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# Soil water retention and maize (*Zea mays* L.) growth as effected by different amounts of Pumice

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**Abstract**

Water availability is one of the most important factors influencing plant growth. Water absorbing materials have been reported to be effective tools in increasing water holding capacity. With regard to problems associated with water resources in the Semi-arid areas, laboratory and greenhouse studies were conducted in 2009-2010 to evaluate the absorption of water by pumice and to study the effect of its application on moisture content, and growth properties of maize. The studied growth characteristics including plant height, leaf area index (LAI), stem diameter, 1000-seed weight and grain yield. Under laboratory study, the water absorption value of 1g pumice was measured in 1000 ml beaker and the pumice was weighed after 20, 40, 60, 80, 100, and 120 minutes. Based on the results, water absorption improved with time which ranged from 35-90 times their weight over 20-120 minutes. Different Pumice treatments (0.10, 0.20 and 0.30 %), corresponding to 1.2, 2.4 and 3.6 g kg-1, respectively were applied in a greenhouse experiment. A control treatment (without Pumice) was included. Pumice levels were uniformly mixed with soil and pots were filled with twelve kg of soil mixture. The results showed that pumice significantly ($p < 0.05$) increased the amount of soil moisture retention compared to control. Growth characteristics of maize (vegetative growth and yield) were significantly improved ($p < 0.05$) with increasing amount of pumice concentration. Maximum height, LAI, stem diameter, 1000-seed weight and grain yield were obtained with 0.30% pumice application which was followed by 20, and 10%, and control plants, respectively.

**Keywords:** Maize (*Zea mays* L.), Pumice, Superabsorbent, Yield components, Soil moisture, Environmental stress.
**Abbreviations:** SAM– Super absorbent material; LAI– Leaf area index; EC– Electrical Conductivity.

## Introduction

Plants both in natural and agricultural conditions are frequently exposed to environmental stresses. Some factors such as soil water content may be stressful after a short time. Iran is located on a dry climate with very hot summer and cold winter (FAO, 1997). About 10 percent of the Iran's areas have more than 500 mm of rainfall over the years and the rest have to be watered for the plants growth (Mazaheri and Mjnoun-hosseini, 2005). Therefore, according to geographical location and topographic conditions, Iran has always been faced with drought over the last centuries (Ghamsari et al., 2009). According to Hayat and Ali (2004), Moisture stress is a limiting factor for crop growth in arid and semi-arid regions due to low and uncertainty precipitation. Crop production is mainly dependent on ecological and soil conditions. Maize (*Zea mays* L.) is one of most important crop that plays a great role in human nutrition (20-25%) (Emam, 2004). Water shortage is a critical problem limiting maize growth through impact on anatomical, morphological, physiological and biochemical processes. The severity of drought damage depends on stress duration and crop growth stage (Setter et al., 2001). The limited water resources to increase agricultural efficiency joined to low rainfall and high evapotranspiration, which most plants do not have the ability to resist or poorly grow albeit it can be tolerated, emphasize the need to access different tools to soil moisture retention for crop growth, development and yield. In many cases problems can be resolved using water absorbent. Super absorbent materials (SAMs) are hydrophilic polymer complexes that have potential to absorb large volumes of aqueous fluids within a short time and under stress conditions can hold the absorbed water. Pumice is one of the super absorbents, being a type of extrusive volcanic rock, produced when lava with a very high content of water and gases is extruded from a volcano and serves to open up the mix and reduce the moisture retention properties of the soil (Akbal, 2004). The application of super absorbent polymer has a significant impact in reducing drought stress effects and to improve plants yield and stability in agriculture production (Khadem et al., 2010). Woodhouse and Johnson (1991) reported that hydro-absorbents can play a crucial role in germination rates because of improving water accessibility. Johnson and Piper (1997) found that fruit quality was better using polymers in the growing media as water stress reduced during the growth cycle. Application of hydrogel at the rate of 2 g/kg increased the water holding potential of sand from 171% to 402% (Johnson, 1984). The objective of the present study was to determine the effects of pumice on water retention in soil and on maize growth characteristics.

