

Contents available at ISC and SID

Journal homepage: www.rangeland.ir



Research and Full Length Article:

Effects of Mycorrhiza, Zeolite and Superabsorbent on Growth and Primary Establishment of *Agropyron desertorum* in Mining Field (Case Study: Mashhad's Shargh Cement Factory, Iran)

Reyhaneh Azimi^{A*}, Golam Ali Heshmati^B, Mohammad Farzam^C, Morteza Goldani^D

^APh.D. Rangeland Sciences, Faculty of Rangeland and Watershed Management, Gorgan University of Agricultural Science and Natural Resources, Gorgan, Iran. *(Corresponding Author), Email: Reyhaneazimi36@yahoo.com

^B Professor, Faculty of Rangeland and Watershed Management, Gorgan University of Agricultural Science and Natural Resources, Gorgan, Iran.

^CProfessor, Department of Range and Watershed Management, Faculty of Natural Resources and Environment, Ferdowsi University of Mashhad, Mashhad, Iran.

^DAssociate Professor, Department of Agronomy, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran.

Received on: 21/04/2018

Accepted on: 09/09/2018

Abstract. The most important and sensitive level in the modification of rangelands surrounding the mine is the initial seedling establishment of plants, which often faces failure due to adverse environmental conditions, poor soil nutrients, disturbance of soil different layers and its instability and unstable soil around the mines. New methods of rangeland improvement using biological and non-biological materials (zeolite, superabsorbent and mycorrhiza) and strategies may help to establish plants in the soil around abandoned mines. This research aims to investigate the possibility of improving the primary establishment and growth of *Agropyron desertorum* Schult (Fisch.Ex Link) in mine areas infected with heavy metals. Initially, seeds were sown in paper pots. After two months, pots were treated with *Glomus intraradices*, zeolite and superabsorbent along with control. Pots were transplanted in the field in semi-arid lands of East Mashhad cement factory using a completely randomized block design with four replicates in 2016. The plants were irrigated only once for the establishment. Data were collected about establishment rate, plant height, the percentage of mycorrhiza root inoculation and shoot, root and total dry weight. The results showed that the application of mycorrhiza, zeolite and superabsorbent increased plant establishment rate (50, 42 and 25%) and root dry weight (62, 72 and 15%) higher than that for control. Application of the mycorrhiza and zeolite treatments increased plant height (44 and 42%), aboveground dry biomass (51 and 61%) and total dry matter biomass (54 and 66%) higher than that for control treatment. The results showed that mycorrhiza and zeolite treatments had the greatest effect on increasing the initial establishment and improving the growth characteristics of *A. desertorum*. It was concluded that using zeolite and *Glomus intraradices* may be effective method for the initial establishment of plants in areas contaminated with heavy metals in the mining area in the semi-arid regions.

Key words: Heavy metals, Inoculation, Seedling establishment

Introduction

Today, it has become clear that mining and extraction operations are one of the major factors in the destruction of vegetation (Sheoran *et al.*, 2010). These areas can contaminate air, water, soil and ground water and affect the environment in case of the non-recovery of vegetation in the mined areas and stabilization of soils contaminated with heavy metals (Laurence, 2011; Bacchetta *et al.*, 2015). Heavy metals contamination in soils is one of the world's major environmental problems, posing significant risks to human health as well as ecosystems (Moameri *et al.*, 2017). The usage of plants for the refining and clearing of the environment and their roles in restraining and controlling the pollution have been discussed as an effective method in order to conduct soil treatments in situ (Norozi Fard *et al.*, 2015). The continuous erosion of abandoned mining lands can affect soil stability, vegetation regeneration and water quality. Toxic heavy metals in the "wastes" of abandoned mines migrate into the environment, causing severe and extensive contamination of rangeland soils, agricultural soils and waterways (Beane *et al.*, 2016; Ma *et al.*, 2016). In recent decades, restoring the vegetation of contaminated soils in industrial, agricultural and urban areas has been a big challenge due to human activities (Li *et al.*, 2015; Xiao *et al.*, 2015). Establishment of vegetation in mining areas often fails due to poor environmental conditions, poor nutrient content, the collapse of different soil layers and soil instability. The soil of these areas usually has high levels of heavy metals, toxic substances and nutrient poverty (Wu *et al.*, 2009). Also, the slippage of unstable soils of the mining lands on the steep slopes causes to move the soil, cut off the root of the plants and ultimately destroy the plants (Adams & Lamoureux, 2005).

Crested wheatgrass (*Agropyron desertorum*) is a perennial bunchgrass

and one of the important species of the Poaceae family (Mueller & Richards, 1986). This plant is resistant to dry and cold conditions. It grows well, except in heavy clay or sandy soils and is somewhat resistant to soil alkalinity. This species is prevalent due to the ease of planting and growth in unfavorable conditions (Bassiri *et al.*, 1988). The success of establishment of vegetation in these lands depends on the combination of important elements in the contaminated bed and the choice of appropriate amendments and inoculants (Neagoe *et al.*, 2005; Azimi *et al.*, 2014). Zeolites are minerals of which aluminum silicates are the main component. Zeolites have a large surface and liquid absorption properties that are widely used in the removal of heavy metal ions through ion exchange processes, adsorption, surface deposition and dissolution (Mozgawa *et al.*, 2005; Doula *et al.*, 2012). Other amendments such as super-absorbents or hydrogels, a hydrophilic polymer network store water several times more than their weight. These materials contract to provide water and fertilizers to roots (Behbahani *et al.*, 2005). Hydrogel maintains elements such as nitrates, phosphates, potassium, iron, zinc, and various types of vitamins and prevents from wasting them (Khodadadi Dehkordi, 2016). In a research in the coalmine of China, they succeeded in planting soybeans and revitalizing the mining area using soybean and corn plants with superabsorbent at the time of cultivation.

