{e}	39.55^{e}	38.94^{e}	24.66^{f}	27.55^{e}	26.11^{h}
	Optimum	30.23^{b}	32.76^{b}	31.50^{b}	17.05^{bc}	20.87^{b}	18.96^{cd}
	Late	35.08^{d}	40.07^{ef}	37.56^{de}	21.34^{d}	22.47^{c}	21.91^{ef}
Chefe	Early	42.62^{gh}	43.07^{g}	42.83^{gh}	28.09^{g}	30.03^{f}	29.06^{i}
	Optimum	35.42^{d}	37.53^{d}	36.48^{d}	22.67^{def}	23.53^{c}	23.10^{f}
	Late	38.45^{e}	40.56^{ef}	39.51^{ef}	24.65^{f}	27.56^{e}	26.11^{h}
Teje	Early	43.34^{h}	45.95^{h}	44.65^{h}	31.67^{h}	34.45^{g}	33.06^{j}
	Optimum	40.45^{f}	41.67^{fg}	41.06^{fg}	24.05^{ef}	26.67^{de}	25.36^{gh}
	Late	41.76^{fg}	43.03^{g}	42.42^{g}	28.97^{g}	30.07^{f}	29.52^{i}
LSD (0.05)		1.55	1.74	2.05	2.55	1.35	1.95
CV (%)		7.89	9.56	8.56	12.45	11.08	11.89

LSD least significant difference at 5% level of significant, CV coefficient of variation in percent, DI % disease incidence percentage and PSI percentage severity index; Mean values in the same letter within a column are not showed significantly different at 5% probability.

Chefe variety (28.09 and 30.03%) in early sowing date during 2017 and 2018 cropping season respectively (Table 2).

Based on the mean disease severity value of the two years, the minimum percentage severity index of 15.45% was recorded from variety of Dhera in optimum sowing date, followed by variety of Habru in optimum sowing date and Dhera variety in late sowing date (16.79 and 17.92% respectively) (Table 2). This result is in line with Jirata (2016), who reported that the minimum percentage severity index was recorded in resistance variety applied at mid sowing date followed by late sowing.

Area under disease progress curve (AUDPC%-day)

Area under Disease Progress Curve at P< 0.05 was significantly influenced by both main effects such as varieties and sowing dates but there was no significant difference among interaction effects (Table 1). Among varieties, the minimum AUDPC value of 663.56%-days and 670.85%-days was recorded from Dhera variety, followed by Habru which recorded 684.86%-day and 696.56%-day during 2017 and 2018 cropping season respectively; the maximum AUDPC value of 714.76%-day and 721.67%-day was recorded from Teje variety during 2017 and 2018 cropping season respectively (Table 3).

According to the mean value of two years the minimum AUDPC value of 667.21%-day and 690.71%-day was recorded from Dehra and Habru variety respectively whereas the maximum AUDPC value of 718.22%-day and 710.81%-day was recorded from Teje and Chefe variety respectively (Table 3). This means that Dhera variety has more resistance against the Ascochyta blight incidence compared to other tested varieties. The AUDPC%-day value of the disease was higher for susceptibility than that of resistant variety in respect to location. This is in agreement with previous findings of other researchers (Aslam et al., 2014; Ghazanfar, 2010).

On the contrary among sowing dates; the maximum AUDPC values of 687.85%-day and 703.04%-day were recorded from early sowing while the minimum AUDPC values of 657.87%-day and 687.34%-day were recorded from optimum sowing dates during 2017 and 2018 cropping season respectively (Table 3). Based on the mean AUDPC%-day value of the two years; the maximum AUDPC value of 695.45%-day was recorded

Table 3. Main effects of chickpea varieties and sowing date on AUDPC%-day and disease progress rate of ascochyta blight at West Belesa district during 2017 and 2018 cropping season.