## Results and discussions

### *Studies of moisture content absorbed by Pumice (Laboratory studies)*

Results from moisture content absorbed by Pumice after 20, 40, 60, 80, 100 and 120 minutes confirmed that water absorption this material increased by addition of experimental time period. Pumice absorbed water as much as 35, 53, 68, 76, 90 and 95 times its weight after 20, 40, 60, 80, 100 and 120 minutes, respectively (Fig. 1). Other materials have been tested to relief soil dryness; for example, Hayat and Ali (2004) found that average absorption of water by Aquasorb after 30, 60, 90, 120, 150, 180 and 210 minutes was 83, 98, 146, 185, 204, 207 and 219 times its weight, respectively.

***Evaluation of moisture content of soil (Greenhouse Experiment)***

Results from moisture content of clay loam soil are presented in Table 1. As found, moisture content is different at various time intervals. Data obtained on May 4 2009 and 2010 showed that uppermost soil moisture content (33.7) was found in 30% pumice application in soil which had remarkably different in comparison with other level of pumice. Application of 20% and 10% pumice could largely increase moisture content of clay loam soil compared to control treatment. The lower amount of moisture content was detected in the untreated soil. Overall observation showed that the highest moisture content of clay loam soil at different time intervals was assigned to 30% pumice application which was followed by 20% and 10% pumice application. soil was found in the no pumice soil which was considerably lower than other treatments. These finding confirmed previous scientific results (Al-Omran et al., 1987; Chaudhry, 1995; Hayat and Ali 2004) that stated soils treated by polymers have higher potential in moisture retention. Also, Nangare et al., (2010) reported that application of Adjuvant-80 (APSA-80™)" in soil improved both water retention in soil and cowpea (Vigna unguinculata L. (Walp.)) yield.

***Plant height***

Maize height was markedly affected by experimental treatments (Table 2). Maximum height of maize (2.10 cm) was found with application 0.30% of Pumice (D treatment) which was significantly different to all other levels of pumice (Table 3). Among treatments studied the lower height (1.62 cm) was observed in control plants. Although, 20% Pumice application induced better maize height, it was not different from 0.10% pumice application. Furthermore, 10% pumice application (B treatment) and control treatment were statistically in the same group. This finding is in agreement with Yazdani et al., (2007) observation, based on increasing of soybean height with application of super absorbent in soil. Ingram and Yeager (1987) and Akhter et al. (2004) found contradictory results with the findings obtained from this work. They showed that there was no effect of soil amendment with hydrogel on emergence, early seedling growth and plant height in different plant species. This contradiction might be due to differences in the plant species, soil characteristics, climate conditions and superabsorbent type (Al–Omran et al., 1987; Hayat and Ali, 2004; Moazzen-Ghamsari et al., 2009).

***Leaf area index (LAI)***

Maize LAI was affected by different rates of pumice (Table 2). Highest value of maize LAI (5.09) was observed in the soil treated with 0.30% of pumice (D treatment), which was followed by 0.20% (3.57) (Table 3). Even though, 0.20% pumice application treatment induced greater LAI compared to 0.10% pumice application and control treatments, there were not significant differences between them (Table 3).

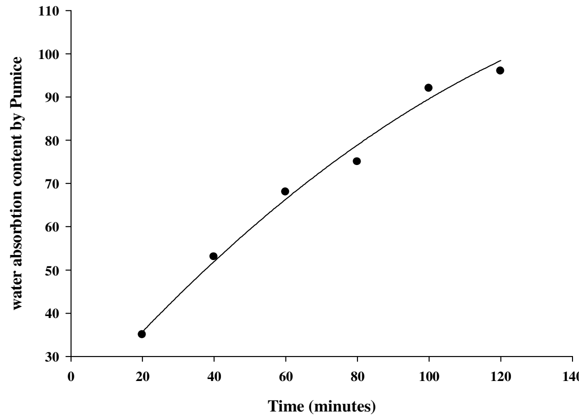


**Fig 1.** Water content absorbed at different times.

Generally, the LAI increased with an increase pumice concentration from 0.10 to 0.30%. The high amount of LAI for high amounts of pumice can be related to the role of this superabsorbent in the increase of retaining capacity of moisture and the used water in soil and followed by increase of growth rate of plant aerial parts (Nazarli et al., 2010). Moazzen-Ghamsari et al. (2009) reported that maize LAI increased by rising super absorbent concentration which was maximized with 300 kg ha-1 of super absorbent.

