OPEN ACCESS

May 2020
ISSN 1996-0824
DOI: 10.5897/AJPS
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

About AJPS

African Journal of Plant Science (AJPS) provides rapid publication (monthly) of articles in all areas of Plant Science and Botany. The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in AJPS are peer-reviewed.

Indexing

The African Journal of Plant Science is indexed in:

CAB Abstracts, CABI's Global Health Database, Chemical Abstracts (CAS Source Index), China National Knowledge Infrastructure (CNKI), Dimensions Database
Google Scholar, Matrix of Information for The Analysis of Journals (MIAR)
Microsoft Academic

AJPS has an h5-index of 12 on Google Scholar Metrics

Open Access Policy

Open Access is a publication model that enables the dissemination of research articles to the global community without restriction through the internet. All articles published under open access can be accessed by anyone with internet connection.

The African Journal of Plant Science is an Open Access journal. Abstracts and full texts of all articles published in this journal are freely accessible to everyone immediately after publication without any form of restriction.

Article License

All articles published by African Journal of Plant Science are licensed under the Creative Commons Attribution 4.0 International License. This permits anyone to copy, redistribute, remix, transmit and adapt the work provided the original work and source is appropriately cited. Citation should include the article DOI. The article license is displayed on the abstract page the following statement:

This article is published under the terms of the Creative Commons Attribution License 4.0

Please refer to https://creativecommons.org/licenses/by/4.0/legalcode for details about Creative Commons Attribution License 4.0

Article Copyright

Self-Archiving Policy

The African Journal of Plant Science is a RoMEO green journal. This permits authors to archive any version of their article they find most suitable, including the published version on their institutional repository and any other suitable website.
Please see http://www.sherpa.ac.uk/romeo/search.php?issn=1684-5315

Digital Archiving Policy

The African Journal of Plant Science is committed to the long-term preservation of its content. All articles published by the journal are preserved by Portico. In addition, the journal encourages authors to archive the published version of their articles on their institutional repositories and as well as other appropriate websites.
https://www.portico.org/publishers/ajournals/

Metadata Harvesting

The African Journal of Plant Science encourages metadata harvesting of all its content. The journal fully supports and implement the OAI version 2.0, which comes in a standard XML format. See Harvesting Parameter

Memberships and Standards

Academic Journals strongly supports the Open Access initiative. Abstracts and full texts of all articles published by Academic Journals are freely accessible to everyone immediately after publication.

Crossref is an association of scholarly publishers that developed Digital Object Identification (DOI) system for the unique identification published materials. Academic Journals is a member of Crossref and uses the DOI system. All articles published by Academic Journals are issued DOI.

Similarity Check powered by iThenticate is an initiative started by CrossRef to help its members actively engage in efforts to prevent scholarly and professional plagiarism. Academic Journals is a member of Similarity Check.

CrossRef Cited-by Linking (formerly Forward Linking) is a service that allows you to discover how your publications are being cited and to incorporate that information into your online publication platform. Academic Journals is a member of CrossRef Cited-by.

Academic Journals is a member of the International Digital Publishing Forum (IDPF). The IDPF is the global trade and standards organization dedicated to the development and promotion of electronic publishing and content consumption.

Contact

Editorial Office: ajps@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJPS

Submit manuscript online http://ms.academicjournals.org

Academic Journals
73023 Victoria Island, Lagos, Nigeria
ICEA Building, 17th Floor,
Kenyatta Avenue, Nairobi, Kenya.

Editors

Editorial Board Members

Table of Content

Vol. 14(5), pp. 172-182, May 2020
DOI: 10.5897/AJPS2020.1988
Article Number: 750620963647
ISSN 1996-0824

http://www.academicjournals.org/AJPS

ACADEMIC JOURNALS
expand your knowledge

African Journal of Plant Science

Full Length Research Paper

Assessment of woody species diversity, key drivers of deforestation and community perception; the case of Hotessa Forest, Bensa Woreda, Sidama Zone, Southern Ethiopia

Sintayehu Tamene Beyene

Wondo Genet College of Forestry and Natural Resources, Hawassa University, P .O. Box 128, Shashemene, Ethiopia.

Received 13 March, 2020; Accepted 22 April, 2020

In Ethiopia, deforestation is a major challenge which leads to increased human encroachment upon wild areas and threats to biodiversity. In line with this, the aim of the current study was to assess woody species diversity and threats in Hotessa forest. Systematic sampling method was used to collect vegetation data. Accordingly, 100 plots each with 400 m^2 (20 m × 20 m) for woody species was laid along transect line. In each of these plots, all woody species were collected. Simple random sampling was used to identify target population and in-depth interviews were conducted with farmers living in close vicinity to the forest to identify challenges and threats on the forest. A total of 43 woody species distributed to 37 genera and 28 families were identified and documented. Fabaceae is the dominant families in terms of species richness. The Shannon-Wiener diversity index computed for the three different altitudinal gradients and showed that lower altitude is the most diverse and has more or less even distribution of species. In general, the diversity and evenness of woody species in the forest was 2.575 and 0.98 respectively. The result of analysis of the responses to human-induced factors responsible for deforestation in the study revealed that most of the respondents attributed population growth (80.82%) as the major factor responsible for deforestation in the study area.

Key words: Diversity index, Shannon-Wiener, farmers, interview, sampling.

INTRODUCTION

Different scholars in their study reported that in our world, the total global forest area has declined by 3%, from 4128 million ha in 1990 to 3999 million ha in 2015 (Keenan et al., 2015). Previous study by Reynolds et al. (2007) state that, the decline of vegetation cover is one of the most serious challenges facing humankind today. Same applies to country Ethiopia which also facing severe land degradation (Solomon, 2015). According to FAO (2016) land-use change is not necessarily the same as land-cover change. Land cover is the observed

E-mail: sintebeye@gmail.com. Tel: +25 1911053605.

biophysical cover of the earth's surface, but land use reflects the actions of people and their intentions and the former is far more widespread than the latter, with deforestation occurring when people clear forests and use the land for other purposes, such as agriculture, infrastructure, human settlements and mining (FAO, 2016). Daniel (2016) in his study reported that land cover is constantly changing with different patterns and magnitudes in sub-Saharan Africa and the Sahel in particular. Currently in Ethiopia, the natural vegetation is highly affected by several factors such as, agricultural expansion, settlement, deforestation, land degradation, and increment in invasive species occurrence and logging practice which seriously damages the structure and composition of natural woody plant species and leading to the declining of forest biodiversity and agricultural yield in Ethiopia (Mohammed, 2011; Khumalo et al., 2012; Ariti et al., 2015; Gashaw and Dinkayoh, 2015; Bessie et al., 2016; Negasi et al., 2018) and with the present annual rate of deforestation 2% it continues (Moges et al., 2010).

Ethiopia is a mountainous country with great geographic diversity like rugged mountains, flat-topped plateaus and deep gorges incised river valleys and rolling plains (Teweldebrhan, 1988). This makes the country one of the largest forest resources in the horn of Africa and it owns a total of 53.1 million ha covered by woody vegetation which consists of 12.5 million ha of forest land and 40.6 million ha of woodland (FAO, 2016). The total forest area of the country has declined from 15.1 million ha in 1990 to 12.5 million ha in 2015. The annual rate of forest land decline is 104, 600 ha per year that is 0.8% of forest cover of the country (FAO, 2016). According to this report in total, Ethiopia lost 18.6% of its forest cover or around 2,818,000 hectare between 1990 and 2010.

Similarly, Stern (2006) the underlying causes of deforestation and degradation based on a framework analysis were identified as population growth, insecure land tenure, and poor law enforcement. The decline of forest capacity at the global and national level is a great problem that currently affects the livelihoods of people in different ways also reported by Asfaw and Fekadu (2018). However, there are evidences that indicate sustainable farming practices, like agroforestry. The same as in Bensa Woreda, there was high rate of agricultural expansion observed, especially in mountainous area which leads to deforestation and high rate of loss of woody species and sparsely diversified trees due to over population, logging and land fragmentations. Study has not been conducted before on floristic diversity and the threats of this area and has necessitated the qualitative and quantitative assessment of vegetation and threats on forest resources of the Woreda. Regarding this, systematic field survey of flora and fauna is a prerequisite for developing effective conservation programs and its implementation Kent and Coker (1992). The resulting information on vegetation is essential to solve ecological problems, for biological conservation and management purposes as indicated by Noriko et al. (2012). Thus, it is important to identify plant species diversity, species composition and drivers of deforestation of Hotessa forest. Additionally, the current study serves as spring border to narrow the gap on those forest management planners to use this information in their decisions on forest conservation and product use.

MATERIALS AND METHODS

Description of the study area

This study was conducted in Bensa Woreda, Sidama zone in Southern Nations Nationalities and Peoples' Region (SNNPR) of Ethiopia. Bensa Woreda is one of the 19 districts in Sidama zone that extends into the Oromia region of Bale Zone or Borana-like peninsula. Bensa Woreda is bordered on the south and north by the Oromia Region, with Bona Zuria on the west, Arbegona district on the northwest, Chere district on the east, and Aroresa district on the southeast. Daye, the capital of Bensa Woredat, is located at 420 km southeast of Addis Ababa and 135 km northeast of Hawassa city, the SNNPR capital city. Bensa Woreda is located at altitude which ranges from 1452 to 3129 m above sea level. The two rainy seasons are the *belg* (short rainy season), which covers from late February to May, and the *kremt* (main rainy season), which extends from late June to early October. The average annual rainfall of the area is 1208.5 mm. The average annual temperature of the Woreda is 19°C. The Woreda has three major agro ecologies, with 50% were moist weyna dega (mid-altitude), 36% moist dega (highland) and 14% moist kola (lowland) (Bensa woreda pilot Learning Site diagnosis and program design, LIVES, 2012) (Figure 1).

The dominant soil type in the study area is loam soil. During the reconnaissance survey together with Woreda agricultural office expert informal communication, from the total area of the study site about half was covered by dense forest before one or two decades. However at present, the forest cover has diminished and the hazard of soil erosion and land degradation has increased. The cause for diminishing forest cover is increasing agricultural land expansion, fuel wood demand and timber production. As learned from the local elders, indigenous tree species like *Olea europea, Hygeia abyssinica, Podocurpus falcatus* and Bamboo (arborescent grass) were dominant before two decades. Nonetheless, currently *H. abyssinica* and *P. falcatus* has totally disappeared from the forest area. The total population of the study area is estimated to be 342,545 (Bensa Woreda Administration office, 2018).

Sampling design, sampling size determination and data collection

Bensa Woreda was purposively selected based on its floral diversity and unstudied area. A reconnaissance survey was made to obtain an impression on the general physiognomy of the vegetation and to identify sampling sites. Twenty transect lines was systematically laid to ensure that sample sites were cover representatives of major vegetation types occurring in the study area based on altitude gradient: namely, upper altitude (3 transect lines), middle (10 transect lines) and lower (7 transect lines) proportionally to their size. A total of 100 quadrants, Plots size of 20 × 20 m (400m2), were used for collection of floristic data at 100 m distance interval

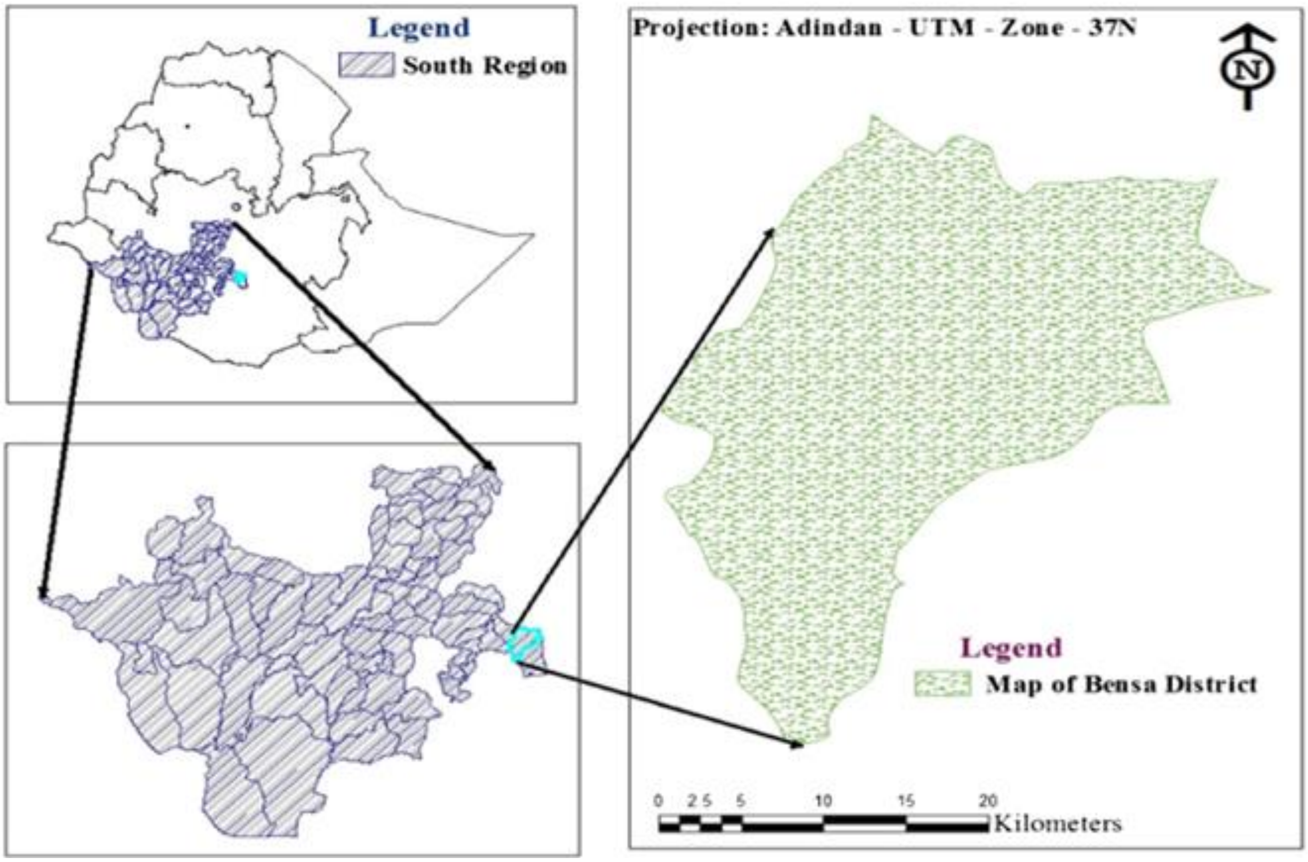

Figure 1. Map of the study area.

(Muller-Dombosis and Ellenberg, 1974). From each 20 x 20 m plot, a complete list of shrubs (woody plants having several stems 2 m tall and trees (woody plants having a dominant stem and more than 2m tall) was recorded. Plant identification was carried out at the field and confirmed at National Herbarium. Nomenclature followed the published volume of Flora of Ethiopia and Eritrea (Edwards et al., 2000; Hedberg et al., 2006, 2009) and Azene (2007).

Regarding the target population, the sampled population was identified using simple random sampling on the number of house hold leader to analyze the factors currently creating a threat to plant diversity. The questionnaire covered various socio-economic and demographic characteristics of the households, forest livelihood and forest land-use (Appendix 1). Socio-economic factors include age and education of the household head and land holdings (Appendix 1). The structure of the questionnaire was designed to meet the objectives of the study and pre-coded for ease of data collection and analysis. The questionnaire was semi-structured in and allowing for flexibility in responding to the questions (Appendix 1). The questionnaire was administered to all the household heads in selected villages. The criteria for village selection were based on agricultural practices and accessibility to forest. The sample size for the target population was determined using the following sample size determination formula (Kothari, 1985).

$$n = z^2pqN / E^2 (n-1) + z^2pq$$

Where n=sample size, E=Error (5%), N= Total population number, α = 0.05, q=1-p, p=estimated population element in the variable of interest (0.95), Z=95% - confidence interval (1.96).
Therefore

$n = z^2pqN / E^2 (n-1) + z^2pq$
$= (1.96)^2(0.05)\ (0.95)\ x\ 342545/\ (0.05)^2(342545-1) + (1.96)^2(0.05x0.96)$
$= 62506.24/856.54= 73$
$n = 73$

Data analysis

Descriptive statistical methods were used to summarize and analyze the data. The raw data were from recorded woody plant species and data from focus group discussion, questionnaire survey, field observation and field work were entered an Excel spreadsheet. Then these data were transferred to various forms as table and chart with possible combinations. Descriptive statistics methods such as densities, frequencies, abundance, relative frequencies were applied. Shannon-Wiener diversity index, species richness and evenness were computed to describe the diversity of woody species of the area. These methods are among those of the most widely used approaches in measuring the diversity of species. Shannon-Wiener diversity index was calculated as follows.

$$H' = -\sum_{i=1}^{s} \text{Pi} \ln \text{pi}$$

Where, H'= Shannon Diversity Index, S= the number of species, Pi=the proportion of individuals.

The equitability or evenness of abundance of woody species was measured as follows (Kent and Coker, 1992):

$$E = \frac{H'}{Hmax} = \frac{H'}{\ln S}$$

Where J= Evenness, H' = Shannon-Wiener diversity index and ln S **=** where **s** is the number of species.

Abundance is the number of individual plants per unit area. To measure of plant abundance, it requires the counting of individual plants by species in a given area which can be used to show spatial distribution and ranges over time. Relative abundance is calculated as follow:

$$\text{Relative abundance} = \frac{\text{Number of Individuals of tree species}}{\text{Total number of Individuals}} * 100$$

$$\text{Density (D)} = \frac{\text{Number of Individuals of species A}}{\text{Area sampled}} * 100$$

$$\text{Relative density (RD)} = \frac{Di}{DN} * 100$$

Where: Di=Number of individual of species A., DN=Total number of individual in the area.

RESULTS AND DISCUSSION

Woody species composition of the forest

A total of 43 species (26 trees and 17 shrubs) belonging to 28 families and 37 genera were recorded and identified from 100 quadrats examined from the study area (Table 1). Of all the families, Fabaceae, Anacardiaceae and Apocynaceae were the three most dominant families represented by 6, 2 and 2 genera, and 8, 3 and 3 species respectively. These three dominant families together constituted 14 (32.6%) of the total species richness in Hotessa forest. The next dominant families Acanthaceae, Asteraceae, Euphorbiaceae and Moraceae (each represented by 2 species or 18.6% together) and the remaining 21 families were mono specific (Table 1).

The study area is rich in species diversity and home for different plant communities. In this study, top seven families contributed to about 51% of all the 28 plant families recorded in the area. Other scholars studies conducted in woodlands of Ethiopia also reported similar findings. For instance Eba and Lenjisa (2017) identified 18 species; Zerihun et al. (2017) 15 species; Dagne and Tamru (2018) 15 species; Tesfaye et al. (2019) 5 species respectively in their study. In terms of species richness, the dominance of Fabaceae was reported from similar vegetation studies done by different scholars in the country such as Zerihun et al. (2017) and Tesfaye et al. (2019). The dominance of Fabaceae is also in line with the assessment results that show the dominance positions in the Flora of Ethiopia and Eritrea (Zerihun et al. (2017). This might have got the top dominant position probably due to having efficient pollination and successful seed dispersal mechanisms that might have adapted it to a wide range of ecological conditions in the past (Ensermu and Teshome, 2008; as cited by Zerihun et al. 2017). Some plant species like *Bougainvillea glabra, Casuarina equisetifolia, Coffee arabica, Melia azedarach, Euphorbia tirucalli* and *Dracaena steudneri* observed both in the forest and on the fence and farm lands of the marginal or adjacent villages of the forest. This might be easy to domesticate and local people used as ornamental plants (*Bougainvillea glabra, Coffee arabica* and *Dracaena steudneri*) and as a fence for ther farm land (*Euphorbia tirucalli*) and *Melia azedarach* and *Casuarina equisetifolia* as fodder for their cattle and fuel wood.

