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Research Paper

Maize (*Zea mays* L.) agro-physiological response to varying nitrogen regime in Botswana

P. K. Mashiqa[1]* • O. G. Moatshe-Mashiqa[1] • K. Safi[1] • O. Molosiwa[2]

[1]Department of Agricultural Research, Private Bag 0033, Gaborone, Botswana.
[2]National Agricultural Research and Development Institute, Private Bag 00177, Gaborone, Botswana.

*Corresponding author E-mail: pat3mash@gmail.com

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Abstract. A field experiment was conducted at the Department of Agricultural Research site in Sebele during 2018 and was repeated in 2019, with the aim of determining the response of maize yield and yield components to varying nitrogen regimes. The experiment was laid out in a split-plot design with three replications, and a plot size of 3 m × 3 m. The main plot comprised of two maize varieties KEP and BWM523 while sub-plots were four levels of nitrogen (0, 125, 200 and 300 kg/ha). Inter row spacing was 30 cm and inter-row spacing was 75 cm and with 4 rows in each plot. The results of this investigation revealed that nitrogen significantly affected most yield and yield components of maize varieties. Applying the nitrogen at the rate of 200 kg/ha significantly increased the number of grain per ear, biomass, one thousand grain mass, harvest index and grain yield of maize over the other rates. Grain yield increased up to 3320.75 kg/ha and 3291 kg/ha at 200 kg/ha of nitrogen for 2018 and 2019 respectively, thereafter reduced when more nitrogen was added. At the 200 kg/ha nitrogen treatment, the grain yield was increased by 37.60 and 39.13% for 2018 and 2019, respectively. The addition of nitrogen significantly increased some physiological attributes of maize varieties. Consistently nitrogen applied at 200 kg/ha increased the photosynthesis rate, stomatal conductance, transpiration rate and flag leaf area of the maize varieties over other rates. Genotype BWM523 performed better than genotype KEP in most attributes measured.

Keywords: Maize, nitrogen rate, stomatal conductance, leaf photosynthesis rate, grain yield.

INTRODUCTION

Maize is one of the key crops in Botswana as it forms part of the most consumed crops after sorghum. It is used as food in grain, ground porridge and green cob. In order to satisfy demand, the Botswana government food import bill is about USD 720 million, of which cereals contribute 15.3% of the budget. In the country, maize is produced from a total of about 130,042 ha, and the potential yield of maize genotypes grown in the country is up to 6 t/ha, but the grain yields realised are often below 2 ton/ha. Even though many abiotic and biotic factors can contribute to these large yield gaps, soil fertility reduction and poor nutrient management are among the major factors contributing to low productivity. In order to achieve maximum production, it is important to apply nitrogen to maize and manage it at the right amount.

Since nitrogen (N) deficiency is considered one of the major limiting factors of maize yield (Kamara *et al*., 2006; Badu-Apraku *et al.*, 2011)., the challenge in properly managing N is that the relationship between N and maize yield is impacted by many factors such as climate, soil type, tillage, topography, hybrid genetics, and their interactions (Sogbedji, 2001). Maize growers can influence management decisions on nitrogen rate that can directly impact the nitrogen levels found in the soil, and ultimately the grain yield. Also, crop response to different N fertilization rates may vary across soil types and locations or ecological zones (Moraditochaee *et al*., 2012). Therefore, it is important to optimize nitrogen fertilization in relation to specific soil and crop needs for optimum productivity (Achiri *et al.*, 2017; Selassie, 2015).

Nitrogen fertilizers are commonly used to improve soil fertility and plant nutrition, but nitrogen inputs can only increase maize yield up to a maximum rate for any particular site based on soil and climatic conditions

Table 1. Physico-chemical characteristics of the soil.

Soil property	2018	2019
Organic carbon (%)	0.49	0.40
Electrical Conductivity (dSm^{-1})	0.33	0.26
pH	5.7	5.5
Nitrogen (%)	0.0039	0.0028
Available P (mg/kg)	9.47	10.34
Available K (mol/kg)	0.27	0.35
Sand (%)	64	
Silt (%)	26	
Clay (%)	20	
Textural class	Sandy-loam soil	

(Wondesen and Sheleme, 2011; Alemayehu and Shewarega, 2015). Nitrogen is vital as a plant nutrient and a major yield determining factor required in maize production (Shanti *et al*., 1997). It is a component of protein and nucleic acids and normal growth is reduced if nitrogen is sub-optimum (Haque *et al*., 2001). Nitrogen mediates uptake and utilization of other nutrients and contributes to maize growth and yield (Onasanya *et al*., 2009).