***Stem diameter***

Maize stem diameter was significantly affected by rates of pumice (Table 2). Based on the results as more pumice rate applied, further maize stem diameter is induced. Highest value (2 cm) of stem diameter was observed with 30% Pumice application which was followed by 20% (C treatment). Whereas the lowest value (1.33 cm) was found in control plants (Table 3).

***1000-Seed weight***

1000-seed weight of maize was markedly affected by experimental treatments (Table 2). There was a significant difference in 1000-seed weight of maize between control (without Pumice) and pumice treated soil pots (Table 3). Comparison of means demonstrated that 1000-seed weight increased by increasing amount of pumice, as the highest 1000-seed weight (254.250 g) was obtained in 30% pumice application and the lowest 1000-seed weight (230.250 g) was attained in control treatment (Table 3). This finding is in agreement with other reports suggesting that Hydrogel application improved 1000-kernel weight of rice crop (Rehman et al, 2011). Also, there was no significant difference between control and 10% pumice application treatments. The 1000-seed weight depends on length and rate of seed filling period. High percentage of moisture retention with the superabsorbent application during the growth period especially in the genesis stage is results in high photosynthesis rate and the length of seed filling period (Nazarli et al., 2010). They studied influence of hydrogel composed of carbonyl amide polymer 25% on the efficiency of aerobic rice sown under various techniques. Use of this hydrogel led to increase 1000-seed weight of rice crop in all the three sowing techniques as compared to soil without

**Table 1.** Effect of different concentrations of Pumice on moisture retention (%) of soil (clay loam) at different time intervals

| Treatment*, ** | 4 May | 19 May | 5 June | 20 June | 6 July | 20 July | 5 August | 20 August | 5 September | 22 September | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A Control (No Pumice) | 22.0±1.5$^d$ | 24.5±1.2$^d$ | 23.8±2.1$^d$ | 21.8±3.1$^d$ | 22.2±$^d$ | 20.8±2.5$^d$ | 23.0±1.1$^d$ | 23.1±0.4$^d$ | 21.2±0.4$^d$ | 22.5±0.8$^d$ | 22.4±0.4$^d$ |
| B 0.10% Pumice (1.2 g $kg^{-1}$) | 27.5±1.1$^c$ | 26.8±2.1$^c$ | 27±1.4$^c$ | 27.5±2.0$^c$ | 26.2±$^c$ | 26.7±1.7$^c$ | 25.3±0.3$^c$ | 26.8±0.2$^c$ | 26.8±0.5$^c$ | 25.4±0.4$^c$ | 25.4±0.0$^c$ |
| C 0.20% Pumice (2.4 g $kg^{-1}$) | 29.8±2.3$^b$ | 29.3±0.6$^b$ | 29.5±0.5$^b$ | 30.6±1.0$^b$ | 30.6±$^b$ | 30.1±0.0$^b$ | 28.3±0.8$^b$ | 29.6±1.3$^b$ | 29.7±1.5$^b$ | 29.8±2.8$^b$ | 29.4±1.6$^b$ |
| D 0.30% Pumice (3.6 g $kg^{-1}$) | 33.7±3.4$^a$ | 34.4±2.0$^a$ | 33.8±0.9$^a$ | 33.8±1.9$^a$ | 34.3±$^a$ | 34.5±0.4$^a$ | 33.6±1.4$^a$ | 34.5±2.9$^a$ | 35.2±1.5$^a$ | 35.8±1.3$^a$ | 34.3±1.8$^a$ |

*Means within each column sharing the same letter(s) are not significantly different based on LSD test at $p = 0.05$.