Species richness of the study area

According to Kent and Coker (1992) the Shannon Weiner index is the most frequently used index for the combination of species richness and relative abundance. With respect to this, the Shannon-Wiener diversity index was computed for the three different altitudinal gradients (Table 2). Lower altitude is found to be more diversified in species richness followed by middle and upper altitude. Pielou (1969) also stated that value of the index of Shannon-Weiner usually lies between 1.5 and 3.5; although in exceptional case, the value can exceed 4.5. Thus, the value of Shannon-Wiener Diversity Index of this study area occurs between 2.325 and 2.787. Here the analysis showed that the entire three altitudinal gradients were rich in species diversity. This might have due to the presence of sparsely distributed woody plant species compositions in all parts of the forest. During data collection the researcher observed that the local people still high contact with forest core zone (at middle and upper altitude) than the margin (buffer zone) of the forest. Equitability (evenness) is used to measures the relative abundance of different species. The higher the value of J, the more even the species is in their distribution. Thus, middle altitude has the highest even distribution whereas upper and lower altitude has the least even distribution respectively. In general, the diversity and evenness of woody species in the forest was 2.575 and 0.98 respectively. This is indicating that the diversity and distributions of woody species in the forest were relatively high.

Important value index

Out of the 43 species recorded in the site *Carissa edulis* accounted, 11.45% of the relative abundance followed by *Buddleja polystachya* (11.01), *B. glabra, Sesbania*

Table 1. List of woody species recorded from Hotessa Forest with their scientific and family name: Habit (Ha): Tree (T), Shrub (Sh): Frequency (Fr): Relative frequency (Rf).

Species name	Family	Ha	Fr	Rf
Acacia abyssinica [Hochst.ex] Benth.	Fabaceae	T	20	2.88
Acacia albida Del.	Fabaceae	T	8	1.15
Acacia mearnsii De Wild.	Fabaceae	T	11	1.59
Acokanthera schimperi (A. DC.) Schweinf.	Apocynaceae	Sh	9	1.29
Adhatoda schimperiana Hochst*. ex.* Nees	Acanthaceae	Sh	12	1.73
Albizia gummifera (J.F. Gmel.) C.A. Sm.	Fabaceae	T	14	2.02
Arundinaria alpina K. Schum.	Poaceae	Sh	21	3.03
Bersama abyssinica Fresen.	Melianthaceae	T	22	3.17
Bougainvillea glabra choisy	Nyctaginaceae	Sh	23	3.32
Buddleja polystachya Fresen.	Loganiaceae	Sh	25	3.61
Calpurnia aurea (Aiton) Benth.	Fabaceae	Sh	17	2.45
Carissa edulis Vahl.	Apocynaceae	Sh	26	3.75
Carissa spinarum L.	Apocynaceae	Sh	19	2.74
Casuarina equisetifolia. L.	Casuarinaceae	T	15	2.16
Celtis integrifolia Lam.	Ulmaceae	T	13	1.88
Coffea arabica L.	Rubiaceae	Sh	14	2.02
Cordia africana Lam.	Boraginaceae	T	16	2.31
Croton macrostachyus Hochst. ex Delile	Euphorbiaceae	T	21	3.03
Dodonaea viscosa (L.) Jacq.	Sapindaceae	Sh	17	2.45
Dracaena steudneri Engl.	Asparagaceae	Sh	8	1.15
Entada abyssinica Steud.ex A. Rich	Fabaceae	Tr	10	1.44
Euclea schimperi (*A.DC*.) Dandy	Ebinaceae	T	20	2.88
Euphorbia tirucalli L.	Euphorbiaceae	T	18	2.59
Ficus sur Forssk.	Moraceae	T	16	2.31
Ficus vasta Forssk.	Moraceae	T	18	2.59
Juniperus procera Hochst. ex Endl.	Cupressaceae	T	15	2.16
Justicia schimperiana (Hochst. ex Nees) T. Anderson	Acanthaceae	Sh	9	1.29
Lannea schimperi (Hochst. ex. A. Rich.) Engl.	Anacardiaceae	T	13	1.88
Maytenus senegalensis (Lam.) Exell	Celastraceae	T	9	1.29
Melia azedarach Forssk.	Meliaceae	T	23	3.32
Millettia ferruginea (Hochs.) Baker	Fabaceae	T	20	2.88
Olea europea subsp*. cuspidate* (Wall.ex G. Don) Cif.	Oleaceae	T	6	0.87
Polyscias fulva (Hiern) Harms	Araliaceae	T	7	1.01
Podocarpus falcatus (Thunb.) R.Br. ex Mirb.	Podocarpaceae	T	15	2.16
Pouteria altissima (A.Chev.) Baehni	Sapotaceae	T	14	2.02
Prunus africana (Hook.f.) Kalkman.	Rosaceae	T	10	1.44
Phytolacca dodecandra L'Herit.	Phytolaccaceae	Sh	19	2.74
Rhus glutinosa Hochst. ex A. Rich.	Anacardiaceae	T	20	2.88
Rhus natalensis (Krauss).	Anacardiaceae	T	22	3.17
Sesbania sesban (L.) Merr.	Fabaceae	Sh	23	3.32
Syzygium guineense (Willd.) DC. *subsp. giuneense*	Myrtaceae	Sh	15	2.16
Vernonia amygdalina Del.	Asteraceae	Sh	21	3.03
Vernonia auriculifera Hiern.	Asteraceae	Sh	19	2.74

sesban and *M. azedarach (*10.13) (Table 3). According to Premavani et al. (2014) important value index values have helped to understand the ecological significance of tree species in community structure. Shamble (2011) also indicated that important value index of woody species were calculated either from relative density or relative

Table 2. Shannon-Weiner Diversity Index (H') and evenness (J) for the three elevation types of Hotessa Forest.

Elevation	No of species	H'	Evenness (J)
Lower	313	2.787	0.97
Middle	236	2.613	0.99
Upper	143	2.325	0.97

Table 3. Species distribution in the three altitudinal gradients.

Lower elevation	Middle elevation	Upper elevation
Prunus africana	*Dodonaea viscosa*	*Acacia albida*
Acacia abyssinica	*Cordia africana*	*Justicia schimperiana*
Bersama abyssinica	*Casuarina equisetifolia*	*Entada abyssinica*
Buddleja polystachya	*Juniperus procera*	*Olea europea*
Albizia gummifera	*Phytolacca dodecandra*	*Maytenus senegalensis*
Coffee arabica	*Croton macrostachyus*	*Euphorbia tirucalli*
Euclea schimperi	*Ficus sur*	*Carissa edulis*
Pittosporum abyssinicum	*Podocarpus falactus*	*Ficus vasta*
Bougainvillea glabra	*Rhus glutinosa*	*Rhus natalensis*
Acokanthera schimperi	*Arundinaria alpine*	*Sesbania sesban*
Acacia mearnsii	*Polyscias fulva*	
Adhatoda schimperiana	*Pouteria altissima*	
Calpurnia aurea	*Vernonia amygdalina*	
Dracaena steudneri	*Vernonia auriculifera*	
Celtis integrifolia		
Lannea schimperi		
Melia azedarach		
Millettia ferruginea		
Dracaena steudneri		

dominance or relative frequency. With respect to this, the important value index of woody species of Hotessa forest was calculated. As a result, ten most dominant tree species of Hotessa forest occupied 32.75% of the total important value index (Table 1). Those dominant species were *Carissa edulis*, Buddleja polystachya, *Bougainvillea glabra*, *M. azedarach*, Sesbania sesban, *Rhus natalensis*, *Bersama abyssinica*, *Arundinaria alpine*, *Croton macrostachyus* and *Vernonia amygdalina*. These trees were said to be tolerant and well adapted to the ecological interaction and the wider distribution shows their higher socio-economic and environmental role of the specific study site. From those species *Bougainvillea glabra* and *Melia azedarach* were found in the lower altitude and common in the forest and adjacent villages; whereas, *Sesbania sesban* is found in the upper altitude and important ecological role. In terms of abundance and distribution the contribution of *Carissa edulis* and *Buddleja polystachya* were the highest of all tree species; while Olea *europea* subsp*. cuspidate* had low relative frequency than the other. This might be due to over exploitation of the species for specific uses like timber, construction and firewood in the study area (Table 3). This indicates the species is under threat and needs immediate conservation measures from the concerned bodies. It has been well recognized through this study that different species has sparse distribution. The total density of woody plants was 551 individuals (stems) per hectare. Which means Density= number of individual tree /total sampling area (0.72 ha) and the relative density was 765/ha.

Socioeconomic characteristics of the interviewed respondents

As seen from Table 4, respondents were mostly males (71.2%) and aged between 41 to 50 (30.1%) with most of them having not attended formal education and some

Table 4. Distribution of respondents according to socio-economic characteristics.

Socioeconomic characteristics	Number of respondents	Percentage
Gender		
Male	52	71.2
Female	21	28.8
Age (years)		
20-30	11	15.1
31-40	19	26
41-50	22	30.1
>50	21	28.8
Education		
Non formal education	31	42.5
Primary education	29	39.7
Secondary education	13	17.8
Post-secondary education	-	
Farm size (Ha)		
Below one	31	42.5
One to two	28	38.3
Two to three	9	12.4
Above three	5	6.8

attended primary school (42.5 and 39.7%) and possessed at least a hectare of farmland (57.5%). The dominance of the aged and youth population in this survey is an indication that agriculture has been abandoned, which is a challenge to food insecurity and the people are mostly limited to subsistence farming, with most of them adopting outdated and environmentally unfriendly agricultural techniques. This invariably contributes to deforestation and soil degradation. Again, the fact that most of them attained primary school (39.7%) is an indication that they may not be in tune with new farming techniques that lay more emphasis on conservation tillage, contour plowing to control erosion, and adoption of intensive farming rather than extensive farming to control deforestation and prevent loss of valuable species of economic and medicinal values.

Respondent opinion on causes of woody species diversity decrement

Understanding drivers of deforestation and degradation is fundamental for the development of policies and pre-request measures (Noriko et al., 2012). The result of analysis of the responses to factors responsible for deforestation in the study area is presented (Table 5) and it revealed that most of the respondents attributed population growth (80.82%) as the major factor responsible as a threat for deforestation in the study area. This is in line with Salafsky et al. (2008), who saw it as level 1 threat followed by Urbanization and infrastructure development and identified as level 2 threat (76.7%), logging as level 2 threat (76.7%), expansion of farming land as level 1 threat (75.34%) and fuel wood and charcoal as level 2 threat (71.23%). The implication therefore is that population growth is regarded as the overwhelming cause of deforestation in the study area.

According to Salafsky et al. (2008) threats are defined as the proximate activities or processes that have caused, are causing, or may in the future cause the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (global, national, or subnational). For purposes of threat assessment, only present and future threats are considered. Similarly, in the study area, as a result of increment in population, people resort to clearing of forest to provide shelter and gate their basic needs. Increment of population in the rural areas has forced people to exploit forest resources in an unsustainable way and to clear the forests for agricultural purposes. This area expansion of agricultural land, logging, urbanization and infrastructure development has impacted negatively on the biodiversity and soil condition in the area. Clearance of forest for the purpose of agriculture has exposed the soil to erosion and

Table 5. The causes (threats) of woody species diversity loss.

Factors for plant diversity loss		Factors with percentage	1	2	3	4	Total
1	Fuel wood and charcoal	Threats	29	23	11	10	73
		Percentage	39.72	31.51	15.07	13.67	100
2	Expansion of farming land	Threats	30	25	10	8	73
		Percentage	41.09	34.25	13.67	10.96	100
3	Logging	Threats	29	27	11	6	73
		Percentage	39.72	36.98	15.07	8.22	100
4	Urbanization and infrastructure development	Threats	31	25	18	21	73
		Percentage	42.46	34.24	24.66	28.77	100
5	Population growth	Threats	33	26	6	8	73
		Percentage	45.20	35.62	8.22	10.96	100

1= strongly agree (SA), 2= agree (A), 3 = disagree (DA), 4= strongly disagree (SD).

Table 6. Possible solution for conservation.

S/N	Way forwarded as a solution	Solutions with percentage	1	2	3	4	Total
1	Awareness related problem	Solution	27	25	15	6	73
		Percentage	36.98	34.25	20.55	8.22	100
2	Using alternative energy sources	Solution	28	21	14	10	73
		Percentage	38.35	28.77	19.18	13.69	100
3	Reforestation	Solution	33	23	9	8	73
		Percentage	45.2	31.5	12.3	10.96	100
4	Afforestation	Solution	26	29	10	9	73
		Percentage	35.6	39.7	13.7	12.3	100

1= strongly agree (SA), 2= agree (A), 3 = disagree (DA), 4= strongly disagree (SD).

leaching of nutrients. This has led to low farm productivity as complained of by most of the farmers. Low farm productivity in turn results in low farm income or poverty. The rapid construction works going on in the Woreda is an attestation to the rate of modernization and urbanization. This could be seen in the form of road construction, building of houses, hospitals and a host of others, all of which require the destruction of forest ecosystem. There is need to strike a balance between construction works and preservation of forest ecosystem. The human-induced problems/threats were encountered as major influencing factors/threats in the study area.

Similarly Negasi et al. (2018) as well as Dagne and Tamru (2018) in their study reported that human-induced threats were recorded as the major threats to forest degradation in Ethiopia.

Possible solutions suggested on woody species conservation in the study area

Focus group discussion was implemented to triangulate the responses from household interview on possible solutions of threats of deforestation in the study area. From the analysis of informants suggestion as possible solution of deforestation, reforestation was taken as priority to cope up problems of threats (76.7%) and a major way to minimize the loss of plant diversity followed by afforestation (75.3%), awareness creation (71.23%) and using alternative energy (67.12%) in the community nearby to the forest (Table 6).

The control or reversal of deforestation can, therefore, be achieved by addressing the drivers identified to be currently contributing to deforestation in the study area.

The promotion of alternative energy sources (like biogas and solar energy) should be encouraged to reduce dependence on the use of firewood. Reducing deforestation would also require creating and strengthening reversal of deforestation such as awareness rising on consequences of deforestation (public education) and strengthening participatory forest restoration and protected area expansion programs. This is in line with the same recommendation from Asfawa and Fikadu (2018). It is vital therefore, that the Woreda natural resource administrative body or Forest and environment office to enhances the land use planning process in addition to identifying and implementing appropriate decision to mitigate harmful effects of development activities (like illegal agricultural expansion, urbanization and infrastructure development) on forest resources. During data collection session the researcher observed that, the nearby society still rely on the forest for their daily life activities and most people cut down trees for fuel wood and charcoal production. In general, the rural people in the country and Bensa Woreda get their basic needs from the nature gifted areas without sustainable utilizations and conservation. Wise utilization of natural resources and responsibilities must be considered.

Conclusion

Understanding the resources and process of forest degradation is vital for informing forest management and conservation policy and for an efficient conservation of interventions. This study has quantified the Hotessa forest woody species diversity and dynamics of forest resource degradation and its drivers in southern Ethiopia Sidama Zone Bensa Woreda. A total of 43 woody plants species were identified and recorded. The plant resource in the study area is considerable, the Woreda being relatively rich in plant diversity. Based on Shannon-wiener diversity index analysis, the distributions of species were natural with less human intervention. Socioeconomic characteristics of the respondents showed that mostly males and aged with most of them without any formal education and primary school education and possessed at least a hectare of farmland. Expansion of agricultural land, logging, urbanization and infrastructure development were recorded as a major challenges and negative impact on the biodiversity and soil condition in the area. In the course of this study, it was noticed that farming activities in relation with population growth were greater and a lot of pressure placed on natural resources. Forest might have been losing its diversity through above indicated threats. The long history of exploitation may result to unequal distribution of woody plant species in the forest, and woody plant species before reaching the seedling and sapling stage is under destruction. Hence, proper and integrated approach in implementing policies and strategies related to land resources management should be considered and future study on seedling regeneration status and LULC change is recommended.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

ACKNOWLEDGEMENTS

The author appreciates Hawassa University for providing fund for this research and also grateful to the staff of Wereda Agricultural Office and farmers of Bensa Wereda for their input in data collection.

REFERENCES

Ariti AT, Vliet JV, Verburg PH (2015). Land use and land cover change in the Central Rift Valley of Ethiopia: Assessment of perception and adaptation of stakeholders. Applied Geography 65:20-37.

Asfaw Z, Fekadu B (2018). Factors affecting smallholder farmers' participation in degraded forest rehabilitation practices. The case of Gemachis District, West Hararghe Zone, Oromia Region, Ethiopia. Journal of Agricultural Extension and Rural Development 10(11):234-244.

Azene B (2007). Useful Trees of Ethiopia: Identification, Propagation and Management in 17 Agro-ecological Zones. Nairobi: RELMA in ICRAF project, p. 552.

Bessie S, Beyene F, Hundie B, Goshu D, Mulatu Y (2016). Land use/lan d cover change and its effect on bamboo forest in Benishangul Gumu zregion, Ethiopia. International Journal of Sustainable Development a nd World Policy 5(1):1-11.

Dagne A, Tamru DT (2018). Floristic Composition and Structure of Zerat Forest, Central Ethiopia. American Scientific Research Journal for Engineering, Technology and Sciences (ASRJETS) ISSN (Print) 2313-4410, ISSN (Online) 2313-4402.

Daniel E (2016). Deforestation and forest degradation in southern Burkina Faso: Understanding the drivers of change and options for re-vegetation. Dissertation, Helsinki.

Eba M, Lenjisa D (2017). Assessment of Plant Species Diversity, Relative Abundances and Distribution in Haramaya University, Ethiopia. Journal of Physical Science and Environmental Studies 3(3):30-35.

Edwards S, Mesfin T, Sebsebe D, Hedberg I (2000). Flora of Ethiopia and Eritrea. The National Herbarium, Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala 2(1):13.

Ensermu K, Teshome S (2008). Interface of Regeneration, structure, diversity and use of some plant species in Bonga Forest: a Reservoir for wild coffee gene pool. SINET, Ethiopia Journal of Science 31:21-134.

FAO (2016). State of the World's Forests. Forests and agriculture: land-use challenges and opportunities. Rome.

Gashaw T, Dinkayoh T (2015). Land use/land cover dynamics in hulet Wogedamea Kebele, northern Ethiopia. Current Research in Agricultural Sciences 2(1):36-41.

Hedberg I, Ensermu K, Edwards S, Sebsebe D, Persson E (2006). Flora of Ethiopia and Eritrea 5.The National Herbarium, Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala. p. 36.

