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SCREENING OF MAIZE CULTIVARS GROWN IN LESOTHO FOR DROUGHT TOLERANCE -2

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Abstract: *Drought is increasingly becoming a common natural phenomenon that adversely affects maize productivity in Lesotho necessitating mitigation strategies. Irrigation may be a viable option but water is becoming scarce, hence choice of drought tolerant cultivars maybe the best alternative. The study was conducted in Lesotho with the aim of (1) verifying the differences among maize cultivars in response to induced water deficit stress, (2) evaluating maize cultivars against different concentration levels of Polyethylene glycol which induces drought stress in germinating seed and seedling growth and (3) identifying cultivars of maize tolerant to drought stress. Complete Randomized Design with three replications and 22 treatments were employed in the laboratory experiment. Twenty-two different accessions of maize were collected from Department of Agricultural Research in Maseru, Lesotho, were evaluated for their genetic potential to drought tolerance at seedling stage. Water stress was induced by non-ionic water soluble polymer polyethylene glycol (PEG) of molecular weight 6000 using the procedure which was described by Michel and Kaufiman (1973). After ten days, data were collected on plumule length, radicle length, coleoptile length, radicle fresh weight, plumule fresh weight, coleoptile fresh weight, radicle dry weight, plumule dry weight and coleoptile dry weight. Analysis of variance was performed using Genstat recovery Version 14 to establish the difference among treatments. The results showed significant differences (P<0.05 and P<0.01) among the accessions, PEG-6000 concentrations and their interactions for evaluated seedling traits suggesting a great amount of variability for drought tolerance in maize cultivars. It was further revealed that as concentration of PEG is increased, values of the parameters measured decreased. The maize cultivars which outperformed the others in terms of drought tolerance were CAP 9019, SNK 2778, DKC 78-27, PAN3MO1 and Natal.*

KEYWORDS: Maize, Cluster Analysis, Drought Tolerance, Peg.

INTRODUCTION

Maize (Zea mays L.) is a major staple cereal crop in Lesotho ranking first, followed by sorghum and wheat as evidenced by production level and area under which it is grown (Bureau of Statistics, 2013/2014). It is important to the economy due to its wide range of uses. It is used to create a variety of food and non-food products such as corn meal, sweeteners, corn oil, starch and ethanol, which are used as the cleaner-burning alternative to gasoline. Maize is a plant of enormous modern day economic importance as food stuff and alternative energy source. Nutritionally, it is an important source of carbohydrates, protein, iron, vitamin B and minerals comparing favorably with other starchy crops such as rice and potatoes (Olaniyan, 2015; IITA, 2002). In addition, it is fed to livestock as whole grain in the farms or can be processed into variety of products by feed mills. It is produced by all farming house-holds for mainly home consumption and low amount for sale in four ecological zones, namely; mountain areas, foothills, lowlands and Senqu river valley which have varying altitude, climate and edaphic

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conditions (Wilkem, 1978; Moeletsi, 2004). It is grown widely throughout the world in a range of agro-ecological environments (FAO, 2015).

Maize is a temperate crop and requires adequate amount of rainfall well distributed across the growing season with warm temperature conditions. These good rains should fall at around its flowering time. However, the crop grown in rain fed areas is highly affected by drought stress (Kebede *et al*. 2001). The most dominant maize producers in Lesotho are smallholder farmers and some few commercial farmers who sell maize grains to the two Milling companies and Breweries existing in the country. The production techniques used to produce this crop depends on the correct application of production inputs that will sustain agricultural production as well as environment. These inputs are adapted high yielding maize cultivars, inorganic fertilizers, herbicides, irrigation and pesticides (du Plessis, 2013).