** Treatments performed from May 2009 to September 2010.

**Table 2.** The results of ANOVA for the effects of Pumice on height, leaf area, leaf biomass, stem biomass, stem diameter, 1000 seed-weight and yield of maize

| SOV | DF | Height | LAI | Stem diameter | 1000 Seed-weight | Yield |
|---|---|---|---|---|---|---|
| Treatment | 3 | 0.36490312** | 6.84401804** | 0.68735313** | 908.197917** | 0.15774583** |
| Error | 28 | 0.01767545 | 0.14628813 | 0.01138259 | 27.816964 | 0.00631036 |
| CV (%) | | 7.379652 | 10.21043 | 6.569280 | 2.190444 | 2.024307 |

** Significant at $p = 0.01$ level

**Table 3.** Mean values of different treatment of Pumice on height, leaf area, leaf biomass, stem biomass, stem diameter, 1000 seed-weight and yield of maize

| Treatments | Height (m) | LAI | Stem diameter (cm) | 1000 Seed-weight (g) | Yield (ton $ha^{-1}$) |
|---|---|---|---|---|---|
| A Control (No Pumice) | 1.62±0.03$^c$ | 3.06±0.09$^c$ | 1.33±0.05$^d$ | 230.25±7.77$^c$ | 3.80±0.02$^c$ |
| B 0.10% Pumice (1.2 g $kg^{-1}$) | 1.69±0.09$^{bc}$ | 3.24±0.07$^{bc}$ | 1.46±0.14$^c$ | 234.625±4.59$^c$ | 3.83±0.08$^c$ |
| C 0.20% Pumice (2.4 g $kg^{-1}$) | 1.78±0.22$^b$ | 3.57±0.32$^b$ | 1.68±0.05$^b$ | 244.00±9.89$^b$ | 3.95±0.03$^b$ |
| D 0.30% Pumice (3.6 g $kg^{-1}$) | 2.10±0.32$^a$ | 5.09±0.75$^a$ | 2.00±0.16$^a$ | 254.25±6.75$^a$ | 4.11±0.18$^a$ |
| LSD | 0.1362 | 0.3917 | 0.109 | 5.4018 | 0.08 |

*Means within each column sharing the same letter(s) are not significantly different based on LSD test at $p = 0.05$.

**Table 4.** Physical and chemical characteristics of soil and Pumice used for the study

| Soil characteristic | Value* | Pumice characteristic | Value* |
|---|---|---|---|
| Texture | Clay loam | Color | Light gray/Tan |
| Soil depth (cm) | 25.0±5.0 | Toxics | No |
| Saturation (%) | 1.39±0.02 | Water soluble | A little |
| EC(ds $m^{-1}$) | 3.30±0.04 | Humidity (%) | 3.40±0.05 |
| pH | 7.82±0.01 | Density (g/ml) | 0.951±0.004 |
| OC | 0.65±0.02 | pH | 7.30±0.06 |
| P (ppm) | 8.20±0.05 | Dimension (mm) | 15.0±10.0 |
| K (ppm) | 340.0±16.0 | - | - |
| N (%) | 0.07±0.00 | - | - |

* (No. of observations = 3)

hydrogel. Yezdani et al. (2007) obtained more 1000-seed weight of soybean by application of hydrogel in drought-prone soils. Khadem et al. (2010) and Allahdadi et al. (2005) also showed that the adding superabsorbent polymer can linearly increase 1000-seed weight of corn and soybean crops, respectively.

***Grain yield***

The results of ANOVA for the effects of different treatments of pumice on maize grain yield are summarized in Table 2. As shown, seed yield was significantly affected by different amounts of pumice. According to the results, the seed yields of maize increased with increasing amounts of pumice. The highest (4.1 ton $ha^{-1}$) and lowest (3.8 ton $ha^{-1}$) maize grain yield were found with 0.30% pumice application and control plants, respectively (Table 3). This can probably be attributed to the higher emergence and better crop establishment as a result of moisture supply (Bhardwaj et al., 2007). Hayat and Ali (2004) also found that absorption of water by synthetic polymer and its effect on yield parameters helps to increase the yield of crops. Increasing in corn yield by application of super absorbent polymer was previously reported by Khadem et al. (2010). Rehman et al. (2011) observed use of hydrogel significantly increased the kernel yield of rice (2.39 ton $ha^{-1}$) as compared to no hydrogel (2.25 ton $ha^{-1}$). Moreover, Johnson and Piper (1997) demonstrated that the application of polymers to growing media due to the reduced impact of water stress during the growing cycle can improve crop quality.

