Advances in Crop Science and Technology

Open Access

Evaluation of Maize (Zea mays L.) Hybrids for Grain Yield and Nitrogen Use Efficiency under Moisture stress Areas of Ethiopia

Jemal Bekere Adem*

Melkassa Agricultural Research Center, Ethiopian Institute of Agricultural Research, P. O. Box 2003, Addis Ababa, Ethiopia

Abstract

Maize is an important food security crop in central rift valley of Ethiopia. Applying excess Nitrogen fertilizer in maize production entails costs to smallholder farmers and results in nitrous oxide emission to the atmosphere exacerbating
WKH SUREOHP RI FOLPDWH FKDQJH 6FUHHQLQJ QLWURJHQ XVH HˆFLHQW K\EULG
cost of production, maintain environmental pollution and enhance crop productivity. This experiment was conducted to
GHWHUPLQH WKH H‡HFW RI QLWURJHQ IHUWLOL]HU RQ \LHOG DQG \LHOG UHODWH
QLWURJHQ XVH HˆFLHQF\ LQGLFHV (LJKW PDL]H K\EULGV ZHUH HYDOXD JHQRW\SH
UHYHDOHG WKDW WKH LQWHUDFWLRQ RI WKH WKUHH IDFWRUV ORFDWLRQ QLWU
LQGH[QXPEHU RI NHUQHO SHU HDU DJURQRPLF DQG SK\VLRORJLFDO HˆFLHQF\
0+ 4 ZLWKRXW QLWURJHQ IHUWLOL]HU WR NJ KD :(GXH WR DSSOLFD
DQG :(FRXOG EH UHFRPPHQGHG IRU SURGXFWLRQ LQ WKH VWXG\ DUHDV +RZ
experiment has to be repeated for one more season at both locations.

for maize production for all the six major maize agro-ecology zones. However, the overall Ethiopia`s average fertilizer use is low and stands at ground level and dried at 70 °C until constant weight was reached for dry weight determination and partitioned into straw and grain. e dried samples were milled, and the grain and straw N content of the plant samples were determined using the micro-Kjeldahl method as stated by American Association of Cereal Chemists (AACC, 2000). e laboratory analysis was done at Melkassa Agricultural Research Center, Soil Laboratory [13].

Data collection

Phenology, growth, yield and yield components data were collected. Crop growth rate was suggested by Watson (1956). e CGR explains the dry matter accumulated per unit land area per unit time (gm-2 day-1).

CGR= (W2-W1) p(t2-t1)

Where, W1 and W2 are whole plant dry weight at time t1 – t2 respectively.

is the ground area on which W1 and W2 are recorded.

CGR of a species are usually closely related to interception of solar radiation

Nitrogen use e ciency (NUE) evaluated in terms of agronomic e ciency and physiological e ciency. Agronomic e ciency was determined as kg grain produced per kg of nitrogen applied, whereas physiological e ciency was determined as kg grain produced per kg of nutrient uptake. It was calculated using the equation established as agronomic e ciency and physiological e ciency by (Fageria and Baligar, 2005) as below [14].

Agronomic e ciency (AE) = Gf¬- Gu= kg grain/kg N-fertilizer

Na

Where Gf is the grain yield in the fertilized plot (kg), Gu is the grain yield in the unfertilized plot (kg), and Na is the quantity of nutrient applied (kg).

Physiological e ciency (PE) = Yf - Yu = kg kg-1

Nf - Nu

Where Yf is the total biological yield (grain plus straw) of the fertilized plot (kg), Yu is the total biological yield in the unfertilized plot (kg), Nf is the nutrient accumulation in the fertilized plot (kg), and Nu is the nutrient accumulation in the unfertilized plot (kg) [15].

Data analysis

Data collected from each location was subjected to analysis of variance (ANOVA) for individual location and combined ANOVA over location was also done using the procedure of SAS version 9.2 (SAS Institute, 2008). F-ratio homogeneity test was conducted to error variances as outlined in (Gomez and Gomez, 1984). Following the presence of signi cant di erence among hybrids for parameters, the mean values of maize hybrids was compared using least signi cant test (LSD) at 5% probability level [16].