Increasing levels of nitrogen in the soil under different soil and management condition showed increased grain yield, above-ground biomass, number of kernels per ear and plant height of maize (Ayub *et al*., 2002; Muhammad et al., 2004; Hani *et al***.**, 2006). Normally to maximize grain yield, farmers often apply a higher amount of N fertilizer than the minimum required for maximum crop growth. However, excess nitrogen input might affect soils and jeopardize sustainable development that can only be achieved when arable systems are resource-conserving, socio-culturally supportive, and environmentally friendly (Ngosong *et al*., 2019). Fageria and Baligar (2005) indicated that the application of abundant nitrogen favours ammonia losses, especially if the supply is in excess of plant requirements. Investigations by Gehl *et al.* (2005) revealed that nitrogen application beyond the optimum requirement of maize could not increase yield and may lead to an elevated level of nitrate ion in the soil and susceptibility of nitrate ion loss by leaching. Likewise, numerous other authors reported that excessive application of nitrogen fertilizer has negative effects on crops, greatly reduces N use efficiency (NUE), and causes significant nitrate leaching losses (more than 50% N to the environment) and contamination of groundwater (Ahmad *et al.*, 2018; Erisman *et al.*, 2013; McBratney and Field, 2015; Suchy *et al.*, 2018; Wang *et al*., 2019).

Currently, in Botswana, there are no proper recommendations for nitrogen application rates to the maize crop, and generally, blanket estimates are used by farmers. Therefore, if the maximum benefit is to be derived from fertilizer N, then we need to come up with a more precise prescription of nitrogen in maize. Thus, maize production practices are moving towards a strategy of maximizing maize yield by producing more crops on the same area of land to meet the increasing demands. It is because of the outlined gap that this study was undertaken with the sole objective of determining the application rate of N fertilizer to maize with regard to crop growth and development, hence the need for this investigation.

MATERIALS AND METHODS

Study area and experimental design

A field trial was conducted at the Department of Agricultural Research site in Sebele (24° 33' S, 25° 54' E, 994 m above sea level) during 2018 and was repeated in 2019. The experiment was laid out in a split-plot design arrangement with three replications, and a plot size of 3 m × 3 m. The main plot comprised of two maize varieties KEP and BWM523 while sub-plots were four levels of nitrogen (0, 125, 200 and 300 kg/ha). Inter row spacing was 30 cm and inter-row spacing was 75 cm and with 4 rows in each plot.

Soil sampling and analysis

Before the commencement of the trial, soil samples were taken from the field using zig-zag method (DAR, 1990) at a depth of 0.30 m using a soil auger. The soil samples were mixed to form a composite sample, then a representative was taken and analysed for physicochemical properties; analysis of major elements, including nitrogen, phosphorus and potassium was performed (Table 1).

The following soil properties were determined: pH was done in a soil: water ratio of 1:2.5 in 0.01 $CaCl_2$; particle size with the hydrometer method; organic matter using Black and Walkey (1947) method; electrical conductivity (EC) in deionised water in a soil saturated paste; phosphorus in Bray II (1990) procedure; % N using

Kjeldahl method and exchangeable cations (K) after extraction with neutral ammonium acetate. All procedures are found in Page *et al.* (1982).

Crop establishment and management practices

The seeds were sown at 2 seeds per hill on the first week of November and harvested on the first week of March the following year for two seasons. Plants were thinned to one plant per hill after two weeks. The nitrogen fertilizer applied was urea (46.5% N) and half of the nitrogen was applied at the time of planting while the remaining half was applied one week after seedling emergence. Phosphorus (single super phosphate, SSP 9%) was applied at sowing at the rate of 55 kg/ha (DAR, 2012). Weeds were removed manually using hoes, and meteorological data were collected with assistance from the Department of Agricultural Research meteorology station. Irrigation was done three times a week for an hour each time to field capacity, estimated according to irrigation scheduling recommendations by Ngwako and Mashiqa (2013) from previous work.

Data collection

Data were taken on five randomly selected plants from all three replicates of each treatment of each plot. Data recorded included numbers of days to tasselling, days to silking, days to physiological maturity, the number of grains per ear, 1000-grains mass, flag leaf area, biological yield, harvest index, plant height and grain yield. Flag leaf area was calculated by measuring the length and width of flag leaves of four representative plants from each treatment at silking. The mean single flag leaf area was estimated by the formula (Leaf area = Leaf length × Leaf width × 0.75) as used by Mashiqa *et al*. (2011).

