

Full Length Research Paper

Ecophysiological influences of zeolite and selenium on water deficit stress tolerance in different rapeseed cultivars

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This experiment was carried out to study the ecophysiological influences of zeolite and selenium on water deficit stress tolerance in different rapeseed cultivars at Karaj, Iran using a factorial-split-plot design with three replications during 2009 - 2010. The main-plot factors included: irrigation regimes (control and irrigation interrupted during the flowering stage), zeolite (non-application and 10 ton/ha) and selenium (non-application and 30 g/l) while the sub-plot factor included three cultivars (Opera, SLM 046 and Modena) of winter rapeseed (*Brassica napus* L.). The results showed that total dry weight (TDW), life area index (LAI), relative growth rate (RGR) and crop growth rate (CGR) were all highly significantly different among the rapeseed cultivars, whereas drought stress had effects of practical significance on TDW, LAI, RGR and CGR and zeolite and selenium applications reduced the water deficit stress damages. The results also showed that the highest TDW, LAI, RGR and CGR were obtained from Opera cultivar by zeolite and selenium applications under no-drought condition. The findings firmly established that drought stress sorely reduces physiological growth indices of winter rapeseed cultivars under conditions of Karaj in Iran while, zeolite and selenium applications were reduced the water deficit stress damages.

Key words: Ecophysiological influences, zeolite, selenium, water deficit stress, winter rapeseed cultivars.

INTRODUCTION

Zeolites are microporous, aluminosilicate minerals commonly used as commercial adsorbents. The term zeolite was originally coined in 1756 by Swedish mineralogist Axel Fredrik Cronstedt, who observed that upon rapidly heating the material stilbite, it produced large amounts of steam from water that had been adsorbed by the material. Based on this, he called the material zeolite, from the Greek meaning "boil" and λίθος (*lithos*), meaning "stone". Natural zeolites form where volcanic rocks and ash layers react with alkaline groundwater. Zeolites also crystallize in post-depositional environments over periods ranging from thousands to millions of years in shallow marine basins. Naturally occurring zeolites are rarely

pure and are contaminated to varying degrees by other minerals, metals, quartz, or other zeolites. For this reason, naturally occurring zeolites are excluded from many important commercial applications where uniformity and purity are essential.

Selenium is a chemical element with atomic number 34, represented by the chemical symbol Se, an atomic mass of 78.96. It is a non-metal, chemically related to sulfur and tellurium, and rarely occurs in its elemental state in nature. Isolated selenium occurs in several different forms, the most stable of which is a dense purplish-gray semi-metal (semi conductor) form that is structurally a trigonal polymer chain. It conducts electricity better in the light than in the dark, and is used in photocells (see section Allotropes below). Selenium also exists in many non-conductive forms: a black glass-like allotrope, as well as several red crystalline forms built of

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eight-membered ring molecules, like its lighter cousin sulfur.

The compost must be added to conventional NPK fertilizer to improve soil structure, making the soil easier to cultivate, encouraging root development, providing plant nutrients and enabling their increased uptake by plants. Moreover, compost aids water absorption and retention by the soil, reducing erosion and run-off and thereby protecting surface waters from sedimentation, help in binding agricultural chemicals, keeping them out of water ways and protecting ground water from contamination (Lea-Master et al., 1998). Compost has already been established as a recommended fertilizer for improving the productivity of several medicinal and aromatic plants, as amaryllis (El-Ashry et al., 1995), peppermint (O'Brien and Barker, 1996) and *Tagetes erecta* (Khalil et al., 2002). Water stress is a major environmental problem which affects agricultural land in Iran. Drought stress is especially important in areas where crop production is essentially rain-fed (Boyer, 1982; Ludlow and Muchow, 1990). Drought stress causes an increase in solute concentration in the soil and root-zone environment leading to an osmotic flow of water out of plant cells. This in turn causes the solute concentration inside plant cells to increase, thus lowering water potential and disrupting membranes along with essential processes like photosynthesis. These drought-stressed plants consequently exhibit poor growth and yield. In worst case scenarios, the plants completely die. Certain plants have devised mechanisms to survive such low soil moisture conditions. These mechanisms have been classified as tolerance, avoidance or escape (Kramer and Boyer, 1995; Neumann, 1995). Drought tolerance is the ability of crops to grow and produce seeds or propagules under conditions of water deficit. Long-term drought stress effects on plant metabolic reactions vary with plant growth stage, water storage capacity of the soil and physiological aspects of plant. Drought tolerance of cultivated crop plants is different from that of wild plants. When crop plants get encountered with severe water deficit, they often die or seriously lose yield while conversely wild plants face similar conditions of drought, they survive well with often little/no yield loss. Because of water deficit in most arid regions, tolerance of crops to drought has always been of great importance for the plant breeder (Alizadeh, 2004). According to Lessani and Mojthaedi (2006), one of the main aspects of drought tolerance is the ability of plant cells to survive severe water loss without suffering deleterious damages. When the plant cell dries up, usually the vacuole crumples more than the cell wall and thus results in tearing up of the protoplasm. The authors believe that such damages are the main reasons for cell death which has no tolerance mechanism. Plant yield loss under insufficient water has always been an important issue for plant breeders to improve using drought tolerance indices to select genotypes (Mitra, 2001). Biabani et al. (2008) investigated variations in SPAD (writing a long version of