Results and Discussions

Soil physico-chemical properties of the experimental sites

e results of physical and chemical analyses of the soil sample for each location. e textural class of the soils was sandy loam and sandy-clay loam at Dera and Melkassa sites respectively. e soil pH was neutral for Melkassa site and moderately alkaline for Dera as per the rating suggested by (Tekalign, 1991) [17]. According to (FAO, 2008), suitable pH range for most crops is between 6.5 and 7.5 in which N availability is optimum. us the results of soil test indicated the suitability of the soil reaction in the experimental sites for optimum crop growth and yield (Table 3).

e soil organic matter content (OM) (1.56 and 2.10%), total nitrogen (TN) (0.09 and 0.12%), organic carbon (OC) (0.91 and 1.23%) and cation exchange capacity (CEC) (0.3 and 1.0 cmol kg-1 soil) were low at Dera and Melkassa sites respectively, as suggested by (Berhanu, 1980; Tekalign, 1991 and FAO, 2006). According to the rating suggested by Olsen et al. (1954), the soil for the two sites had medium available P content (Dera, 5.02 ppm and Melkassa, 6.12ppm) but slightly saline soil at Dera site. As suggested by (EthioSIS, 2016) the N nutrient of the soils at both sites were low; hence, amending the soils of the sites with fertilizer was important for enhancing crop yield as well as soil health [18].

e soils of the study sites had higher sand to clay ratio at (Dera, the sand to clay ratio is 3.63:1.and at Melkassa the sand to clay ratio is 1.73:1), low organic matter and low organic carbon. is indicated that the soil fertility of the two sites was low. If the CEC is low, it is necessary to consider the increasing inputs of organic matter through additional inputs of organic materials (Botta, 2015). According to (Aweke, et al., 2014), loss of soil organic matter due to topsoil erosion along with poor physicochemical properties is the prominent causes for the

Location					
Soil property	Dera			Melkassa	Reference
Physical properties	9D O X H	Rating	9 D O X H	Rating	
6 D Q G					

deterioration of soil fertility and productivity. Balanced and careful use of external inputs together with eco-friendly and environmentally sounds soil management practices are essential issues for sustainable agriculture production (Kumar et al., 2015) [19].

Weather conditions of the experimental sites

e weather condition of the experimental sites in 2020 cropping season are presented in (Figure 1 and Figure 2). e two sites received rainfall every month starting from March 2020 in which the Dera and Melkassa sites received the maximum 165.9 and 248.5 mm rainfall respectively. e lowest precipitation for Dera site was 2.1mm received during October 2020 while, Melkassa site received the lowest rainfall during November (1.1mm). e total rainfall received during 2020 cropping season was 764.4 and 832.8mm at Dera and Melkassa site respectively. e average monthly maximum and minimum rainfall distribution and relative humidity of the sites were suitable for maize production at both sites [20].

Dera and Melkassa sites had the maximum temperature during produce grain yield in response to the rates of nitrogen fertilizer. e signi cant e ect of nitrogen x genotype interaction on all yield and yield related traits except phenology (days to maturity) and plant height indicated the e ort of increasing the maize yield and yield related traits should be towards the identi cation of the responsive maize hybrids to nitrogen fertilizer and produce high yield [26]. e presence of signi cant di erences for genotypes x nitrogen interaction, and three way interaction (location x genotype x nitrogen) for maize hybrids were reported by many authors. Seyoum et al. (2019) who reported that signi cant di erences among ten maize hybrids for grain yield, thousand kernels weight, leaf area index and harvest index evaluated at four sites (Bako, Hawassa, Melkassa and Adamitulu) in 2013 and 2014 cropping season. e result was in agreement with the nding of (Tadesse and Kim, 2015) who reported that signi cant variation on maize variety for grain yield, leaf area index, 1000 kernels weight, above ground biomass and harvest index and the interaction of genotype x nitrogen fertilizer e ects on these traits evaluated at two sites (Melkassa and Adamitulu) in 2014 main cropping season [27].