Hedberg I, Friis I, Epersson E (2009). Flora of Ethiopia and Eritrea 8. General Part and Index to 1-7. Addis Ababa, Ethiopia and Uppsala,

Sweden.
Keenan RJ, Reams GA, Achard F, de Freitas JV, Grainger A, Lindquist E (2015). Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. Forest Ecology and Management 352:9-20.
Kent M, Coker P (1992). Vegetation Description and Analysis: A Practical Approach Belhaven Press, London. 438p.
Kothari CR (1985). Research Methodology, Methods and Techniques. Wiley Eastern Limited, New Delhi.
Khumalo S, Chirwa PW, Moyo BH, Syampungani S (2012). The Status of Agrobiodiversity Management and Conservation in Major Agroecosystems of Southern Africa. Agriculture, Ecosystems and Environment 157:17-23.
LIVES (Livestock and irrigation value chain for Ethiopian Smallholders) (2012). Bensa woreda pilot Learning Site diagnosis and program design.
Moges Y, Eshetu, Z, Nune S (2010). Ethiopia Forest resources: Current status and future management options in view of access to carbon finances, literature review prepared for the Ethiopian climate change networking. Addis Ababa, Ethiopia: United Nation Development Program (UNDP).
Mohammed A (2011). Perception of Local Community Towards Deforestation: The Case of Edigetber And Selamber Kebele Around Wolkite Town, Gurage Zone, Snnprs (Doctoral dissertation, Addis Ababauniversity)
Muller–Dombois D, Ellenberg DH (1974). Aims and Methods of vegetation ecology. - John Willy and sons, Inc., New York.
Negasi S, Hadgu H, Ted A, Opoku P, Isaac KA, Emiru B (2018). Forest Cover Change, Key Drivers and Community Perception in Wujig Mahgo Waren Forest of Northern Ethiopia.
Noriko H, Martin H, Veronique DS, Ruth SDF, Maria B, Louis V, Arild A, Erika R (2012). An assessment of deforestation and forest degradation drivers in developing countries. Lop Publishing. Environmental Research Letters 7 (044009):12.
Pielou EC (1969). An introduction to Mathematical Ecology. Wiley, New York.
Reynolds JF, Smith DMS, Lambin EF, Turner IIBL (2007). Global desertification: building a science for dryland development. Science 316:847e85.
Salafsky ND, Salzer AJ, Stattersfield C, Hilton TR, Neugarten SHM, Butchart B, Collen N, Cox LL, Master SO, Connor DW (2008). A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conservation Biology 22:897-911.
Stern N (2006). The Economics of climate change: The Stern Review. Cambridge, UK: Cambridge University Press.
Solomon G (2015). Community perception on rangeland degradation: a case study in two different settled areas of northern Ethiopia. Journal of Agricultural Research and Development 5(1).
Tesfaye A, Anteneh B, Tessema Z (2019). Woody species diversity, population structure, and regeneration status in the Gra-Kahsu natural vegetation, southern Tigray of Ethiopia. Heliyon 5:e01120. doi: 10.1016/j.heliyon.2019. e01120.
Teweldebrhan G (1988). Vegetation and environment of the mountains of Ethiopia: implications for utilization and conservation. Mountain Research and Development 8:211-216.
Zerihun T, Ensermu K, Tamrat B (2017). Floristic composition and plant community analysis of vegetation in Ilu Gelan district, West Shewa Zone of Oromia region, Central Ethiopia. International Journal of Tropical plant research. https://doi.org/10.22271/tpr.2017.v4.i2.045.

APPENDIX 1

Questionnaire on Drivers of deforestation and perception of the local community
Name of the interviewer --------------------------------- Date ------------------------Signature ---------
Survey area: District: ____________ Kebele: __________ Village: _________
Distance from the forest ________________
Personal information; Name of household head: ________________________
Gender of head M ---------------- F ---------------- Age of respondent ------------
Educational status ---
Farm size in ha --
2. What are the major uses of forests in your area?
3. Do you think that deforestation is the major problem in your locality?
4. How is today's coverage of the forest when compared to the conditions before 2019?
A. Declined B. Increased C. No change
5. According to your knowledge, is severe and rapid forest cover change observed? A. yes B. No
6. If the answer to question number '5' is yes, what were/are the major causes of deforestation?
Rank the drivers; Population growth, Agricultural land expansion, Fuel wood, Charcoal production, Urbanization and infrastructure development and logging
7. What is your major source of income? A. Sale of cash crops B. Sale of wood and charcoal C. Other ___________
8. What types of fuel do you use for household needs (List them in order).
9. On the basis of your knowledge, what are the impacts of deforestation/forest cover change in the area? (Put in order).
10. Are there species of "trees" and wild animals, in danger of extinction due to forest cover change from the local region? Please mention if any?
11. What do you think about the possible solution to alleviate the current problem of deforestation and to use forest resources in a sustainable manner?
12. What are the existing efforts to reduce deforestation and forest degradation in the study region?
13. What are the challenges in implementing the efforts to reduce deforestation and forest degradation in the study region/area?

Vol. 14(4), pp. 183-191, May 2020
DOI: 10.5897/AJPS2020.1990
Article Number: DDABEE363739
ISSN 1996-0824

http://www.academicjournals.org/AJPS

ACADEMIC JOURNALS
expand your knowledge

African Journal of Plant Science

Full Length Research Paper

Grain yield and protein content of upland rice (*Oryza sativa* L.) varieties as influenced by combined application of primary secondary and micronutrients under Nitisols

Girma Wolde[1*] and Sisay Tomas[2]

[1]Department of Plant Science, College of Agriculture and Natural Resource, Wolkite University, Wolkite, Ethiopia.
[2]Department of Plant Science, College of Agriculture and Natural Resource, Mizan-Tepi University, Mizan-Aman, Ethiopia.

Received 23 March, 2020; Accepted 24 April, 2020

Field experiment was conducted on Nitisols to evaluate the effects of combined application of primary, secondary and micronutrients on grain yield and protein content of upland rice varieties compared to the national recommendation. Factorial combination of five nutrient combinations (control, NP, NPK, NPKSZn and NPKSCaZn) and three upland rice varieties (Nechu Eruze, Superica-1 and NERICA-4) were laid out in a randomized complete block design with three replications. The result revealed that nutrient combinations significantly affected plant height and number of effective tillers m^{-2}. The highest grain number per panicles of 122 and 1000 grain weights of 30.9 g were recorded from NPKSZn. The maximum grain yield (4055.6 kg ha^{-1}) was also obtained from NPKSZn, followed by NPKSCaZn. Moreover, maximum grain protein content was registered from NPKSZn and NPKSCaZn. In contrast, the lowest value of these parameters was scored from the control. Among the varieties, NERICA-4 performed better than both varieties in yield and yield components. However, grain protein content of rice varieties was statistically similar. Overall, combined application of primary, secondary and micronutrients significantly improved grain yield and protein content of upland rice compared to nationally recommended NP combinations.

Key words: Nechu Eruze, NERICA-4, Nitosols, nutritional security, rice grain yield, Superica-1.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population, providing over 20% of the total calorie and 15% of the protein that human needs (Seck et al., 2012). It is the most promptly growing source of food in Africa, and is of noteworthy importance to food security in an increasing number of low-income food-deficit countries (FAO, 2015). In sub-Saharan Africa (SSA), rice is currently one of the rapidly growing food

*Corresponding author. E-mail: woldgirma@gmail.com.

crops in production and consumption (Kinfe et al., 2017). Cultivated area in SSA is reaching 10 million hectares with annual production of about 23 million tons and average per capita consumption of 24 kg per year (FAO, 2015). Upland rice is one of the main staple food crops in inter-tropical highland areas and much of the future expansion of the world's rice varieties depends on it (Negusseie et al., 2008). Further, about 14 million hectares of land is dedicated to upland rice, accounting for 4% of global rice production (Kinfe et al., 2017).

In Ethiopia, rice is among the target strategic commodities that have received great focus and is considered as the "millennium crop" that is expected to contribute in ensuring food security in the country and it plays a critical role in nutritional security (Mekonnen et al., 2017). The total rice area coverage in Ethiopia including upland rice in 2016 was estimated at 48,418 ha with average annual production and productivity of 136000 tones and 2.9 t ha^{-1}, respectively (CSA, 2017). This however, is much lower than the world's average rice yield of 4.64 t ha^{-1} (FAOSTAT, 2017).

Soil nutrient depletion and shortage of adapted varieties are among the major constraints for the yield gap. The gap was further increased due to lower use of external inputs that led to negative nutrient balances in the soil (Rhodes et al., 1996). Kumar and Yavdav (2005) related the decline in productivity of rice with continuous cropping to deficiency of primary, secondary and micronutrients mainly N, P, K, S, Zn and imbalanced nutrition. In Southern Ethiopian, Nitisols are among the most extensive agricultural soils though, soil degradation threatens their productive (Eyasu, 2017) and nutrient balances at field level for Nitisols were found to be −102, −45 and −67 kg ha^{-1} for NPK, respectively (Elias, 2002). Moreover, Ethiopian Soil Information Service (2013) reported that most arable lands in Ethiopia including the study area are deficient with secondary and micronutrients in addition to the lower level of primary macronutrients (NPK). Potentially, these limit rice production, despite continued use of only NP nutrient combination as blanket recommendation over decades (Abebe et al., 2020). Sillanpaa (1982) identified micronutrient deficiencies for selected cereals in Ethiopia, and highlighted the need for micronutrient supply especially Zn to address observed deficiencies and to realize full potential in crop productivity. Crop response to secondary and micronutrients such as S and Zn has been reported (Abebe et al., 2020; Demiss et al., 2019).

Despite the importance of secondary and micronutrients in enhancing crop productivity, they are hardly studied in Ethiopia. In the country, the main focus has been on primary macronutrients, that is NPK but there is emerging, though, scattered evidence of crop productivity being limited by secondary and micronutrients (Kihara et al., 2017). On the other hand, balanced supply of macro and micronutrients has a paramount importance and may guarantee optimal crop production, better food quality and benefit smallholder farmers. Therefore, information is required to identify nutrients that limit rice production which could be used for fertilizer blending to produce blends of the right formulation (Kaizzi et al., 2018). However, little if any has been done on the impact of combined application of primary, secondary and micronutrient except nitrogen and phosphorous on rice productivity in Ethiopia. Owing to the above facts, this study was designed to evaluate the effect of combined application of primary secondary and micronutrients on grain yield and protein content of upland rice varieties compared to the national recommendation.

MATERIALS AND METHODS

Description of the study area

Field experiment was conducted at Guraferda District of Bench-Maji Zone, Southern Nations, Nationalities and Peoples' Regional State, Ethiopia. The experiment was undertaken during 2015 main cropping season. The district lies between altitudes of about 850 and 1995 m above sea level. The annual rainfall pattern is unimodal with rainy season from mid-March to mid-November (Kassa et al., 2017). The average annual temperature and rainfall ranges from 25 to 39°C and 1200 to 1332 mm, respectively (Weldegebriel, 2015). The predominant soil type in the study area is Nitisols (FAO, 2001); primary, secondary and micronutrients: N, P, K, S and Zn, were deficient in the soil (ATA, 2016). The soil was relatively highly weathered well drained, clay in texture and strongly to moderately acidic in reaction.

Treatments, experimental design and procedure

Factorial combination of 5 nutrient combinations, that is control without fertilization (control), nationally recommended NP, NPK, NPKSZn and NPKSCaZn and 3 rice varieties (Nechu Eruze, Superica-1 and NERICA-4) were laid out in Randomized Complete Block Design (RCBD). NERICA 4 and Superica-1 are popular and typical upland rice varieties in Ethiopia, and dominantly produced by private companies in the study area; Nechu Eruze is a local variety produced by most small holder framers. Treatment combinations were replicated 3 times. Each replication had 15 plots corresponding to the 15 treatment combinations. A uniform size of 4 m × 2.5 m (10 m^2) was used for each plot. The plot size accommodated 16 rows at the spacing of 25 cm between rows. A 1 m wide-open strip separated the blocks, whereas the plots within a block were 0.5 m apart from each other. The experimental field was ploughed and leveled properly before planting. The required agronomic practices were followed uniformly in all plots throughout the growing period.

N and P in the NP and NPK combinations were applied in the form of DAP fertilizer; whereas these two primary macronutrients were supplied in the form of NPS ($19N\text{-}38P_2O_5\text{-}7S$) fertilizer for NPKSZn and NPKSCaZn combinations. The remaining two secondary macronutrients and the micronutrient; K, Ca^{2+} and Zn^{+2}, were applied in the form of KCl (60 K_2O), $CaCO_3$ and $ZnSO_4$ (23 Zn and 10 S), respectively. Urea to all fertilizer combinations and TSP to NPKSZn and NPKSCaZn combinations were applied in order to make N and P of the nutrient combinations equal to the recommended level. All nutrient sources except urea were applied at sowing. However, since the N content of DAP and NPS was not equal, the difference was applied to DAP at planting as urea to

Table 1. Composition of nutrients combination for the experiment.

Nutrient combinations	Nutrient composition (kg ha^{-1})					
	N	P_2O_5	K_2O	S	$ZnSO_4$	Ca^{2+}
NP	64	46				
NPK	64	46	60			
NPKSZn	64	46	60	7	20	
NPKSCaZn	64	46	60	7	20	100

Table 2. Physical and chemical characteristics of surface soils of the study site before sowing.

Soil characteristics	Value
Sand (%)	31
Silt (%)	29
Clay (%)	40
Textural class	Clay
pH in water (1:2.5)	5.6
Organic carbon (%)	1.69
Total N (%)	0.13
Na (cmol(+) kg $^{-1}$)	0.08
K (cmol(+) kg $^{-1}$)	1.30
Ca (cmol(+) kg $^{-1}$)	5.2
Mg (cmol(+) kg $^{-1}$)	4.55
CEC (cmol(+) kg $^{-1}$)	33.9
Av. P (mg kg $^{-1}$)	1.30
Av. S (mgkg^{-1})	8.01
Fe (mg kg $^{-1}$)	40.22
Mn (mg kg $^{-1}$)	50.5
Zn (mg kg $^{-1}$)	0.42
Cu (mg kg $^{-1}$)	3.99

balance the N content between the nutrient combinations. The remaining N was applied in split in the form of urea. Detail of nutrient compositions is presented in Table 1. Days to 50% emergence, flowering and physiological maturity were collected at plot level. Plant height (cm) was recorded from the two outer rows excluding the border and central rows. Whereas, total number of grain panicles $^{-1}$, number of effective tillers per mater square, thousand seeds weight (g) and grain yield (kg ha^{-1}) were recorded from the central rows.

Grain protein analysis

Grain samples collected at harvest were dried for the determinations of N concentrations in grain. The grain samples were grounded and sieved through 0.5 mm size sieve and were saved for laboratory analysis. Nitrogen in the grain was analyzed by wet-oxidation procedure of the modified Kjeldahal method (Nelson and Sommers, 1973). Grain protein content (GPC) (%) was determined by multiplying total N with 5.75 (Brahmanand et al., 2009).

Soil sampling, sample preparation and analysis

Thirty sub-samples using random sampling technique were collected from the study area at a depth of 0-20 cm and a composite was made before planting; it was analyzed for particle size distribution, $pH_{(H2O)}$, soil organic carbon, available N, P, K, S, CEC, exchangeable bases and micronutrients following standard procedures.

Statistical analysis

Data were subjected to the analysis of variance (ANOVA) using statistical analysis systems (SAS Version 9.1.3) (SAS, 2003). Whenever significant differences were detected in the F-test, the means were compared using the least significance difference (LSD) test at 5% levels of significance.

RESULTS AND DISCUSSION

Soil physical and chemical characteristics

Results of the composite soil analysis of the study areas before planting indicated that textural classes of the surface soil were clay (Table 2). The soil was found to be moderately acidic in reaction with a pH of 5.6 as per the rating of Tekalign (1991). According to Landon (2014), organic carbon and total nitrogen contents of the soils were in a low range. On the other hands, available phosphorus contents were in a very low range as stated by Olsen and Sommers (1982). Cation exchange capacity (CEC) was medium according to the rating of Landon (2014). Moreover, available S content of the soil was low according to Havlin et al. (2014). The result is in line with the finding of Abebe et al. (2020) who reported low S content in Nitisols of Central Ethiopia. Exchangeable Ca and Mg were the dominant cations in the soil sample. Concentrations of exchangeable cations were generally in the order of Ca > Mg > K > Na. Cation exchange capacities (CEC) of the studied soils were rated as high according to the rating of Landon (2014). In contrast to available Zn which is deficient in the soil, available Fe, Mn and Cu were sufficient. This is in agreement with the finding of Abebe et al. (2020).

Days to 50% emergence, flowering and days to physiological maturity

None of the nutrient combinations, varieties or their interaction influenced crop emergence and date to 50%

Table 3. Effect of variety and nutrient combinations on days to 50% emergence, flowering and physiological maturity.

Treatments	50% emergence	50% flowering	DTPM	PH (cm)	NET/m^2
Nutrient combinations					
Control	7.1	64.5	97^b	74.0^c	166.6^c
NP	7.0	65.0	105^a	78.0^b	235.9^b
NPKSZn	7.1	65.0	103^a	87.0^a	279.9^a
NPKSCaZn	7.0	66.5	103^a	85.0^a	249.3^b
NPK	7.0	65.8	103^a	80.8^b	244.3^b
LSD 5%	NS	NS	3.4	3.8	28.6
Varieties					
NERICA-4	7.1	63.0	104^a	77^b	260.3^a
Superica-1	7.1	62.9	101^b	90^a	226.8^b
Nechu Eruze	7.0	63.1	103^{ab}	75^b	218.5^b
LSD 5%	NS	NS	2.6	3.0	22.1
CV (%)	7.5	9.0	3.4	5.0	12.6

Means followed by the same letter in the same column are not significantly different at $p < 0.05$ probability level, NS: Not significantly DTPM: Days to physiological maturity, PH: Plant height NET/m2: Number of effective tiller per meter square

flowering significantly. Favorable moisture condition due to uniform rainfall distribution during planting might contribute to smooth and even germination of rice on similar dates. Uniform germination of rice and wheat was also reported under different levels of N fertilizer (Yesuf and Worku, 2018) and varieties (Melesse, 2007), respectively.

Nutrient combinations had a significant ($p < 0.05$) effect on mean days to physiological maturity of rice. The result revealed that the highest delay was observed in NP combination, which delayed 8 days as compared to the control (Table 3). However, this was not significantly different from treatments that received NPKSZn, NPKSCaZn and NPK. Delayed physiological maturity with N containing fertilizers might be attributed to higher uptake of N fertilizer in the straw that encouraged excessive vegetative growth resulting in delayed maturity. Similarly, Brady and Weil (2002) reported that compared to unfertilized plants, application of N delayed plant maturity. Moreover, WARDA (2008) reported that application of N to NERICA variety delayed maturity as compared to the control; this is in agreement with our result.

Days to physiological maturity was also significantly ($p < 0.05$) varied among rice varieties. However, the interaction effects of nutrient combinations and varieties had no significant effect on days to physiological maturity. Maturity of NERICA-4 was significantly delayed by 3 days compared with Superica-1 (Table 3). Differences in maturity can be caused by the difference in the genetic makeup of the varieties (Bhuiyan et al., 2014). It might also be due to the agronomic characteristics and to the climate adaptability of different rice varieties to the local condition (Romualdo and Jesusa, 2014). Difference in days to physiological maturity among rice varieties has also been reported (Tefera et al., 2019).

Plant height

Combined application of primary secondary and micronutrients significantly increased plant height compared to the recommended NP. The recommended NP combinations also significantly increased plant height over the control. The lowest mean plant heights of rice (74 cm) was recorded at control treatments, while a maximum height of 87 cm was recorded from the application of NPKSZn; however, this result was statistically at par with the height of rice crop obtained from the application of NPKSCaZn (85 cm). Omission of secondary and micronutrients from NPKSZn and NPKSCaZn application significantly reduced plant height by 6.2 and 4.2 over NPK fertilizer (Table 3). This result contradicts the finding of Abebe et al. (2020) who reported a reduction in plant height with the omission of Zn. However, the result is in agreement with Sudha and Stalin (2015) and Singh et al. (2012) who reported a significant reduction in plant height of upland rice with omission of S and Zn from fertilizer schedule. Furthermore, Chimdessa (2016) reported that application of NPKSBZn blended fertilizer increased plant height of maize by 16 and 111 cm over the recommended NP fertilizer and the control respectively in Western Ethiopia. The same source attributes the increment in plant height with combined application of primary, secondary and micronutrients to increase in cell elongation and more vegetative growth due to different nutrient contents of the fertilizer: NPKS and micronutrients (Chimdessa, 2016). An increase in plant height might also be attributed to the adequate supply of zinc that contributed to accelerate the enzymatic activity and auxin metabolism in plants(Fayez and Khan, 2016).