	AUDPC (%-days)		Mean of two years (%)	Disease progress rate		Mean of two years (%)
	2017	**2018**		**2017**	**2018**	
Varieties						
Dhera	663.56^{a}	670.85^{a}	667.21^{a}	0.0416^{a}	0.0535^{a}	0.0476^{a}
Habru	684.86^{ab}	696.56^{b}	690.71^{ab}	0.0574^{ab}	0.0724^{ab}	0.0649^{ab}
Ejeri	696.05^{bc}	709.45^{bc}	702.75^{bc}	0.0773^{b}	0.0895^{bc}	0.0834^{b}
Chefe	704.35^{bc}	717.26^{bc}	710.81^{bc}	0.0846^{b}	0.0956^{c}	0.0901^{b}
Teje	714.76^{c}	721.67^{c}	718.22^{c}	0.0889^{c}	0.0999^{c}	0.0944^{b}
Mean	692.72	703.16	697.94	0.0699	0.0822	0.0761
LSD (5%)	**25.56**	**22.55**	**24.45**	**0.03**	**0.02**	**0.03**
Sowing date						
Early	687.85^{a}	703.04^{a}	695.45^{a}	0.0958	0.0998	0.0978
Optimum	657.87^{b}	687.34^{b}	672.61^{b}	0.0505	0.0706	0.0606
Late	663.05^{b}	692.56^{b}	677.81^{b}	0.0745	0.0874	0.0809
Mean	669.59	694.31	681.95	0.0736	0.0859	0.0798
LSD (0.05)	23.57	10.58	17.08	NS	NS	NS
CV (%)	12.45	8.45	10.45	4.56	8.57	6.56

LSD least significant difference at 5% level of significant, CV coefficient of variation in percent, NS non significance, AUDPC area under disease progress curve; Mean values in the same letter within a column are not showed significantly different at 5% probability.

from early sowing date while the minimum of 672.61%-day was recorded from optimum sowing date, followed by late sowing date (677.81%-day) (Table 3).

Ascochyta blight disease progress rate

The disease progress rate exhibited significant difference at P<0.05 among the main effects of varieties and sowing dates but not their interaction (Table 1). The progress rate of Ascochyta blight disease infection rate was faster (0.0889and 0.0999) per day units on the susceptible Teje variety than Dhera resistant variety (0.0416 and 0.0535) in which slower infection rate was noticed during 2017 and 2018 cropping season respectively (Table 3). Infection progress rate greatly determines varietal differences more on susceptible varieties than resistant ones (Ejeta and Hussein, 2015; Zewdie, 2018a, b). On the other hand, the higher infection rate progressed rapidly on early sowing date (0.0958 and 0.0998) while the lower infection rate of 0.0505and 0.0706 was recorded from optimum sowing date during 2017 and 2018 cropping season respectively.

Number of pod per plant

Significant differences at P < 0.05 were observed among varieties and sowing date on number of pod per plant but not their interaction (Table 1). Among the mean value of two years experiment, the maximum (49.50) number of pod per plant was recorded from Dhera variety, followed by Habru (46.00) while the minimum number of pod per plant (34.64) was recorded from Teje variety, followed by Chefe (38.16) (Table 4). Similarly the results of Shamsi et al. (2010) showed that varietal differences are more associated with pods per plants and used as criteria for selection of best materials. On the other hand, the maximum number of pod per plant (43.58) was recorded from optimum sowing date while the minimum (35.25) was obtained from early sowing date, followed by late sowing date (41.46). The result is conformity with findings of Ramanappa et al. (2013).

Hundred seed weight

The main effects of chickpea varieties and sowing date showed significant difference at P < 0.05 on hundred seed weight (Table 1). Among the mean value of two years the highest hundred seed weight (24.35 and 23.11 g) was recorded from Dhera and Habru variety while the lowest hundred seed weight (16.05 and 18.17 g) was recorded from Teje and Chefe variety, respectively (Table 4). On the mean value of two years the highest hundred seed weight (24.01 g) was obtained from optimum sowing date while the lowest (19.94 g) was recorded from early sowing, followed by late sowing date (21.04 g). However, they did not show significance difference. Similar findings were previously reported by Turhan et al. (2011) and Sattar et al. (2013) that minimum hundred seed weight was obtained from early sowing date.

Table 4. Mean of chickpea varieties as influenced sowing date on number of pod per plant and hundred seed weight at West Belesa district during 2017 and 2018 cropping season.