the unit -the relative chlorophyll concentration of leaves) meter readings of rapeseed leaves under different treatment combinations of four cultivars (Hayola 401, Hayola 308, Option and RGS) and irrigation regimes (no-stress that is, irrigation at field capacity-FC; 75, 50 and 25% FC) in a pot experiment conducted under a controlled glasshouse conditions in Iran. Their results showed that with increasing drought stress, SPAD meter readings were conversely decreasing. Further implications of the results were such that drought stress had a significant effect on net photosynthesis (A), stomata conductance (g_s), intercellular CO₂ concentration (C_i) and leaf area (LA) of rapeseed both at vegetative and flowering stages. In general, Hayola 401, had the highest yield under both conditions of drought and no-drought, followed by Hayola 308, whereas RGS had the lowest yield among the cultivars. The cultivars Hayola 401 and 308 exhibited the highest g_s under no-drought but the lowest under drought stress. The ranking of the cultivars in their overall tolerance to drought was found to follow Hayola 401 > Hayola 308 > Option > RGS. Investigations by Champolivier and Merrien (1996) revealed that yield and yield components of rapeseed were affected by water shortage occurring from flowering to the end of seed set. Number of seeds per plant was the yield component affected most although some compensation occurred when the water supply was restored. The thousand seed weight was only affected by low water stress only if it occurs during the period from the stage of siliques swelling to seeds coloring. The results also demonstrated that a marked reduction in oil concentration was evident when water deficit occurred from anthesis to maturity. Furthermore, they found that oil and protein concentrations were inversely related. Therefore, the aim of the present investigation is to determine the ecophysiological influences of zeolite and selenium applications on water deficit stress tolerance in different rapeseed cultivars in Karaj Region, Iran.

MATERIALS AND METHODS

This study was conducted on experimental field of Islamic Azad University, Shahr-e-Qods Branch at Iran (27°38' N, 40°21' E; 1417 m above sea level) during 2009 - 2010, with clay loam soil, mean annual temperature (31°C) and rainfall in the study area is distributed with an annual mean of 215 mm. This experiment was carried out to study the ecophysiological influences of zeolite and selenium applications on water deficit stress tolerance in different rapeseed cultivars at Karaj, Iran using a factorial-split-plot design with three replications during 2009 - 2010. The main-plot factors included: irrigation regimes (control (I1) and irrigation interrupted during the flowering stage (I2)), zeolite (non-application (Z1) and 10 ton/ha (Z2)) and selenium (non-application (S1) and 30 g/l (S2)) while the sub-plot factor included three cultivars (Opera (V1), SLM 046 (V2) and Modena (V3)) of winter rapeseed (*Brassica napus* L.). Phosphorus and potassium were applied each at the rate of 100 kg ha⁻¹ in the form of triple super phosphate (TSP) and K₂O. While the former was applied at planting, the latter was applied right after cultivation. Nitrogen fertilizer was added in three splits whereby the first application (50% gave the rate 100 N ha⁻¹) was made at the