Maize is affected by several harsh environmental stresses that adversely affect growth, development, quality and yield. Several abiotic and biotic factors affect the growth in higher maize (Lichtenthaler, 1996, 1998). Drought, salinity, extreme temperatures, flood, pollutants and radiation are the important abiotic stress factors limiting the productivity of maize (Lawlor and Cornic, 2002). Among these, drought is a major abiotic factor that limits maize production (Nemth *et al*, 2002; Chaves and Oleveira, 2004). Maize experience drought stress either when the water supply in the soil becomes difficult for the roots to extract or when the transpiration rate becomes very high exceeding water absorbed by the roots. Drought stress along with the growing world population threatens stable global food availability. Drought results in reduction of yield and plant growth. It limits the photosynthesis which subsequently limits availability of photosynthetic assimilates and energy to the plant. It is imperative for plants to use this limited supply of nutrients to their maximal advantage to survive under stress. Apparently, under drought stress conditions, an urgent need for plants would be to increase the uptake of water, which is usually more available deep down in the soil profile (Xiong *et al*. 2006). Water stress affects almost every developmental stage of the plant. However, damaging effects of this stress was more noted when it coincided with various growth stages such as germination; seedling shoot length, root length and flowering (Rauf, 2008; Khayatnezhad *et al*. 2010). Some management practices can contribute to the increase of maize yield under drought conditions, like irrigation although it is impossible to be practiced when there is no water for irrigation, thus it is important to identify cultivars which are tolerant to drought so that they can be used during drought periods and for breeding purposes. There is a wide variation among cultivars of maize in terms of tolerance to drought. Some cultivars are susceptible to drought and give low yield while others are tolerant and yield higher. The ones that yield better and survive on drought conditions are the ones that are recommended to be used during drought conditions.

Various methods have been employed from time to time to identify drought tolerant genotypes and efforts have been made in the past to screen different varieties of plants which differed in drought tolerance (George *et al*, 2013). Polyethylene glycol (PEG) compounds were used to induce osmotic stress in petri dish for plants to maintain uniform water potential during the experimental period. Polyethylene glycol (PEG) has been used often as abiotic stress inducer in many studies to screen drought tolerant germplasm (Turkan *et al*, 2005; Landjeva *et al*, 2008; Almaghrabi, 2012; Ahmad *et a*l, 2013; Jatoi *et al*, 2014). PEG is a polymer and considered as better chemical than others to induce water stress artificially (Larher *et al*, 1993; Kaur *et al*, 1998). PEG is one of the dependable approaches for the selection of desirable genotypes to study in detail on water scarcity on plant germination indices (Kocheva *et al*, 2003). Identification of maize genotypes that can withstand inadequate water condition is vital to

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increase the crop production and this can be accomplished only by exploring the drought tolerant germplasm of maize.

In Lesotho, drought has increasingly become a common natural phenomenon that adversely affected maize productivity over the years resulting in high amount of imports into the country. It affects both quantity and quality alike, hence a need to find a solution. To alleviate this situation, there are two options as alluded earlier. One is to irrigate maize field during drought but water is becoming scarce under this condition. The other viable option is to identify the drought tolerant maize cultivar which is feasible considering a great variability among maize cultivars. It is therefore with reason that the study was conducted in Lesotho with an object of (1) verifying the differences among maize cultivars in response to induced water deficit stress, (2) evaluating maize cultivars against different concentration levels of Polyethylene glycol which induces drought stress in germinating seed and seedling growth and (3) identifying cultivars of maize tolerant to drought stress.

MATERIALS AND METHODS

Study area

The study was conducted at The National University of Lesotho, Faculty of Agriculture, in the Department of Crop Science situated 34 km South East of Maseru, the capital town of Lesotho. Coordinates of The University are 29^0 26' 48 South latitude and 27^0 42' 29 East longitudes with the altitude of 1610 m above-sea level. The facilities in Department of Crop Science were used such as laboratory and equipment.

Laboratory experiment

Complete Randomized Design with three replications and 22 treatments were employed. Treatments were seeds of maize cultivars obtained from Department of Agricultural Research in Maseru, Lesotho and four different concentrations of PEG-6000. The experiment was carried out from November 2016 to January 2017 to investigate the effects of PEG-induced drought on germination and seedling growth of twenty-two maize cultivars.