Application of mycorrhiza treatments increased plant establishment higher than that for control (Huang *et al.*, 2015). Other amendments include mycorrhiza bio-fertilizers which help the initial establishment of plants in harsh environmental conditions (Azimi, 2013). Research showed that arbuscular mycorrhiza fungi increased the growth and establishment of an indigenous grass (*Panicum virgatum* L.) in areas around

mines with less phosphorus (Jonson, 1998). In a study, it was determined that the mycorrhiza fungi coexistence with the *Atriplex nummularia* Lindl restored the vegetation and areas contaminated with oil materials and saline soils (Keiffer et al., 2002). Currently, many studies have been limited to laboratory and greenhouse studies and only a small number of studies have been carried out in real-world conditions and actual results are likely to be different from laboratory or greenhouse studies because in reality, different factors affect them simultaneously. Factors such as temperature, precipitation, humidity, plant pathogenic factors and herbivores, unequal distribution of pollutants, soil type, acidity and soil structure affect the phytoremediation. Initial establishment and plant production should be investigated in real terms in order to assess the feasibility of this technology for commercialization. Therefore, this

study was carried out to investigate the application of biological and non-biological approaches to increase production and the possibility of initial establishment of *A. desertorum* in soils contaminated by heavy metals around the abandoned mines of Shargh Mashhad Cement Factory.

Materials and Methods

In this experiment, the effect of mycorrhiza (*Glomus intraradices*), superabsorbent (A200) and zeolite (Clinoptilolite) were assessed on the establishment and production of *Agropyron desertorum* in the semi-arid area (mining lands of Shargh Mashhad cement factory) in latitude 36° 28' 29.96" and longitude 59° 44' 46.99". The average rainfall of the study area is 255 mm. Precipitation occurs in the cold season with ununiformed distribution. The area is located at an altitude of 1120 to 1130 m above sea level. Before plants cultivation, soil samples were taken from depths of 0 to 30 cm. Then, soil properties, heavy metals, soil acidity, electrical conductivity and soil texture were measured (Table 1).

Table 1. Some chemical and physical properties of soil, cement factory mining area of East Mashhad

EC (dS.m ⁻¹)	pH	Soil texture	Cd	Co	Ni	Zn	Cu	Cr	Mn	Ar	Pb
2.6	8.16	Silty loam	1.1	18.46	58	88.23	45	45.7	287.5	6.7	12
Allowable level of Heavy metals in soil (mg.kg ⁻¹)*			0-0.7	1-10	2-50	3-50	1-20	2-50	15-150	0-4.5	0.5-5

* (Raisi, 2013; Vodyanitskii, 2016)

Research Method

Seeds of the *Agropyron desertorum* were sown in 160 trays in greenhouse of the Department of Agricultural, Ferdowsi University of Mashhad in mid-January 2016. After one month, the seedling was transferred to pots (dimensions 7 × 9 cm) containing about 160 g of soil. The soil of the pots was the same as the mining area of the Mashhad Cement Factory. During the transfer of pots to the mining area (March 19th), in separate treatments, *Glomus intraradices* mycorrhiza were added to soil from 1 to 10 (as a layer to 2 kg of soil) (Maestre et al., 2002; Azimi et al., 2014; Azimi et al., 2016; Sharma & Sharma, 2013) and zeolite treatments at rate of 2% (40g.kg⁻¹) (Bagherifam et al., 2014; Yari et al., 2013) and 0.4%

superabsorbent (8 g.kg⁻¹ soil) (Al Humaid & Moftah, 2007; Abedi Koupai & Mesforoush, 2009; Banedj Schafie, 2015) was added into the pits containing 2kg soil and then cultivated. Mycorrhiza soil was obtained from Fanavar Turan Company. According to the company's catalog, there were at least 50 live spores per gram of mycorrhiza soil. The inoculum also included soil, spore, plant roots, and mycorrhiza fungal hyphae. Zeolite was prepared from Alvand Sangsar Agricultural Development Company of Semnan and Polymer was used from the Polymer Research Institute of Iran.

Data collection

The plants of pots were transplanted in the field based on a completely randomized block design with four replications in March 2016 and data were collected at the end of the experiment in July in the same year. Irrigation was done only once at planting time. Data were collected prior to plants going to yellowish leaves and falling. At the end of the experiment, for each treatment, two seedlings in each plot were randomly selected and establishment rate, plant height, and dry weight of leaves, roots, and stems of plants were measured. Then, the samples were dried in an oven at 70°C for 48 h and reweighted for dry matter yield. The root colonization percent was assessed in two experiments. In the greenhouse experiment, the coexistence of plant with mycorrhiza in the soil of mining area was assessed. For this propose, the plants of four pots were inoculated with mycorrhiza and grown in the greenhouse until March 2016. Then, the percentage of colonization was examined in the roots of the plants. In the field, experiment seedlings were inoculated with mycorrhiza during plant growth in the field and at the end of July, the percentage of roots colonization of was measured.

To determine the root colonization by mycorrhiza, a part of the fresh root of the plants (about 0.2 g) was randomly selected, washed and cut from 1 cm and then, transferred into the glasses containing 10% KOH and stored at room temperature for 60 h. In the next step, the roots were placed in 1/10 molar HCl solution to neutralize the alkaline medium for two minutes. The roots were stained with Phillips & Hayman (1970) method. Then, the method of Giovannetti *et al.* (1980) was used to determine the degree of symbiosis of mycorrhiza fungus with roots.