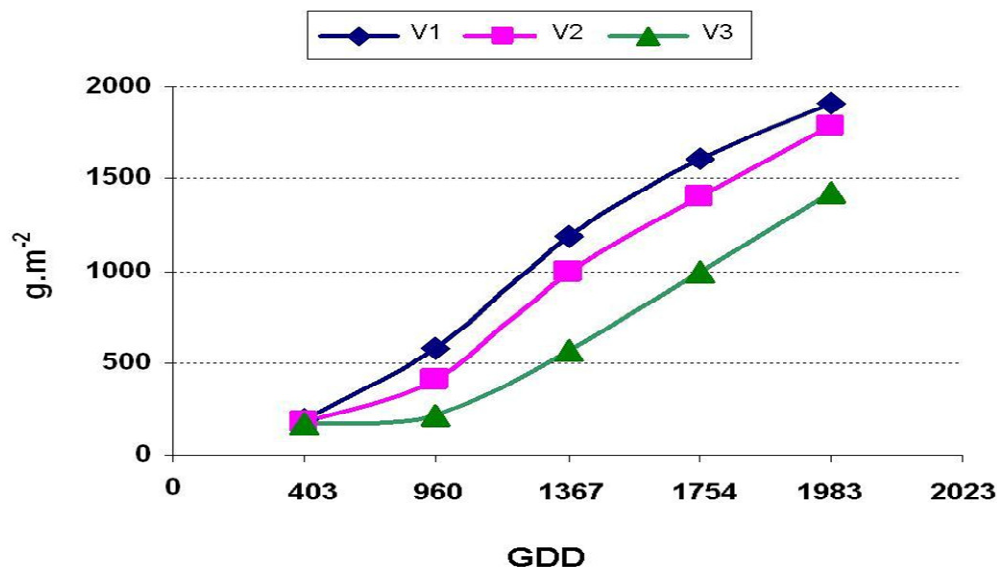


Figure 1. TDW variations of different rapeseed cultivars by zeolite and selenium applications under no-drought condition.

time of cultivation while the second and third, applications, each constituting 25% of the total rate, were respectively made at the stages of stem elongation and beginning of flowering. In order for the determination of TDW, from 20 days after germination to harvesting time, 10 plants were selected randomly in all plots each 15 days regularly. Samples were placed under 75°C in electrical oven for 48 h and were weighed by electrical scale and then determined TDW in each sampling stage. To determine LAI, leaves area of upon samples were estimated by leaf area meter before placing in oven and then determined LAI in each sampling stage. Finally, RGR and CGR were determined by growth degree day (GDD) the following formulas (Aliabadi et al., 2009).

$$\text{GDD} = \{[(\text{Maximum daily temperature} - \text{Minimum daily temperature}) / 2] - \text{Base temperature}\}$$

$$\text{RGR} = [(\text{Ln}W_2 - \text{Ln}W_1) / (T_2 - T_1)]$$

$\text{Ln}W_2 - \text{Ln}W_1$ = Logarithm natural of dry matter variations

$T_2 - T_1$ = Time variations as day

$$\text{CGR} = \{[(W_2 - W_1) / (T_2 - T_1)] \times \text{GA}\}$$

$W_2 - W_1$ = Dry matter variations

$T_2 - T_1$ = Time variations as day

GA = Ground Area.

Finally, after determination of TDW, LAI, RGR and CGR were supplied their graphs by Excel computer software.

RESULTS

The final results also showed that the highest TDW, LAI, RGR and CGR were obtained by zeolite and selenium applications under no-drought condition from Opera cultivar (Figures 1 to 4).

DISCUSSION

Zeolites are the aluminosilicate members of the family of microporous solids known as "molecular sieves." The term molecular sieve refers to a particular property of these materials, that is, the ability to selectively sort molecules based primarily on a size exclusion process. This is due to a very regular pore structure of molecular dimensions. The maximum size of the molecular or ionic species that can enter the pores of a zeolite is controlled by the dimensions of the channels. These are conventionally defined by the ring size of the aperture, where, for example, the term "8-ring" refers to a closed loop that is built from 8 tetrahedrally coordinated silicon (or aluminum) atoms and 8 oxygen atoms. These rings are not always perfectly symmetrical due to a variety of effects, including strain induced by the bonding between units that are needed to produce the overall structure, or coordination of some of the oxygen atoms of the rings to cations within the structure. Therefore, the pores in many zeolites are not cylindrical. Selenium salts are toxic in large amounts, but trace amounts of the element are necessary for cellular function in most, if not all, animals, forming the active center of the enzymes glutathione peroxidase and thioredoxin reductase (which indirectly reduce certain oxidized molecules in animals and some plants) and three known deiodinase enzymes (which convert one thyroid hormone to another). Selenium requirements in plants differ by species, with some plants apparently requiring none. Organic and inorganic amendments are often added to sand-based root zones to improve water and nutrient retention and to decrease bulk density. Zeolite provides an ideal physical root zone media for bentgrass putting greens due to its particle size