Procedure

Twenty-two different accessions of maize were evaluated for their drought tolerance at germination and seedling stage. Water stress was stimulated by non-ionic water soluble polymer polyethylene glycol of molecular weight 6000. Solution of PEG-6000 having osmotic potential of -1.0 bar as described by Michel and Kaufiman (1973) was prepared by dissolving different concentrations of PEG (117,78,39 and 0g) in 1000ml of distilled water. For control conditions, distilled water was used. Screening these cultivars was done by allowing them to grow for (10) ten days under PEG-6000 solution of -1.0 bar. Germination rate data were recorded every day. After ten days data were recorded for easily measurable seedling traits such as coleoptile length, root length, fresh coleoptile weight, dry coleoptile weight, fresh root weight and dry root weight under control as well as water stress conditions.

Seeds of different cultivars were first surface-sterilized with 0.1% Sodium hyperchloride (w/v) for 2 minutes. Ten sterilized seeds of each cultivar were spread over a blotting paper in a petri-dish of 9cm size separately. Three different concentrations of PEG that were mentioned

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previously were added in different petri dishes every day. The whole set was placed in the growth chamber with bright diffused light, 70 - 80% relative humidity and 25 – 30^{0}C temperature.

Data collection

The following seed germination and seedling parameters were measured; Germination %, length of coleoptile, rate of growth, radicle length, plumule length, radicle dry weight, plumule dry weight, coleoptile dry weight, fresh coleoptile weight, fresh radicle weight and fresh plumule weight. Germination rate was taken daily from day 1 to day 10 after planting. Germination percentage at day 10, plumule length, radicle length, coleoptile length, plumule fresh and dry weight, radicle fresh and dry weight and coleoptile fresh and dry weight under varying concentrations of PEG.

Data analysis

Genstat recovery Version 14 was used to analyse data collected above and Analysis of variance generate. Least significant difference was used to separate the means.

RESULTS

The analysis of variance depicted in table 1 revealed highly significant difference ($P<0.01$) among PEG concentrations, maize cultivars and interaction of maize cultivars evaluated for germination percentage, germination seed index, plumule dry weight, plumule fresh weight, plumule length, radicle dry weight, radicle fresh weight and radicle length. Means of different PEG concentrations are shown in Table 2.

PEG Concentrations

The grand mean for germination percentage of all four different concentrations of PEG was 85.4%. The highest germination percentage was obtained where control (0 PEG) was employed having 89% followed by 87% where 39g (-0.5bars) PEG was applied. The lowest germination percentage of 78% was exhibited in a PEG concentration of 117g (-1.5bars). Germination seed index revealed a grand mean 0.68 of with the highest index of 1.50 where control (0 PEG) was employed. The lowest index was found where the PEG concentration was 117g (-1.5bars) which was 0.68. The radicle length had a grand mean of 11.48cm. The longest length of 13.86cm was obtained where PEG concentration is 39g (-0.5bars) while the shortest length of 8.47cm was found where 117g PEG (-1.5bars) was applied. The overall mean of radicle fresh weight is 0.19 g with PEG 39g (-0.5bars) having the highest weight of 0.27g and the lowest of 0.15g , which was obtained from PEG 117g and 78g (-1.5 and -0.1bar). Radicle dry weight had a grand mean of 0.03g with the highest weight of 0.06g and lowest weight of 0.01g obtained from the PEG concentration of 78g and control, respectively. The overall grand mean of plumule length for four PEG concentrations recorded was 3.12cm with the highest and lowest being 4.05cm and 1.87cm where 39g PEG and 117g were added to the solution, respectively. The grand mean of plumule fresh weight was 0.35g with the highest weight of 0.48g where PEG concentration was 39g (-0.5bar) and lowest weight of 0.21g was observed with concentration of 117g PEG (-1.5 bars). Plumule dry weight had a grand mean of 0.02g with the highest weight of 0.04g obtained where 39g (-0.5bar) and 78g (-1.0 bar) PEG were dissolved in the solution. The lowest plumule dry weight was 0.01g where 117g (-1.5 bars)