The experimental design was based on a completely randomized block design with four replications including mycorrhiza,

zeolite and super absorbent and control treatments in the mining lands of Mashhad cement factory. Data were analyzed for variance using SPSS18 software and the means comparison was done using Duncan method. The non-normal data were converted.

Results

The effect of treatments on seedling establishment and growth of *A. desertorum* based on the analysis of variance, it was determined that zeolite, mycorrhiza and superabsorbent treatments had a significant effect on plant height, dry matter of shoot, root and whole plant and establishment rate of the *A. desertorum* in the field (Tables 3 and 4).

For Root dry weight, the effect of zeolite, mycorrhiza and superabsorbent was significant ($p \leq 0.05$) (Table 2). Treatments of mycorrhiza, zeolite and superabsorbent increased dry root weight (59, 72 and 15%, respectively) more than that for control (Table 3).

For shoot dry weight, the effects of zeolite and mycorrhiza were significant ($p \leq 0.01$) (Table 2). Means comparison of treatments showed that the inoculated plants with mycorrhiza and zeolite had the highest dry weight of the shoot as 51 and 61% more than that for control, respectively (Table 3).

For plant, dry weight result showed that zeolite and mycorrhiza treatments had a significant effect on total plant dry weight ($p \leq 0.01$) (Table 2). Regarding the means comparison between treatments, the result showed that mycorrhiza and zeolite treatments increased total dry weight (54 and 66%) more than that for control (Table 3).

For plant height, results showed that the effects of zeolite and mycorrhiza were significant ($p \leq 0.05$) (Table 2). Application of the zeolite and mycorrhizae treatments increased the plant height to 44 and 42% as compared to control (Table 3).

In general, for all of traits, mycorrhiza with average values of 0.6 g/p, 0.8 g/p, 1.4 g/p, 17.7 cm and 06 % had higher root, shoot, total dry weight, plant height, and Establishment, respectively. For

zeolite, the average values of 0.7 g/p, 0.9 g/p, 1.6 g/p, 17.4 cm and 87 % had higher root, shoot, total dry weight, plant height, and Establishment, respectively (Table 3).

Table 2. The result of analysis of variance and the effect of zeolite, mycorrhiza and superabsorbent treatment on seedling establishment and growth of *A. desertorum*

SOV	DF	MS				
		Root dry weight	Shoot dry weight	Total dry weight	Height plant	Establishment
Block	3	0.04	0.1	0.25	16.46	328.8
Treatment	3	0.17*	0.28**	0.88**	61.5*	1938.9**
Error	9	0.01	0.02	0.04	1.4	109.6
CV	-	48.46	44.44	44.8	28.54	30.44

** , * and ns: significant in level 0.01, 0.05 and no significant, respectively.

Table 3. Means comparison of the effect of zeolite, mycorrhiza and superabsorbent treatments on seedling establishment and growth of *A. desertorum*.

Treatments	Root dry weight (g.plant ⁻¹)	Shoot dry weight (g.plant ⁻¹)	Total dry weight (g.plant ⁻¹)	Plant Height (cm)	Establishment (%)
Control	0.2 ^c ± 0.1	0.4 ^b ± 0.1	0.6 ^c ± 0.2	10.0 ^b ± 0.1	46 ^c ± 6.4
Zeolite	0.7 ^a ± 0.1	0.9 ^a ± 0.1	1.6 ^a ± 0.2	17.4 ^a ± 1.1	87 ^{ab} ± 6.4
Superabsorbent	0.4 ^b ± 0.1	0.5 ^b ± 0.1	0.9 ^{bc} ± 0.2	11.8 ^b ± 1.1	71 ^b ± 6.4
Mycorrhizae	0.6 ^a ± 0.1	0.8 ^a ± 0.1	1.4 ^a ± 0.2	17.7 ^a ± 1.1	96 ^a ± 6.4

In each column and for each factor, averages that have common letters have no significant difference in 0.05% level according to Duncan's multiple range test (Average± Standard error)

Root colonization using mycorrhiza (greenhouse vs. field)

The root colonization of *A. desertorum* using *Glomus intraradices* was significant in the greenhouse and after transfer and cultivation in the field ($p \leq 0.01$) (Table 4). The result showed colonization of *A. desertorum* root with *G. intraradices* mycorrhiza in the field (66%) and greenhouse (80%) indicating 14% higher values of root colonization in glasshouse than the field (Fig. 1). The success of the arbuscular mycorrhiza can be explained by fungal colonization (arbuscular, vesicles, and hyphae) in the plant roots (Fig. 2).

Table 4. Analysis of variance of root colonization percent of *A. desertorum* with mycorrhiza at the site of cultivation (field and greenhouse)

SOV	DF	MS
Block	3	1.39 ^{ns}
root colonization (greenhouse vs. field)	1	401.39**
Error	3	18.52
CV	-	11.31

**and ns: significant in level 0.01 and no significant, respectively.

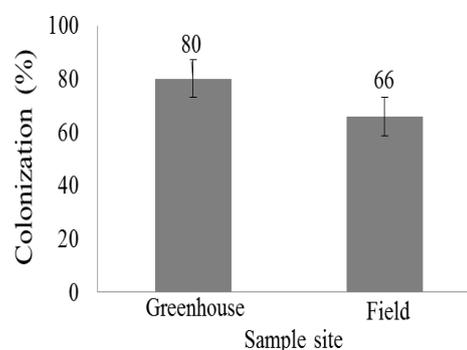


Fig. 1. Means comparison of colonization percent for *A. desertorum* at field and greenhouse