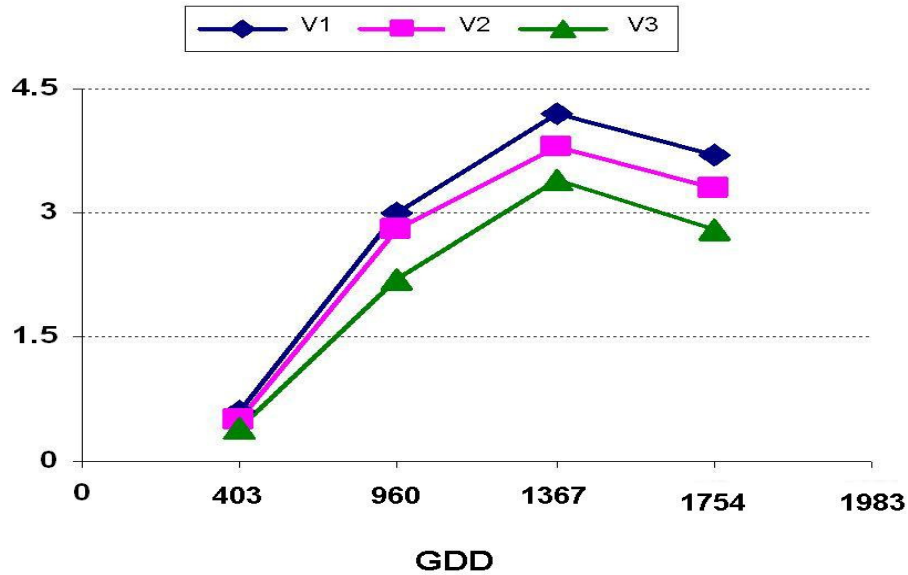


Figure 2. LAI variations of different rapeseed cultivars by zeolite and selenium applications under no-drought condition.

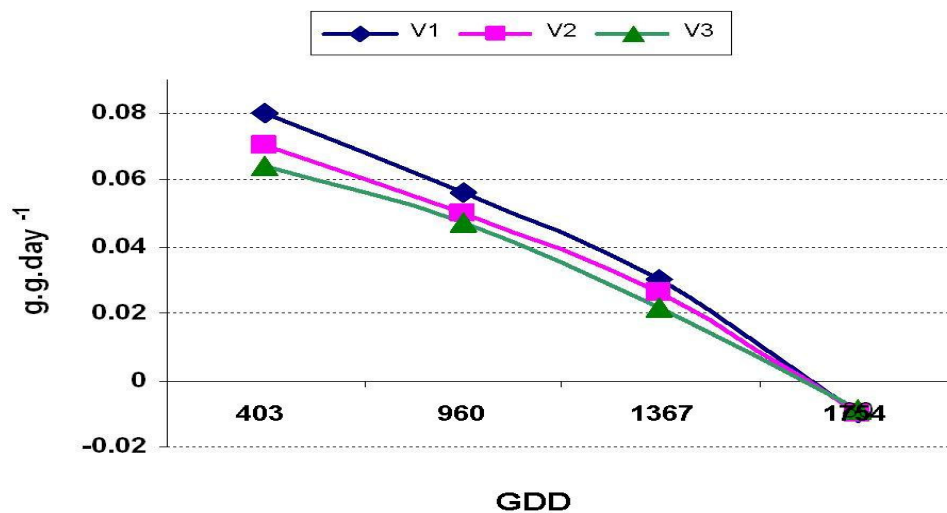


Figure 3. RGR variations of different rapeseed cultivars by zeolite and selenium applications under no-drought condition.

distribution, which provides a firm surface for foot traffic while remaining highly permeable. However, sands have low water and nutrient retention properties (Hummel, 1993; Huang and Petrovic, 1994). The use of inorganic amendments for putting green root zone mixtures such as zeolite may offer a number of benefits for improving sand-based root zones. Some of these materials possess high cation exchange capacities (CECs) and water-holding capacities without reducing air-filled pore space (Huang and Petrovic, 1994). Creeping bentgrass establishment (Nus and Brauen, 1991) was reported to be significantly higher (36%) for zeolite-amended, sand-based root zones

compared with sawdust-amended root zones; however, establishment with zeolite-amended root zones was not significantly better than with peat-amended root zones. Additionally, zeolite is a more permanent addition to the root zone, demonstrating good stability in weathering, impact, and abrasion tests (Petrovic and Wasiura, 1997). The addition of zeolite has improved the nutrient status of sand-based root zones, especially selective retention of NH_4^+ and K^+ ions (Nus and Brauen, 1991; Petrovic, 1993). As the results of this study indicated, drought stress has negative effects on physiological growth indices of winter rapeseed. This implies that rapeseed plants