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PEG was added. The overall grand mean of coleoptile length for four PEG concentrations recorded was 1.35cm with the highest and lowest being 1.90cm and 0.89 cm where 78g (-1.0bar) PEG and 117g (-1.5bars) were added to the solution, respectively. The grand mean of coleoptile fresh weight was 0.15g with the highest weight of 0.21g where PEG concentration was 39g (-0.1bars) and lowest weight of 0.10g was observed with concentration of 117g (-1.5 bars) PEG. There was no significant difference among the concentrations which were applied on coleoptile dry weight.

Variability in maize cultivars

Among the twenty-two cultivars of maize used in this study, highly significant differences (P<0.01) were obtained on all above-mentioned parameters except for few parameters namely; coleoptile length and coleoptile dry weight. CAP 444, PAN 14 and DKC2147 obtained the highest average germination percentage (98, 96 and94% respectively). The lowest average germination percentage was experienced by QN 633, PAN301and QN 623 with 51, 63 and 64% respectively. Germination seed index revealed that PAN 4M19, CAP 311 and PAN 3Q222 scored highest values. QN 633 obtained very low value, followed by DKC 8031. The longest radicle length was observed from PAN 301, CAP 9019 and PAN 14 while the shortest length was found on QN633 and QN 623. Radicle fresh weight was high in SNK 2778, PAN 14 and NATAL. The lowest values were obtained in CAP 311, QN 633 and NELSON CHOICE. High radicle dry weight was observed in PAN 301, PAN 14 and NATAL and the lowest radicle dry weight was obtained in QN 633 and CRN3505. Plumule length was found longest in CAP 9019, PAN 301 and SNK 2778 while the shortest length was obtained in CRN3505 and DKC2147. The cultivars with high plumule fresh weight were PAN 3m01, CAP 9019, NATAL and PAN 14 while CRN3505, QN 633 and PAN 3Q222 had the lowest plumule fresh weight. The cultivars with high plumule dry weight were CAP 9019 and PAN 3m01 and the lowest dry weight were obtained from QN 633. The maximum value of coleoptile fresh weight was found on SNK 2778, PAN 14 and NATAL while the lower values were obtained from QN 633 and OPV61. There was no significant difference among cultivars on the coleoptile length and coleoptile dry weight.

There was a difference amongst 22 varieties of maize evaluated for 11 parameters mentioned earlier. CAP 9019 performed high on seven parameters, namely; germination percentage, plumule length, coleoptile dry weight, plumule dry weight, radicle fresh weight, plumule fresh weight and radicle dry weight. SNK 2778 followed with good performance on six parameters, namely; coleoptile length, plumule length, radicle length, coleoptile fresh weight, radicle fresh weight and plumule fresh weight. Furthermore, three varieties followed with five parameters, namely; DKC78-27, PAN3M01 and NATAL. DKC 78-27 has performed well on coleoptile length, germination percentage, plumule length, coleoptile fresh weight and coleoptile fresh weight while NATAL performed well on coleoptile length, coleoptile dry weight, coleoptile fresh weight, plumule dry weight and radicle dry weight. PAN3M01 did well on plumule length, radicle length, radicle dry weight, radicle fresh weight and plumule fresh weight. Then followed by CAP 444, DKC 8031, CAP 311 and PAN4M19 with high performance on four parameters such as coleoptile length, germination percentage, plumule length and radicle length. CAP 311 performed well on plumule length, germination percentage, plumule dry weight and radicle dry weight while DKC 8031 performed well on radicle length, coleoptile dry weight, radicle dry weight and radicle fresh weight. Lastly, CAP4M19 performed well on plumule length, radicle length, and coleoptile dry weight and on GSI.