Data on plant height (cm) at physiological maturity was recorded from base to the tip of the tassel with the help of a meter rod by selecting eight plants randomly from each plot and then averaged were worked out. Days to physiological maturity were recorded from the date of sowing till the date when all the plants get physiological maturity in each treatment. The number of grains per ear was calculated on eight randomly selected ears from each plot and were threshed and was averaged. After threshing, the grain mass of randomly 1000 grains was taken from the seed lot of each plot and was weighted with the help of electronic balance and thousand-grain mass was recorded. Data on biological yield was recorded by harvesting two central rows in each plot, the plants along with cobs were sun-dried for several days and weighed, and then converted into biological yield kg ha^{-1}. Physiological parameters measured from five randomly selected plants from each plot in each treatment included stomatal conductance, transpiration rate and net assimilation rate using a non-destructive method. These variables were assessed at the anthesis stage using a portable photosynthesis system (LI-6400, Licor, Lincon, USA) under the following conditions: airflow 500 µmol s^{-1}, leaf temperature of 25°C, CO^2 Concentration in the air coming into the chamber 360 to 380 μL^{-1}, relative humidity in the chamber between 30 and 70% and irradiance (PAR) of 1000 µmol m^{-2} s^{-1} , which represent a condition of light saturation for the maize plant in the field at 08:30 am.

Statistical analysis

Data for attributes collected from each plot was subjected to two-way analysis of variance (ANOVA) using STATISTICA software package, version 13.1. The significant differences between genotypes and nitrogen levels were determined using the least significant difference (LSD) test at a 5% level of significance.

RESULTS AND DISCUSSION

In 2018 genotypes significantly increased the number of grains per ear, 1000-grain mass, plant height, biological yield and grain yield, but not harvest index at $p \leq 0.05$, and a similar pattern was realised in the 2019 season (Tables 2 and 3). The genotype BWM523 had significantly higher mean values of the measured parameters compared to genotype KEP. Higher mean values of the above attributes for genotype BWM523 might be attributed to its improved genetic characters and therefore the genotype was able to better adoption to the prevailing environmental conditions there were grown on compared to genotype KEP.

In the present study, all the above-measured yield components understudy and plant height were significantly influenced by nitrogen rate during both the 2018 and 2019 seasons (Tables 2 and 3). Significantly higher mean values for the number of grains per ear, 1000-grain mass, plant height, biological yield and grain yield were obtained from the 200 kg/ha nitrogen treatment, although the means were non-significant for harvest index 125, 200 and 300 kg/ha of nitrogen treatments. Interaction between varieties and nitrogen rate was non-significant except for1000-grain mass and biological yield.

It is evident that nitrogen application increased the yield components, yield and plant height of maize up to 200 kg/ha, thereafter decreased. The increase in the number of grains per ear may be attributed to adequate nitrogen nutrition for the maize crop, and nutrition is the basis for plant growth and development. In agreement with our results, Yihenew (2015) also reported that the number of grains per ear was improved with the application of nitrogen up to the rate of 200 kg ha^{-1}. Results of the increased number of grains per ear at increased nitrogen fertiliser have also been reported by Onasanya *et al*. (2009).

Table 2. Effect of genotype and nitrogen on yield and yield-related parameters of maize varieties during 2018.

Treatments Genotype	No. of grains/ear	1000-grain mass	Harvest index	Plant height (cm)	Biological yield (kg/)	Grain yield (kg/ha)
KEP	367.01[b]	335.49[b]	32.97[a]	200.15[b]	8305.54[b]	2753.91[b]
BWM523	383.00[a]	346.78[a]	32.92[a]	204.32[a]	8818.64[a]	2922.07[a]
LSD	3.85	3.70	1.08	2.65	204.48	85.24
Nitrogen rate						
0 kg/ha	315.83[c]	321.45[c]	27.30[b]	195.13[b]	7587.2[d]	2072.02[d]
125 kg/ha	414.13[a]	348.41[b]	33.65[a]	203.45[b]	9042.8[b]	3126.22[b]
200 kg/ha	416.68[a]	356.73[a]	35.24[a]	211.80[a]	9343.8[a]	3320.75[a]
300 kg/ha	353.83[c]	339.45[d]	34.59[a]	198.93[c]	8274.6[c]	2862.97[c]
LSD	5.44	5.24	1.54	3.75	289.18	120.55
Mean	375.00	341.13	32.94	202.24	8562.08	2837.98
CV (%)	1.18	1.25	3.82	1.51	2.75	3.47
Variety*N-rate	NS	4.31*	NS	NS	NS	NS

Means in a column with the same letters are statistically not significant at $p \leq 0.05$ (*)

Table 3. Effect of genotype and nitrogen on yield and yield-related parameters of maize varieties during 2019.