Varieties also had a significant effect on mean plant height of rice. The maximum plant height of 90 cm was

Table 4. Effect of nutrient combinations and varieties on number of grain per panicle, thousand grain weights and grain yield of rice.

Treatments	NGPP	TGW (g)	GY (kg ha^{-1})
Nutrient combinations			
Control	81.44^{e}	25.96 ^{c}	3157.20^{c}
NP	95.00^{d}	27.13^{bc}	3577.80^{b}
NPKSZn	117.67^{a}	30.90^{a}	4055.60^{a}
NPKSCaZn	115.00^{b}	28.89 ^{ab}	4038.90^{a}
NPK	103.22^{c}	28.310b^{c}	3600.00^{b}
LSD 5%	10.8	2.51	409.63
Varieties			
NERICA-4	105.53^{a}	30.66^{a}	4098.30^{a}
Superica-1	101.60^{b}	27.13^{b}	3806.70^{b}
Nechu Eruze	100.33^{b}	26.93^{b}	3175.00^{b}
LSD 5%	NS	1.9	318.37
CV (%)	10.5	9.2	11.51

Means followed by the same letter in the same column are not significantly different at $p < 0.05$ probability level, NS: not significantly, NGPP: number of grain per panicle, TGW: thousand grain weight and GY: Grain yield.

recorded at variety Superica-1 while the minimum plant height of 75 cm was observed in the Nechu Eruze variety (Table 3). The difference in plant height could be attributed to the varietal characteristics of the crops planted (Tefera et al., 2019). Plant height is the end product of several genetically controlled factors mostly governed by the genetic make-up of the genotypes (Sadiqur et al., 2018). In line with our finding, significant variations in height among rice varieties were also reported by Delessa (2007) and Tefera et al. (2019). Interaction effects of nutrient combination and variety on mean plant height of rice was non-significant.

Number of effective tillers

Applying secondary and micronutrients in combination with primary macronutrients increased number of effective tillers. The highest number of effective tillers was recorded from the combination of S and Zn with NPK followed by NPKSCaZn. The lowest value of this parameter was obtained from the control. Compared to the control treatment, application of locally recommended NP nutrients increased number of effective tillers by 68.6% (Table 3). Similar result was reported by Ferdous et al. (2018). Increased effective tiller production of NPKSZn compared to the recommended NP and NPK can be attributed to the ability of Zn to increase N use efficiency and Zn induced enzymatic activity as well as auxin metabolism in plants (Arif et al., 2018; Rana and Kashif, 2014).

Number of effective tillers was also significantly different among the rice varieties. The highest value of this parameter was scored from NERICA-4 and the lowest value from Nechu Eruze variety that was statistically similar with the variety Superica-1 (Table 3). This might be due to different capacity of varieties in tiller production (Suleiman et al., 2014).

Number of grain per panicles

Nutrient combinations significantly increased ($p < 0.01$) number of grain per panicles. The main effect of varieties and its interaction with nutrient combinations did not show significant difference in mean number of grain per panicles. The highest number of grain per panicles (122) was recorded from the treatment that received NPKSZn followed by NPK application (111.3) which however was statistically at par with that obtained from NPKS CaZn (109). The lowest mean number of grain per panicles (84.9) was scored from the control treatment (Table 4). Compared to NP and NPK nutrient combinations, mean values of number of grain per panicles were increased by 22 and 10 % for the application of NPKSZn, respectively. In agreement with our finding, Chimdessa (2016) reported a significant increase in number of kernels per row through balanced nutrient supply including S and Zn. Moreover, the result of Singh et al. (2012) showed that number of grains per panicle of rice was significantly increased by 13 and 14 grains per panicle with the application of S and Zn over control. Higher grain production due to zinc might be attributed to its involvement in many metallic enzyme system, regulatory functions, and auxin production (Sachdev et al., 1988) enhanced synthesis of carbohydrates and their transport to the site of grain production (Pedda-Babu et al., 2007).

Thousand grain weight

Thousand grain weight of rice was significantly ($p \leq 0.01$) affected by the nutrient combinations. The highest 1000 grain weight of 30.9 g was recorded at a nutrient combination of NPKSZn, which however, was statistically similar with that recorded from the application of NPKSCaZn. In contrast, the lowest 1000 grain weight of 26 g was obtained from the control treatments (Table 4). Combined application of primary secondary and micronutrients resulted in the highest 1000 grain weight, which was significantly higher than the control, recommended NP and NPK combinations. The mean values of 1000 grain weight from the combination of primary, secondary and micronutrients (NPKSZn) increased by 14 and 9.2% as compared to the recommended NP and NPK fertilizers, respectively; while it increased by 19% as compared to control. The more grain weight of rice for NPKSZn in the present finding might be attributed to the positive interaction of nutrients in this treatment.

This result is in line with the finding of Chimdessa (2016) who reported that application of blended fertilizes significantly increased 1000 grain weight of maize by 220 g over the control. Similarly, Fayaz and Hamayoon (2016) observed that NPKZn combinations significantly increased 1000 grains weight of rice by 5 g over NPK alone. Moreover, a significant increase in 1000 grain weight of rice by 13.6% through S incorporation in NPKBZn combination was reported by (Dash et al., 2015).

The highest 1000 grain weight of rice from NPKSZn might also be attributed to an increase in availability of Zn in the soil solution. An increase in1000 grains weight of rice up on Zn fertilization might also be due to its involvement in the carbonic anhydrase activity and more carbohydrate accumulation in the seeds (Sudha and Stalin, 2015). Furthermore, Cliquet et al. (1990) reported significant difference on grain yield through direct or indirect effects of K on other morphological and physiological parameters. In a similar scenario, Havlin et al. (2014) explained that K is involved in the working of more than 60 enzymes, in photosynthesis and the movement of its products (photosynthates) to storage organs (seeds, tubers, roots and fruits). The result also revealed that 1000 grain weight of rice was significantly ($p < 0.00$) influenced by the main effect of variety. Despite this, its interaction with fertilizer treatments did not show significant difference in this parameter. The highest1000 grain weight of 30.1 g was obtained from NERICA-4. In contrast, the lowest value of this parameter (26.9 g) was scored from Nechu Eruze that was statistically similar with that recorded from variety Superica-1 (26.9 g) (Table 4). Previous result also confirmed the present finding (Mayumi et al., 2017).

Grain yield

Primary, secondary and micronutrient combinations significant increased grain yield of rice. The omission of all macro and micro nutrients from the experimental plot drastically decreased yield than plots fertilized with complete treatments; NPKSZn and NPKSCaZn. The highest grain yield of 4055.6 kg ha^{-1} was obtained from NPKSZn application that was statistically similar with that obtained from NPKSCaZn. In contrast, the lowest grain yield of rice was obtained from the control; all the other fertilization treatments performed in between. Compared to the recommended NP and NPK combinations mean grain yield was increased by 477.8 and 455.6 kg ha^{-1} with the application of NPKSZn nutrients, respectively (Table 4). A similar result on upland rice was also reported (Kaizzi et al., 2018). Our result is also in agreement with the finding of Shah et al. (2008) who reported that long-term omission of major nutrient individually from the complete treatment (NPKSZn) significantly decreased rice yield and was significantly higher than control . Furthermore, the finding of Dash et al. (2015) showed that highest significant grain yield was recorded when rice received primary secondary and micronutrients (NPKSBZn) and yield decreased by 19.4- 27% due to omission of NPK or PK and by 17.1- 32.6% in absence of S and Zn individually or in combination. The lowest yield in control plots might be due to reduced vegetative development that resulted in lower radiation interception and, consequently, low efficiency in the conversion of solar radiation (Sallah et al., 1998). The increase in grain yield with the balanced nutrient supply which contained primary, secondary and micronutrients was an indicator of low soil fertility level in Guraferda District of Southwestern Ethiopia for rice production. Benti (1993) stated that, although adoption of new varieties is moving fast in Ethiopia, fertilizer management techniques need to supplement the existing potential of the varieties. This showed that low soil fertility is among the greatest constraints to crop production in Ethiopia (Kelsa et al., 1992). Grain yield increase with NPKSZn and NPKSCaZn which contained K^+ indicated that there is a need to supplement the element for rice production. In this scenario, Fageria and Baligar (2005) reported that many soils of the tropical regions are unable to supply sufficient K^+ to field crops. Hence, application of this element in adequate amount is essential for obtaining optimal crop yields. Many other researchers also have reported an increase in yield through potassium application (Grunes et al., 1998; Johns and Vimpany, 1999; Abebe et al., 2020). The increase in grain yield could be attributed to beneficial influence of yield contributing

Table 5. Main effect of variety and fertilizer type on crude protein content of the grain (%).

Treatments	Crud protein (%)
Nutrient combinations	
Control	1.96[c]
NP	2.17[c]
NPKSZn	2.77[a]
NPKSCaZn	2.57[ab]
NPK	2.43[b]
LSD 5%	0.218
Varieties	
NERICA-4	2.48
Superica-1	2.35
Nechu Eruze	2.31
LSD 5%	NA
CV (%)	9.5

Means followed by the same letter in the same column are not significantly different at $p < 0.05$ probability level, NS: not significantly.

characters and positive interaction of nutrients in the crop through the application of primary, secondary and micronutrients. Grain yield increase with NPKSZn compared to NPK highlighted the need to supplement S and Zn for rice production in the study area. A significant yield increase of rice with combined application of S and Zn was also reported (Singh et al., 2012). Grain yield of rice was also affected by the main effect of varieties. The highest grain yield of rice was obtained at variety NERICA-4, while the lowest value was obtained with variety Superica-1 followed by Nechu Eruze (Table 4). This confirmed the report of Tefera et al. (2019) and Islam et al. (2010) that varieties with longer growth duration usually produce more grain yield than the varieties with shorter growth duration. Further, the difference in yield among the varieties might also be attributed to the difference in the number of productive tillers, varietal yielding capabilities and also to the growth performance of every variety tested (Romualdo and Jesusa, 2014).

Grain protein content

Combined application of S and Zn with macronutrients increased grain protein of rice. The highest grain protein concentration of 2.77% was recorded at a nutrient combination of NPKSZn, which however was statistically similar with that recorded from the application of NPKSCaZn (2.57%). In contrast, the lowest grain protein was obtained from the control treatments (Table 5). Application of NPKSZn resulted in the highest grain protein content, which was significantly higher than the recommended NP and NPK fertilizer. The mean values of grain protein in NPKSZn increased by 41.3% as compared to control. The highest grain protein concentration from the combinations of primary, secondary and micronutrients might be attributed to the presence of N, S and Zn. This is also in agreement with the findings of Hakoomat et al. (2014) who reported that protein contents of rice grain were significantly improved by combined application of N and Zn application. Moreover, significant increase in grain protein content of rice with the application of S was also reported by Rahman et al. (2007). Rice protein is valuable as it has unique hypoallergenic properties and ranks high in nutritive quality (rich in the essential amino acid lysine) among the cereal proteins (Nasrollah and Seyed, 2014). Liu et al. (2008), in their research, showed a significant positive correlation between activities of protein synthesizing enzymes and absorption of nitrogen in grain. The highest protein content in Zn containing nutrient combination might also be due to the fact that application of Zn increased N-metabolism which enhanced accumulation of amino acids and drastically increased the rate of protein synthesis and consequently protein content in grain (Sudha and Stalin, 2015). The role of Zn in increasing protein might also be due to the fact that zinc application enhanced Zn concentration in the plant which might be associated with RNA and ribosome induction. The result accelerated protein synthesis (Keram et al., 2014).

Conclusion

Balanced nutrient supply based on limiting nutrients for a cereal crop improved yield and nutritional value of the grain. Combined application of primary, secondary and micronutrients on upland rice showed a significant effect on grain yield and protein content in the study area. On the other hand, nationally recommended NP combinations performed low compared to NPKSZn, indicating that rice production in the study area needs application of secondary and micronutrients in addition to primary nutrients. The result revealed maximum grain yield, 1000 grain weight, grain protein content, number of grain per panicle and number of effective tiller per m^{-2} from NPKSZn. Among the rice varieties, NERICA-4 performed better in all parameters. Therefore, to improve grain yield and protein content of rice in the study area combined application NPKSZn might be recommended. However, further research has to be done to get strong recommendations for fertilizers and varieties in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

Financial support from Mizan-Tepi University is gratefully appreciated. The author extend their thanks to their colleagues for their unremitting efforts to this experiment and also grateful to Mr. Minyahil Tilahun for his assistance in an early version of this manuscript.

REFERENCES

Abebe A, Abera G, Beyene S (2020). Sorption characteristics, growth and yield response of wheat (*Triticum aestivum* L.) to application of essential nutrients on Nitisol and Vertisol of Central Highland of Ethiopia. African Journal of Plant Science 14(3):108-120.

Africa Rice Center (WARDA) (2008). NERICA: the New Rice for Africa a Compendium. In: Somado AE, Guei GR, Keya OS (eds), Cotonou, Benin: Africa Rice Center (WARDA). Rome, Italy: FAO; Tokyo, Japan: Sasakawa Africa Association. P. 210.

Arif M, Zahid M, Tasneem M, Bashir F, Shafiq M, Akhtar N, Yaseen G, Anwar A, Tariq I (2018). Exogenously applied nitrogen and zinc fertilizers improved the rice productivity. Current Investigations in Agriculture and Current Research DOI: 10.32474/CIACR.2018.04.000183.

Benti T (1993). The need and objective of the 1st National Maize Workshop. In: Proceedings of the 1st National Maize Workshop of Ethiopia, 5-7 May, 1992, IAR and IMWIC, Addis Ababa, Ethiopia.

Bhuiyan MS, Zahan A, Khatun H, Iqbal M, Alam F, Manir MR (2014). Yield performance of newly developed test crossed hybrid rice variety. International Journal of Agronomy and Agricultural Research 5(4):48-54.

Brady NC, Weil RR (2002). The nature and properties of soils 13th edition. Prentice-Hall. Inc New Jersey, USA

Brahmanand PS, Ghosh BC, Sahoo N (2009). Effect of organic and inorganic sources of nitrogen on productivity of rice in rice-fish farming system. Archives of Agronomy and Soil Science 55(6):663-670.

Chimdessa D (2016). Blended fertilizers effects on maize yield and yield components of Western Oromia, Ethiopia. Agriculture, Forestry and Fisheries 5(5):151-62.

Cliquet JB, Deléens E, Mariotti A (1990). C and N mobilization from stalk and leaves during kernel filling by ^{13}C and ^{15}N tracing in *Zea mays* L. Plant Physiology 94:1547-1553.

CSA (2017). Statistical report on area and production of crops. Volume I. Statistical bulletin 584. Addis Ababa, Ethiopia.

Dash AK, Singh HK, Mahakud T, Pradhan KC, Jena D (2015). Interaction effect of nitrogen, phosphorus, potassium with sulphur, boron and zinc on yield and nutrient uptake by rice under rice - ricecropping system in Inceptisol of Coastal Odisha . International Research Journal of Agricultural Science and Soil Science 5(1):14-21.

Delessa A (2007). Effect of sowing method and seeding rate on yield and yield components of rainfed rice (*Oryza sativa* L.) varieties in Woliso, South-West Shoa Zone of Oromia Region. MSc Thesis, Haramaya University.

Demiss M, Beyene S, Kidanu S (2019). Biomass accumulation and potassium concentrations in tissue of Teff (*Eragrostis tef* Zucc. Trotter) at three growth stages in Vertisols and Nitisols of the central highlands of Ethiopia. African Journal of Agricultural Research 14(6):345-353.

Elias E (2002). Farmers perceptions of soil fertility change and management. In: SOS-Sahel and institute for sustainable development, Addis Ababa.

Ethiopian Agricultural Transformation Agency (ATA) (2016). Soil fertility status and fertilizer recommendation atlas of the Southern, Nations, Nationalities and Peoples' Regional State, Ethiopia.

Ethiopian Soils Information System (EthioSIS) (2013). Towards improved fertilizer recommendations in Ethiopia – Nutrient indices for categorization of fertilizer blends from EthioSIS woreda soil inventory data. Addis Ababa, Ethiopia.

Eyasu E (2017). Characteristics of Nitisol profiles as affected by land use type and slope class in some Ethiopian highlands. Environmental Systems Research 6:20.

Fageria NK, Baligar VC (2005). Growth components and zinc recovery efficiency of upland rice genotypes. Pesquisa Agropecuária Brasileira 40(12):1211-1215.

FAO (2001). Lecture notes on the major soils of the world. Driessen P, Deckers J, Nachtergaele F (eds.). Food and Agricultural Organizations. Rome, Italy. P. 334.

FAO (2015). Rice market monitor. Vol XVI1I: Issue No. 1

FAOSTAT (Food and Agriculture Organization Statistics) (2017). Agricultural database. /http://faostat.fao.org./ (accessed on February 18, 2018)

Fayez A, Khan H (2016). Effect of different fertilizer treatments on the performance of some local rice varieties under SRI (system of rice intensification) and conventional management practices at district Swat. Pure and Applied Biology 5(1):37-47.

Ferdous A, Syeda M, Noor HM, Hoque M, Hossain Md, Hasan KA (2018). Enhancing rice yield in acidic soil through liming and fertilizer management. Journal of Bangladesh Agricultural 16(3):357-365.

Grunes A, Alpaslan M, Inal A (1998). Critical nutrient concentrations and antagonistic and synergistic relationships among the nutrients of NFT-grown young tomato plants. Journal of Plant Nutrition 21:2035–2047.

Hakoomat A, Zuhair H, Ahmad NS, Naeem S, Muhammad KQ, Shazia K, Muhammad FQ (2014). Nitrogen and Zinc interaction improves yield and quality of submerged basmati rice (*Oryza sativa* L.). Notulae Hotanicae Horti Agrobotanici Cluj-napoca 42(2):372-379.

Havlin JL, Beaton JD, Tisdale SL, Nelson WL (2014). Soil fertility and fertilizers. Prentice Hall Inc, New Jersely, USA.

Islam MS, Peng S, Visperas RM, Bhuiya MSU, Hossain SA, Julfiquar, AW (2010). Comparative study on yield and yield attributes of hybrid, inbred, and NPT rice genotypes in a tropical irrigated ecosystem. Bangladesh Journal of Agricultural Research 35(2):343-353.

Johns GG, Vimpany IA (1999). Interaction of pH amendment and potassium fertilizer on soil chemistry and banana plant growth. Australian Journal of Agricultural Research 50:199-210.

Kaizzi KC, Nansamba A, Kabanyoro R, Lammo J, Rware H (2018). Upland rice response to fertilizer in three agroecological zones of Uganda. African Journal of Plant Science 12(3):65-72.