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Interaction of PEG concentrations and maize cultivars

The interaction of cultivar with PEG showed high significance (P<0.01) for germination percentage, radicle length, radicle fresh weight, radicle dry weight, plumule fresh weight and coleoptile fresh weight. Significant difference (P<0.05) was obtained in germination stress index. Plumule length, coleoptile length, plumule dry weight and coleoptile dry weight did not show any significance. Interaction of maize cultivars and PEG concentration at 117g (-1.5 bars) revealed low germination percentage of 36% and PEG concentration of 39g showed a germination of 90% on CRN3505. This also happened to QN 633 whereby germination percentage was 43% at PEG concentration of 117g (-1.5 bars) and at 39g (-0.5 bars) was 73%. Control where PEG was not applied germination percentage was very high close to 100% with most of the cultivars. The lowest value of germination percentage on control was 73% which is close to 100% and the highest value is 100%. Regarding germination stress index, significant difference at (P< 0.05) was found among 28 cultivars of dry beans. 0 was the lowest value which was found on control in almost all the cultivars. The highest value of germination stress index was found to be 1.333 which was obtained from PEG 117g (-1.5bars).

Highly significant difference (P <0.01) was obtained among cultivars for radicle length. Where 117g (-1.5 bars) of PEG concentration was applied, radicle length was 5.30cm and it was found on QN 623 while at 78g (-1.0 bars) the length was11.43cm. The longest radicle length was 19.83cm DKC 78-27 where 39g (-0.5 bars) PEG was applied. Control had the longest radicle length of 45.17cm. Radicle fresh weight exhibited a significant difference (P<0.01) among maize cultivars. PEG concentration of 78g (-0.1 bar) resulted in a radicle fresh weight of 0.00g on QN 633 and it was the lowest value but 39g had 0.16g which was higher even than control on this cultivar. The highest value was for radicle fresh weight was 0.58g on PAN14 where 117g (-1.5 bars) PEG was applied. Radicle dry weight was found to be 0 in most concentrations of PEG on QN 633 all concentrations was found to have 0 radicle dry weight. The highest value was found to be 0.083g on 78g (-1.0 bars) PEG concentration and was found in most of cultivars. The highest plumule fresh weight obtained was 0.73g on PAN14 where 39g (-0.5 bars) PEG was applied while the lowest was 0 at control. The lowest value of coleoptile dry weight was found to be 0 on several cultivars at 117g PEG (-1.5 bars) concentration.

Table 1 Mean squares of maize cultivars for various parameters

Source of Variation	d.f	GP	GSI	RL	PL	CL	RFW	PFW	CFW	RDW	PDW	CDW
PEG	3	1723.0**	15.24**	329.07*	55.05**	15.44*	0.23**	0.85**	0.13**	0.03**	0.02**	0.00
V	21	1745.8**	0.17**	2.29**	2.88**	3.37	0.07 **	0.06**	0.04**	0.00 **	0.00**	0.00
PXV	63	605.2 **	0.08*	54.38**	1.55	2.83	0.03**	0.05**	0.01**	0.00**	0.00	0.00
Error	176	122.7	0.05	49.75	1.13	2.65	0.01	0.02	0.01	0.00	0.00	0.00
GM		85.4	0.68	11.48	3.12	1.35	0.19	0.35	0.15	0.03	0.02	0.00
LSD		17.79	0.36	11.37	1.72	2.62	0.14	0.24	0.12	0.04	0.05	0.02

*Significant at 0.05% probability level, ** Significant at 0.01% probability level, GM=grand mean, PEG=Polyethylene glycol

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V=varieties, PXV=Interaction of PEG and varieties, radicle length(RL), Plumule length(PL), Coleoptile length(CL), Radicle fresh weight(RFW), Plumule fresh weight(PFW), Coleoptile fresh weight (CFW), Radicle dry weight (RDW), Plumule dry weight(PDW), Coleoptile dry weight (CDW), Germination percentage(GP), Germination stress index (GSI)