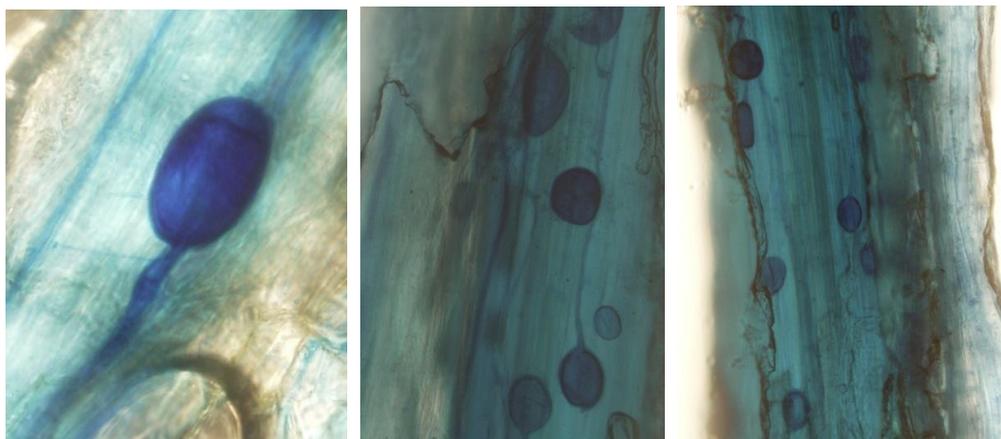


Fig. 2. The contaminated root of *A. desertorum* by numerous vesicles and hyphae

Discussion

The results showed that zeolites and mycorrhiza had a significant impact on some morphological characteristics and plant growth of *A. desertorum*. In this study, mycorrhiza increased plant height, root and shoot dry weight. The fungus absorbs water and nutrients through the net of hyphae outside root and gives them to the plant, and the plant provides the carbohydrates needed for the fungus (Azimi *et al.*, 2014). In addition, mycorrhiza fungi with the production of plant hormones can intensify plant growth or root growth, thus increasing the absorption of nutrients and keeping the plants in avoiding drought (Barea *et al.*, 2005). A research conducted on the coexistence of mycorrhiza *G. intraradices* of *Sorghum bicolor* L. in lead-contaminated soils showed higher values of shoot and root dry weight than that for control, but it had no significant effect on the plant height (Amanifar *et al.*, 2010). In the study on *Trifolium subterraneum* L, inoculated plant with the *Glomus* family mycorrhiza enhanced the plant roots growth and conversion of insoluble nutrients into accessible state, increased the absorption of nutrient elements of plants and ultimately increased plant biomass (Li-ping *et al.*, 2009). Another study suggested that application of zeolite controls soil pH and N retention, absorption of Pb, Cd, Zn and other heavy metals by cation exchange provided plant nutrients requirement and

microorganisms (Fenn *et al.*, 2006; Fenglian *et al.*, 2011). In a study, Shaheen *et al.* (2015) succeeded in corn establishment via inoculation of plants with 2.5% of zeolites in contaminated soils around the Greek copper mine using mycorrhiza and zeolite, superabsorbent treatments that increased the root dry weight and establishment rate as compared to the control. Hutterman *et al.* (1999) using superabsorbent found that the seedlings grow, the survival rate of *Pinus halepensis* were increased under drought conditions in clay loam soils, and they suggested application of 0.4% of superabsorbent. They also showed that water evaporation from the soil surface decreased from 90% to 50%, and the seedlings survival rate increased from 49 to 82 days (Hutterman *et al.*, 1999). Zangoeei Nasab *et al.* (2013) in Birjand, Iran studied *Holoxylon* sp. by the addition of hydrogel to soil and found higher root dry weight and establishment rate. They suggested that soil polymerization with 0.3% of polymer had the best result (Zangoeei Nasab *et al.*, 2013). The effect of A200 superabsorbent polymer on plant growth indices of an ornamental shrub in green space showed that mixing 4 or 6 g of polymer with 1 kg of soil reduces the water needed for the plant by at least one third due to the increase of the usable water (Abedi Koupai & Asadkazemi, 2006). In the similar study, the effect of A200 superabsorbent on the reduction of drought stress of olive trees (*Olea*

europaea) using superabsorbent in soil at a ratio of 0.3% had a higher dry weight and plant height in drought stress (Talaii & Asadzadeh, 2005). For plant establishment, the mean values of plants inoculated with mycorrhiza and zeolite were higher than that of superabsorbent and control in the field. Similar to our study, application of natural zeolites was effective in removing heavy metals from mines water. Their result showed that zeolite induced better growth of *Dieffenbachia amoena* and improved growth indices including leaf, stem and root dry weight, leaf number, diameter and plant height, and also improved nutrient uptake by the plant (Mohammadi Torkashvand et al., 2013). This is probably due to increased P, N and K uptake in zeolite-grown plants (Ahmed et al., 2010). Maloupa et al. (1999) concluded that despite the zeolite, the concentration of K and Mg may grow the plant tissue and the plants' growth in such a bed was better (Maloupa et al., 1999). Mycorrhiza colonization in soils contaminated with heavy elements increases the effective root level for nutrients absorption. The fungal hyphae can penetrate to the large depth of soil and absorb a large number of nutrients including heavy elements. In highly contaminated soils, arbuscular mycorrhiza fungus (VAM) can protect plants against the harmful effects of these metals and improve their response to water loss at cellular, anatomical and morphological levels (Bano et al., 2013). Mycorrhiza like a filter prevents the introduction of certain metals (heavy metals such as Ar and Cd, etc.) into plant cells, thereby reducing plant damage by toxic metals and increasing the probability of the establishment of plants in the field (Sharma & Sharma, 2013). In a study, Kohler et al. (2015) observed that mycorrhiza induced establishment of *Anthyllis cytisoides* seedlings in semi-arid areas with mining activity infected with heavy metals. They showed that using

