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EFFICIENCY OF MAIZE (*ZEA MAYS*. L) VARIETIES FOR SEEDLING ESTABLISHMENT UNDER DROUGHT STRESS

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ABSTRACT

Drought stress is one of the major abiotic factors affecting seed germination and plant growth, especially in arid and semi-arid regions. The effect of drought stress on seed germination and seedling growth of four varieties of maize was studied using randomized complete block design with three replications. Germination percentage (GP), germination index (GI), mean germination time (MGT), root length (RL), shoot length (SL) and dry root weight (DRW) were measured to evaluate the varieties' response to field drought stress. Drought stress, variety, and the interaction drought × variety had a significant effect on all studied parameters. GP and GI decreased with the increase in stress level, while MGT increased. Shoot length decreased with increasing drought stress but different varieties show different performance under stress environment. Root length decreased with increasing level of severe drought stress. Water stress was found to affect the growth of roots the most. The varieties 'Paheli local' and 'Manakamana 3' exhibited the highest germination percentage and the best early seedling growth, given their higher biomass and longer root length. Thus, they could be recommended for environments with early cropping cycle drought.

Keywords: Drought, dry root weight, germination, growth trend, rainfed

INTRODUCTION

Maize is the second most important staple food crop both in terms of area and production after rice in Nepal (MOAD, 2017). It is a traditional crop cultivated as food, feed, and fodder on steep lands in the hills (Shrestha et al. 2019). It is grown under rainfed conditions during the summer (April-August) as a single crop or relayed with millet later in the season. Under the rainfed condition, drought severely limits plants' growth, development and productivity, particularly in arid and semi-arid regions, where the rainfall varies from year to year. This is also the case for the research site, which is in a semi-arid region of Nepal. However, depending upon plant species, certain stages such as germination, seedling or flowering could be the most critical stages for drought stress (Pena & Hughes, 2007). Proper seed germination depends on the availability of appropriate moisture contents for metabolic activation to breakdown the dormancy or to convert stored food into consumable form (Hadas, 2004). Among different stages, critical crop establishment is accomplished up to the development of 7th or 8th leaf. Crop density or number of emerged seeds, meantime for emergence and synchronization of emergence are characteristic features which determined the efficacy of seedling establishment (Finch-Savage, 1995).

Seedling growth after germination is another important stage for the life cycle of plants, which would affect the size, development and genetic variation ability of plant population (Woltz et al., 2006). Successful establishment of plants depends on their germination quality which in turn depends on water availability (Ma, Liang, & Kong, 2008).

Global warming is likely to increase the incidence of drought in many established maize growing areas (Zaidi et al., 2004). Drought can be defined as a period of below-normal precipitation that limits plant productivity in a natural or agricultural system (Kramer and Boyer, 1995). Understanding the physiological behavior of plants under drought conditions may result in predicting drought-tolerant varieties of crops (Kerepesi and Galiba, 2000). Differences in resistance to drought are known to exist within genotypes of plant species and were found in many studies of maize (Lorens et al., 1987; Adhikari et al., 2021). The objective of this study was to determine the effects of deficit water stress on germination and seedling establishment of maize genotypes. Germination is regulated by the duration of wetting and the amount of moisture in the growth medium (Gill et al., 2002). Seedling growth after germination is another important stage for the life cycle of plants, which would affect the size, development and genetic variation ability of plant population (Woltz et al., 2006).

MATERIALS AND METHODS

Site of the research

The research was conducted at two locations;

- Farmer’s Field (Gyan Bahadur Gurung), Sidhhicharan MP 4, Okhaldhunga. The site was at an elevation of 1750 masl with 28º 65’ N latitude and 82º 16’ E longitude

- Plastic house in District Agriculture Development Office, Siddhicharan MP 4, Okhaldhunga. The site was also at an elevation of 1750 masl with 27°30' N latitude and
86°50' longitude.