**Materials and methods**

These experiments were included laboratory and green house studies which were conducted during 2009 and 2010 at Agriculture Research Center of Eastern Azerbaijan, Iran.

***Estimation of Pumice moisture content (Laboratory studies)***

To check the amount of water absorbed by Pumice a weighed quantity (1 g) of this super absorbent was placed in a beaker containing 1000 ml and whose weight of pumice was recorded after 20, 40, 60, 80, 100 and 120 minutes.

***Evaluation of moisture content of soil (Green House Experiment)***

The soil was a clay loam. The experiment was laid out in a completely randomized design with four replications. Soil samples collected from farmer's field of desired district were air-dried, thoroughly mixed and passed through 2-mm sieve. Physical and chemical characteristics of the soil are shown in Table 4. For this experiment, 32 pots were used and each pot was filled with 12 kg of soil. The tested treatments were as below:

A) Control (without Pumice); B) 0.10% Pumice (1.2 g $kg^{-1}$); C) 0.20% Pumice (2.4 g $kg^{-1}$) and D) 0.30% Pumice (3.6 g $kg^{-1}$).

***Planting and irrigation conditions***

To enhance soil fertility, before planting, diammonium phosphate (18-46-0 N-P-K) and urea were used at the rate of 250 and 150 kg $ha^{-1}$, respectively. At maize 6-8 leaf stage, 200 kg $ha^{-1}$ N (as urea) was added. Pots were saturated with tap water before planting/transplanting the seedling and excess water was drained from the bottom of the pot. The maize hybrid "Singles Cross 704" was planted on May 4 in both years (2009-2010). Two seeds were planted in each pot for plant growth and then thinned to the target densities (1 plant per pot) after their establishment. Pots were irrigated soon after planting. Irrigation also was done every 24 hours until seed germination. Moreover, the plants were watered only when they showed signs of water shortage.

***Soil moisture contents***

To determine moisture, soil samples were periodically gathered with a tube soil sampler before the next irrigation. The moisture percentage was measured using gravimetric method.

***Yield and yield components***

The fresh and senesced leaves (i.e. yellowed and dead leaf tissues still attached to the plant) of maize were separated, and the leaf area of fresh leaves was measured with a Delta England leaf-area meter (Delta-T Devices, Cambridge, England). At physiological maturity, maize plants of different treatments were harvested. The harvest was transferred to the laboratory and height, stem diameter, 1000-seed weight (One hundred grains were counted and weighed, and the result was converted to 1000-grain weight) and grain yield of maize in each treatment were determined. (Gharibzahedi et al., 2011b).

***Statistical analysis***

The results were subjected to analysis of variance (ANOVA), applying completely randomized design (CRD), using the GLM procedure of SAS 9.1 (SAS Institute, 2002) software.

Fisher's Least Significant Difference (LSD) test was used to separate means at a 5% level of significance.

## Conclusion

This study confirmed that pumice plays an important role in the maintenance of soil moisture, due to changes in soil particles distribution and liquid and gas phases by adding water which increases the proportion of liquid compared to gas. Management practices and applying advanced techniques to maintain soil moisture storage and increasing water-holding capacity of soil are critical to increase irrigation efficiency and thus improve the utilization of limited water resources in the country. Using pumice material is a new method to achieve the above mentioned purposes. Pumice is extracted by mining companies in Iran and it can be obtained for a reasonable price; however, it normally is expensive. Pumice increases irrigation period approximately 2-fold in dry areas; so, it can be expected that irrigation costs decrease by half therefore economically justify its use.

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