Kassa H Dondeyne S, Poesen J, Frankl A, Nyssen J (2017). Impact of deforestation on soil fertility, soil organic carbon and nitrogen stocks: the case of the Gacheb catchment in White Nile Basin,

Ethiopia. Agriculture Ecosystem and Environment 247:273-282.
Kelsa K, Tadesse Y, Tesfa B (1992). Influence of fertilizer and its management practices on maize grain yields in major maize producing areas of Ethiopia. In: proceedings of the first national maize work shop of Ethiopia. IAR (Institute of Agricultural Research), Ethiopia.
Keram KS, Sharma BL, Kewat ML, Sharma GD (2014). Effect of zinc fertilization on growth, yield and quality of wheat grown under agro-climatic condition of Kymore plateau of Madhya Pradesh, India. The Bioscan 9(4):1479-1483.
Kihara J, Weldesemayat GS, Nziguheba G, Kinyua M, Zingore S, Sommer R (2017). Application of secondary nutrients and micronutrients increases crop yields in sub-Saharan Africa. Agronomy and Sustainable Development 37(25).
Kinfe H, Tsehaye Y, Redda A, Welegebriel R, Yalew D, et al. (2017). Yield and yield related performance of upland rice genotypes in Tselemti district, north Ethiopia. Journal of Rice Research 5(187).
Kumar A, Yavdav SD (2005). Influence of continuous cropping and fertilization on nutrient availability and productivity of alluvial soil. Journal of Indian Society of Soil Science 55(2):194-198.
Landon JR (2014). Booker tropical soil manual: A hand book for soil survey and agricultural land evaluation in the tropics and subtropics.
Liu J, Wu YH, Yang JJ, Liu YD, Shen FF (2008). Protein degradation and nitrogen remobilization during leaf senescence. Journal of Plant Biology 51(1):11-19.
Mayumi K, Daigo M, Naoya A, Akira M, Yoshinori Y (2017). Growth and yield responses of upland NERICAs to variable water management under field conditions. Plant Production Science 20(1):36-46.
Mekonnen G, Woldesenbet M, Yegezu E (2017). Determination of critical period of weed-crop competition in rice (*Oryza sativa* L.) in Bench Maji and Kaffa Zone, South Western Ethiopia. Journal of Plant Sciences 5(3):90-98.
Melesse H (2007). Response of bread wheat (*Triticum aestivum* L.) varieties to N and P fertilizer rates in Ofla district, southern Tigray, Ethiopia. M.Sc.Thesis Haramaya University.
Nasrollah AZ, Seyed AH (2014). Relationship between nitrogen fertilization and rice grain (*Oryza sativa* L.) properties. Bull. Environmental Pharmacology and Life Science 3(2):83-91.
Negusseie SZ, Zewde G, Tareke B (2008). Moving up in Ethiopia. Rice today international magazine of international rice research institute.
Nelson DW, Sommers LE (1973). Determination of total nitrogen in plant material. Agronomy Journal 65(1):109-12.
Olsen SR, Sommers LE (1982). Phosphorus. pp. 403-429. In: Page AG ed. Methods of Soil Analysis, part 2: Chemical and microbiological properties. Agronomy 9. Madison, WI.
Pedda BP, Shanti M, Rajendra PB, Minhas PS (2007). Effect of zinc on rice in rice –black gram cropping system in saline soils. Andhra Agriculture Journal 54(2):47-50.
Rahman MN, Sayem SM, Alam MK, Islam MS, Mondol IA (2007). Influence of S on nutrient content and uptake by rice and its balance in old Brahmaputra floodplain soil. Journal of Soil and Nature 1(3):5-10.
Rana KW, Kashif RS (2014). Effect of different zinc sources and methods of application on rice yield and nutrients concentration in rice grain and straw. Journal of Environmental and Agricultural Sciences 1(9).
Rhodes E, Bationoa A, Smaling AE, Viskerc A (1996). Nutrient stocks and flows in West African soils. In: Wuange A, DeJager A, Smaling AM (eds.), Key to Sustainable Development, pp 22-32.
Romualdo MO, Jesusa DO (2014). Testing and evaluation of upland rice varieties In: Prospects in Asian Agriculture. International Rice Research Conference, Bangkok, 3- 5 June 1996.
Sachdev P, Dep DL, Rastogi DK (1988). Effect of varying levels of zinc and manganese on dry matter yield and mineral composition of wheat plant at maturity. Journal of Nuclear Agriculture and Biology 17:137-143
Sadiqur R, Taslima J, Syed M. Mizanur R, Musfiqur R, Moynul H, Abu A (2018). Evaluation of some transplanted AUS rice genotypes for morphology, yield and disease incidence. European Academic Research 6:291-302.
Sallah PY, Ehlke NJ, Geadelmann JL (1998). Progress from selection in maize population evaluated under three nitrogen fertilizer levels. African Journal of Crop Science 6:241-248.
SAS Institute (2003). SAS user's guide, statistics version 9.1 ed. SAS Inst., Cary, NC, USA.
Seck PA, Diagne A, Mohanty S, Wopereis MCS (2012). Crops that feed the world: rice. Food Science 4:7-24.
Shah AL, Haque MM, Zaman SK (2008). Implications of long-term missing element trial: efficacy of potassium fertilizer to increase rice yield. Bangladesh Rice Journal 14:55-59.
Sillanpaa M (1982). Micronutrients and the nutrient status of soils: a global study, Issue 48. FAO, Rome.
Singh AK, Manibhushan, MK, Ashutosh U (2012). Effect of sulphur and zinc on rice performance and nutrient dynamics in plants and soil of Indo Gangetic Plains. Journal of Agricultural Science 4(11).
Sudha S, Stalin P (2015). Effect of zinc on yield, quality and grain zinc content of rice genotypes. International Journal of Farm Sciences 5(3):17-27.
Suleiman AA, Nganya JF, Ashraf MA (2014). Effect of cultivar and sowing date on growth and yield of wheat (*Triticum aestivum* L.) in Khartoum, Sudan. Journal of Forest Products and Industries 3(4):198-203.
Tefera W, Dilnesaw Z, T/Michael K, Adane A, Getie A (2019). Performance evaluation of six rice (Oryza sativa L.) varieties at beles sugar development project, Ethiopia. International Journal of Advanced Research in Biological Sciences 6(2):121-128.
Tekalign T (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working document No. 13. International livestock research center for Africa, Addis Ababa, Ethiopia.
Weldegebriel DG (2015). Assessment of production and reproductive performances of cattle and husbandry practices in Bench-Maji Zone, Southwest Ethiopia. Global Journal of Animal Scientific Research 3(2):441-452.
Yesuf E, Worku W (2018). Effect of sowing methods and applied nitrogen rates on growth and productivity of upland rice (*Oryza sativa*) in the lowland plains of Gambella. International Journal of Comprehensive Research in Biological Sciences 5(6):34-44.

Vol. 14(4), pp. 192-204, May 2020
DOI: 10.5897/AJPS2019.1839
Article Number: 4FA003C63780
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Standard heterosis and trait association of maize inbred lines using line x tester mating design in Ethiopia

Abenezer Abebe[1]*, Legesse Wolde[1] and Wosene Gebreselassie[2]

[1]Holetta Agricultural Research Center, Senior Maize Breeder, Ethiopia.
[2]Department of Horticulture and Plant Science, College of Agriculture and Veterinary Medicine, Jimma University, Ethiopia.

Received 28 May, 2019; Accepted 3 July, 2019

Maize is one of the high priority crops to feed the ever increasing population in Africa, however, its production limited by shortage of high yielding variety coupled with biotic and abiotic stresses. The study was initiated to evaluate the heterotic performances of the F_1 hybrids over the standard checks (Kolba and Jibat). Fifty entries consists 48 F_1 single crosses developed from 24 inbred lines and 2 testers using line x tester design and two commercial check hybrids used in the study. The experiment was conducted using alpha lattice design with two replications at Ambo and Holeta Agricultural Research Center. Analysis of variance revealed existence of significant genetic variation among genotypes for all studied traits except for plant aspect. Location x entry interaction for most of the traits was not significant which suggests hybrid performance was consistent across tested locations. The magnitude of standard heterosis over Kolba and Jibat for grain yield ranged from -40.31 (L13 x T1) to 32.44% (L23 x T1). Cross L23 x T1 exhibited maximum standard heterosis (32.44%) over Kolba and Jibat for grain yield followed by L11 x T1 (22.18%). Positive and significant genotypic, phenotypic correlation coefficient were recorded for yield with plant height (rg=48 and rp=40**), ear height, ear per plant, number of kernels per row, ears length, ear diameter and number of kernel rows per ear. Number of ears per plan (1.08) had the highest positive direct effect on grain yield followed by ear diameter (0.95), number of kernels per row and number of kernel rows per ear indicating the effectiveness of direct selection. Finally, crosses with high standard heterosis for yield and yield components could be used for developing high yielding maize hybrids in the future maize breeding program.**

Key words: Heterosis, Hybrid, correlation, path analysis.

INTRODUCTION

Maize (*Zea mays* L., 2n = 20) is a monoecious; C4 plant belongs to the tribe Maydeae of the family Poaceae. It is a tall, robust, annual, usually with a single dominant stem, although there may be few tillers in some genotypes and environments. Prasanna et al. (2001) noted that the crop is a vital source of calorie, protein and some important

*Corresponding author. E-mail: abenezerabebetefera@gmail.com, Tel.: +251913449020.

vitamins and minerals to billions of people world-wide, particularly in Africa, South America and Asia.

Approximately 88% of maize produced in Ethiopia is consumed as food, both as green and dry grain (Tsedeke et al., 2015).

Maize is cultivated globally as one of most important cereal crops and ranks third next to wheat and rice. CSA (2017) reported that in Ethiopia by 2016/2017 main cropping season out of the total grain crop area, 81.27% was under cereals of which maize share as large area as 16.98%, after tef (24%). Regarding total annual production, cereals contributed 87.42% in which maize ranked first 27.02% followed by teff and sorghum (CSA, 2017). The national average yield in Ethiopia is still as low as 3.675 t ha^{-1} (CSA, 2017) compared to that of the developed world of 10.96 t ha^{-1} (FAS, 2017) which implies the importance of increasing maize productivity as high national priority issue. The shortages of high yielding varieties or potential parent materials and the effect of biotic and abiotic stresses are the major constraints limiting maize production and productivity (Mosisa et al., 2012). This implies the need for developing high yielding maize varieties from suitable parents or crosses.

Hybrid varieties are the first generations (F1) from crosses between two pure lines, inbred lines, open pollinated varieties or other populations that are genetically dissimilar. Breeding strategies based on selection of hybrids require expected level of heterosis. Heterosis is important in breeding program especially for cross pollinated crop and is a great achievement to meet the world's food needs (Duvick, 1999). Feng et al. (2015) pointed out that understanding the magnitude of hybrid vigor (heterosis) helps us for effective selection of best combinations of parents for predicting breeding goal.

The efficiency of breeding programme depends mainly on the direction and magnitude of association between yield and its components and also the relative importance of each factor involved in contributing to grain yield (Jakhar et al., 2017). Munawar et al. (2013) noted estimation of trait association is important for the selection of favorable plant types for effective maize breeding programs. Mallikarjuna et al. (2011) and Zeeshan et al. (2013) also reported that correlation and path coefficient analysis were used to measure the level of relationships between the traits, give reliable and useful information on nature, extent and direction of selection. The path analysis provides the effective measures of direct and indirect causes of association and depicts the relative importance of each factor involved in contributing to the final product (Jakhar et al., 2017).

Heterosis and trait association has been studied in Ethiopia for different sets of new maize inbred lines (Dagne et al., 2007; Worku et al., 2008; Girma et al., 2015 and Tolera et al., 2017). Highland maize breeding program at Ambo Agricultural Research Center (AARC) in collaboration with CIMMYT recently developed crosses whose standard heterosis has not been studied. Hence, this study was conducted to evaluate the heterotic performances of the F_1 hybrids over the standard checks and trait association for yield and yield related traits.

MATERIALS AND METHODS

The experiment was conducted at Ambo and Holeta Agricultural Research Centers of the Ethiopian Institute of Agricultural Research (EIAR), Ethiopia during the main cropping season of May 2017 to December 2018. Holeta Agricultural research center (HARC) is located in West Showa zone of the Oromia region, 33 km west of Addis Ababa at 09° 04' 12" N and 38° 29' 45" E and an elevation of 2400 m.a.s.l. The center receives an average rainfall of 1102 mm per annum. The maximum and minimum temperatures of this site are 6 and 22°C, respectively. The center has nitosols and vertisols soil types with pH of 6.0 (Tamene et al., 2015).

Ambo Agricultural Research Center (AARC) is located in West Showa zone of the Oromia region, 114 km west of Addis Ababa at 8° 57' N latitude and 37° 51' E longitudes with an altitude of 2225 m.a.s.l. The site receives an average rainfall of 1115 mm. The maximum and minimum temperatures of this site are 11.7 and 25.4°C, respectively. The soil type of Ambo is clay (heavy vertisols) with a pH of 7.8 (Demissew, 2014).

Experimental materials

The experiment consisted of 50 maize entries which include 48 testcrosses and two hybrid checks (AMH853-Kolba and AMH851-Jibat). The testcrosses (48) were generated from crossing of 24 inbred lines (female parents) with two testers (male parents) in line x tester mating design during 2015/2016 cropping season at AARC. The inbred lines were developed at Ambo Agricultural Research Center from CYMMYT materials using ear-to-row selection and subsequent selfing until they attain homozygosity. The inbred line testers used for the formation of the testcrosses were FS59 (Tester 1) and FS67 (Tester 2) as shown in Table 1. The first tester was from heterotic group B, while the second was from heterotic group A. Ambo maize breeding program commonly uses these testers in the identification of promising inbred lines. The hybrid checks are commercial maize hybrids released for highland and sub-humid agro ecologies of Ethiopia. AMH851 (Jibat) and AMH853 (Kolba) are three-way cross hybrid varieties released by Ambo Agricultural Research Center, highland maize breeding program in 2011 and 2015, respectively. They take about 178 days for grain mature at Ambo and similar environments. Besides, hybrid checks are high yielding, tolerant/resistance to major maize disease in the country and well adapted to the altitude ranging from 1800-2600 m in the highland sub-humid agro-ecological conditions of the country (MoANR, 2016).

Experimental design and procedure

The experimental materials along with two hybrid checks were grown during the 2016/2017 main cropping season using alpha lattice design (Patterson and Williams, 1976) with two replications, 10 incomplete blocks and 5 plots per the incomplete blocks at both locations. Each entry was planted in a single row plot of 5.25 m length with a spacing of 75 cm between rows and 25 cm between plants. Seeds were planted with two seeds per hill and later thinned to one plant at four leaf stage.

Data collection and analysis

Data were collected days to 50% anthesis (AD), days to 50%

Table 1. List and pedigree of parents and hybrid checks used for the study.

S/N	Line code	Pedigree	
1	L1	(CML442*/OFP4)-B-4-2-2-B-B-B-#	
2	L2	(CML495*/OFP14)-7-1-5-1-1-B-B-#	
3	L3	(CML442*/OFP4)-B-17-1-1-B-B-B-#	
4	L4	(CML495*/OFP6)-B-27-1-1-B-#	
5	L5	(CML539*/OFP14)-2-1-1-2-2-B-B-#	
6	L6	(CML442*/OFP4)-B-17-5-1-B-B-B-#	
7	L7	(CML395*/OFP105)-1-1-1-1-1-B-B-#	
8	L8	(CML395*/OFP105)-1-2-3-1-1-B-B-#	
9	L9	CML539*/OFP1)-B-11-2-2-B-B-B-#	
10	L10	(CML444*/OFP23)-6-3-1-1-1-B-B-#	
11	L11	(LPSC7-F96-1-2-1-1-B-B-B*/OFP9)-3-2-1-1-1-B-B-#	
12	L12	(CML444*/OFP14)-3-2-4-1-2-B-B-#	
13	L13	(CML444*/OFP4)-B-4-1-1-B-B-B-#	
14	L14	(CML444*/OFP4)-B-6-1-1-B-B-B-#	
15	L15	(CML537*/OFP106)-6-1-3-1-2-B-B-#	
16	L16	(CML537*/OFP106)-7-1-2-1-2-B-B-#	
17	L17	(CML491*/OFP4)-B-10-1-2-B-B-B-#	
18	L18	CML546-#	
19	L19	([SYN-USAB2/SYN-ELIB2]-12-1-1-1-B*4-B-B-B*/OFP105)-4-2-1-1-2-B-B-#	
20	L20	([CML312/[TUxPSEQ]C1F2/P49-SR]F2-45-3-2-1-BB//INTA-F2-192-2-1-1-1-BBBB]-1-5-1-1-1-BBB-B-B-B*/OFP106)-1-2-2-2-1-B-B-#	
21	L21	([CML444/CML395//DTPWC8F31-1-1-2-2-BB]-4-2-2-1-2-BB-B-B-B*/OFP105)-1-4-3-3-2-B-B-#	
22	L22	([CML444/CML395//DTPWC8F31-1-1-2-2-BB]-4-2-2-1-2-BB-B-B-B*/OFP105)-2-1-1-2-1-B-B-#	
23	L23	(LPSC7-F71-1-2-1-2-B-B-B*/OFP2)-B-1-3-2-B-B-B-#	
24	L24	[CML444/CML395//DTPWC8F31-1-1-2-2-BB]-4-2-2-2-1-B*7-B-#	
25	T1	Tester	FS59
26	T2		FS67
27	-	Checks	JIBAT
28	-		KOLBA

Source: Ambo plant protection research center, highland maize breeding program (2017).

female flowering (SD), anthesis-silking interval (ASI), ear aspect (EA), plant aspect (PA), grain yield (GY), number of ears per plant (EPP) and thousand kernel weight (TKW) on plot basis. On plant basis data were collected on plant height (PH), ear height (EH), ear length (EL), ear diameter (ED), number of kernel rows per ear (KRPE) and number of kernels per row (KPR).

The data obtained for different traits from field measurements were organized and analyzed using SAS statistical package (SAS, 2014). Analysis of variance across location was conducted with PROC GLM procedure (SAS, 2014) by considering location, replication and blocks as random and entry/genotype as fixed factors with statement of RONDOM and TEST option.

Estimation of standard heterosis

Standard heterosis was calculated for traits that showed statistically significant differences among genotype based on the procedure suggested by Falconer and Mackay (1996).

$$\text{Standard heterosis (SH)} = \left(\frac{F1-SC}{SC}\right) x\ 100$$

Where; SH = standard Heterosis, F1 = mean value of the crosses, SC = mean value of standard checks. The significant difference for percentage of standard heterosis was tested by t-test. Standard error of difference for heterosis and t-value will be computed as follows;

$$\text{SE (d) for SE (d)} = \sqrt{\frac{2MSe}{r*loc}}\ ,\ t = \frac{F1-SC}{SE(d)}$$

Where, SE (d) is standard error of the difference, MSe =error mean (Paschal and Wilcox, 1975).

Correlation and path coefficient analysis

Phenotypic and genotypic correlations were estimated for the characters from variance of each character and the covariance components for each pair of characters (Comstock and Robinson, 1952; Miller et al., 1958). The analysis was performed using SAS 9.3 software package and test of significance of correlation coefficients were carried out comparing the computed values against table *r*

Table 2. Analysis of variance for yield and yield related traits of maize genotypes evaluated at Holeta and Ambo.