Treatments Genotype	No. of grains/ear	1000-grain mass	Harvest index	Plant height (cm)	Biological yield (kg/ha)	Grain yield (kg/ha)
KEP	368.9[b]	333.76[b]	33.27[a]	200.4[b]	8090.87[b]	2709.89[a]
BWM523	381.6[a]	344.36[a]	32.57[a]	207.3[a]	8475.54[a]	2776.97[a]
LSD	4.14	5.33	1.34	3.36	171.07	88.88
Nitrogen rate						
0 kg/ha	313.7[d]	319.45[c]	27.80[c]	194.78[b]	7209.2c	2003.98[c]
125 kg/ha	412.6[b]	343.65[b]	32.85[b]	209.22[a]	8947.5a	2884.44[b]
200 kg/ha	422.9[a]	355.55[a]	36.80[a]	213.68[a]	8809.7a	3291.10[a]
300 kg/ha	351.8[c]	337.60[b]	34.22[b]	197.63[b]	8166.5b	2794.20[b]
LSD	5.86	7.53	1.90	4.75	241.93	125.7
Mean	375.26	339.06	32.92	203.8	8283.21	2743.43
CV (%)	1.28	1.82	4.12	1.91	2.38	3.94
Variety*N-rate	NS	NS	NS	NS	5.9*	1.19*

Means in a column with the same letters are statistically not significant at $p \leq 0.05$ (*).

With regards to 1000-grain mass, the highest mean value was recorded at 200 kg/ha of N, while the lowest was realised at 0 kg/ha of N treatment in both seasons. The increase in 1000-grain mass with increasing N is attributed to a higher amount of photosynthates to grains. These results tally well with those reported by Sharar *et al.* (2003), who reported the 1000-grain mass of 226.5 gm at a higher application of 210 kg N ha^{-1}. Several other investigators reported increased 1000-grain mass with increased nitrogen levels in maize (Karki, 2002; Adhikari *et al.*, 2021).

Our results showed that nitrogen application increased biological yield in both the 2018 and 2019 seasons. Consistently, the 200 kg/ha N treatment recorded the highest biomass while the lowest was recorded at nil nitrogen rate treatment. The increase in biological yield with increased nitrogen was due to the increased number of grains per ear, 1000-grain mass and improved plant height, as these components make up the total dry mass of the maize crop. These results are in agreement with those of Ullah *et al.* (2007) and Sanjeev *et al.* (1997) who reported that biological yield increased with the increase in nitrogen level.

Plant height showed a significant difference between nitrogen application rates during the 2018 and 2019 seasons (Tables 2 and 3). Nitrogen application increased the plant height of maize up to 200 kg/ha, thereafter the height decreased. Maximum mean plant height was observed at 200 kg/ha, and this increase in height may be associated with an increased number of internodes. Nitrogen as part of chlorophyll was supplied at an adequate level which helped in photosynthates manufacture and some were distributed to increase the length of nodes. Furthermore, nitrogen promotes growth, therefore the length of internodes increased with the addition of nitrogen which resulted in increased plant height. Moreover with the higher dose of N application, the cell division, cell elongation, nucleus formation, green foliage, and thus the chlorophyll content increases which increased the rate of photosynthesis and extension of stem resulting in increased plant height (Thakur *et al*., 1998). Our findings were in similarity with those of Gasim (2001) and Amin (2011). In addition results of this study are in conformity with those reported by Sharifi and Namvar (2016), who found the maximum plant height (185.2 cm) with the application of 225 kg/ha of nitrogen. Dawadi and Sah (2012) also reported the increased nitrogen level from 120 to 200 kg/ha also increased the plant height of hybrid maize varieties.

The data presented in the present study showed that the grain yield of maize was significantly increased by different nitrogen treatments and genotypes during the two seasons studied (Tables 2 and 3). Genotype BWM523 produced a higher grain yield compared to genotype KEP, but the differences in means were significant only during the 2018 season. The higher grain mean value for genotype BWM523 might be due to its improved genetic characters and better adoption to the prevailing environment compared to genotype KEP.