	NPPP(No)		Mean of NPPP (No)	HSW(g)		Mean of HSW (g)
	2017	2018		2017	2018	
Variety						
Dhera	50.34^{a}	48.65^{a}	49.50^{a}	25.04^{a}	23.65^{a}	24.35^{a}
Habru	46.65^{ab}	45.34^{ab}	46.00^{ab}	23.87^{a}	22.34^{a}	23.11^{a}
Ejeri	42.28^{bc}	40.23^{bc}	41.26^{bc}	21.86^{ab}	19.67^{ab}	20.77^{ab}
Chefe	39.45^{c}	36.87^{cd}	38.16^{cd}	19.38^{bc}	16.96^{b}	18.17^{bc}
Teje	37.04^{c}	32.23^{d}	34.64^{d}	17.05^{c}	15.05^{b}	16.05^{c}
Mean	43.15	40.66	41.91	21.44	19.53	20.49
LSD (0.05)	5.35	6.57	5.96	4.35	4.76	4.56
Sowing date						
Early	37.46a	33.04^{a}	35.25^{a}	20.48^{a}	18.79^{a}	19.64^{a}
Optimum	45.09b	42.07^{a}	43.58^{b}	24.87^{a}	23.15^{b}	24.01^{a}
Late	43.35b	39.56^{a}	41.46^{ab}	22.03^{a}	20.05^{ab}	21.04^{a}
Mean	41.97	38.22	40.10	22.46	20.66	21.56
LSD (0.05)	5.67	9.25	7.46	6.05	3.75	4.9
CV (%)	8.56	12.34	9.56	12.45	14.65	11.34

LSD least significant difference at 5% level of significant, CV coefficient of variation in percent, NPPP number of pod per plant; HSW hundred seed weight; Mean values in the same letter within a column are not showed significantly different at 5% probability.

Grain yield of chickpea

Analysis of variance showed that grain yield of chickpea was significantly affected by chickpea varieties, sowing dates and their interaction at $P < 0.05$ (Table 1). Among interaction effects, the maximum grain yield (35.75 and 31.23 q/ha) was recorded from Dhera variety in optimum sowing date, followed by Habru variety in optimum sowing date (34.34 and 31.05 q/ha) during 2017 and 2018 cropping season, respectively; the minimum grain yield (19.37 and 17.34 q/ha) was recorded from Teje variety in early sowing date, followed by Chefe variety in early sowing (20.59 and 17.45 q/ha) during 2017 and 2018 cropping season, respectively (Table 5). These results are in line with the finding of Tobe et al. (2013) who stated that the grain yield was highest on optimum sowing date followed by late sowing date. Similarly, Yigitoglu (2006) reported the highest grain yield in optimum sowing date with a resistant variety. The highest grain yield production depends on sowing date (Shamsi et al., 2010; Varma et al., 2014).This finding is in accordance with the findings of Sadeghipour and Aghaei (2012), who reported that sowing date and varietal difference could affect grain yield production.

Relative grain yield losses

Among interaction effects of varieties and sowing date, the maximum mean relative grain yield losses of 44.97% (15.14 q/ha) was recorded from Teje variety which was applied in early sowing date, followed by Chefe variety in early sowing date 43.45% (14.47 q/ha).This was because, in early sowing there was abundant inoculum of Ascochyta rabiei on infested chickpea residue that served as a source of initial inoculum; this in turn resulted in higher blighting in all the leaves of the plants before their physiological maturity. On the other hand, the mean minimum relative grain yield loss was obtained from Dhera variety which was applied in optimum sowing date; it resulted in significant loss, followed by Habru variety in optimum sowing date and Dhera variety in late sowing date 2.26%(0.79 q/ha) and 12.2%(4.15 q/ha) respectively (Table 5).

Conclusion

Generating reliable information on ascochyta blight management practices such as use of high performance varieties and appropriate sowing date is quite important to come up with profitable and sustainable chickpea production and productivity. In view of this, an experiment was conducted to evaluate resistant varieties and sowing date against ascochyta blight management; yield and yield components of chickpea. The findings of the present study suggest that the adoption of resistant variety Dhera and Habru with applied optimum sowing date may result in reduced ascochyta blight disease progress with a corresponding increased grain yield of chickpea. Further, undoubtedly the ascochyta blight appears to be an important disease that calls for better attention in the

Table 5. Interaction effect of chickpea varieties and sowing date on grain yield of chickpea and their corresponding losses due to Ascochyta blight at West Belesa district during 2017 and 2018 cropping season.