The soil type is sandy loam and climatically upper-tropical with an average annual rainfall of 1868.5 mm. The research location is characteristics of sub-tropical to a temperate climate. Rainfall in Okhaldhunga during the time of the study March to May 2018 was 700 mm while the average temperature was 20^0C as obtained from mfd.gov.np

Table 1. Name of varieties, recommended site and site of collection used in the study

SN	Name of Variety	Recommended site	Collected from
1.	Manakamana-3	Inner terai to Mid hills	Siddhicharan Municipality Office, Okhaldhunga
2.	Khumal-Hybrid 2	Inner terai to Midhills	NARC, Khumaltar
3.	Arun 6	Inner terai to Foothills	NMRP, Chitwan
4.	Nutan IL60 (Comm. Hyb)	1000 to 1800 masl	Seed Distributor, Khumaltar
5.	Paheli local	Okhaldhunga	Local farmer, Siddhicharan, Okhaldhunga

The experiment was a double factorial randomized complete block design, with three replications. The first factor was the variety, with five levels, and the second was the induced water condition with two levels namely rain-fed and water stress-induced. Water stress was induced by choosing a plastic house raised above the ground and restricted water. Seeds were sown in both conditions at 75 X 30 cm^2spacing with 20 plants per row and 3 rows per plot.

Germination parameters were counted after 8, 14, 18- and 21-days following sowing. Seeds were considered germinated when they appeared above the soil profile. For germination percentage, the number of seeds germinated by day 21 was considered.

Germination Percentage (GP) = (No. of germinated seeds/ Total no. of seeds sown) x 100

Germination index (GI) = $(\text{No. of germinated seed})/(\text{Days of the first count}) + \cdots + (\text{No. of germinated seed})/(\text{Days of the last count})$

(Moradi, Akbari, Ramshini, & Khorasani, 2012)

Mean Germination Time (MGT) = $(\sum TiNi)/\sum Ni$

Where, Ti = Total time for germination

Ni = number of seedlings emerged

Unit = day

Shoot length was measured from the cotyledons to the collar, and the root length was measured from the collar to the root tip.

Statistical analysis was conducted with the software package Agricolae in R studio. Data were subjected to an analysis of variance (ANOVA) to determine statistically significant differences among varieties, drought stress, and their interaction levels. Duncan's multiple range test (DMRT) was applied to compare treatment means. A multivariate ANOVA was also conducted to study the growth profile in different conditions of water availability.

RESULTS AND DISCUSSION

Drought stress effects on germination

Results of analysis of variance indicated that drought stress significantly affected maize seed germination percentage (GP), germination index (GI) and mean germination time (MGT). There was also a significant effect of variety and its interaction with drought on these parameters (Table 1). GP and GR decreased, while MGT increased with the increase in water stress (Figure 1 & 2).

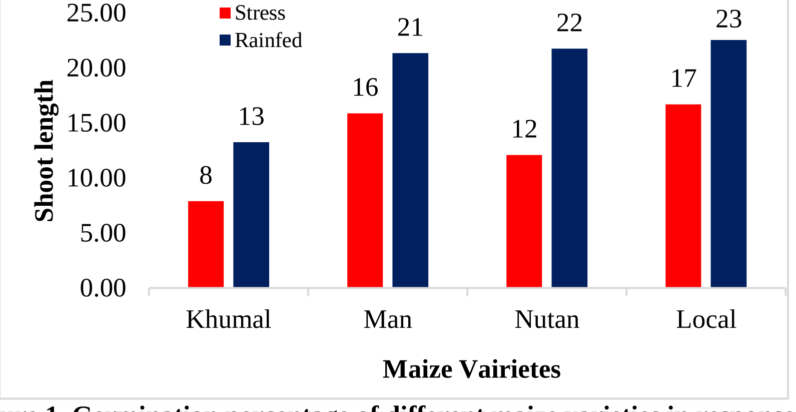

Figure 1. Germination percentage of different maize varieties in response to field water condition