Trait	L, df=1	Rep(L)df=2	Blk(L*R) df=36	Ent df=49	Ent*L df=49	Error df=62	Mean±SE(m)	CV%
GY(kg)	8.38*	0.03	1.29	4.41*	2.63**	1.1	7.53± 0.52	13.9
AD(days)	14162.4**	24.23**	2.96	13.33**	2.77	3.18	104.52±0.89	1.71
SD(days)	18489.6**	19.34**	2.60	15.66**	2.51	3.31	105.15±0.91	1.73
ASI(days)	0.63**	0.001	0.005	0.007*	0.005	0.004	1.2± 0.03	5.52
PH(cm)	574.6**	779.0**	161.6	1631.89**	237.4*	139.1	251.07±5.9	4.70
EH(cm)	5724.5**	398.33**	45.04	943.11**	85.85*	54.64	136.66±3.7	5.41
EPO(%)	0.07**	0.0002	0.001	0.004**	0.0007	0.002	0.54±0.02	7.33
EPP(no)	1.49**	0.007	0.03	0.13**	0.05	0.03	1.70±0.09	10.18
EA(scale)	0.78*	0.91**	0.13	0.43**	0.19	0.13	3.12±0.18	11.56
PA(scale)	2.88**	0.75*	0.15	0.20	0.14	0.20	3.30±0.22	13.69
EL(cm)	1.69	8.82**	0.98	3.61**	1.21	0.81	15.47±0.45	5.82
ED(mm)	1.62**	0.004	0.03	0.10**	0.03**	0.03	4.32±0.09	3.84
KRPE(no)	10.76**	0.58	0.63*	1.21**	0.47	0.37	12.86±0.3	4.74
KPR(no)	19.22*	25.22**	7.43*	8.51**	6.50	4.22	32.3±1.03	6.37
TKW(gm)	193827.8**	27.26	743.1	3102.2**	1603.9*	947.3	305.0±15.39	10.09

**significant (0.01), *significant (0.05), L=location, Rep=replication, Blk=blocks, Ent= Entry, GY= grain yield, AD=anthesis days, SD=silking days, ASI=anthesis silking interval, PH=plant height, EH= ear height, EPO= ear position, EPP=ear per plant, EA=ear aspect, PA=plant aspect, EL=ear length, ED=ear diameter, KRPE=kernel rows per ear, KPR=kernels per row, TKW=thousand kernel weight.

values at 5 and 1% probability levels at n-2 degree of freedom (Fisher and Yates, 1963). Path coefficient analysis carried using the model and the formula which was adopted by Dewey and Lu (1959) the path and residual effect were computed. The residual effect, U $=\sqrt{1-R^2}$, $R^2 = \sum \mathrm{pij\ rij}$ Retherford and Choe (2011), rij = pij+ Σrikpkj, where, rij = mutual association between the independent character (i) and dependent character (j) as measured by the correlation coefficient, pij = component of direct effects of the independent character (i) on dependent character (j) as measured by the path coefficient and, ∑rikpkj = summation of components of indirect effect.

RESULTS AND DISCUSSION

The analysis of variance, standard heterosis, correlation and path coefficient analysis were conducted and the results are discussed below.

Analysis of variance

The analysis of variances for yield and yield related traits combined location are presented in Table 2. Significant differences were detected between the two locations for all of the studied traits except for ear length, indicating that the two locations differed in the environmental conditions to cause variation which agreed with the finding of Aly et al. (2011). Entry mean squares were significant (p<0.01 or p<0.05) for all traits except for plant aspect as shown in Table 2.

The significance differences obtained among the entries for almost all studied traits indicates the presence of high degree of genetic variation and had potential of making high yielding hybrids. Similarly, Dagne et al. (2010), Amiruzzaman et al. (2010), Amare et al. (2016) and Ziggiju et al. (2017) reported significant difference among genotypes for grain yield and yield related traits of different sets of maize genotypes. Mean squares of entry x location interaction for most of the studied traits were non-significant, suggesting the consistence in performance of genotypes from one location to another regarding these traits as illustrated in Table 2. On the other hand, variables like grain yield, plant and ear height, ear diameter and 1000 kernels weight showed significant entry x location interaction mean squares, disclosing entries differed in their performance from one location to another for these traits.

Similar to the current finding, Gudeta et al. (2015) found significant entry x location interaction for grain yield, 1000 kernels weight and ear height for different maize genotypes. Alake et al. (2008), Beyene et al. (2011) and Murtadha et al. (2016) also reported significant entry x location interaction effect for certain traits and referred to the presence of wide variability with regard to tested entry and locations. The result showed the location played significant role in the variation of these traits. If significant genotype x location interaction mean squares existed, different genes were involved in controlling the traits showing the inconsistency of the genes over locations (Dagne, 2008). The interaction of entry with location suggests further evaluation of the genotypes across more number of locations to remove environmental effect from computation genetic variance. Variation among locations, and single cross hybrids which interact more with environment would be responsible for the interaction of entry by location.

Standard heterosis

The estimates of standard heterosis over the standard checks were computed for combined data of grain yield and yield related traits that showed significant difference among genotypes as shown in Table 3. The magnitude of standard heterosis over Kolba and Jibat for grain yield ranged from -40.31 (L13 x T1) to 32.44% (L23 x T1). The cross L23 x T1 (32.44%) exhibited maximum standard heterosis for grain yield followed by L11 x T1 (22.18%). Nine crosses showed negative significant standard heterosis over the best hybrid check (Kolba) for grain yield, while two crosses revealed positive and significant standard heterosis. Several scholars Amiruzzaman et al. 2010, Kustanto et al. 2012, Hiremath et al. 2013, Melkamu et al. 2013, Habtamu 2015, Bitew 2016, Gemechu et al. 2017 and Ziggiju et al. 2017 reported positive and negative significant standard heterosis for grain yield. High level of heterosis observed in the current study could be mainly because of the involvement of more distant related inbred lines. Fato (2010) and Hallauer and Miranda (1988) also suggested that full exploitation of heterosis requires crossing of distantly related materials. The crosses with higher grain yield standard heterosis. Natol (2017) also found that crosses with high standard heterosis also had good specific combining ability. In contrast, Kumar et al. (2014) reported crosses with good specific combining ability effects, but non-significant standard heterosis for grain yield. The difference in these findings might be due to the influence of environmental factors and tested materials.

The standard heterosis for days to 50% anthesis, days to 50% silking and anthesis silking interval ranged from 0 to 8.75%, -1.21 to 8.11% and 1.68 to -13.14%, respectively as illustrated in Table 3a. The current study found none of crosses with significant standard heterosis for days to 50% anthesis and silking towards the desirable direction, which was in agreement with the findings of Dufera et al. (2018). This states the lack of genetic divergence among crosses for selection of early flowering materials; however, Ram et al. (2015), Patil et al. (2017) and Natol et al. (2017) found negative and significant standard heterosis for days to 50% anthesis and suggested that earliness is a desirable character. For anthesis-silking interval, crosses L6 x T1, L9 x T2, L11 x T2, L12 x T2, L19 x T2 and L22 x T1 revealed negative and significant standard heterosis with respective values of -6.99, -10.38, -8.09, -11.58, -10.38 and -9.22%. Negative heterosis for anthesis-silking interval is desirable as it is indicated in pollen shedding and silk receptive synchronization, thereby increasing seed set.

The magnitude of standard heterosis for plant height ranged from -19.96 (L18 x T2) to 13.15% (L5 x T1) and for ear height ranged from -24.18 (L23 x T2 and L24 x T2) to 36.78% (L12 x T2) as shown in Table 3b. Ten crosses had positive and significant heterosis, while 22 crosses showed negative and significant standard heterosis for plant height over the best standard checks, respectively. For ear height, 9 and 27 crosses had positive and negative significant standard heterosis over the best standard checks, respectively. Various workers (Melkamu et al., 2013; Melkamu, 2014; Hailegebrial et al., 2015; Natol, 2017) also found positive and negative significant standard heterosis for plant and ear height. So, crosses with shorter plant and ear height over the standard checks are desirable for lodging resistance and mechanical harvesting. Natol et al. (2017) and Yazachew et al. (2017) also suggested negative standard heterosis for plant and ear height is in desirable; however, Sharma et al. (2017) reported the desirability of for ear height negative standard heterosis, while for plant height either negative or positive. Hence, the negative heterosis for plant and ear height is desirable to enable the selection of effective shorter plant, with reduction of lodging.

Estimate of standard heterosis ranged from -18.80 (L8 x T2) to 48.57% (L23 x T1) for number of ear per plant, -23.47(L9 x T2) to 21% (L15 x T2) for ear length and -13.54 (L7 x T2) to 9.36% (L10 x T1) for ear diameter. The positive standard heterosis for these traits is in a desirable direction. For number of ears per plant, 26 crosses showed positive and significant standard heterosis over hybrid standard checks. Regarding ear length, only L15 x T1 cross showed positive and significant standard heterosis over Kolba. Shushay (2014) and Arsode et al. (2017) for number of ears per plant, Raghu et al. (2011) and Asif et al. (2014) for ear length found comparable results to the current findings. Though ear diameter revealed significantly positive and negative standard heterosis, none of the crosses had wider ear diameter than the best standard checks (Kolba). The positive standard heterosis for number of ear per plant and ear length indicates possibilities of breeding maize for increasing number of ears per plant and ear length thereby improve grain yield.

Standard heterosis for number of kernel rows per ear, number of kernels per row and 1000 kernel weight varied from -8.02 (L21 x T2) to 13.52% (L11 x T1), -17.04 (L9 x T2) to 5.77% (L15 x T1) and -33.76 (L19 x T1) to 27.64% (L21 x T2), respectively. For number of kernels row per ear, 12 crosses exhibited positive and significant standard heterosis over best hybrid check (Kolb) as shown in Table 3c. Maximum positive standard heterosis for number of kernel rows per ear was recorded for cross L11 x T1 (13.52%) followed by L20 x T1 (12.16%). This indicates increased number of kernel rows per ear as compared to the standard checks would be increase grain yield. As to the number of kernels per row and 1000 kernel weight, none of the crosses had positive and significant standard heterosis over the standard checks. This signifies the non-availability of variation among genotypes investigated for these traits. But, Reddy and Jabeen (2016), Gemechu et al. (2017) and Patil et al. (2017) found positive and negative and significant standard heterosis for number of kernels per row and 1000 kernel weight and indicated the possibility of exploitation of the crosses for commercial release. According to Singh (2015), heterosis was positively correlated with genetic distance and specific combining ability. In line with this, crosses with higher

Table 3a. Standard heterosis of 48 testcrosses and two commercial checks hybrids for yield and yield related traits for combined data, 2017.

S/N	Entry	GY (%)		AD (%)		SD (%)		ASI (%)	
		Kolba	Jibat	Kolba	Jibat	Kolba	Jibat	Kolba	Jibat
1	L1xT1	4.89	6.29	0.98	2.75*	0.73	1.97	-0.93	-2.68
2	L1xT2	-0.16	1.17	0.74	2.50	-0.73	0.49	-5.91*	-7.57**
3	L2xT1	10.41	11.89	3.19*	5.00**	2.18	3.44**	-3.85	-5.54*
4	L2xT2	-24.85*	-23.84*	0.49	2.25	0.24	1.47	-0.93	-2.68
5	L3xT1	-29.51**	-28.57*	5.41**	7.25**	6.07**	7.37**	2.67	0.85
6	L3xT2	-11.31	-10.13	5.41**	7.25**	4.85**	6.14**	-1.88	-3.61
7	L4xT1	-1.74	-0.42	0.74	2.50	1.21	2.46	1.80	0.00
8	L4xT2	-7.39	-6.16	0.98	2.75*	0.00	1.23	-3.85	-5.54*
9	L5xT1	12.86	14.36	0.25	2.00	0.49	1.72	0.91	-0.87
10	L5xT2	-3.76	-2.48	0.00	1.75	-0.73	0.49	-2.85	-4.57
11	L6xT1	0.10	1.43	2.46	4.25**	0.73	1.97	-6.99**	-8.63**
12	L6xT2	-22.60*	-21.56*	1.97	3.75**	0.73	1.97	-4.87*	-6.55*
13	L7xT1	-17.94	-16.84	4.91**	6.75**	5.58**	6.88**	2.67	0.85
14	L7xT2	-10.77	-9.58	6.14**	8.00*	4.85**	6.14**	-4.87*	-6.55*
15	L8xT1	15.69	17.23	2.95	4.75**	3.64**	4.91**	2.67	0.85
16	L8xT2	-21.89*	-20.85*	2.46	4.25**	1.94	3.19*	-1.88	-3.61
17	L9xT1	8.94	10.39	0.00	1.75	0.00	1.23	0.00	-1.76
18	L9xT2	-4.28	-3.00	1.23	3.00*	-1.21	0.00	-10.38**	-11.96**
19	L10xT1	0.10	1.43	5.41**	7.25**	5.34**	6.63**	0.00	-1.76
20	L10xT2	9.93	11.40	3.44**	5.25**	2.18	3.44**	-4.87*	-6.55*
21	L11xT1	22.18*	23.81*	4.67**	6.50**	4.61**	5.90**	0.00	-1.76
22	L11xT2	10.09	11.56	4.18**	6.00**	2.18	3.44**	-8.09**	-9.71**
23	L12xT1	9.71	11.17	5.65**	7.50**	4.37**	5.65**	-4.87*	-6.55*
24	L12xT2	-7.30	-6.06	3.93**	5.75**	1.21	2.46	-11.58**	-13.14**
25	L13xT1	-40.31**	-39.51*	6.88**	8.75**	6.80**	8.11**	0.00	-1.76
26	L13xT2	-6.88	-5.64	2.70*	4.50**	1.70	2.95*	0.00	-5.54
27	L14xT1	12.83	14.33	5.16**	7.00**	5.10**	6.39**	-3.85	-1.76
28	L14xT2	-10.58	-9.38	5.16**	7.00**	4.61**	5.90**	0.00	-3.61
29	L15xT1	16.36	17.92	4.18**	6.00**	3.88**	5.16**	-1.88	-2.68
30	L15xT2	14.05	15.57	2.21	4.00**	2.18	3.44**	-0.93	-1.76
31	L16xT1	13.85	15.37	0.49	2.25	0.00	1.23	0.00	-3.61
32	L16xT2	-20.06*	-18.99	3.93**	5.75**	2.67*	3.93**	-1.88	-6.55*
33	L17xT1	-9.19	-7.98	1.72	3.50**	1.46	2.70*	-4.87*	-2.68
34	L17xT2	0.61	1.95	1.72	3.50**	7.52**	8.85**	-0.93	-1.76
35	L18xT1	-2.44	-1.14	0.74	2.50	1.70	2.95*	0.00	1.69
36	L18xT2	-22.40*	-21.37*	1.97	3.75**	-0.49	0.74	3.52	-11.96**
37	L19xT1	-13.60	-12.44	1.97	3.75**	1.70	2.95*	-10.38**	-2.68
38	L19xT2	-21.73*	-20.68*	3.19*	5.00**	2.43	3.69**	-0.93	-4.57
39	L20xT1	7.91	9.35	1.72	3.50**	1.70	2.95*	-2.85	-1.76
40	L20xT2	-7.75	-6.51	3.44**	5.25**	1.94	3.19**	0.00	-7.57*
41	L21xT1	-21.28*	-20.23*	4.91**	6.75**	4.61**	5.90**	-5.91*	-2.68
42	L21xT2	-15.33	-14.20	1.23	3.00	-0.97	0.25	-0.93	-10.82**
43	L22xT1	-3.44	-2.15	5.65**	7.50**	5.34**	6.63**	-9.22**	-2.68
44	L22xT2	-7.07	-5.83	3.19*	5.00**	2.43	3.69**	-0.93	-4.57
45	L23xT1	30.70**	32.44**	1.72	3.50**	0.97	2.21	-2.85	-4.57
46	L23xT2	5.46	6.87	1.97	3.75**	1.21	2.46	-2.85	-4.57
47	L24xT1	-2.80	-1.50	1.72	3.50**	1.94	3.19*	-2.85	-0.87
48	L24xT2	10.09	11.56	2.95*	4.75**	1.21	2.70*	0.91	-8.63**
SE(d)		0.75		1.25		1.29		0.91	

Table 3a. Contd.

LSD(0.05)	1.17	1.94	2.58	1.82
LSD(0.01)	1.41	2.34	3.43	2.41

**significant (0.01), *significant (0.05), LSD used to compare two heterosis value, GY=grain yield, AD=anthesis days, SD=silking days, ASI=anthesis silking interval.

Table 3b. Standard heterosis of 48 testcrosses and two commercial checks hybrids for yield and yield related traits for combined data, 2017.

S/N	Entry	EL (%)		ED (%)		KRPE (%)		KPR (%)		TKW (%)	
		Kolba	Jibat	Kolba	Jibat	Kolba	Jibat	Kolba	Jibat	Kolba	Jibat
1	L1xT1	-17.34**	-10.49*	-7.15**	-0.53	1.34	-0.02	-14.54**	-13.68**	-22.13**	-6.52
2	L1xT2	-12.75**	-5.52	-9.99**	-3.57	2.70	1.32	-10.53*	-9.62*	-17.89**	-1.43
3	L2xT1	-6.64	1.09	-5.79*	0.94	2.72	1.34	-0.75	0.25	-32.92**	-19.47**
4	L2xT2	-11.48**	-4.14	-8.96**	-2.46	4.03	2.64	0.51	1.52	-13.39*	3.97
5	L3xT1	-6.38	1.38	-9.99**	-3.57	6.73	5.30	-5.77	-4.81	-20.93**	-5.08
6	L3xT2	-10.71**	-3.32	-5.95*	0.76	8.11*	6.66	-12.53**	-11.65**	-14.38*	2.78
7	L4xT1	-0.77	7.46	1.26	8.48**	12.14**	10.64**	3.26	4.30	-16.02**	0.81
8	L4xT2	0.26	8.57*	-5.79*	0.94	2.70	1.32	2.51	3.54	-14.39*	2.76
9	L5xT1	-3.32	4.69	-5.30*	1.46	0.00	-1.34	-1.00	0.00	-14.26*	2.93
10	L5xT2	-3.57	4.43	-4.92	1.87	-1.36	-2.68	-4.01	-3.04	-17.75**	-1.27
11	L6xT1	-7.15	0.55	-3.17	3.74	6.75	5.32	-3.76	-2.79	-22.25**	-6.66
12	L6xT2	-8.68*	-1.11	-4.10	2.75	8.09*	6.64	-4.26	-3.30	-15.75**	1.14
13	L7xT1	2.56	11.06*	-8.25**	-1.70	8.09*	6.64	-3.01	-2.03	-31.78**	-18.10*
14	L7xT2	-0.51	7.74	-13.54**	-7.37**	1.34	-0.02	1.50	2.53	-26.49**	-11.76
15	L8xT1	1.03	9.40*	-5.52*	1.23	12.14**	10.64**	1.26	2.28	-19.18**	-2.98
16	L8xT2	0.28	8.59*	-5.30*	1.46	4.03	2.64	-1.76	-0.77	-3.99	15.25*
17	L9xT1	-7.39	0.28	-6.01*	0.70	6.75	5.32	-4.26	-3.30	-30.86**	-17.00**
18	L9xT2	-23.47**	-17.12**	-4.21	2.63	5.39	3.98	-17.04**	-16.21**	-17.04**	-0.41
19	L10xT1	-5.62	2.20	2.08	9.36**	9.46**	8.00*	-0.50	0.50	-13.83*	3.45
20	L10xT2	5.88	14.65**	-1.64	5.38	6.75	5.32	1.00	2.02	-15.38*	1.58
21	L11xT1	-18.37**	-11.60**	0.00	7.14*	13.52**	12.00**	-11.28**	-10.39*	-12.72*	4.77
22	L11xT2	-8.92*	-1.38	-2.73	4.21	2.68	1.30	1.26	2.28	-3.10	16.32*
23	L12xT1	-2.02	6.10	-0.33	6.79*	9.44**	7.98*	-0.25	0.76	-9.68	8.43
24	L12xT2	0.26	8.57*	-6.12*	0.59	-1.36	-2.68	3.01	4.05	-7.45	11.10
25	L13xT1	-18.09**	-11.30**	-1.64	5.38	6.75	5.32	-3.51	-2.54	-30.00**	-15.97*
27	L14xT1	7.13	16.01**	-2.68	4.27	9.46**	8.00**	4.26	5.31	-26.79**	-12.12
28	L14xT2	-6.37	1.39	-3.66	3.22	6.75	5.32	-7.52	-6.59	-13.22*	4.17
29	L15xT1	2.82	11.34**	-4.81	1.99	10.78**	9.30**	4.51	5.57	-27.65**	-13.15
30	L15xT2	11.74**	21.00**	-4.31	2.52	4.05	2.66	2.00	3.03	-17.22**	-0.63
31	L16xT1	-5.88	1.92	-5.84*	0.88	2.68	1.30	-3.01	-2.03	-18.33**	-1.96
32	L16xT2	-9.95*	-2.49	-9.72**	-3.28	-4.05	-5.34	-7.26	-6.33	-23.25**	-7.87
33	L17xT1	-1.27	6.91	-9.45**	-2.98	1.34	-0.02	-3.01	-2.04	-19.24**	-3.06
34	L17xT2	-10.96**	-3.58	-9.07**	-2.57	-2.72	-4.02	-9.52*	-8.61*	-7.05	11.58
35	L18xT1	-3.05	4.99	-1.31	5.73*	5.39	3.98	2.51	3.55	-20.32**	-4.35
36	L18xT2	-5.60	2.22	-5.63*	1.11	2.70	1.32	-6.02	-5.07	-14.65*	2.46
37	L19xT1	-9.93*	-2.47	-7.92**	-1.35	6.75	5.32	1.50	2.53	-33.76**	-20.48**
38	L19xT2	-11.46**	-4.13	-12.51**	-6.26*	2.70	1.32	-10.03*	-9.12*	-18.55**	-2.23
39	L20xT1	-3.83	4.14	-1.97	5.03	12.16**	10.66**	3.00	4.04	-16.80**	-0.12
40	L20xT2	-1.78	6.36	-1.04	6.03*	9.44**	7.98*	-2.50	-1.52	-8.32	10.05
41	L21xT1	-8.40*	-0.81	-0.16	6.96*	5.39	3.98	-10.78*	-9.88*	3.09	23.75**
42	L21xT2	-1.78	6.36	-5.79*	0.94	-6.77	-8.02*	-1.76	-0.77	6.33	27.64**

Table 3b. Contd.