Regarding nitrogen, previous investigations have reported the increase in maize yield and yield components in response to elevated levels of N fertilizer (Liu *et al.*, 2021; Iqbal *et al.*, 2016). In this study, maximum grain yield mean value was observed at a nitrogen application rate of 200 kg/ha, with the lowest mean recorded at nil nitrogen application rate. An increase in grain yield at higher nitrogen levels might be as a result of lower competition for nutrients which leads to more canopy of plant contributing higher photosynthetic activity to gather more biomass with the grain. Similar results of an increase in grain yield as nitrogen was increased were reported by Shrestha *et al*. (2018) who found that applying a high dose of nitrogen at 200 kg/ha produced the highest grain yield. Still in concurring with our results, Shrestha *et al*. (2018), also reported that applying a high dose of nitrogen at the rate of 200 kg/ha produced the highest grain yield. Sharifi and Namvar (2016) also reported the highest grain yield by applying nitrogen at the rate of 225 kg/ha. Zeidan *et al.* (2006) and Onasanya *et al.* (2009) also found out that with increasing nitrogen dose, the maize grain yield also increased.

It seems nitrogen provided better nutrition to maize which resulted in better plant growth and improvement in yield attributes, hence increased grain yield. Therefore, at 200 kg/ha of nitrogen increased number of grains per ear, 1000-grain mass contributed to a higher mean of grain yield, since these attributes make up grain yield (Tables 2 and 3). However, Shiferaw *et al.* (2018) also reported increased grain yield under increased nitrogen fertilizer application as a result of higher number of grains per ear and higher grain mass. An increase in the number of grains may be attributed to adequate nitrogen nutrition that is the basis for plant growth and development. Therefore, it is evident that application of nitrogen up to 200 kg/ha resulted in increased grain yield of maize, and this was supported by many other researchers: Jehan *et al.* (2006), Tenaw (2000) and Kolawole and Joyce (2009) who found increased in maize grain yield with an increase in nitrogen levels.

However, the decline in maize grain yield and other yield components' response to nitrogen application above 200 kg/ha may be due to toxicity of the N at 300 kg/ha. Shiferaw *et al.* (2018) also found similar results working on maize. Additionally, Sharma *et al.* (2019) also reported the highest yield of 10.5 t/ha with 150 kg/ha N in maize and a lower yield of 8.81 t/ha yield as N was increased to 240 kg/ha during 2017.

A similar trend was observed during the 2019 season where the genotype effect significantly influenced yield components, except for the harvest index (Table 3). Furthermore, variety had no significant effect on the grain yield of maize during the same season. Regarding nitrogen rate, all the measured attributes were significantly influenced by the addition of nitrogen during the 2019 season, except for plant height and biological yield observed at 125 and 200 kg/ha. The interactive effect between varieties and nitrogen rates was not significant for measured attributes except for biological yield and grain yield in 2019.

According to results shown in Table 4, there were significant differences in flag leaf area, photosynthesis rate, transpiration rate and stomatal conductance between the two genotypes during the 2019 season. For all of these parameters, genotype BWM523 exhibited higher mean values compared to genotype KEP, still proving its genetic superiority over genotype KEP.

In respect to the effect of nitrogen application on the above measured physiological parameters, there were significant differences for all parameters. The 200 kg/ha of N treatment exhibited the highest flag leaf area, photosynthesis rate, transpiration rate and stomatal conductance mean values, while nil nitrogen rate gave minimum values and the means were significantly different from that of other N treatments.

In plants, the physiological processes of photosynthesis rate, transpiration rate and stomatal conductance often work together in a linkage during plant growth to enable the plant to synthesize its own food. In this regard, it is perhaps unavoidable to discuss these processes jointly as they work hand in hand as the plant grows to ultimately result in an improved yield.

According to results depicted in Table 4, nitrogen at 200

Table 4. Effect of genotype and nitrogen on flag leaf area, photosynthesis rate, transpiration rate and stomatal conductance of maize varieties during 2019.