mycorrhiza with organic fertilizers increased the *Anthyllis cytisoides* aerial biomass. Symbiotic fungi of *Glomus versiforme* and *G. intraradices* contributed to the establishment and optimal growth and absorption of nutrients in maize, soybean, clover, ground clover, tomato and eucalyptus in soils contaminated with Cd, Pb, Zn, Ar and petroleum (Sadrahi & Gharacheh, 2013). These fungi inactivate pollutants by fixing them in their hyphal net out of the root. Therefore, symbiotic fungi can contribute greatly to the biological restoration of contaminated lands (Sadrahi & Gharacheh, 2013). The application of mycorrhiza fungi increased the plant's resistance to environmental stresses, exacerbate photosynthesis, increase the growth and development of plants and increase the yield and absorption of water and nutrients (Porrás et al., 2009; Subramanian et al., 2006). The effective symbiosis between plant roots and AMF is very different in terms of nutrient uptake, depending on the species of fungi and genotype of the plant (Marschner, 1995). AMF are affected by soil bed characteristics such as fertilization and physical and chemical properties. However, all types of AMF can carry at least P and N (Khan, 2005; Powell et al., 2007).

Among different treatments, the percentage of establishment in species inoculated with mycorrhiza and zeolite was higher than superabsorbent treatment and control in the field because most mycorrhiza fungi increase host plant resistance (Jones et al., 1988). The effects of these toxic metals can be reduced using suitable fungi as an inoculum in heavy metals contaminated lands (Bano et al., 2013). The intrinsic mycorrhiza relationship is also involved in bioaccumulation and emulsification of toxic heavy metals in the soil. Requena et al. (2001) found that *G. intraradices* mycorrhiza had the greatest impact on the improvement of plant establishment in

the desert areas. Shetty *et al.* (1994) found the effects of mycorrhiza fungi and other soil microorganisms on the establishment of the two kinds of grass *Andropogon gerardii* Vitm and *Festuca arundinacea* Schreb in soils contaminated with heavy metals and minerals. They found none of the plants was capable of establishing and growing in mining lands. *Andropogon gerardii* grew only in the presence of mycorrhiza in these soils and the *Festuca arundinacea* produced more colonies than other plants with mycorrhiza. Wingenfelder *et al.* (2005) in Germany used natural zeolites to remove heavy metals from water in mines. Zeolite was more effective in reducing Fe and Pb more than two Cd and Zn metals. Banedj Schafie (2015) in studying the effect of polymer on vegetative traits of *Panicum antidotale* Retz observed that adding superabsorbent in a weight ratio of 0.3% to soil increased soil moisture storage capacity and the success of establishment rate of *Panicum antidotale* in arid areas.

Jonson (1998) in the study of the effect of colonization of the root of *A. desertorum* with mycorrhiza treatment showed that the *A. desertorum* is able to coexist with mycorrhiza. The percentage of colonization of the root of *A. desertorum* in the pre-cultivation stage (greenhouse stage) was higher than that in the field. It was due to the mycorrhiza that increased rapidly in the pre-cultivating stage (greenhouse stage) due to the proper host conditions and the absence of environmental stresses such as drought and soil disturbance (Jonson, 1998) but after cultivation in the field, the plant does not support the fungus and reduces the population of mycorrhiza due to climate changes and adverse environmental conditions. Azimi (2013) studied seedlings of *Bromus kopetdaghensis* and *Ziziphora clinopodioides* inoculated with *Glomus mosseae* and *Glomus intraradices* mycorrhiza and colonization of the roots

in the greenhouse and field. Results showed that the percentage of root colonization of plants in the greenhouse was higher than field conditions (Azimi, 2013).

Some mycorrhiza fungi are also affected by heavy metals in the soil. Boyd (2007) showed that mycelium development and sporulation were affected by heavy metals in the soil and some mycorrhiza species can tolerate heavy metal stresses, which *Glomus intraradices*, and *Glomus mosseae* are the most important species for heavy metal (Sharma & Sharma, 2013). Therefore, the selection of mycorrhiza strains resistant to heavy metals is an important step in obtaining healthy plants in lands contaminated with metals. Sharma & Sharma (2013) showed that the heavy metals are often accumulated in the hyphae and in the arbuscular fungus. The higher absorption of Zn into mycelium of arbuscular mycorrhiza fungus showed symbiosis with *Trifolium subterraneum* L and *Lolium temulentum*. Increasing symbiosis of hyphae and sporulation was observed under high concentrations of Cd and Zn in the *G. intraradices* fungus (Boyd, 2007).

Conclusion

In this research, zeolite and mycorrhiza treatments had a positive effect on the increase in yield and establishment of the *A. desertorum* seedling in the mining lands of a cement factory in Mashhad, Iran. Therefore, given the existence of millions of tons of zeolite in Iran, they can be purchased at very cheap prices and used in agriculture and natural resources. This issue is especially important in the fields of natural resources in arid and semi-arid regions where rainfall and soil moisture content are low and plant establishment depends on rainfall and can be considered by researchers and executives. Mycorrhiza *G. intraradices* can be proposed as a biological fertilizer for

enhancement of yield, the initial establishment of *Agropyron desertorum* and restoration of the vegetation of lands contaminated with heavy metals in the mining area of the cement factory of Mashhad.