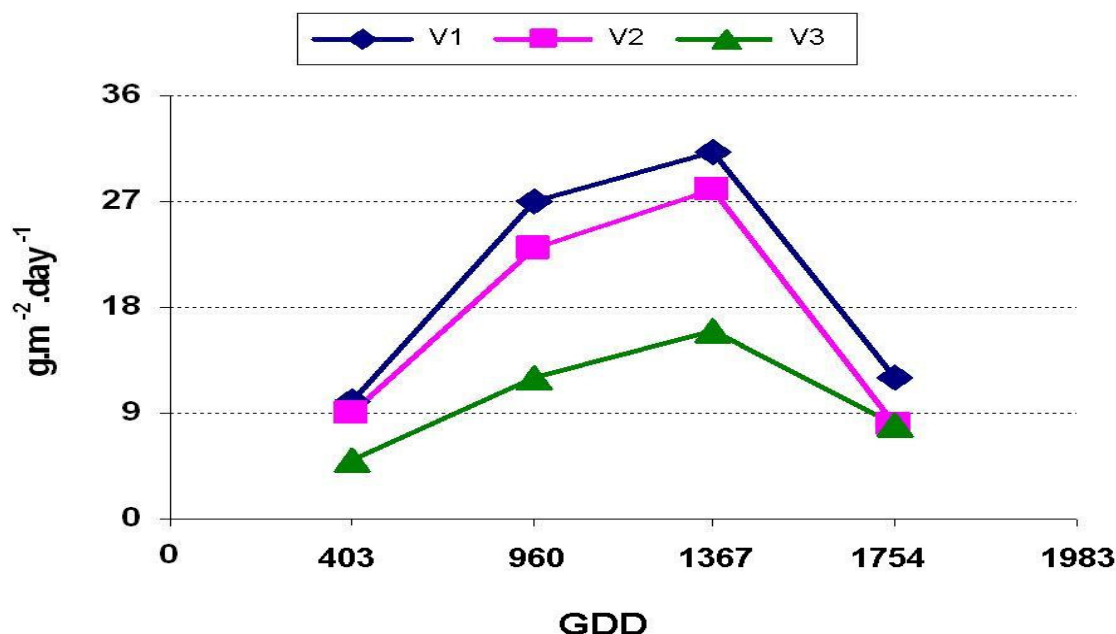


Figure 4. CGR variations of different rapeseed cultivars by zeolite and selenium applications under no-drought condition.

plants use different mechanisms to resist drought stress. Great reduction in the leaf area, plant height and lateral stem number, all contribute to the reduction of plant's evaporation area and consequently reduction in the produced dry matter is the final result of the reduction in the plant's photo-synthesis which in turn, is the result of drought stress. Under drought stress, stomata's become blocked or half-blocked and this leads to a decrease in absorbing CO₂ and on the other hand, the plants consume a lot of energy to absorb water, these cause a reduction in producing photosynthetic matters. It was also seen that as drought stress increased, its height plant, stem dia-meter and stem yield decreased. Shoot reduction could be due to the reduction in the area of photosynthesis, drop in producing chlorophyll, the rise of the energy consumed by the plant in order to take in water, increase the density of the protoplasm and to change respiratory paths and the activation of the path of phosphate pentose, or the reduction of the root deploy, etc. The physiological growth indices decreased winter rapeseed cultivars, the interaction between the amount of the TDM and LAI is considered important as two components of the CGR. As can be seen in figures, by exerting stress, the amount of the TDM was dropped. This study's results were similar to Ranjbar et al. (2004). They also reported that the effect of soil humidity discharge on physiological growth indices has been significant. In addition, these results corresponded to Tso (1990) who claimed that enough soil humidity provides the earlier flowering in tobacco (Tso, 1990). While Ranjbar et al. (2004) reported the effect of zeolite and its interaction with water was not significant on physiological

growth indices which do not correspond to the current research's results (Ranjbar et al., 2004). Moreover, the analysis of physiological growth indices corresponded to Chelopecka and Andriano (1997) results. The impact of water stress on physiological growth indices was not significant which corresponded to Nakhjavani and Ghahraman (2005) results; they proclaimed that the water stress does not have any significant effect on the physiological growth indices. It can be seen that the interaction of zeolite and water stress on the physiological growth indices in this study was the same as Tso's results (1990).

Conclusion

This study was conducted to introduce zeolite as an environment-friendly mineral for increasing physiological growth indices. It was also designed to determine whether zeolite increases rapeseed cultivars drought tolerance and if this introduced tolerance is related to level of water stress. Our results depicted that the increasing of zeolite and water stress have a significant effect on physiological growth indices which is the most important parameter in seed oil plants. This can have very important environmental implications through decreasing the amount of water stress damages.

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