43	L22xT1	-3.31	4.71	-9.72**	-3.28	5.39	3.98	-5.76	-4.81	-11.70	6.00
44	L22xT2	-4.33	3.60	-10.81**	-4.45	-5.43	-6.70*	-3.26	-2.29	-8.89	9.37
45	L23xT1	-5.60	2.22	-8.52**	-1.99	1.34	-0.02	-3.50	-2.53	-17.07**	-0.45
46	L23xT2	-7.65	0.00	-9.07**	-2.57	5.41	4.00	2.51	3.55	-14.33*	2.84
47	L24xT1	2.05	10.51*	-11.74**	-5.44	-1.36	-2.68	-0.25	0.76	-19.76**	-3.68
48	L24xT2	-2.80	5.25	-7.21**	-0.59	5.37	3.96	2.51	3.54	-8.21	10.19
SE(d)		0.64		0.12		0.42		1.45		21.76	
LSD(0.05)		1.28		0.24		0.65		2.25		43.51	
LSD(0.01)		1.70		0.32		0.78		2.71		57.84	

**significant (0.01), *significant (0.05), EL=ear length, ED=ear diameter, KRPE=kernel rows per ear, KPR=kernels per row, TKW=thousand kernel weight.

Table 3c. Standard heterosis of 48 testcrosses and two commercial checks hybrids for yield and yield related traits for combined data, 2017.

S/N	Entry	EL (%)		ED (%)		KRPE (%)		KPR (%)		TKW (%)	
		Kolba	Jibat	Kolba	Jibat	Kolba	Jibat	Kolba	Jibat	Kolba	Jibat
1	L1xT1	-17.34**	-10.49*	-7.15**	-0.53	1.34	-0.02	-14.54**	-13.68**	-22.13**	-6.52
2	L1xT2	-12.75**	-5.52	-9.99**	-3.57	2.70	1.32	-10.53*	-9.62*	-17.89**	-1.43
3	L2xT1	-6.64	1.09	-5.79*	0.94	2.72	1.34	-0.75	0.25	-32.92**	-19.47**
4	L2xT2	-11.48**	-4.14	-8.96**	-2.46	4.03	2.64	0.51	1.52	-13.39*	3.97
5	L3xT1	-6.38	1.38	-9.99**	-3.57	6.73	5.30	-5.77	-4.81	-20.93**	-5.08
6	L3xT2	-10.71**	-3.32	-5.95*	0.76	8.11*	6.66	-12.53**	-11.65**	-14.38*	2.78
7	L4xT1	-0.77	7.46	1.26	8.48**	12.14**	10.64**	3.26	4.30	-16.02**	0.81
8	L4xT2	0.26	8.57*	-5.79*	0.94	2.70	1.32	2.51	3.54	-14.39*	2.76
9	L5xT1	-3.32	4.69	-5.30*	1.46	0.00	-1.34	-1.00	0.00	-14.26*	2.93
10	L5xT2	-3.57	4.43	-4.92	1.87	-1.36	-2.68	-4.01	-3.04	-17.75**	-1.27
11	L6xT1	-7.15	0.55	-3.17	3.74	6.75	5.32	-3.76	-2.79	-22.25**	-6.66
12	L6xT2	-8.68*	-1.11	-4.10	2.75	8.09*	6.64	-4.26	-3.30	-15.75**	1.14
13	L7xT1	2.56	11.06*	-8.25**	-1.70	8.09*	6.64	-3.01	-2.03	-31.78**	-18.10*
14	L7xT2	-0.51	7.74	-13.54**	-7.37**	1.34	-0.02	1.50	2.53	-26.49**	-11.76
15	L8xT1	1.03	9.40*	-5.52*	1.23	12.14**	10.64**	1.26	2.28	-19.18**	-2.98
16	L8xT2	0.28	8.59*	-5.30*	1.46	4.03	2.64	-1.76	-0.77	-3.99	15.25*
17	L9xT1	-7.39	0.28	-6.01*	0.70	6.75	5.32	-4.26	-3.30	-30.86**	-17.00**
18	L9xT2	-23.47**	-17.12**	-4.21	2.63	5.39	3.98	-17.04**	-16.21**	-17.04**	-0.41
19	L10xT1	-5.62	2.20	2.08	9.36**	9.46**	8.00*	-0.50	0.50	-13.83*	3.45
20	L10xT2	5.88	14.65**	-1.64	5.38	6.75	5.32	1.00	2.02	-15.38*	1.58
21	L11xT1	-18.37**	-11.60**	0.00	7.14*	13.52**	12.00**	-11.28**	-10.39*	-12.72*	4.77
22	L11xT2	-8.92*	-1.38	-2.73	4.21	2.68	1.30	1.26	2.28	-3.10	16.32*
23	L12xT1	-2.02	6.10	-0.33	6.79*	9.44**	7.98*	-0.25	0.76	-9.68	8.43
24	L12xT2	0.26	8.57*	-6.12*	0.59	-1.36	-2.68	3.01	4.05	-7.45	11.10
25	L13xT1	-18.09**	-11.30**	-1.64	5.38	6.75	5.32	-3.51	-2.54	-30.00**	-15.97*
27	L14xT1	7.13	16.01**	-2.68	4.27	9.46**	8.00**	4.26	5.31	-26.79**	-12.12
28	L14xT2	-6.37	1.39	-3.66	3.22	6.75	5.32	-7.52	-6.59	-13.22*	4.17
29	L15xT1	2.82	11.34**	-4.81	1.99	10.78**	9.30**	4.51	5.57	-27.65**	-13.15
30	L15xT2	11.74**	21.00**	-4.31	2.52	4.05	2.66	2.00	3.03	-17.22**	-0.63
31	L16xT1	-5.88	1.92	-5.84*	0.88	2.68	1.30	-3.01	-2.03	-18.33**	-1.96
32	L16xT2	-9.95*	-2.49	-9.72**	-3.28	-4.05	-5.34	-7.26	-6.33	-23.25**	-7.87
33	L17xT1	-1.27	6.91	-9.45**	-2.98	1.34	-0.02	-3.01	-2.04	-19.24**	-3.06
34	L17xT2	-10.96**	-3.58	-9.07**	-2.57	-2.72	-4.02	-9.52*	-8.61*	-7.05	11.58
35	L18xT1	-3.05	4.99	-1.31	5.73*	5.39	3.98	2.51	3.55	-20.32**	-4.35

Table 3c. Contd.

36	L18xT2	-5.60	2.22	-5.63*	1.11	2.70	1.32	-6.02	-5.07	-14.65*	2.46
37	L19xT1	-9.93*	-2.47	-7.92**	-1.35	6.75	5.32	1.50	2.53	-33.76**	-20.48**
38	L19xT2	-11.46**	-4.13	-12.51**	-6.26*	2.70	1.32	-10.03*	-9.12*	-18.55**	-2.23
39	L20xT1	-3.83	4.14	-1.97	5.03	12.16**	10.66**	3.00	4.04	-16.80**	-0.12
40	L20xT2	-1.78	6.36	-1.04	6.03*	9.44**	7.98*	-2.50	-1.52	-8.32	10.05
41	L21xT1	-8.40*	-0.81	-0.16	6.96*	5.39	3.98	-10.78*	-9.88*	3.09	23.75**
42	L21xT2	-1.78	6.36	-5.79*	0.94	-6.77	-8.02*	-1.76	-0.77	6.33	27.64**
43	L22xT1	-3.31	4.71	-9.72**	-3.28	5.39	3.98	-5.76	-4.81	-11.70	6.00
44	L22xT2	-4.33	3.60	-10.81**	-4.45	-5.43	-6.70*	-3.26	-2.29	-8.89	9.37
45	L23xT1	-5.60	2.22	-8.52**	-1.99	1.34	-0.02	-3.50	-2.53	-17.07**	-0.45
46	L23xT2	-7.65	0.00	-9.07**	-2.57	5.41	4.00	2.51	3.55	-14.33*	2.84
47	L24xT1	2.05	10.51*	-11.74**	-5.44	-1.36	-2.68	-0.25	0.76	-19.76**	-3.68
48	L24xT2	-2.80	5.25	-7.21**	-0.59	5.37	3.96	2.51	3.54	-8.21	10.19
SE(d)		0.64		0.12		0.42		1.45		21.76	
LSD(0.05)		1.28		0.24		0.65		2.25		43.51	
LSD(0.01)		1.70		0.32		0.78		2.71		57.84	

**significant (0.01), *significant (0.05), EL=ear length, ED=ear diameter, KRPE=kernel rows per ear, KPR=kernels per row, TKW=thousand kernel weight.

standard heterosis for certain traits could be the result of divergent inbred lines and higher *sca* effects. Heterosis over standard checks helps in either a hybrid variety would be accepted or rejected for commercial cultivation. Ram et al. (2015) suggested that over 20% of standard heterosis has high commercial value. L23 x T1 and L11 x T1 crosses proved to be outstanding in grain yield over the best hybrid check (Kolba) with standard heterosis value of 30.70 and 22.18%, respectively. Devi and Singh (2011) suggested that appearance of crosses could be predicted based on the relationship between mean of grain yield, heterosis and specific combining ability. The best performing crosses might indicate the recovery of vigor that was lost during inbreeding as functional gene often absent. These crosses also had high per se performance and positive *sca* effects. Hence, they are ready for further evaluation in different location and commercial use. Furthermore, for traits with inferior performance in these crosses, breeders may improve via accumulation of favorable alleles from other good performing crosses for the trait of interest.

Correlation and path coefficients

Genotypic and phenotypic correlations among significant traits for F_1 hybrids analyzed from the combined data over the two locations shown in Table 4. Ratner (2009) categorized the Pearson correlation coefficient as weak, moderate and strong for values ranging from 0 to ±0.29, ±0.3 to ±0.69 and ±0.7 to ±1.0, respectively. Grain yield exhibited positive and significant genotypic and phenotypic correlations with plant height, ear height, ears per plant and number of kernels per row as shown in Table 4. The results are in accordance to the finding of Pavan et al. (2011), Kumer et al. (2014), Hailegebrial et al. (2015), and Pandey et al. (2017). In contrast, Zorana et al. (2011) and Silva et al. (2016) reported negative of correlations for grain yield with plant and ear height.

Tall plant with higher ear placement increases grain yield due to high number of leaves possessed and stem reserve mobilization which is in agreement with the findings of Zeeshan et al. (2013) and Al-Tabbal and Al-Fraihat (2012). Moreover, ear length, ear diameter and number of kernel rows per ear showed positive significant genotypic and phenotypic correlation with grain yield, which is in conformity to the findings of Izzam et al. (2017) and Wuhaib et al. (2017). Positive genotypic correlations for these traits imply the presence of moderate inherent relationship, thereby discloses the improvement of maize grain yield was linked with the selection for these traits. Grain yield exhibited negative and significant genotypic and phenotypic correlation with days to 50% anthesis and silking, anthesis silking interval which is analogous to the findings of Raghu et al. (2011), Munawar et al. (2013), Kumer et al. (2014) and Pandey et al. (2017). On the contrary, Dagne (2008) and Dar et al. (2015) found positive and significant phenotypic correlations for grain yield with days to 50% anthesis and silking. The negative genotypic association of days to flowering with grain yield implies that these traits are not co-inherited together with grain yield. Narrow anthesis silking interval period would increase grain yield due to the synchronization of pollen shedding and silking emergence.

Highly significant positive genotypic and phenotypic correlations observed between days to 50% anthesis and

Table 4. Genotype (above diagonal) and phenotype (below diagonal) correlation coefficients for yield and yield related traits of 48 hybrids evaluated across two locations, 2017.

Trait	GY	AD	SD	ASI	PH	EH	EPO	EPP	EL	ED	KRPE	KPR	TKW
GY	1.00	-0.21**	-0.14*	0.25**	0.48**	0.37**	0.02	0.56**	0.24**	0.20**	0.22**	0.38**	-0.03
AD	-0.17*	1.00	0.91**	-0.19*	-0.07	0.08	0.30**	-0.06	0.04	0.08	0.33**	-0.06	-0.08
SD	-0.18*	0.99**	1.00	0.49	0.08	0.20**	0.31**	-0.01	0.05	0.04	0.33**	-0.06	-0.14*
ASI	-0.14*	0.59**	0.58**	1.00	0.26**	0.23**	0.09	0.07	0.04	-0.05	0.08	-0.02	-0.12
PH	0.40**	-0.08	-0.07	-0.01	1.00	0.90**	0.34**	0.26**	0.14*	0.35**	0.33	0.15*	-0.23**
EH	0.32**	-0.24**	-0.23**	-0.17*	0.81**	1.00	0.72**	0.13	0.11	0.38**	0.33**	0.09	-0.01
EPO	0.04	-0.33**	-0.34**	-0.29**	0.16*	0.65**	1.00	-0.12	0.03	0.25**	0.19**	-0.03	-0.03
EPP	0.44**	0.29**	0.27**	0.20**	0.20**	0.05	-0.18*	1.00	-0.12	-0.30**	-0.01	-0.05	-0.24*
EL	0.17*	0.06	0.07	0.09	0.08	0.03	-0.04	-0.07	1.00	0.06	0.04	0.72**	0.05
ED	0.20**	-0.34**	-0.33**	-0.33**	0.23**	0.33**	0.25**	-0.31**	-0.23**	1.00	0.52	0.15*	0.25**
KRPE	0.21**	0.30**	0.27**	0.12	0.18*	0.15*	0.02	0.08	-0.21**	0.28**	1.00	0.14*	-0.28**
KPR	0.33**	-0.10	-0.12	-0.05	0.08	0.11	0.09	-0.14*	0.02	0.09	0.38**	1.00	-0.08
TKW	0.18*	-0.58**	-0.58**	0.1	-0.05	0.05	0.14	-0.29**	-0.14*	0.43**	-0.25**	0.04	1.00

**Significant ($p<0.01$), *significant ($p<0.05$), GY=grain yield, AD=anthesis days, SD=silking days, ASI=anthesis silking interval, PH=plant height, EH=ear height, EPO =ear position, EPP=ear per plant, EA=ear aspect, EL=ear length, ED=ear diameter, KRPE=kernel rows per ear, KPR=kernels per rows, TKW=thousand kernels weight.

silking (rg=0.91**, rp=0.99**) are in conformity to the findings of Nataraj et al. (2014), Hailegebrial et al. (2015) and Hussain et al. (2016). This infers jointly improvement of these traits could be possible due to positive genotypic correlation. Negative and significant genotypic and phenotypic correlations obtained between days to 50% silking and 1000 kernel weight are in agreement with the finding of Kumar et al. (2014). In contrast, Nataraj et al. (2014) and Varaprasad et al. (2016) found positive and significant genotypic and phenotypic correlation for days to 50% silking with 1000 kernel weight. Such differences might be attributed to the differences in locations used and the genetic make-up of studied materials (Iqbal et al., 2011). Based on the current findings, early silking could be responsible for timely pollination and grain filling thereby increase weight of kernels. Zhou et al. (2017) confirmed that climate variation from silking to maturity were the main factors affecting kernel weight.

Plant and ear height had positive and significant genotypic correlation with ear position, ear diameter and number of kernel rows per ear, which indicates that increase in plant and ear height would simultaneously increase these traits. These results support the findings of Mathew (2015) and Prasad and Shivani (2017). Number of ear per plant had negatively significant genotypic and phenotypic correlation with ear diameter, number of kernel rows per row and 1000 kernel weight which confirms the finding of Ziggiju et al. (2015). Eleweanya et al. (2005) suggested that positive associations among traits indicate positive responses in the levels of one character when the other is selected, while the negative signify the reverse situation. Magnitudes of genotypic correlations were relatively higher than phenotypic one for most of studied traits which indicates presence of greater inherent relationship among the traits which allows simultaneous improvement of these traits. Hallauer et al. (2010) noted the more importance of genetic correlation as it represents the heritable fraction of parent characters to progeny.

Estimates of direct and indirect effects towards grain yield for individual traits with significant correlation are presented in Table 5. Lenka and Mishra (1973) categorized the path coefficient into negligible (0.00-0.09), low (0.1-0.19), moderate (0.2-0.29), high (0.3-1) and very high (>1). Based on this, days to 50% silking, number of ears per plant, ear diameter, number of kernels per row and number of kernel rows per ear exerted higher positive direct effect towards grain yield. Similar findings were reported by Rafiq et al. (2010) and Raghu et al. (2011) for number of kernels per row and ear diameter, Pavan et al. (2011) for days to 50% silking and number of kernel rows per ear and Reddy and Jabeen (2016) for number of ear per plant.

Though plant height and ear length had positive genotypic correlation, they exerted negative direct effect towards grain yield. Similar results were reported by Selvaraj and Nagarajan (2011) for plant height, Zarei et al. (2012) for days to 50% anthesis and Bullo (2015) for ear length. In contrast, Praveen (2013), Poudel et al. (2016) and Varaprasad et al. (2016) found that days to 50% anthesis, plant height and ear length with positive direct effect. Positive higher indirect effect on grain yield was obtained from days to 50% silking via days to 50% anthesis, ear diameter via number of kernel rows per ear, plant height, ear height, and number of kernels per row via ear length and number of kernel rows per ear. Satyanvesh (2016) also found positive indirect effect from number of kernels per row through ear length and number of kernel rows per ear. Furthermore, higher, negative indirect effects on grain yield noted for days to 50% anthesis via days to

Table 5. Direct (diagonal) and indirect effect of genotypic path coefficient among yield and yield related traits of 50 maize hybrids evaluated at two locations, 2017.