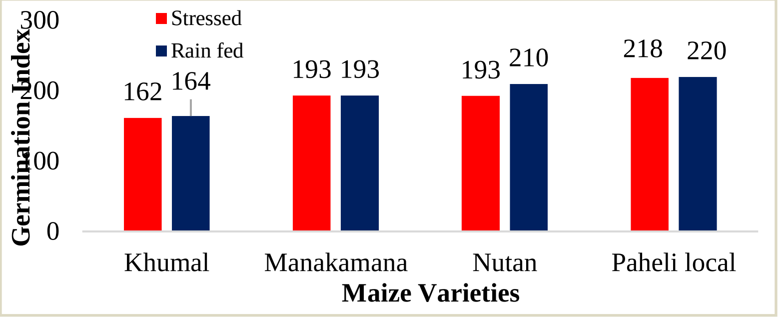

Figure 2. Germination indices of different maize varieties in response to a field water condition

The highest GP (75 %) was observed under rainfed condition, and the most significant decline was seen in Nutan IL60 which is also a commercial hybrid.

Germination index of drought resistance

The Paheli local showed similar GI for both rain-fed (217.3) and stressed condition (217.7). The varieties showed higher GI for rainfed condition compared to stress condition. The best one was Paheli local followed by Nutan IL60, Manakamana 3 and Khumal Hybrid 2.

Table 2. Analysis of variance (mean squares) for seed germination and seedling growth-related traits of maize varieties vs. field water condition

SOV	**df**	**GP**	**GI**	**MGT**	**SL**	**RL**	**DRW**
Variety	3	213.90***	2203.4***	1.80	52.22***	9.18**	0.01***
Condition	1	973.92***	112.4***	0.50	389.81***	7.27*	0.27***
Vareity X Condition	3	7.1	63.9***	0.70	15.51*	0.59	0.00***

Abbreviation: SOV: Source of Variation GP: Germination Percentage; GI: Germination Index; MGT: Mean Germination Time; SL: Shoot Length; RL: Root Length; DRW: Dry Root Weight

Shoot length and root length

hanges in morphological characters are the ultimate determinants of stress effects on plants (Jaleel *et. al*., 2009). Following germination, cellular growth appears to be the most sensitive response to drought stress (Rezaeieh & Eivazi, 2012). A study has shown that water shortage declines corn canopy height, leaf area index and root growth (Hirich, Fatnassi, Ragab, & Choukr-Allah, 2016) Paheli local, Manakamana 3 and Nutan IL60 performed better than Khumal Hybrid 2 regarding shoot length which means that drought inhibited the cellular growth the most in Khumal Hybrid 2.

Genotypes could be declared as tolerant and susceptible based on traits like root length, dry root weight, fresh root weight, fresh shoot weight, etc (Naveed et. Al., 2015). In this study, the highest root length under drought stress belonged to Paheli local and the shortest one belonged to Khumal Hybrid 2. Manakamana 3 and Nutan IL60 were at par considering their root lengths at both stressed and rainfed condition. Higher root length of Paheli local followed by Manakamana 3 and Nutan IL60 theoretically signifies higher chances of exploration and absorption of water and nutrients from the soil under drought stress. Therefore, in an unfavorable environment, with water deficit, root growth is very important to allow greater exploration of the soil in search of water, without excessive energy consumption. Decreased root length in Khumal Hybrid 2 was probably because of low photosynthetic assimilates devoted to parts of the plant due to diminished photosynthesis. This was mentioned in a study by (Moradi, Akbari, Ramshini, & Khorasani, 2012).

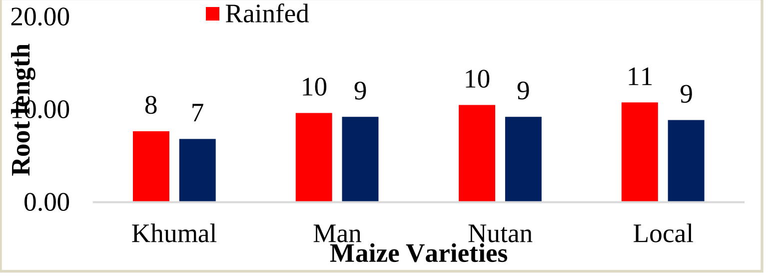

Figure 3. Root length of different maize varieties in response to a field water condition