References

- Abedi Koupai, J. and Asadkazemi, J., 2006. Effects of a hydrophilic polymer on the field performance of an ornamental plant (*Cupressus arizonica*) under reduced irrigation regimes. Iranian Polymer Journal, 15(9): 715-225. (In Persian)
- Abedi Koupai, J. and Mesforoush, M., 2009. Evaluation of Superabsorbent Polymer Application on Yield, Water and Fertilizer Use Efficiency in Cucumber (*Cucumis sativus* L.). Iranian Journal of irrigation and drainage, 2(3): 100-111. (In Persian)
- Adams, P. W. and Lamoureux, S., 2005. A literature review of the use of native northern plants for the re-vegetation of Arctic mine waste and mine tailings. Environment and natural resources. Northwest Territories.
- Ahmed, O. H., Sumalatha, G. and Nik Muhamad, A. M., 2010. Use of zeolite in maize (*Zea mays*) cultivation on nitrogen, potassium and phosphorus uptake and use efficiency. International Journal of the Physical Sciences, 5(15): 2393-2401.
- Al Humaid, A. and Moftah, A. E., 2007. Effects of hydrophilic polymer on the survival of Buttonwood seedlings grown under drought stress. Journal of Plant Nutrition, 30(1), 53-66.
- Amanifar, S., Aliasgharzad, N., Najafi, N., Oustan, S. H. and Bolandnazar, S., 2010. Effect of Arbuscular Mycorrhiza Fungi on Lead Phytoremediation by Sorghum (*Sorghum bicolor* L.). Journal of Water and Soil Science, 22(1): 155-168. (In Persian)
- Azimi, R., 2013. The effect of mycorrhiza on the establishment and morphological characteristics species *Bromus kopetdaghensis*, *Medicago sativa*, *Thymus vulgaris* and *Ziziphora clinopodioides* in Baharkish Ghoochan rangelands. Mashhad Ferdowsi University, Iran. (In Persian).
- Azimi, R., Jankju, M. and Asghari, H., 2014. Effect of mycorrhiza inoculation on seedlings establishment and morphological parameters of *Medicago sativa* L. under field conditions. Journal of Agroecology, 5(4): 424-432. (In Persian).
- Azimi, R., Hossein Jafari, S., Kianian, M. K., Khaksarzade, V. and Amini, A., 2016. Studying Arbuscular Mycorrhiza Symbiotic Effects on Establishment and Morphological Characteristics of *Bromus kopetdaghensis* in Cadmium-Contaminated Soil. Taiwan Water Conservanc, 64(3): 82-91.
- Bacchetta, G., Cappai, G., Carucci, A. and Tamburini, E., 2015. Use of native plants for the remediation of abandoned mine sites in Mediterranean semiarid environments. Bulletin of Environmental Contamination and Toxicology, 94:326–333.
- Bagherifam, S., Lakziyan, A., Fotovat, A., Khorasani, R., Akbarzadeh, S. and Motedayen, A., 2014. Immobilization of arsenic in a calcareous soil using an iron, manganese and aluminum-modified zeolite. Journal of Environmental Science and Technology, 16(61): 39-54. (In Persian).
- Barea, J. M., Pozo, M. J., Azcon, R. and Azcon, C., 2005. Microbial co-operation in the rhizosphere. Journal of Experimental Botany, 56(417): 1761-1778.
- Bassiri, M., Wilson, A. M. and Crami, B., 1988. Dehydration effects on seedling development of four range species. Journal Range Management, 41(5): 383-386.
- Bano, S. A. D. and Ashfaq, D., 2013. Role of mycorrhiza to reduce heavy metal stress. Natural Science, 5(12): 16-20.
- Beane, S. J., Comber, S. D., Rieuwerts, J. and Long, P., 2016. Abandoned metal mines and their impact on receiving waters: a case study from Southwest England. Chemosphere, 153:294–306.
- Behbahani, M., Asadzadeh, A. and Jebelli, J., 2005. Evaluation of the effect of superabsorbent hydrogels and irrigation treatments in maintaining nutrient in hydroponic beds, the third period educational and seminars specialized use of superabsorbent hydrogels, Iran Polymer and Petrochemical Institute, 16 November, Tehran, Iran. (In Persian).
- Banedj Schafie, S., 2015. Effect of a superabsorbent polymer on the growth of *Panicum antidotale* and nitrogen leaching. Iranian Journal of Range and Desert Research, 22(3): 595-605. (In Persian)
- Boyd, R. S., 2007. The defense hypothesis of elemental hyper accumulation status, challenges and new directions. Plant Soil, 293: 153-176.
- Doula, M. K., Elaiopoulos, K., Kavvadias, V. A. and Mavraganis V., 2012. Use of *clinoptilolite* to improve and protect soil quality from disposal of oil mills wastes. Journal Hazard Mater, 207–208: 103–110.
- Ernest, W., Joachimkarauss, J., Verkleij, J. and Wesenbfrg, D., 2008. Interaction of heavy