TRAITT	AD	SD	ASI	PH	EH	EPP	EL	ED	KRE	KPR	RGY
AD	-0.50	0.48	0.01	0.01	0.03	-0.03	0.00	0.07	-0.24	-0.02	-0.19
SD	-0.45	0.52	0.00	-0.04	0.06	-0.08	0.00	0.11	-0.33	0.05	-0.16
ASI	0.09	-0.04	-0.04	-0.03	0.03	-0.04	-0.01	-0.11	0.06	-0.14	-0.25
PH	0.02	0.07	0.00	-0.30	0.22	0.28	-0.01	0.35	-0.25	0.13	0.52
EH	-0.06	0.12	0.00	0.26	0.25	0.15	0.00	0.36	-0.25	0.08	0.38
EPP	0.01	-0.04	0.00	-0.08	0.03	1.08	0.00	-0.29	0.02	-0.18	0.57
EL	-0.01	0.06	-0.01	-0.05	0.03	-0.14	-0.04	0.06	-0.04	0.36	0.22
ED	-0.04	0.06	0.01	-0.11	0.09	-0.32	0.00	0.95	-0.38	-0.06	0.20
KRPE	-0.17	0.25	0.00	-0.10	0.09	-0.03	0.00	0.52	0.70	0.37	0.22
KPR	0.01	0.03	0.01	-0.04	0.02	-0.21	0.21	-0.06	-0.28	0.92	0.38

Residual effect (U) = 0.22.

50% silking, number of ear per plant through ear diameter, and number of kernels per row via days to 50% silking. The contrasting findings could be due to the difference of materials and environments encountered. Finally, number of ear per plant, ear diameter, number of kernel rows per ear, number of kernels per rows and ear height excreted positive direct effect and they are good indicators in indirect selection for higher grain yield.

Residual effect, determines how best the causal variables (anthesis days, silking days, anthesis silking interval, plant height, ear height, ear per plant, ear length, ear diameter, number of kernel rows per ear and kernels per row). Its estimate of 0.22 indicated that the causal variables explained about 78% of the variability in grain yield and only 22% of the variability remained unexplored.

CONCLUSION

The estimation of standard heterosis identified various crosses revealed greater standard heterosis for more than one trait. Crosses L23 x T1 and L11 x T1 revealed higher standard heterosis for grain yield per hectare as compared to Kolba and Jibat hybrid checks and they also had positive higher standard heterosis for number of ear per plant and number of kernel rows per ear. This indicates the possibility of developing three ways cross hybrid varieties using these crosses as parent.

According to the results, in order to bring an effective improvement of grain yield, more attention should be given for traits such as ear diameter, number of kernels per row and number of kernel rows per ear which showed high positive phenotypic and genotypic correlation coefficients with a considerable direct and indirect effect on grain yield. Further evaluation of these and other hybrids at more locations and over years is advisable to confirm the promising results observed in present study. Finally, it may be concluded that the information from this study could be valuable for researchers who intend to develop high yielding varieties of maize.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors express heartfelt gratitude to Holetta Agricultural Research Center maize breeding staffs for hosting the trials and collecting the data. Appreciation is also extended to Ethiopian Institute of Agricultural Research for financial support.

REFERENCES

Alake O, K Ojo, A Oduwaye and A Adekoya (2008). Genetic Variability and Correlation Studies in Yield and Yield Related Characters of Tropical Maize (*Zea Mays* L.). ASSET: An International Journal 8(1):14-27.

Al-Tabbal A, Al-Fraihat H (2012). Genetic Variation, Heritability, Phenotypic and Genotypic Correlation Studies for Yield and Yield Components in Promising Barley Genotypes. Journal of Agricultural Science 4(3):193.

Amare S, Dagne W, Sintayehu A (2016). Test Cross Performance and Combining Ability of Elite Highland Maize (*Zea Mays* L.) Inbred Lines At Jimma, South West Ethiopia. International Journal of Trend in Research and Development 3(2):13-26.

Amiruzzaman M, Islam MA, Hassan L, Rohman MM (2010). Combining Ability and Heterosis for Yield and Component Characters in Maize. Academic Journal of Plant Sciences 3(2):79-84.

Arsode P, Krishna KM, Sunil N, Sree V, Charan AR (2017).Combining Ability and Heterosis Studies for Grain Yield and Its Components in Hybrids of Quality Protein Maize (*Zea Mays* L.). International Journal of Current Microbiology and Applied Sciences 6(12): 2538-2545.

Asif A, Liaqat S, Shah KA, Shamsur R (2014). Heterosis for Grain Yield and Its Attributing Components in Maize Variety Azam Using Line x Tester Analysis Method. Academia Journal of Agricultural Research 2(11):225-230.

Beyene Y, Mugo S, Gakunga J, Karaya H, Mutinda C, Tefera T, Njoka S, Chepkesis D, Shuma JM, Tende R (2011). Combining ability of maize (*Zea mays* L.) inbred lines resistant to stem borers. African Journal

of Biotechnology 10(23):4759-4766.
Bitew T (2016). Heterosis and Combining Ability of Mid Altitude Maize (*Zea Mays* L.) Inbred Lines for Grain Yield, Yield Related Traits and Reaction to Turcicum Leaf Blight (*Exserohilum Turcicum Leonard and Suggs*). Msc Thesis Presented to the School of Graduate Studies of Haramaya University. 115 p.
Bullo N (2015).Correlation and Path Coefficients Analysis Studies among Yield and Yield Related Traits of Quality ProteinMaize (QPM) Inbred Lines. International Journal of Plant Breeding and Crop Science 1(2): 006-017.
Central Statistical Agency (CSA) (2017). Agricultural Sample Survey 2016/2017: Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season) Volume I. Statistical Bulletin, Addis Ababa, Ethiopia 195(2):183-195.
Comstock E, Robinson F (1952). Genetic Parameters, Their Estimation and Significance. Proceeding 6th Intercropping, Grassland Congress pp. 284-291.
Dagne WB, Vivek S, Birhanu T, Koste A, Mosisa W, Legesse W (2010). Combining Ability and Heterotic Relationships Between CIMMYT and Ethiopian Maize Inbred Lines. Ethiopian Journal of Agricultural Sciences 21(1-2):82-93.
Dagne W (2008). Genotypic Variability and Combining Ability Of Quality Protein Maize Inbred Lines Under Stress And Optimal Conditions. PhD Dissertation Presented at University of the Free State, South Africa. 300 p.
Dagne W, Habtamu Z, Labuschagne MT, Temam H, Singh H (2007). Heterosis and Combining Ability for Grain Yield and Its Components in Selected Maize Inbred Lines. South African Journal of Plant and Soil 24(3):133-137.
Dar ZA, Lone AA, Alaie BA, Ali G, Gazal A, Gulzar S, Yousuf N (2015). Correlation Studies in Temperate Maize (*Zea Mays* L.) Inbred Lines. Plant Archives 15(2):1191-1194.
Demissew A (2014). Genetic diversity and combining ability of selected quality protein maize (QPM) inbred lines adapted to the highland agro-ecology of Ethiopia. PhD dissertation presented at University of KwaZulu-Natal, Republic of South Africa.178 p.
Devi P, Singh NK (2011). Heterosis, Molecular Diversity, Combining Ability and Their Interrelationship in Short Duration Maize (*Zea Mays* L.)Across The Environments. Euphytica 178(1):71-81.
Dewey R, Lu H (1959). A Correlation and Path Coefficient Analysis of Components of Crested Wheat Grass Seed Production. Agronomy Journal 51(9): 515-518.
Dufera T, Bulti T, Girum A (2018). Heterosis and Combining Ability Analysis of Quality Protein Maize (*Zea Mays* L.) Inbred Lines Adapted to Mid-Altitude Sub-Humid Agro-Ecology Of Ethiopia. African Journal of Plant Science 12(3):47-57.
Duvick DN (1999). Heterosis: feeding people and protecting natural resources. In: Coors JG, Pandey S, eds. The Genetics and Exploitation of Heterosis in New York: Crop Science Society of America pp. 19-30.
Falconer D, Mackay T (1996). Introduction to Quantitative Genetics.*4th* eds*.* Benjamin Cummings*,* England 247 p.
Fato P (2010). Investigation of Heterotic Patterns and Genetic Analysis of Downy Mildew Resistance in Mozambican Lowland Maize (*Zea Mays* L.) Germplasm. PhD Dissertation Presented University of Kwazulu-Natal, South Africa 146 p.
Feng S, Chen X, Wu S, Chen X (2015). Recent Advances in Understanding Plant Heterosis. Agricultural Sciences 6(09):1033.
Foreign Agricultural Service (FAS) (2017). World Agricultural Production Circular Series WAP 07-17, pp. 1-29.
Gemechu N, Leta T, Sentayehu A (2017). Standard Heterosis of the Selected Maize (*Zea Mays* L.)Inbred Lines Hybrids for Grain Yield and Yield Component. Journal of Biology, Agriculture and Healthcare 7(15):51-58.
Girma H, Sentayehu A, Berhanu T, Temesgen M (2015). Test Cross Performance and Combining Ability of Maize (*Zea Mays* L.) Inbred Lines at Bako, Western Ethiopia. Global Journal of Science Frontier Research 15(4):1-24.
Habtamu Z (2015). Heterosis and Combining Ability for Grain Yield and Yield Component Traits of Maize in Eastern Ethiopia. Science, Technology and Arts Research Journal 4(3): 32-37.
Hailegebrial K, Getachew A, Legesse W, Yemane T (2015). Correlation and Path Coefficient Analysis of Grain Yield And Yield Related Traits In Maize (*Zea Mays* L.) Hybrids, At Bako, Ethiopia. Journal of Biology, Agriculture and Healthcare 5(15):44-52.
Hallauer R, Miranda B (1988). Quantitative Genetics in Maize Breeding. Iowa State Univ, Press 468 p.
Hallauer R, Carena M, Miranda F (2010).Testers and Combining Ability. Springer, New York, NY. 423 p.
Hiremath N, Shantakumar G, Adiger S, Gangashetty P (2013). Heterosis Breeding for Maturity, Yield and Quality Characters in Maize (*Zea Mays* L.). Molecular Plant Breeding 4(6):44-49.
Hussain N, Rehman B, Faizal K (2016). Phenotypic and Genotypic Association between Maturity and Yield Traits in Maize Hybrids (*Zea Mays* L.). African Journal of Agriculture and Food Security 4(3):157-160.
Izzam A, Sohail H, Shahzad A, Hussain Q (2017). Genetic Variability and Correlation Studies for Morphological and Yield Traits in Maize (*Zea Mays* L.). Pure and Applied Biology 6(4):1234-1243.
Jakhar S, Singh R, Kumar A (2017). Studies on Path Coefficient Analysis in Maize (*Zea Mays* L.) for Grain Yield and Its Attributes. International Journal of Current Microbiology and Applied Sciences 6(4):2851-2856.
Kumar V, Singh SK, Bhati PK, Sharma A, Sharma SK, Mahajan V (2014). Correlation, Path and Genetic Diversity Analysis in Maize (*Zea Mays* L.). Environment and Ecology 33(2A): 971-975.
Kustanto H, Sugiharto A, Basuki N, Kasno A (2012). Study on Heterosis and Genetic Distance of S_6 Inbred Lines of Maize. Journal of Agriculture and Food Technology 2:118-125.
Lenka D, Misra B (1973). Path-Coefficient Analysis of Yield in Rice Varieties. Indian Journal of Agricultural Sciences 43(4):376-379.
Mallikarjuna N, Chandrashekhar H, Shashibhaskar M, Prahalada G (2011).Genetic Variability and Correlation Studies for Yield and Related Characters in Single Cross Hybrids of Maize (*Zea Mays* L.). Current Biotica 5(2):157-163.
Mathew I (2015). Combining Ability, Genetic Gains and Path Coefficient Analyses of Maize Hybrids Developed From Maize Streak Virus and Downy Mildew Resistant Recombinant Inbred Lines. PhD Dissertation Presented at University of Kwazulu-Natal, Pietermaritzburg, South Africa. 154 p.
Melkamu E, Tadsse D, Yigzaw D (2013).Combing Ability, Gene Action and Heterosis Estimation in Quality Protein Maize. International Journal of Scientific and Research Publications 3(6):1-17.
MoANR (2016). Plant Variety Release, Protection and Seed Quality Control Directorate, Crop Variety Register 19:318.
Mosisa W, Twumasi-Afriyie S, Legesse W, Birhanu T, Girma D, Gezehagn B, Dange W, Prasanna B (2012). Meeting the Challenges of Global Climate Change and Food Security through Innovative Maize Research. Proceedings of 3rd National Maize Workshop of Ethiopia, April 18-20, Institute of Agricultural Research.
Munawar M, Shahbaz M, Hammad G, Yasir M (2013).Correlation and Path Analysis of Grain Yield Components in Exotic Maize (*Zea Mays* L.) Hybrids. International Journal of Sciences: Basic And Applied Research 12(1):22-27.
Nataraj V, Shahi J, Agarwal V (2014).Correlation and Path Analysis in Certain Inbred Genotypes of Maize (*Zea Mays* L.) at Varanasi. International Journal of Innovative Research and Development 3(1):14-17.
Natol B (2017). Combining Ability and Heterotic Grouping in Maize (*Zea Mays* L .) Inbred Lines for Yield and Yield Related Traits. World Journal of Agricultural Sciences 13(6):212-219.
Natol B, Birhanu A, Mandefro N (2017). Standard Heterosis of Maize (*Zea mays* L.) Inbred Lines for Grain Yieldand Yield Related Traits at Southern Ethiopia, *American*- American-Eurasian Journal of Agricultural and Environmental Sciences 17(3):257-264.
Pandey Y, Vyas P, Kumar J, Singh L, Singh C, Yadav C (2017). Heritability, Correlation and Path Coefficient Analysis for Determining Interrelationships among Grain Yield and Related Characters in Maize (*Zea Mays* L.). International Journal of Pure and Applied Bioscience 5(2):595-603.
Paschal E, Wilcox J (1975). Heterosis and Combining Ability in Exotic Soybean Germplasm. Crop Science 15(3):344-349.
Patil B, Ahamed M, Babu D (2017). Heterosis Studies for Yield and Yield Component Characters in Maize (*Zea mays* L.). International Journal of Agriculture, Environment and Bioresearch 10(4):449-455.
Patterson H, Williams E (1976). A New Class of Resolvable Incomplete

Block Designs. Biometrika 63(1): 83-92.
Pavan R, Lohithaswa C, Wali C, Prakash G, Shekara G (2011).Correlation and Path Coefficient Analysis of Grain Yield and Yield Contributing Traits in Single Cross Hybrids of Maize (*Zea Mays* L.). Electronic Journal of Plant Breeding 2(2):253-257.
Poudel M, Poudel H, Shrestha J (2016). Path Analysis for Agro-Morphological Traits in Maize. International Journal of Graduate Researcha Review 2(2):32-37.
Prasad B, Shivani D (2017). Correlation and Path Analysis in Maize (*Zea Mays* L.). Journal of Genetics, Genomics and Plant Breeding 1(2):1-7.
Prasanna B, Vasal S, Kasahun B, Singh N (2001). Quality Protein Maize. Current Science 81(10):1308-1319.
Rafiq M, Rafique M, Hussain A, Altaf A (2010). Studies on Heritability, Correlation and Path Analysis in Maize (*Zea Mays* L.). Journal of Agricultural Research 48(1):35-38.
Raghu B, Suresh J, Kumar S, Saidaiah P (2011). Character Association and Path Analysis in Maize (*Zea Mays* L.). Madras Agricultural Journal 98(3):7-9.
Ram L, Singh R, Singh S, Srivastava R (2015). Heterosis and Combining Ability Studies for Quality Protein Maize. Ekin Journal of Crop Breeding and Genetics 2:8-25.
Ratner B (2009). The Correlation Coefficient: Its Values Range Between+ 1/− 1, or Do They? Journal of Targeting, Measurement and Analysis for Marketing 17(2): 139-142.
Reddy R, Jabeen F (2016). Narrow Sense Heritability, Correlation and Path Analysis in Maize (*Zea Mays* L.). SABRAO Journal of Breeding and Genetics 48(2):120-126.
Retherford R, Choe M (2011). Statistical Models for Causal Analysis. John Wiley And Sons, New York, 258p.
SAS Institute (2014). Statistical Analysis System Version 9.3, SAS Institute, Inc., Cary, NC, USA.
Satyanvesh B (2016). Studies on Line x Tester Analysis of Yield and Yield Contributing Traits in Maize (*Zea Mays* L.). MSc Thesis Presented at Professor Jayashankar Telangana State Agricultural University 130 p.
Selvaraj C, Nagarajan P (2011). Interrelationship and Path-Coefficient Studies for Qualitative Traits, Grain Yield and other Yield Attributes Among Maize (*Zea Mays* L.). International Journal of Plant Breeding and Genetics 5(3):209-223.
Sharma P, Kamboj M, Singh N, Chand M (2017).Heterosis for Grain Yield and Quality Traits in Maize (*Zea Mays* L.). International Journal of Pure & Applied Bioscience 5(5): 241-248.
Shushay W (2014). Standard Heterosis of Maize (*Zea Mays* L.) Inbred Lines for Grain Yield and Yield Related Traits in Central Rift Valley of Ethiopia. Journal of Biology, Agriculture and Healthcare 4(23):31-37.
Silva T, Moro G, Moro F, Santos D, Buzinaro R (2016). Correlation and Path Analysis of Agronomic and Morphological Traits in Maize. Revista Ciência Agronômica 47(2):351-357.
Singh P (2015). Genetic Distance, Heterosis And Combing Ability Studies In Maize For Predicting F1 Hybrid Performance. SABRAO Journal of Breeding and Genetics 47 (1):21-28.
Tamene T, Gemechu K, Hussein M (2015). Genetic progresses from over three decades of faba bean (*Vicia faba* L.) breeding in Ethiopia. Australian Journal of Crop Science 9(1):41-48.
Tolera K, Mosisa W, Habtamu Z (2017). Combining Ability and Heterotic Orientation of Mid-Altitude Sub-Humid Tropical Maize Inbred Lines For Grain Yield and Related Traits. African Journal of Plant Science 11(6):229-239.
Tsedeke A, Bekele Sh, Abebe M, Dagne W, Yilma K, Kindie T, Menale K, Gezahegne B, Berhanu T, Tolera K (2015). Factors That Transformed Maize Productivity in Ethiopia. Food Security 7(5):965-981.
Yazachew G, Pangirayi B, Beatrice E (2017). General and Specific Combining Ability Studies of Selected Tropical White Maize Inbred Lines for Yield And Yield Related Traits. International Journal of Agricultural Science and Research 7(2):381-396.
Zarei B, Kahrizi D, Aboughadaresh P, Sadeghi F (2012). Correlation and Path Coefficient Analysis for Determining Interrelationships among Grain Yield and Related Characters in Corn Hybrids. International Journal of Agriculture and Crop Sciences 4(20):1519-152.
Zeeshan M, Ahsan M, Arshad W, Ali S, Hussain M and Khan M (2013). Estimate of Correlated Responses for Some Polygenic Parameters in Yellow Maize (*Zea Mays* L.) Hybrids. International Journal of Advanced Research 1(5):24-29.
Ziggiju M, Habtamu Z, Legesse W (2017). Ethiopian Standard Heterosis of Pipeline Maize (*Zea Mays* L.) Hybrids for Grain Yield and Yield Related Traits. International Journal of Plant Breeding and Genetics 4(1):249-255.

Related Journals: