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Germination at low osmotic potential as a selection criteria for drought stress tolerance in sweet corn

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Water stress can affect germination by decreasing the percentage of germination. A study was undertaken to evaluate the influence of different osmotic potentials (MPa) on proline content and percentage seed germination of corn. The experiment was conducted in factorial with a randomized complete block design (RCBD) with three replications. Seeds of two open pollinated varieties (Masmadu and Thai super sweet) and three hybrids (968, 969 and 926) sweet corn were germinated at 0, -0.2, -0.5, -0.7, -1.2 and -1.4 MPa osmotic potentials, respectively. Results show that the percentage of germination and coefficient of velocity (CVG) decreased with decrease in osmotic potential while proline content and mean germination time (MGT) increased. Polyethylene glycol (PEG) increased root length (RL) and length per volume (LPV) at low osmotic potential (-0.2 MPa) but decreased at more than -0.7 MPa. Seedling proline content appears not to be related to percentage germination but appears to be related to the decline in osmotic potential in germination media. Seed germination test at -0.7 to -1.2 MPa has the potential to be used as a vigor test in sweet corn.

Key words: Osmotic potential, germination, polyethylene glycol, corn, proline content.

INTRODUCTION

Most of the agriculture land of the world is considered semi-arid, and the main limiting factor is water. Studies have shown that germination of seed is decreased and delayed under water stress (Guo et al., 2012; Patane et al., 2012; Dabbagh mohammadi Nasab, 2011; Hao and De Jong, 1988; Rao and Dao, 1987). Germination percentage decreased in low osmotic potential of Polyethylene glycol (PEG) (Almansouri et al., 2001; Yagmur and Kaydan, 2008).

Roots are very important in plant growth as they absorb soil moisture and nutrients. Drought stress affects root weight of the plant during water stress conditions (Yang et al., 2006). Root length is often directly related to absorbed water from soil (Hamblin and Tennant, 1987). Root growth is an important drought tolerance mechanism in beans for drought avoidance and absorbing water from depth of soil, but root growth decreases in drying soil (Sponchiado et al., 1989). Root elongation and root diameter decreases at low water potentials in maize (Sharp et al., 1988, 2004). Root elongation decreases under drought stress by more than 88% in millet (Radhouane, 2007). Gholami et al. (2009) reported that drought stress decreased root length in corn. Inverse root length is reduced under low osmotic potentials in triti-

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Abbreviations: MPa, Mega Pascal; **OP,** osmotic potential; **MGT,** mean germination time; **CVG,** coefficient velocity of germination; **PEG,** polyethylene glycol; **G (%),** germination percentage; **RL,** root length; **LPV,** length per volume; **RV,** root volume; **AD,** average root diameter; **T.S.S.,** Thai super sweet; **H,** hybrid.

Table 1. Summary of analysis of variance for maximum germination (G), mean germination time (MGT), coefficient velocity of germination (CVG).

Source	G (%)	MGT	CVG
Block	0.45 ns	0.43ns	0.28ns
Variety	12.72**	15.83**	12.5**
Water stress	205.87**	132.91**	106.24**
Varity × stress	3.01**	5.7**	4.75**
Error	45.03	0.131	2.72

*, **Significant difference at P<0.05 and 0.01; ns, not significant.

cale (Yagmur and Kaydan, 2008).

Proline content accumulation is a common metabolic response of higher plants to water deficits and salinity stress and substantially increase in both young and old leaves during a dry period (Tarighaleslami et al., 2012;Din et al., 2011; Pirasteh Anosheh et al., 2011; Aziz and Khan, 2003). Little information is available on the response of seed proline content when seeds are sown under water stress field conditions. The ability of the plant to accumulate proline is important for the plant and may be an adaptation process of the plant over short periods to resist water stress (Jäger and Meyer, 1977).

Therefore, the objective of this study was to evaluate the effects of different osmotic potential on the proline content and influence on sweet corn seed germination.

MATERIALS AND METHODS

Experiments were conducted in the laboratories of Faculty of Agriculture and Department of Crop Science, Universiti Putra Malaysia (UPM). The design of the experiment was Factorial base on randomized completely block design (RCBD) with three replications. Seeds of three sweet corn hybrids (968, 969 and 926) and two open pollinated varieties (Masmadu and Thai super sweet) were used. Twenty five (25) seeds of any cultivar were selected and sterilized in sodium hypochlorite (5%) and then washed twice in water. Seeds were germinated at osmotic potentials of 0.0, -0.2, -0.5, - 0.7, -1.2 and -1.4 MPa of polyethylene glycol 6000 (Cony and Trione, 1998) for nine days in Petri dishes on moist Whatman filter papers at 26°C. The germination data were recorded daily. Percentage germination, mean germination time and coefficient velocity of germination were calculated by the equations 1, 2 and 3, respectively:

1) Germination percentage (%) = Final number of seeds germinated × 100 (Scott et al., 1984).
2) Mean germination time (MGT) (day) $= \Sigma Dn / \Sigma n$

Where, n is the number of seeds, which were germinated on day (D) and D is the number of counted days from the beginning of germination.

3) Coefficient of velocity of germination (CVG) = N1 + N2 + · · · + Nx /100 × N1T1 + · · · + Nx Tx Where, N is the number of seeds germinated each day, T is the number of days from seeding corresponding to N (Jones and Sanders, 1987).

The seedling roots were scanned by using a root scanner WinRHIZO system (WinRHIZO, Regent Instrument, Inc.) on the ninth day of the germination period. Proline content in the nine-day seedlings was measured by Bates et al. (1973) method. The data were analyzed using SAS software (SAS Institute Inc, Cary, NC, USA, SAS (r) Proprietary Software 9.2 (TS1M0)). Treatment means were compared using least significant test (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Results of these experiments show significant effects of osmotic potential and variety on percentage germination, mean germination time (MGT) and coefficient of velocity of germination (CVG) (Table 1).

Percentage germination for open pollinated varieties, hybrid 926 and hybrid 968 declined to <80% as osmotic potential decreased to -1.2 MPa. The high percentage germination in all varieties was at -0.5 MPa (Figure 1). Ghiyasi et al. (2008) reported the highest percentage germination and shorter time to 50% germination (T50) when seeds were germinated at -0.5 MPa. Germination percentage decreased in low osmotic potential of PEG (Almansouri et al., 2001; Yagmur and Kaydan, 2008). Percentage germination decreased with increased PEG 6000 concentration which is due to the reduction in water potential gradient between the seed and surrounding media (Dodd and Donovan, 1999).

Coefficient of velocity of germination (CVG) decreased progressively as osmotic potential decreased to -1.4 MPa, while mean germination time (MGT) increased progressively from 3 to 4 days to >5 days as osmotic potential decreased to -1.4 MP (Figures 2 and 3). MGT is an accurate measure of the time taken for a lot to germinate, but this does not correlate well with the time spread or uniformity of germination. It focuses instead on the day when most germination events occur. CVG does not focus on the final percentage of germination, but places emphasis on the time required for reaching it (Kader, 2005).

Seedling proline content increased progressively with decrease in osmotic potential during germination with the highest proline content observed in hybrid 968 (Figure 4). The present results are in accordance with studies reporting that osmotic stress increased biosynthesis rate of proline content (Boggess et al., 1976; Fattahi Neisiani et al., 2009). The ability of the plant to accumulate proline is important for the plant and may be an adaptation process of the plant to resist short periods of water stress (Jäger and Meyer, 1977).

Results show that proline content in the seedling increased with decreased water osmotic potential. This is because decrease in water osmotic potential of the media reduces the water potential gradient between the seedling and surrounding media, resulting in lower water uptake by the seedling, which may induce water stress in the seedling. Girousse et al. (1996) reported that water deficit increased the proline concentration of the phloem sap in alfalfa.

Seeds of all varieties except hybrid 969 showed >80%

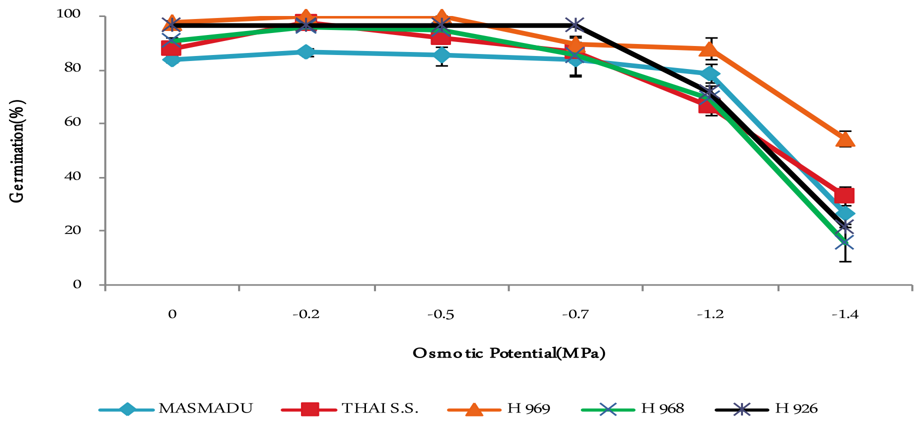

Figure 1. Interactive effects of osmotic potential and variety of sweet corns on percentage Germination. Vertical bar represent ± SE.

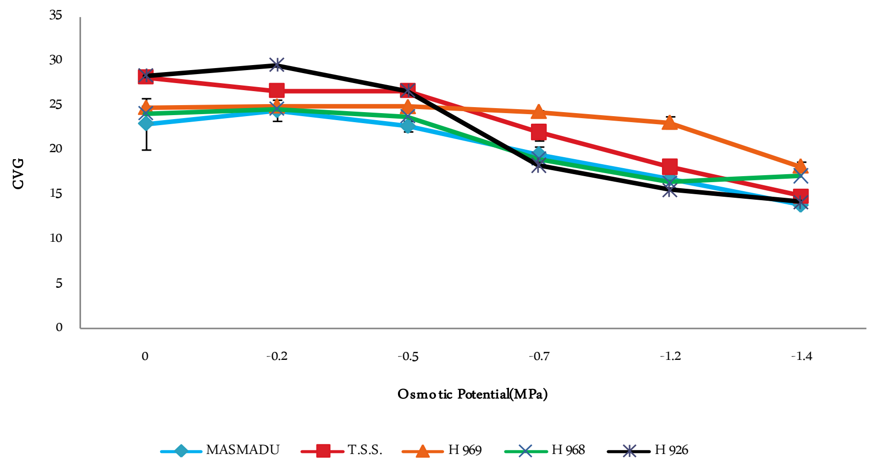

Figure 2. Interactive effects of osmotic potential and variety of sweet corns on Coefficient of Velocity of Germination (CVG). Vertical bar represent ± SE..

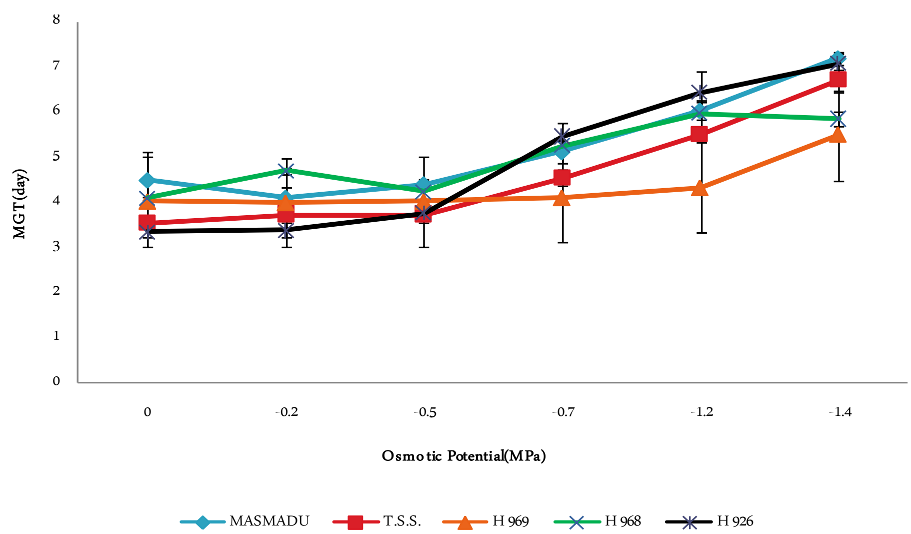

Figure 3. Interactive effects of osmotic potential and variety of sweet corns on Mean Germination Time (MGT). Vertical bar represent ± SE

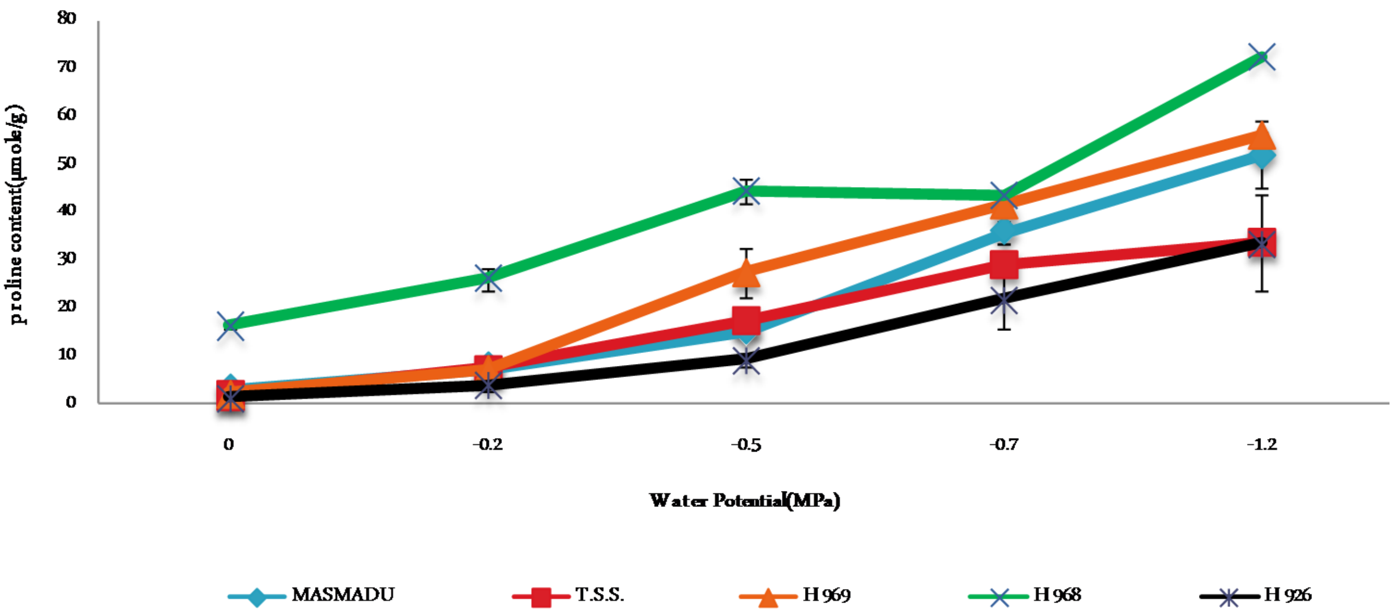

Figure 4. Interactive effects of osmotic potential and variety of sweet corns on seedling proline content. vertical bar represent ± SE.

Table 2. Summary of analysis of variance for root scan including: root length (RL), length per volume (LPV), root volume (RV) and average root diameter (AD).

Source	RL (cm)	LPV (cm/m^3)	RV (cm^3)	AD (mm)
Block	1.09ns	1.15ns	0.31ns	0.54ns
Variety	106.48**	65.92**	88.77**	160.03**
Water stress	55.43**	29.02**	13.36**	2.64*
Varity × stress	4.51**	3.34**	11.07**	13.51**
Error	34.13	65.94	0.4	0.12

*, ** Significant difference at P<0.05 and 0.01; ns, not significant.

germination when imbibed at up to -1.2 MPa (Figure 1). Percentage germination of Thai super sweet, 926 and 968 hybrids declined to < 70% when osmotic potential of germination media was < -0.7 MPa (Figure 1). The present results are in accordance with studies by Thakur and Sharma (2005) who exported that a strong negative correlation between germination capacity and proline accumulation under stress. In potato plants there was reported increased proline content accumulation under water stress (Knipp and Honermeier, 2006).

The results of analysis of variance for root scan parameters are shown in Table 2. Results of these experiments show that the effects of osmotic potentials and variety on Root Length (RL), Average Diameter (AD), Length per Volume (LPV) and Root Volume (RV) are significant (Table 2). Also, interaction affect of osmotic potential × variety was significant (Table 2).

The highest root length (RL) and length per volume (LPV) at all levels of water osmotic potential were observed in hybrid 969 (Figures 5 and 6). The present results are in accordance with many studies that reported that root length decreasing under water deficit (Bilgin et al., 2008; Radhouane, 2007). PEG increased root length at low concentration but decreased sharply at high osmotic potential (Radhouane, 2007; Yagmur and Kaydan, 2008). The average highest root volume (RV) and average diameter (AD) were observed in hybrid 926 (Figures 7 and 8). Root growth is affected by adequate plant water supply during water deficit (O'Toole and Bland, 1987; Sponchiado et al., 1989). Plant growth is generally decreased in decreased osmotic potential and root growth is often less inhibited than shoot growth (Blum et al., 1983; Sharp et al., 1988; Sharp et al., 2004). Results showed that elongation of primary root in corn is very sensitive to decreased water potential of the growth medium.

It has been found that polyethylene glycol 6000 increased root length and length per volume at low concentration (-0.2 MPa) but decreased at high concentration (-0.7 MPa). A variety of high root length is capable of

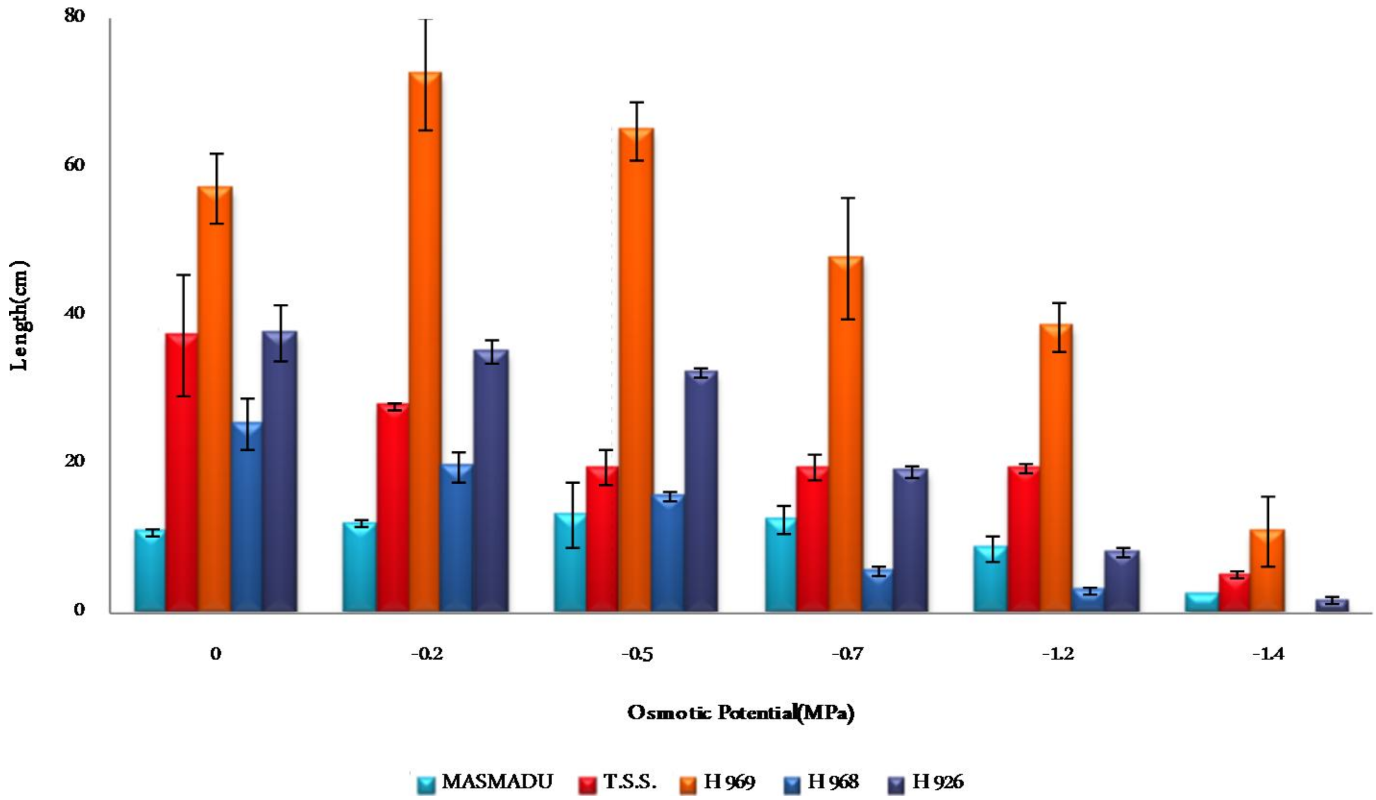

Figure 5. Interactive effects of osmotic potential and variety of sweet corns on Root Length were determined by root scanner WinRHIZO (WinRHIZO, Regent Instrument, Inc.). Vertical bar represent ± SE.

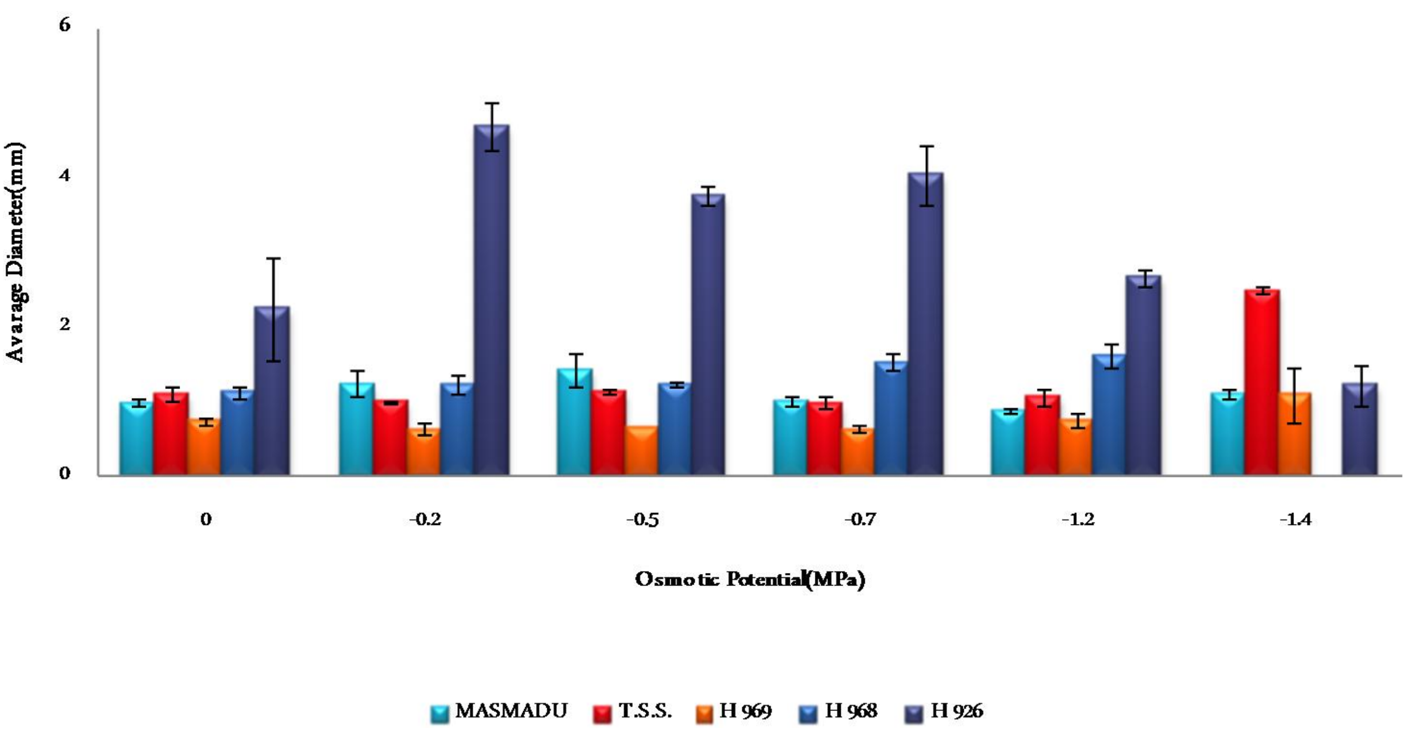

Figure 6. Interactive effects of osmotic potential and variety of sweet corns on Root Diameter were determined by root scanner WinRHIZO (WinRHIZO, Regent Instrument, Inc.). Vertical bar represent ± SE.

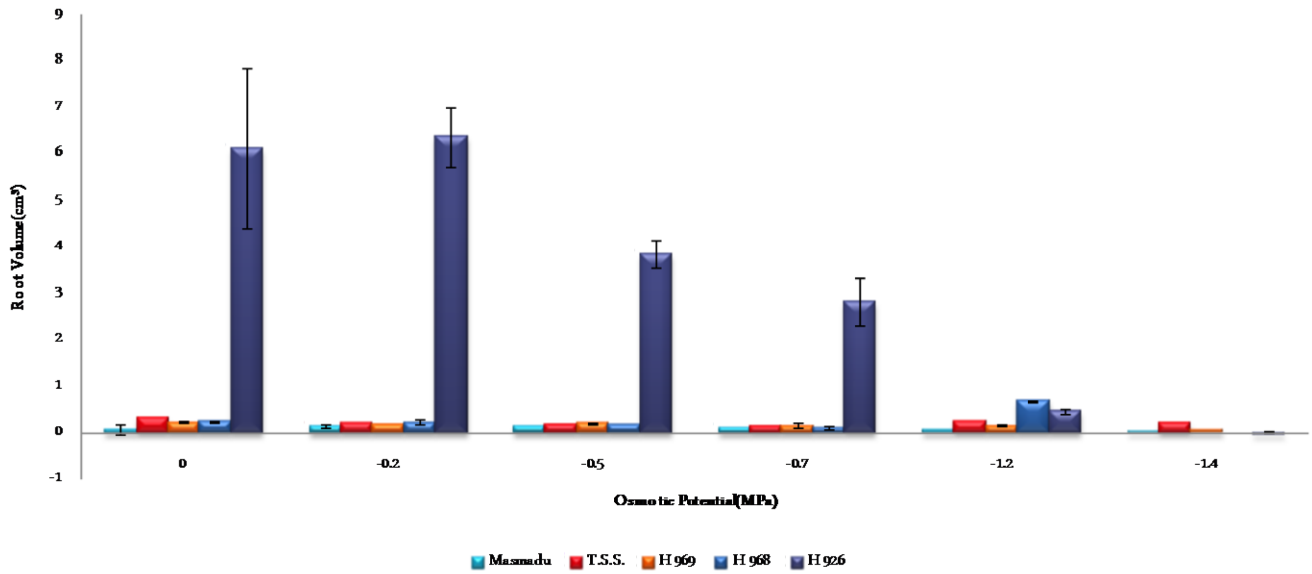

Figure 7. Interactive effects of osmotic potential and variety of sweet corns on Root volume were determined by root scanner WinRHIZO (WinRHIZO, Regent Instrument, Inc.). Vertical bar represent ± SE.

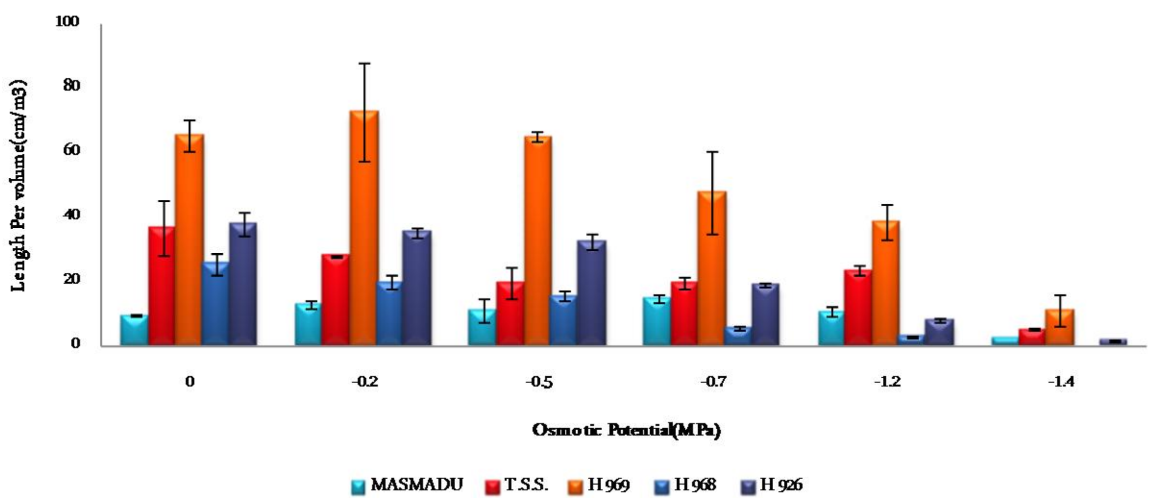

Figure 8. Interactive effects of osmotic potential and variety of sweet corns on Root Length per Volume were determined by root scanner WinRHIZO (WinRHIZO, Regent Instrument, Inc.). Vertical bar represent ± SE.

absorbing more water under water stress conditions compared to control.

The present results are in accordance with the study of Farsiani and Ghobadi (2009) which indicated that the percentage of germination, germination rate, length of radicle and length root decreased under water stress condition. Corine et al. (2000) reported that in *Arabidopsis thaliana,* root diameter and elongation rate reduced under water deficit.

Conclusion

The results of this study show that the increase in seeding proline content in the seedling during germination is due to the decrease in osmotic potential of germination media. High seeding proline content in all levels was observed in hybrid 968. The results did not show a relationship between seedling proline content and percentage germination. Seed germination at -0.7 to -1.2 MPa appears to be a good selection criteria for hybrid and open pollinate varieties to be planted in arid or semi-arid areas.

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REFERENCES

Almansouri M, Kinet JM, Lutts S (2001) .Effect of salt and osmotic stresses on germination in durum wheat *(Triticum durum Desf.)*. Plant Soil 231:243-254.

Aziz I, Khan MA (2003). Proline and water status of some desert shrubs before and after rains. Pakistan J. Bot. 35:902-906.

Bates LS, Waldren RP, Teare ID (1973). Rapid determination of free proline for water-stress studies. Plant Soil 39:205-207.

Bilgin O, Baser I, Korkut KZ, Balkan A, Saglami N (2008). The impacts on seedling root growth of water and salinity stress in maize (*Zea mays indentata Sturt*.). Bulg. J. Agric. Sci. 14:313-320.

Blum A, Mayer J, Gozlan G (1983). Associations between plant production and some physiological components of drought resistance in corn. Plant, Cell Environ. 6:219-225.

Boggess S, Aspinall D, Paleg L (1976). Stress metabolism. IX. The significance of end-Product inhibition of proline biosynthesis and of compartmentation in relation to stress-induced proline accumulation. Funct. Plant Biol. 3:513-525.

Cony MA, Trione SO (1998). Inter-and intraspecific variability in *Prosopis flexuosa* and P*. chilensis*: seed germination under salt and moisture stress. J. Arid Environ. 40:307-317.

Dabbagh MNA (2011). Effects of water potential on germination and seedling growth of two varieties of lentil(Lens Culinaris Medick). Int. J. Agric. Crop Sci. 3(2):61-64.

Din J, Khan SU, Ali I, Gurmani AR (2011). Physiological and agronomic response of canola varieties to drought stress. J. Ani. Plant Sci. 21(1):78-82.

Dodd GL, Donovan LA (1999). Water potential and ionic effects on germination and seedling growth of two cold desert shrubs. Am. J. Bot. 86:1146-1153.

Farsiani A, Ghobadi ME (2009). Effects of PEG and nacl stress on two cultivars of corn (*Zea mays L.*) at germination and early seedling stages. World Academy Sci. Eng. Technol. 57:382-385.

Fattahi NF, Modarres SSAM, Ghanati F, Dolatabadian A (2009). Effect of Foliar Application of Pyridoxine on Antioxidant Enzyme Activity, Proline Accumulation and Lipid Peroxidation of Maize *(Zea mays L.)* under Water Deficit. Notulae Botanicae Horti AgrobotaniciCluj-Napoca. 37:116-121.

Ghiyasi M, Zardoshty MR, Mogadam AF, Tajbakhsh M, Amirnia R (2008) Effect of Osmopriming on Germination and Seedling Growth of Corn *(Zea mays L.)* Seeds. Res. J. Biol. Sci. 3:779-782.

Gholami A, Sharafi S, Sharafi A, Ghasemi S (2009) .Germination of different seed size of pinto bean cultivars as affected by salinity and drought stress. J. Food Agric. Environ. 7:555-558.

Girousse C, Bournoville R, Bonnemain J (1996).Water Deficit-Induced Changes in Concentrations in Proline and Some Other Amino Acids in the Phloem Sap of Alfalfa. Plant Physiol. 111:109-113.

Guo R, Hao W, Gong D (2012).Effects of water stress on germination and growth of linseed seedlings (*Linum usitatissimum* L), photosynthetic efficiency and accumulation of metabolites. J. Agric. Sci. 4(10):253-265.

Hamblin A, Tennant D (1987). Root length density and water uptake in cereals and grain legumes: how well are they correlated. Aust. J. Agric. Res. 38:513-527.

Hao X, De Jong E (1988). Effect of matric and osmotic suction on the emergence of corn and barley. Can. J. Plant Sci. 68:207-209.

Jäger HJ, Meyer HR (1977). Effect of water stress on growth and proline metabolism of *Phaseolus vulgaris* L. Oecologia. 30:83-96.

Jones KW, Sanders DC (1987). The influence of soaking pepper seed in water or potassium salt solutions on germination at three temperatures. Journal of Seed Technology (USA). 11:97-102.

Kader MA (2005) A comparison of seed germination calculation formula and the associated interpretation of resulting data. J. Proc. Royal Soc. New South Wales 138:65-75.

Knipp G, Honermeier B (2006). Effect of water stress on proline accumulation of genetically modified potatoes *(Solanum tuberosum L.)* generating fructans. J. Plant Physiol. 163:392-397.

O'Toole JC, Bland WL (1987). Genotypic variation in crop plant root systems, in: N. C. Brady (Ed.), Advances in Agronomy, Academic Press. pp. 91-145.

Patane C, Saita A, Sortino O (2012). Comparative effects of salt and water stress on seed germination and early embryo growth in two cultivars of sweet sorghum. J. Agron. Crop Sci. 199:30-37.

Pirasteh Anosheh H, Sadeghi H, Emam Y (2011). Chemical priming with urea and KNO_3 enhances maize hybrids (*Zea mays* L.) seed viability under abiotic stress. J. Crop Sci. Biotechnol. 14(4):289-295.

Radhouane L (2007). Response of Tunisian autochthonous pearl millet *(Pennisetum glaucum* (L.) R. Br.) to drought stress induced by polyethylene glycol (PEG) 6000. Afr. J. Biotechnol. 6:1102-1105.

Rao SC, Dao TH (1987). Soil water effects on low-temperature seedling emergence of five Brassica cultivars. Agron. J. 79:517-519.

Scott SJ, Jones RA, Williams WA (1984). Review of data analysis methods for seed germination. Crop Sci. 24:1192-1199.

Sharp RE, Poroyko V, Hejlek LG, Spollen WG, Springer GK, Bohnert HJ, Nguyen HT (2004). Root growth maintenance during water deficits: physiology to functional genomics. J. Exp. Bot. 55:2343-2351.

Sharp RE, Silk WK, Hsiao TC (1988). Growth of the maize primary root at low water potentials. Plant Physiol. 87:50-57.

Sponchiado BN, White JW, Castillo JA, Jones PG (1989). Root growth of four common bean cultivars in relation to drought tolerance in environments with contrasting soil types. Exp. Agric. 25:249-257.

Tarighaleslami M, Zarghami R, Mashhadi A, Boojar M, Oveysi M (2012). Effects of drought stress and different nitrogen levels on morphological traits of proline in leaf and protein of corn seed (*Zea mays* L.). Am-Eurasian J. Agric. Environ. Sci. 12(1):49-56.

Thakur M, Sharma AD (2005). Salt-stress-induced proline accumulation in germinating embryos: Evidence suggesting a role of proline in seed germination. J. Arid Environ. 62:517-523.

van der Weele CM, Spollen WG, Sharp RE, Baskin TI (2000). Growth of *Arabidopsis thaliana* seedlings under water deficit studied by control of water potential in nutrient-agar media. J. Exp. Bot. 51:1555-1562.

Yagmur M, Kaydan D (2008). Alleviation of osmotic stress of water and salt in germination and seedling growth of triticale with seed priming treatments. Afr. J. Biotechnol. 7:2156-2162.

Yang G, Luo Y, Li B, Liu X (2006). The response of winter wheat root to the period and the after-effect of soil water stress. Agric. Sci. China 5:284-290.