Table 2 Means for different concentrations of Polyethylene glycol

PEG	GP	GSI	RL	PL	CL	RFW	PFW	CFW	RDW	PDW	CDW
0	89.69	1.50	11.75	3.40	0.99	0.17	0.38	0.13	0.01	0.02	0.00
39	87.62	1.06	13.86	4.05	1.61	0.27	0.48	0.21	0.03	0.04	0.00
78	86.36	0.98	11.83	3.17	1.90	0.15	0.33	0.15	0.06	0.04	0.00
117	78.03	0.68	8.47	1.87	0.89	0.15	0.21	0.10	0.02	0.01	0.00

Polyethylene glycol (PEG), Germination percentage(GP), Germination stress index (GSI), radicle length(RL), Plumule length(PL), Coleoptile length(CL), Radicle fresh weight(RFW), Plumule fresh weight (PFW), Coleoptile fresh weight (CFW), Radicle dry weight (RDW), Plumule dry weight(PDW), Coleoptile dry weight (CDW).

Table 3 Means for different maize cultivars

VARIETIES	GP	GSI	RL	PL	CL	RFW	PFW	CFW	RDW	PDW	CDW
CAP 309	88.32	0.70	11.64	3.371.12		0.16	0.38	0.12	0.03	0.04	0.00
CAP 311	94.98	0.84	9.87	3.16	1.00	0.09	0.33	0.10	0.03	0.02	0.00
CAP 444	98.32	0.73	11.55	3.41	1.72	0.14	0.30	0.16	0.03	0.01	0.00
CAP 9019	92.48	0.79	13.65	4.21	1.19	0.16	0.46	0.10	0.04	0.06	0.01
CG 4141	79.15	0.68	9.27	3.39	1.23	0.14	0.28	0.12	0.01	0.01	0.00
CRN3505	93.32	0.54	9.44	2.15	1.07	0.12	0.21	0.10	0.00	0.01	0.00
DKC78-27	93.32	0.63	11.55	3.56	1.27	0.16	0.32	0.16	0.02	0.03	0.01
DKC 8031	90.82	0.48	12.02	2.90	1.17	0.17	0.33	0.17	0.03	0.01	0.00
DKC2147	94.98	0.68	12.00	2.50	0.99	0.21	0.34	0.12	0.04	0.01	0.00
NATAL	91.65	0.68	10.67	3.05	1.72	0.28	0.45	0.25	0.06	0.04	0.01
NELSON CHOICE	78.55	0.67	11.43	3.57	1.16	0.11	0.39	0.11	0.02	0.03	0.00
OKAVANGO	89.98	0.62	10.27	2.61	1.21	0.23	0.39	0.21	0.02	0.02	0.00

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OPV61	81.65	0.65	11.18	2.86	0.97	0.16	0.30	0.07	0.03	0.01	0.00
PAN 14	96.65	0.63	12.89	3.22	3.12	0.33	0.44	0.25	0.06	0.03	0.00
PAN 3m01	63.57	0.59	13.67	3.84	1.31	0.28	0.46	0.17	0.07	0.05	0.00
PAN 3Q222	80.82	0.83	12.04	3.15	1.25	0.23	0.26	0.16	0.04	0.01	0.00
PAN 413	80.82	0.79	10.20	3.14	2.29	0.23	0.35	0.13	0.02	0.02	0.00
PAN 4M19	86.65	0.84	11.92	2.84	0.88	0.13	0.33	0.14	0.02	0.02	0.00
PAN 4M21	91.65	0.72	10.66	2.94	1.67	0.14	0.29	0.11	0.03	0.03	0.00
QN 623	64.98	0.77	8.79	2.92	1.07	0.14	0.38	0.12	0.02	0.01	0.00
QN 633	51.65	0.36	8.57	2.33	0.66	0.10	0.24	0.07	0.00	0.00	0.00
SNK 2778	90.82	0.71	12.08	3.60	1.59	0.40	0.42	0.28	0.05	0.04	0.00

Germination percentage(GP), Germination stress index (GSI), radicle length(RL), Plumule length(PL), Coleoptile length(CL), Radicle fresh weight(RFW), Plumule fresh weight (PFW), Coleoptile fresh weight (CFW), Radicle dry weight (RDW), Plumule dry weight(PDW), Coleoptile dry weight (CDW).

DISCUSSION

Drought stress is a massive threat for the future agricultural production globally, hence this problem has been studied by many researchers in a large number of important crops such as common bean (Singh, 1983), wheat (Kerepesi and Galiba, 2000) and grass (Emmerich and Hardegree, 1990), tomato (Taylor *et al*., 1982). The general trend in the results of this study showed germination percentage, germination stress index, plumule dry weight, plumule fresh weight, plumule length, radicle dry weight, radicle fresh weight, radical length, coleoptile dry weight, coleoptile fresh weight and coleoptile length increased with decrease in the concentration of PEG. Where no PEG was applied (distilled water used), most of the parameters were higher than where there was PEG at any concentration.

PEG Concentrations

Water stress due to drought is one of the most significant abiotic factors that limit the seed germination, seeding growth, plants growth and yield (Hartmann *et al*, 2005, Van den Berg and Zeng, 2006). Several methods have been developed to screen drought tolerant germplasm in crop species. Based on the literature available, PEG is considered as a superior chemical to induce water stress (Kaur *et al*, 1998). Polyethylene glycol (PEG) molecules are inert, non-ionic, virtually impermeable chains and have been used frequently to induce water stress in crop plants (Carpita *et al*, 1979; Turkan *et al*, 2005; Landjeva *et al*, 2008; Rauf *et al*, 2006). PEG had higher osmotic potential of absorbing free water from the growing media and denying growing seedlings and germinating seeds access to water. These became severe when the concentration of PEG increased from low to high concentration because free water became scarce for germination.

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The findings of this study revealed that the highest germination percentage and germination stress index were obtained where control (0 PEG) was applied. The values decreased when the concentration of PEG was increased. Similar results were obtained by Mostafavi *et al.* (2011). Seed germination is one of the most critical and sensitive stage in the life-cycle of the plant (Ashraf and Mehmood, 1990). When the germinating seed was exposed to water deficit conditions, it compromised the seedling establishment (Albuquerque and Carvalho, 2003). Under drought stress, germination was decreased due to shortage of water required for early processes of germination. Water stress had a lethal effect on germinating seeds and excessive water shortage hindered seeds water uptake during germination due to the decreased water potential and all this led to decreased germination percentage because the other seeds may germinate while others may not germinate. Seedling growth parameters measured such as radicle also decreased as the concentration PEG increased. In a similar study, radicle length of dry bean cultivars attained the highest values under control (Rephe *et al*, 2017). A strong negative correlation coefficient was noted between PEG concentration and root length (i.e. root length was decreased with the increasing concentration of PEG) on tomato (Taylor *et al*, 1982). The radicle fresh weight also decreased with the increase in PEG concentration. This is because as the concentration of PEG increased, the water moved by osmosis from high concentration which was on root to the lower concentration which was where PEG was concentrated. Then the root started to become dry and have a small weight. Radicle fresh weight was considered to be a valid indicator for drought tolerance and susceptibility. In C4 plants like sorghum, Nour and Weibal (1978) reported that radicle fresh weight was the best and easiest characteristics for the determination of drought resistance. They also indicated that the cultivars having greater radicle fresh weight were the most drought resistant.