Chickpea variety	Sowing date	Grain yield (q/ha)		Mean of grain yield (q/ha)	Relative grain yield loss				Mean of relative grain yield loss %	
					2017		2018			
		2017	2018		Loss (q/ha)	Loss (%/ha)	Loss (q/ha)	Loss (%/ha)	Loss (q/ha)	Loss (%/ha)
Dhera	Early	27.65^{de}	24.76^{d}	26.21^{de}	8.10	22.66	6.47	20.72	7.29	21.69
	Optimum	35.75^{a}	31.23^{a}	33.49^{a}	0.00	0.00	0.00	0.00	0.00	0.00
	Late	30.46^{b}	28.23^{b}	29.35^{b}	5.29	14.79	3.00	9.61	4.15	12.2
Habru	Early	25.04^{fg}	23.09^{e}	24.07^{fg}	10.71	29.96	8.14	26.06	9.43	28.01
	Optimum	34.34^{a}	31.05^{a}	32.70^{a}	1.41	3.94	0.18	0.58	0.79	2.26
	Late	28.75^{cd}	25.65^{cd}	27.20^{cd}	7.00	19.58	5.58	17.87	6.29	18.73
Ejeri	Early	23.23^{h}	20.53^{fg}	21.88^{h}	12.52	35.02	10.70	34.26	11.61	34.64
	Optimum	29.67^{bc}	26.87^{bc}	28.27^{bc}	6.08	17.01	4.36	13.96	5.22	15.49
	Late	26.46^{ef}	23.34^{e}	24.90^{ef}	9.29	25.99	7.89	25.26	8.59	25.63
Chefe	Early	20.59^{ij}	17.45^{h}	18.97^{ij}	15.16	42.41	13.78	44.48	14.47	43.45
	Optimum	27.56^{de}	25.56^{cd}	26.56^{d}	8.19	22.91	5.67	18.16	6.93	20.54
	Late	24.34^{gh}	21.05^{f}	22.70^{gh}	11.41	31.92	10.18	32.59	10.79	32.26
Teje	Early	19.37^{j}	17.34^{h}	18.41^{i}	16.38	45.82	13.89	44.12	15.14	44.97
	Optimum	24.45^{gh}	21.34^{f}	22.90^{gh}	11.30	31.61	9.89	31.67	10.00	31.64
	Late	21.08^{i}	19.55^{g}	20.32^{i}	14.67	41.03	11.68	37.39	13.18	39.21
LSD(5%)		1.55	1.37	1.46						
CV (%)		11.04	9.34	10.56						

LSD least significant difference at 5% level of significant, CV coefficient of variation in percent, Mean values in the same letter within a column are not showed significantly different at 5% probability.

study area in terms of economic management with optimum sowing date and use of Dhera and Habru resistant varieties. It was concluded that using resistant variety with optimum sowing date gave reasonable grain yields and reduced Ascochyta blight incidence and severity; therefore, genetic resistance needs to be investigated further by screening several germ plasms for source of resistance at several testing locations and one more cropping season.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Aslam M, Ahmad K, Maqbool MA, Bano S, Zaman QU, Talha GM (2014). Assessment of adaptability in genetically diverse chickpea genotypes (Cicer arietinum L.) based on different physio-morphological standards under ascochyta blight inoculation. International Journal of Advanced Research 2:245-255.

Benzohra IE, Bendahmane BS, Benkada MY, Labdi M (2014). Evaluation of wild cicer species accessions for resistance to three pathotypes of Ascochyta rabiei (Pass.) Labr. in Algeria. African Journal of Microbiology Research 8(20):2022-2029.

Benzohra IE, Bendahmane BS, Labdi M, Benkada MY (2012). Determination of pathotypes and physiological races in Ascochyta rabiei, the agent of ascochyta blight in chickpea (*Cicer arietinum* L.) in Algeria. African Journal of Agricultural Research 7(7):1214-1219.

Campbell CL, Madden LV (1990). Introduction to plant disease epidemiology. John Wiley & Sons.

Diapari M, Sindhu A, Bett K, Deokar A, Warkentin TD, Taran B (2014). Genetic diversity and association mapping of iron and zinc concentrations in chickpea (*Cicer arietinum* L.). Genome 57(8):459-468.

Ebissa G (2017). Irrigation Water Management and Crop Production. International Journal of Advance Research, Ideas and Innovations in Technology 3(3):843-873.

Ejeta AZ, Hussein T (2015). Epidemiology and Management of

Ascochyta Blight (Didymella rabiei) on Chickpea in Central Rift Valley, Ethiopia. Haramaya University.

Fininsa C (2003). Relationship between common bacterial blight severity and bean yield loss in pure stand and bean? Maize intercropping systems. International Journal of Pest Management 49(3):177-185.