Dry root weight

Khumal Hybrid 2 having less dry weight in both the conditions least tolerant to water stress. On the other hand, Paheli local could be utilized in a breeding program considering its morphological traits are most tolerant to drought. A study by Horne, Ross & Hughes (1992) reported that maize genotypes with low root dry weight are less tolerant to drought stress. So,

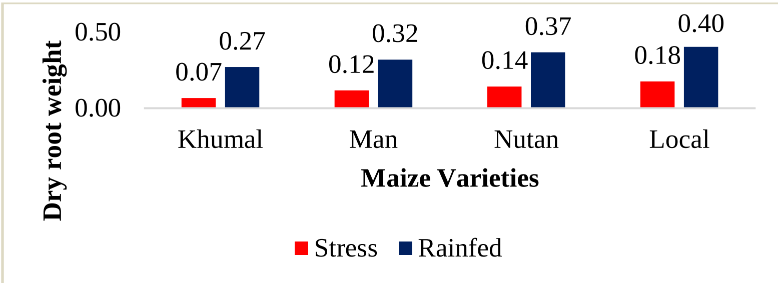

Figure 4. Dry root weight of different maize varieties in response to field water condition

Growth profile study

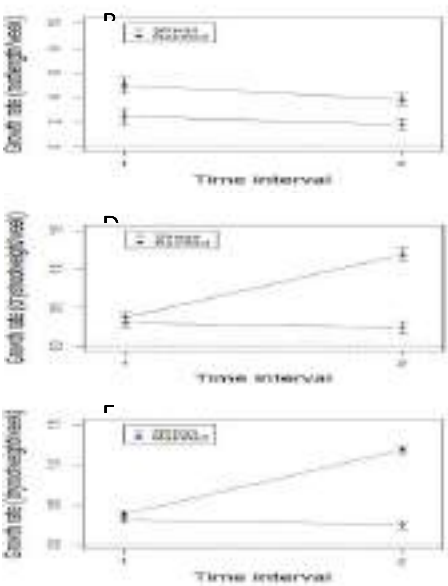

Figure 5. Growth curve of traits per week in stressed and rainfed condition. (A: Shoot length; B: Root length; C: Fresh shoot weight; D: Dry shoot weight; E: Fresh root weight; F: Dry root weight)

The growth profile curve (Figure 5) shows the gain in shoot length every week steadily increased in rainfed condition except in the last two weeks. While in the stressed condition, there was a constant fluctuation in the gain in shoot length throughout the 5 weeks. It decreased during the interval between 2nd and 3rd week and again in the interval between 4th and 5th week. The gain in shoot length every week steadily decreased as the plant matured for both rain-fed condition and stressed condition. There is a significant gain in shoot length for both conditions especially when the plant is of the knee-high stage (4th to 5th week). Similarly, the gain in fresh shoot weight gradually increased from the 1st week to 2nd and then from 2nd to 3rd in both rain-fed and stressed condition. The only difference was that in the case of the rainfed condition, there was a more gain/week. The gain in dry shoot weight per week steadily increased as it is supposed to for the rainfed condition. But for the stressed condition, the gain in dry shoot weight decreased from 2nd week to 3rd week. The gain in dry root weight per week increased for the rain-fed condition while it decreased slightly for stressed condition suggesting a lowered tolerance for drought.

CONCLUSION

Based on the results of this study, the varieties ‘Paheli local’ and ‘Manakamana 3’ germinated better than the other varieties under drought conditions. The observed variation among varieties is a reliable indicator of genotypic differential for drought tolerance in maize. This suggests that the choice of the maize variety to be planted in a given environment should depend upon the presence and the degree of the stress observed in such an environment. In drought-stressed environments, the varieties ‘Paheli local’ and ‘Manakamana 3’, exhibiting the highest germination percentage, should be recommended. These varieties contain traits like longer root length and higher root dry biomass which, according to previous studies, are most linked with drought tolerance ability. Furthermore, it can be identified whether these traits have a role in reducing/altering the grain yield and breeding programs can be designed accordingly.

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ANNEX

Annexe 3: Agrometeorological data during the research period (Source: www.mfda.gov.np)