E ects of location, nitrogen and genotype on yield and yield related traits

Interaction e ect of nitrogen x genotype on ear length

Ear length was signi cantly in uenced by the interaction e ect of nitrogen and genotype. e genotype WE8206 with the application of 65 N kg/ha had signi cantly produced a longer ear length (24.31cm) and, followed by the genotype WE7210 with the application of 32.5 N kg/ha obtained the longer ear length (22.04cm) as compared to other genotypes. e standard check variety, MH138Q was registered a shorter ear length (15.19) at the control plot; however, it had statistically non-signi cant di erence with ear length of other two genotypes obtained from control plots. Ear length of this hybrid (MH138Q) in the control plot had statistically nonsigni cant with the application of 32.5 N kg/ha. e results showed that the hybrids had genetic variation of that had statistically nonsigni cant di erence with WE6205 and WE8203 (65 N kg/ha), WE7210 (0, 32.5 and 65 N kg/ha) and WE8206 (32.5 N kg/ha). e hybrid, WE7210 had higher thousand kernel weight at three levels of N (0, 32.5 and 65 kg/ha) as compared to other genotypes. e results showed that the hybrids had a genetic variation for thousand kernel weights and had di erential response to the rates of N for kernel weight. is result is in line with (Belay, 2020) who reported that the maximum thousand kernel weight was obtained from Bate maize variety where plants were fertilized with 150 kg NPS and 87 kg N/ha at Babile. (Ahmad et al., 2018) also reported that 1000-grain weight was signi cantly a ected by the interaction e ect of genotype by nitrogen [31].

 ousand kernel weight was signi cantly in uenced by the interaction e ect of location and genotype. e highest thousand kernel weight (371.08g) was obtained from the hybrid WE7210 at Melkassa site. e lowest (177.22g) thousand kernel weight was measured from the standard check variety MH138Q at Dera site; but, it had statistically nonsigni cant di erence with thousand kernel weight of other two genotypes obtained from control plots. ousand kernel weight of (WE7210) was highest at both locations as compared to other genotypes, and also at Melkassa site the highest thousand kernel weight was recorded as compared to Dera site; however three genotypes were statistically nonsigni cant. e research results showed that the hybrids had genetic variation across locations for thousand kernel weight. is result was in harmony with (Abera and Adinew, 2020) who reported that the maximum thousand kernel weight was obtained from maize hybrids (Table 6).

Citation: Jemal BA (2024) Evaluation of [redacted]
Ethiopia[redacted]

Table 8: ,QWHUDFWLRQ H‡HFW RI 1LWURJHQ [*HQRW\SH RQ ... eight maize hybrids at two locations during 2020 cropping season.

	1 UDWH)NJ KD		
*HQRW\SH	0		
:(	E I	EFG	HIJ
:(	JK	IJ	EF
:(	E H	EF	J
:(	J	EFG	E
:(	HIJ	IJ	EFG
:(	G J	E J	D
0+ 4	JK	J	E H
0+	K	F J	E J
/6'			

0HDQ YDOXHV ZLWK VLPLODU OHWWHU V LQ FROXPQ ... GL‡HUHQFH DW 3 DQG /6' OHDVW VLJQL¿FDQW GL‡HUHQFH DW ... SUREDELOLW\ level

with the reduction of 7.6 kg grain kg-1 nitrogen than AE at plots that received 32.5 kg N/ha. Whereas hybrids WE8203 and WE8203 showed lower agronomic e ciency reduction of 0.71 and 1.24 kg grain kg-1 nitrogen, respectively, at plots that received 65 kg N/ha than plots received 32.5 kg N/ha. is showed that the agronomic e ciency of hybrids was signi cantly in uenced by location and rates of nitrogen. e results suggested that the higher chance of identifying hybrids with higher agronomic e ciency in response of low rate of nitrogen at both locations and/or speci c location than others as stable and/or t to speci c location. Maize crop had a genotypic variation in nitrate absorption and partitioning of N among plant parts (Chevalier and Schrader. 1977). is result is in line with the reports of (Shiferaw, et al., 2018) that signi cant di erences for maize varieties for agronomic e ciency, evaluated at two sites (Addis Alem and Tepi) in 2016 cropping season (Table 9).