Ghazanfar MU (2010). Induction of resistance by chemicals and plant extracts in chickpea against Ascochyta rabiei. University of Agriculture Faisalabad, Pakistan.

Gomez KA, Gomez AA (1984). Statistical procedures for agricultural research. John Wiley & Sons.

Iqbal S, Bakhsh A, Ghafoor A, Ayub N, Bashir M (2003). Reaction of chickpea genotypes to the isolates of Ascochyta rabiei (Pass.) Laboratory Plant Pathology Journal 2(1):39-47.

Jirata MT (2016). Occurence, Distribution and Management Strategies for Ascochyta Blight (Ascochyta rabiei pass.) of chickpea (*Cicer arietinum* L.) in Ethiopia.

Kanouni H, Taleei A, Okhovat M (2011). Ascochyta blight (Ascochyta rabiei (Pass.) Lab.) of chickpea (*Cicer arietinum* L.): Breeding strategies for resistance. International Journal of Plant Breeding and Genetics 5(1): 1-22.

Madden LV, Hughes G, Van den Bosch F (2007). The Study of Plant Disease Epidemics.

Melese D (2005). Morphological and RAPD marker variation analysis in some drought tolerant and susceptible chickpea (*Cicer arietinum* L.) genotypes of Ethiopia. M. Sc Thesis, Addis Ababa University, Ethiopia pp. 2-5.

Millan T, Clarke HJ, Siddiqu KH, Buhariwalla HK, Gaur PM, Kumar J, Gil J, Kahl G, Winter P (2006). Chickpea molecular breeding: new tools and concepts. Euphytica 147(1-2):81-103.

Nene Y, Reddy M, Haware M, Ghanekar A, Amin K, Pande S, Sharma M (2012). Field Diagnosis of Chickpea Diseases and their Control. Information Bulletin No. 28 (revised). International Crops Research Institute for the Semi-Arid Tropics.

Pande S, Sharm M, Gaur P, Tripathi S, Kaur L, Basandrai A, Khan T, Gowda C, Siddique K (2011). Development of screening techniques and identification of new sources of resistance to Ascochyta blight disease of chickpea. Australasian Plant Pathology 40(2):149-156.

Ramanappa T, Chandrashekara K, Nuthan D (2013): Analysis of variability for economically important traits in chickpea (*Cicer arietinum* L.). International Journal of Research in Applied, Natural and Social Sciences 1:133-140.

Sadeghipour O, Aghaei P (2012). Comparison of autumn and spring sowing on performance of chickpea (*Cicer arietinum* L.) varieties. International Journal of Biosciences 2(6):49-58.

Sattar A, Cheema MA, Wahid M, Saleem MF, Ghaffari M, Hussain S, Arshad M (2013). Effect of sowing time on seed yield and oil contents of canola varieties. Journal of Global Innovations in Agricultural and Social Sciences 1:1-4.

SAS Institute (2002). SAS system for windows Release 9.2.Inc, Cary, Nc, USA.

Shamsi K, Kobraee S, Haghparast R (2010). Drought stress mitigation using supplemental irrigation in rainfed chickpea (*Cicer arietinum* L.) varieties in Kermanshah, Iran. African Journal of Biotechnology 9(27):4197-4203.

Tobe A, Hokmalipour S, Jafarzadeh B, Darbandi MH (2013). Effect of sowing date on some phenological stages and oil contents in spring canola (Brassica napus, L.) cultivars. Middle-East Journal of Scientific Research 13(9):1202-1212.

Turhan H, Gul MK, Egesel CO, Kahriman F (2011). Effect of sowing time on grain yield, oil content, and fatty acids in rapeseed (Brassica napus subsp. oleifera).Turkish Journal of Agriculture and Forestry 35:225-234.

Varma VS, Durga KK, Neelima P (2014). Effect of sowing date on maize seed yield and quality: a review. Review of Plant Studies 1(2):26-38.

Yigitoglu D (2006). Research on the effect of different sowing densities on the yield and yield components of some chickpea (*Cicer arietinum* L.) cultivars that sown in winter and spring in kahramanmaras region. PhD Thesis, Department of Field Crops Institute of Natural and Applied.

Zewdie A (2018a). Assessment of chickpea seed borne di blight (didymella.)

Zewdie A (2018b). Assessment of chickpea seed borne disease with special reference to Ascochyta blight (Didymella rabiei) in Central Ethiopia. International Journal of Life Sciences 6(3):707-712.

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