Treatments Genotype	Flag leaf area (cm^2)	Photosynthesis rate (m mol CO^2 $m^{-2}S^{-1}$)	Transpiration rate (m mol H_2O m^{-2} S^{-1})	Stomatal conductance (m mol m^{-2} S^{-1})
KEP	202.58^b	50.43^b	9.08^b	191.55^b
BWM523	226.68^a	52.37^a	9.32^a	193.85^a
LSD	8.38	0.45	0.14	0.96
Nitrogen rate				
0 kg/ha	128.68^d	42.68^d	8.35^c	160.90^d
125 kg/ha	230.67^b	53.13^b	9.26^b	202.45^b
200 kg/ha	288.51^a	59.86^a	10.11^a	211.03^a
300 kg/ha	210.64^c	49.95^c	9.09^b	196.43^c
LSD	11.85	0.63	0.21	1.36
Mean	214.62	51.40	9.21	192.71
CV (%)	4.51	1.01	1.86	0.58
Variety*N-rate	17.21*	NS	NS	NS

Means in a column with the same letters are statistically not significant at $p \leq 0.05$ (*).

kg/ha rate was adequately supplied enough to stimulate the growth of the plant hence resulting in the increased flag leaf of the maize plant. It is known that nitrogen supply has substantial effects on plant growth and the development yield of maize (Pandey *et al*., 2000). Therefore it seems that in this experiment nitrogen provided better nutrition to maize which resulted in better plant growth, hence increased flag leaf area.

The larger flag leaf area at the 200 kg/ha of nitrogen enabled enhancement in a light interception during a critical period by leaves to aid in making more photosynthates, hence increased photosynthesis rate. The supply of nitrogen is one of the determinant factors for the process of photosynthesis. During the light reaction of photosynthesis, a generated electron is passed to Nicotinamide adenine dinucleotide phosphate (NADP) and helps to create NADPH by accepting hydrogen from the photolysis of water. This NADPH is then used in the carbon dioxide carboxylation process to generate photosynthates (Warren, 2004). Therefore the application of N at 200 kg/ha could have led to increased stomatal conductance and intercellular carbon dioxide concentration due to increased transpiration rate (Table 4) resulting in increased photosynthetic rate than at other nitrogen treatments (Gao *et al*., 2019; Yordanov, 2000) and hence increase in grain yield.

Furthermore, the 200 kg/ha nitrogen rate produced a higher photosynthesis rate, transpiration rate and stomatal conductance; so higher photosynthetic rates lead to higher biomass production and increased grain yield. Yu *et al*. (2001) reported that photosynthesis and transpiration are interdependent: the improvements of one are linked with the development of others. The higher values for both photosynthesis and transpiration rate under split application of nitrogen demonstrates that nitrogen helps to maintain water contents in the leaf, thus resulting in the optimization of net photosynthetic rate, transpiration rate, stomatal conductance and intercellular carbon dioxide, hence increased grain yield. Therefore it is evident that in this study, the higher values of the measured physiological processes helped in explaining greater grain yield realised at the end of the study.

On the other hand, the treatment of 0 kg/ha of nitrogen resulted in significantly lower values of the measured physiological attributes due to less or no nitrogen in the soil. Reduced nitrogen impacted on photosynthetic carbon dioxide assimilation rate by the leaves, resulting in less photosynthetic yield at 0 kg/ha treatment (Jin *et al.*, 2015). The decrease in photosynthesis is more pronounced under nitrogen-limited conditions as less nitrogen supply might limit the development of new sinks and disturb the source-sink balance in plant growth under elevated carbon dioxide (Hymus *et al*., 2001). The phenomena of low nitrogen resulting in decreased stomatal conductance and photosynthesis rate have also been reported by Ainsworth and Long (2005). Therefore, stomatal conductance could be the critical determinant of crop yield and productivity as it balances carbon dioxide uptake and water loss from the leaves as it impacts the total rate of photosynthesis and water use during the crop growing period. Gyuga *et al*. (2002) reported that nitrogen greatly influences photosynthetic processes, and its deficiency leads to declined photosynthesis, hence less grain yield.

CONCLUSIONS AND RECOMMENDATIONS

The results of this investigation revealed that nitrogen significantly affected most yield and yield components of maize varieties. Applying the nitrogen at the rate of 200 kg/ha significantly increased the number of grain per ear, biomass, one thousand grain mass, harvest index and grain yield of maize over the other rates. Grain yield increased up to 3320.75 kg/ha and 3291 kg/ha at 200 kg/ha of nitrogen for 2018 and 2019 respectively, thereafter reduced when more nitrogen was added. At the 200kg/ha nitrogen treatment, the grain yield was increased by 37.60 and 39.13% for 2018 and 2019 respectively. A similar trend was realised as the nitrogen rate significantly increased some physiological attributes of maize genotypes. It is concluded that nitrogen should be applied at 200 kg/ha in order to improve grain yield. The recommendations are that the experiment should be replicated in other areas of Botswana with different soil types and environmental conditions.

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