Interaction e ect of location x nitrogen x genotype on physiological e ciency

e hybrid WE8206 had signi cantly highest physiological e ciency of 43.52 kg grain kg-1 nitrogen at plot received 32.5 kg N/ha, while the standard check variety MH138Q had lowest physiological e ciency (12.56 kg kg-1kg grain kg-1 nitrogen) at plot that received 65 kg N/ha at Melkassa site. Most of maize genotypes had signi cantly higher physiological e ciency with the application of 32.5 kg N/ha than the application of 65 kg N/ha at Melkassa site as compared to Dera. ere was variation among hybrids for the reduction of physiological e ciency at plots that received 65 kg N/ha in which the standard check variety WE6205 hybrid had highest reduction of 19.21 kg grain kg-1 nitrogen followed by MH138Q hybrid with the reduction of 18.03 kg grain kg-1 nitrogen than PE at plots that received 32.5 kg N/ha. Whereas hybrid WE5202 showed lower physiological e ciency reduction of 3.56 kg grain kg-1 nitrogen, at plots that received 65 kg N/ha than plots received 32.5 kg N/ha. e results of the research showed that the physiological e ciency of hybrids was signi cantly in uenced by location and rates of nitrogen. e results suggested that the higher chance of identifying hybrids with higher physiological e ciency in response of low rates of nitrogen at locations and/or speci c location than others as stable and/or t to speci c location. Similarly, (Workneh, et al., 2021) reported that signi cant di erences for maize variety on physiological e ciency, evaluated at three sites (Bako, Central ri valley and Jimma) in 2015 and 2016 cropping season. is result is in agreement with the reports of (Sadegh, 2017) that signi cant variation among three soybean cultivars for physiological e ciency, evaluated at Babol in 2012 and 2013 cropping season [35].

Conclusions

e central ri valley part of Ethiopia is one of the semi-arid areas in the country where the production of crops is su ering with moisture stress. e climate change and variability pose a serious threat to food production in this area contributed signi cantly to the water scarcity and with nutrient stress such as nitrogen. us the development of varieties to moisture stress areas is one of the strategies to withstand the maize production problems brought by water scarcity and temperature increase.

e results of analysis of variance for individual locations indicated that nitrogen and genotypes had a signi cant e ect on leaf area index, ear length, number of kernel per ear, thousand kernel weight, grain yield, biomass yield and harvest index at both locations. In addition, days to physiological maturity and plant height at Dera site and plant height at Melkassa was signi cantly in uenced by nitrogen levels. Genotype had also signi cantly in uence days to physiological maturity at Melkassa site. Nitrogen and genotypes interacted to in uence ear length, thousand kernel weight, grain yield and harvest index at both locations, but leaf area index was signi cantly in uenced by the interaction of nitrogen and genotypes at Melkassa site. e results of combined analysis of variance across locations indicated that the interaction of the interaction of between nitrogen and genotype had signi cant e ect on all traits except days to physiological maturity and plant height. e interactions between location x nitrogen and location x genotype had signi cant e ect on days to maturity and number of kernel per ear. Besides, thousand kernels weight was signi cantly in uenced by the interaction of location x genotype. e interaction of the three factors (location, nitrogen and genotype) had signi cant e ect on only leaf area index and number of kernel per ear.

e genotypes also had signi cant di erences for crop growth rate, agronomic and physiological e ciency. ese traits were signi cantly in uenced by one or more than one of the possible two factors interactions (nitrogen x genotype, location x nitrogen, and location x genotype). e interaction of the three factors (location, nitrogen and genotype) had signi cant e ect on leaf area index, number of kernel per ear, agronomic and physiological e ciency. is showed that the importance of identifying genotypes with high yield and nitrogen use e ciency to increase the productivity of the crop in the study areas.

 e physiological maturity, most of the plant growth traits, yield components, agronomic and physiological e ciency were the function of genotype and nitrogen and/or the interaction of the two factors. us, the e ort of enhancing nitrogen use e ciency of the maize genotypes in the study areas needs to be towards the identi cation of maize hybrids e cient to the utilization of available nitrogen nutrient at di erent locations. Hence, WE8206 and WE7210 could be recommended for production in the study areas. However, further studies will be needed, because the two locations have received su cient rainfall during the experimental year, and the response of the hybrids at both locations with low soil fertility conditions may not be su cient to represent the semi-arid areas of Ethiopia.

Acknowledgement

 e authors would like to acknowledge Africa Center of Excellence for Climate Smart Agriculture and Biodiversity Conservation-Haramaya University and, the World Bank Group and, also the Ethiopian Institute of Agricultural Research for providing nancial support and laboratory facilities to carry out this study.

Con ict of Interest

 e authors declare that there is no con ict of interest regarding the publishing of this work.

References

$ G G L V + D H . . 197 -1.575 -1.-72.1e23D2B0044l447-5t.18598E04C50ecl4475047004C005.18599>-72.F <005imi7 1ee 18597E04C4415 T-72.6eclare51re574C55ecl44

33. 7 R O H U D