- metals with the sulphur metabolism in angiosperms from an ecological point of view. *Plant, Cell and Environment*, 31: 123–143.
- Fallahi, H. R., Aghavani Shajari, M., Taherpour Kalantari, R. and Soltanzadeh, M. G. 2016. Evaluation of superabsorbent efficiency in response to dehydration frequencies, salinity and temperature and its effect on yield and quality of cotton under deficit irrigation. *Journal of Agroecology*, 7(4): 513–527. (In Persian).
- Fenn, M. E., Perea-Estrada, V. M., De Bauer, L. I., Perez-Suarez, M., Parker, D. R. and Centina-Alcala, V. M., 2006. Nutrient status and plant growth effects of forest soils in the basin of Mexico. *Environmental pollution* 140: 187–199.
- Fenglian, F. and Wan, Q., 2011. Removal of heavy metal ions from wastewaters: a review. [Journal of Environmental Management](#), 92(3): 407–418.
- Giovannetti, M. and Mosse, B., 1980. An evaluation of techniques for measuring vesicular-arbuscular mycorrhizal infection in roots. *Journal of New Phytologist*, 84: 489–500.
- Huang, Z., Sun, P., Chen, J. and Zhong, J. Effect of Environmental materials on plant growth and Immobilization of heavy metal lead and cadmium, technology and practice of mine land reclamation, 237–241.
- Hutterman, A., Zomporodi, M. and Reise, K., 1999. Addition of hydrogels to soil for prolonging the survival of *Pinus halepensis* seedlings subjected to drought. *Soil and Tillage Research*, 50: 295–304.
- Johnson, N. C., 1998. Responses of *Salsola kali* and *Panicum virgatum* to mycorrhizal fungi, phosphorus and soil organic matter: implications for reclamation. *Journal of Applied Ecology*, 35: 86–94.
- Jones, M. D. and Hutchinson, T. C., 1988. Nickel toxicity in mycorrhizal birch seedlings infected with *Lactarius rufus* or *Scleroderma flavidum* Effects on growth, photo- synthesis, respiration and transpiration. *New Phytologist*, 108: 451–459.
- Keiffer, C. H. and Ungar, I. A., 2002. Germination and establishment of halophytes on brine-affected soils. *Journal of Applied Ecology*, 39: 402–415.
- Khan, A. G., 2005. Role of soil microbes in the rhizospheres of plants growing on trace metal contaminated soils in phytoremediation. [Journal of Trace Elements in Medicine and Biology](#), 18: 355–364.
- Khodadadi Dehkordi, D., 2016. The Effects of Superabsorbent Polymers on Soils and Plants. *Pertanika Journal of Tropical Agricultural Science*, 39 (3): 267–298.
- Kohler, J., Caravaca, F., Azcon, R., Diaz, G. and Roldan, A., 2015. The combination of compost addition and arbuscular mycorrhizal inoculation produced positive and synergistic effects on the phytomanagement of a semiarid mine tailing, *Science of The Total Environment*, 514: 42–48.
- Laurence, D., 2011. Establishing a sustainable mining operation: an overview. *Journal of Cleaner Production*, 9: 278–284
- Li, N., Li, R., Feng, J., Zhang, Z. and Shen, F., 2015. Remediation effects of heavy metals contaminated farmland using fly ash based on bioavailability test. *Transactions from the Chinese Society of Agricultural Engineering*, 31: 203–219.
- Li-ping, W., Kui-mei, Q., Shi-long, H. and Bo, F., 2009. Fertilizing reclamation of arbuscular mycorrhizal fungi on coalmine complex substrate. *Procedia Earth and Planetary Science*, 1: 1101–1106.
- Ma, Z., Chen, K., Li, Z., Bi, J. and Huang, L., 2016. Heavy metals in soils and road dusts in the mining areas of Western Suzhou, China: a preliminary identification of contaminated sites. *Journal of Soils and Sediments*, 16: 204–214.
- Marschner, H., 1995. Mineral nutrition of higher plants, 2nd ed. Academic, London
- Maestre, F., Bautista, S., Cortina, J. and Diaz, G., 2002. Microsite and mycorrhizal inoculum effects on the establishment of *Quercus coccifera* in a semi-arid degraded steppe. *Ecological Engineering*, 19: 289–295.
- Maloupa, M., Samartzidis, C., Couloumbis, P. and Komninou A., 1999. Yield quality and photosynthetic activity of greenhouse grown 'Madelon' rose on perlite-zeolite substrate mixtures. *Acta Horticulturae*, 481: 97–99.
- Moameri, M., Jafri, M., Tavili, A., Motasharezadeh, B. and Zare Chahouki, M., 2017. Rangeland Plants Potential for Phytoremediation of Contaminated Soils with Lead, Zinc, Cadmium and Nickel (Case Study: Rangelands around National Lead & Zinc Factory, Zanjan, Iran). *Journal of Rangeland Science*, 7(2): 160–171.
- Mohammadi Torkashvand, A., Karami, A. and Mahboub Khomami, A., 2013. Zeolite: An appropriate alternative for peat in growth medium of *Diffenbachia* ornamental plant. *Journal of Science and Technology of Greenhouse Culture*, 4(2): 81–97.
- Mozgawa, W. and Bajda, T., 2005. Spectroscopic study of heavy metals sorption on