Radicle dry weight decreased with the decrease in PEG concentration. Importance of radicle dry weight as the selection criteria of maize for water stress condition was reported by Mehdi *et al*. (2001) who observed significant and positive correlation of radicle dry weight seedling traits like plumule fresh weight, radicle fresh weight, radicle length and plumule length. Thus, the importance of fresh and dry radicle weight to select for drought tolerance in maize is well documented. This meant the variety which showed higher values even on high concentrations of PEG was likely to be drought tolerant. The decrease in plumule length, plumule fresh weight and plumule dry weight were observed in stress condition as compared to control plants. This also happened on the study which was conducted by Batool *et al*. (2014). Shoot cells growth was dependent upon water availability and when cell was exposed to water shortage as result shoot growth decrease. Similarly, coleoptile length and coleoptile fresh weight decreased with the increase in PEG concentration.

Variability in maize cultivars

There was a significant difference (P>0.05) among maize varieties with some showing high value while others showed lower values of the parameters measured. Cultivars such as CAP 9019, SNK2778, DKC78-27, PAN3M01 and NATAL scored very high in most of the parameters while the cultivars with the lowest scores were QN 633, CG 4141and CRN 3505. The other varieties fell within the range. The variation suggested that a choice can be made among the cultivars for water deficit tolerance. Similar study was conducted on maize cultivar named Mugwort (*Artemisia vulgaris* L.) by Almas *et al*. (2013) using different concentrations of PEG. Another study was done on Islamabad gold and Sewan, and it was found that Islamabad gold was resistant to water stress while Sewan was found to be susceptible (Batool, 2014). Similarly, Giancarla *et al*. (2012) evaluated barley cultivars using laboratory experiment

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of PEG and obtained a great variation among cultivars ranging from high scores to low scores. The same study was conducted on fifteen tomato (*Lycopersicon esculentum* Mill.) varieties. Nonetheless, this study also revealed that some cultivars responded the same to PEG when particular concentration was used. This implied that the cultivars were sharing similar genes of drought stress.

Interaction of PEG concentrations and maize cultivars

The analysis of variance performed revealed a great variation in the interaction of PEG concentration and maize cultivars. Variation in the interaction was observed between concentrations and maize cultivars, and within cultivars and PEG concentrations. Each cultivar reacted differently under each PEG concentration implying that their genetic make-up was different. Nonetheless, there were some cultivars that reacted the same showing similarities in their gene composition regarding tolerance to stress. Physiology of the genes indicates that the genes produce proteins which in turn produce enzymes. Enzymes are the ones that are responsible for reactions such as adaptations to water stress or chemical induced stress. Genes responsible for adaption may be high or low in response to water stress and each cultivar possess either of the two but not both. All the parameters under study exhibited highly significant difference in the interaction of PEG concentration and maize cultivars except for Plumule length, coleoptile length, plumule dry weight and coleoptile dry weight. Different concentration of PEG simulated different types of climate conditions where a locality may be favourable for some cultivar and unfavourable for others. In this study, control was considered the most conducive locality whereas increasing PEG concentration was synonymous with increasing severity of the unfavourable conditions. Khakwani *et al*. (2011) conducted a similar study by screening eight cultivars of wheat and observed a wide variation among the interactions of PEG concentration and wheat cultivars. They further established that the PEG concentration of 78g (-1.0 bar) produce best results for this type. Similarly, Giancaria *et al*. (2012) found the interaction of different barley cultivars and different PEG concentrations resulting in a great variation in the parameters that they were studying.

CONCLUSION

The maize cultivars which outperformed the others in terms of drought tolerance were CAP 9019, SNK 2778, DKC 78-27, PAN3MO1 and Natal. Conclusion was based on PEG-6000 concentration of 78g (-0.1) which is considered standard by other researchers. The identification of these maize tolerant cultivars will be of great importance to the farmers who always face drought during growing season. There is a wider choice of six cultivars from which a farmer can be chosen. They are listed above according to their tolerance.

Recommendation

I recommend that varieties like CAP9019, SNK 2778 can be used during drought conditions because they are able to resist drought better than other varieties. Further studies should be done to verify the study.

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