- clinoptilolite* Physics and Chemistry of Minerals, 31: 709–713.
- Mueller, J. and Richards, H., 1986. Morphological Analysis of Tillering in *Agropyron spicatum* and *Agropyron desertorum* Annals of Botany, 58(6): 911–921.
- Neagoe, A., Ebenå, G. and Carlsson, E., 2005. The effects of soil amendments on plant performance in an area affected by acid mine drainage. Chem Erde-Geochem, 65(S1): 115–130.
- Norozi Fard, P., Mortazavi, S. and Ildoromi, A., 2015. Common Reed (*Phragmites australis*) as a Bio Refining and Monitoring Plant of Pollution Resulting from Heavy Metals (Case Study: Dez River, Dezful, Iran). Journal of Rangeland Science, 6(1): 10- 23.
- Phillips, J. M. and Hayman, D. S., 1970. Improved procedure for clearing roots and staining parasites and vesicular–arbuscular mycorrhizal fungi for rapid assessment of infection. Journal of Transactions of the British Mycological Society, 55: 158– 161.
- Porras-Soriano, A., Soriano-Martín, M. L., Porras-Piedra, A. and Azcón, R., 2009. Arbuscular mycorrhizal fungi increased growth, nutrient uptake and tolerance to salinity in olive trees under nursery conditions. Journal of Plant Physiology, 166: 1350- 1359.
- Powell, J. and Klironomos, J., 2007. The ecology of plant-mutualisms. In: Eldor AP (ed) Soil microbiology, ecology, and biochemistry (third edn.). Elsevier Amsterdam, 257– 281.
- Requena, N., Pérez-Solís, E., Azcón-Aguilar, C., Jeffries, P. and Barea, J. M., 2001. Management of indigenous plant -microbe symbioses aids restoration of desertified ecosystems. Journal of Applied and Environmental Microbiology, 67: 495- 498.
- Raisi, T., 2013. Studying Environmental Effects of Heavy Elements on Agricultural Soils. Ariculture and Natural Recourses Engineering Organization, 12(46): 34- 37.
- Sadravi, M. and Gharacheh, N., 2013. The role of mycorrhizal fungi in restoring lands contaminated with toxic substance. Plant Pathology Science, 2(2): 45-60. (In Persian)
- Shaheen, S.M., Tsadilas, C. D. and Rinklebe, J., 2015. Immobilization of soil copper using organic and inorganic amendments. Journal of Plant Nutrition and Soil Science, 178(1):112-117.
- Sharma, A. and Sharma, A., 2013. Role of vesicular arbuscular mycorrhiza in the mycorrhiza in the mycoremediation of heavy toxic metals from soil. International Journal of Life science and Pharma Reviews, 2(3): 418-431.
- Sheoran, V., Sheoran, A.S. and Poonia, P., 2010. Soil reclamation of abandoned mine land by revegetation: a review. International Soil and Water Conservation Research, 3: 1– 20.
- Shetty, K. G., Hetrick, B. A. D., Figge, D. A. H. and Schwab, A. P., 1994. Effects of mycorrhizae and other soil microbes on revegetation of heavy metal contaminated mine spoil, Environmental pollution, 86(2): 181-188.
- Subramanian, K. S., Santhanakrishnan, P. and Blasubramanian, P., 2006. Responses of field grown tomato plants to arbuscular mycorrhizal fungal colonization under varying intensities of drought stress. Journal of Scientia Horticulturæ, 107: 245-253.
- Talaih, A. and Asadzadeh, A., 2005. Scrutiny of the effect of superabsorbent in reducing dryness olive trees. The third seminar courses and agricultural applications superabsorbent. Iran Polymer and Petrochemical Institute. (In Persian).
- Vodyanitskii, Y., 2016. Standards for the contents of heavy metals in soils of some states. Annals of agrarian science 14: 257-263.
- Wingenfelder, U., Hansen, C., Farrer, G. and Schulin, R., 2005. Removal of Heavy Metals from Mine Waters by Natural Zeolites. Environmental Science Technology, 39: 4606-4613.
- Wu, F.Y., Leung, H. M., Wu, S. C., Ye, Z. H. and Wong, M. H., 2009. Variation in arsenic, lead and zinc tolerance and accumulation in six populations of *Pteris vittata* L. from China, Environmental Pollution, 157: 2394– 2404.
- Xiao, R., Sun, X., Wang, J., Feng, J., Li, R., Zhang, Z., Wang, J. and Ali, A., 2015. Characteristics and phytotoxicity assay of biochars derived from a Zn- rich antibiotic residue. Journal of Analytical and Applied Pyrolysis, 113: 575- 583.
- Yari, S., Khalighi-Sigaroodi, F. and Moradi, P., 2013. Effects of different levels of zeolite on plant growth and amount of gel production in *Aloe vera* L. under different irrigation. Journal of Medicinal Plant, 4(48): 72-81. (In Persian).
- Zangooei Nasab, S. H., Emami, H., Astaraei, A. R. and Yari, A. R., 2013. Effects of stockosorb hydrogel and irrigation intervals on some soil physical properties and growth of Haloxylon seedling. Journal of Soil Management and Sustainable Production, 3(1): 167-182.

تاثیر میکوریزا، زئولیت و سوپر جاذب بر رشد و استقرار اولیه گیاه مرتعی *Agropyron desertorum* در اراضی معدن کاوی شده (مطالعه موردی: کارخانه سیمان شرق مشهد)

ریحانه عظیمی^{الف*}، غلامعلی حشمتی^ب، محمدفرزام^ج، مرتضی گلدانی^د
^{الف} دکتری علوم مرتع، دانشکده مرتع و آبخیزداری، دانشگاه علوم کشاورزی و منابع طبیعی گرگان، گرگان، ایران * (نویسنده مسئول)، پست الکترونیک: Reyhaneazimi36@yahoo.com

^ب استاد گروه مدیریت مرتع، دانشکده مرتع و آبخیزداری، دانشگاه علوم کشاورزی و منابع طبیعی گرگان، گرگان، ایران

^ج استاد گروه مرتع و آبخیزداری، دانشکده منابع طبیعی و محیط زیست دانشگاه فردوسی مشهد، مشهد، ایران

^د دانشیار گروه زراعت و اصلاح نباتات، دانشکده کشاورزی دانشگاه فردوسی مشهد، مشهد، ایران

تاریخ دریافت: ۱۳۹۷/۰۲/۰۱

تاریخ پذیرش: ۱۳۹۷/۰۶/۱۸

چکیده. مهم‌ترین و حساس‌ترین مرحله در اصلاح اراضی مرتعی اطراف معادن، استقرار اولیه نشاء گیاهان است، که اغلب به دلیل شرایط نامساعد محیط، فقر عناصر غذایی خاک، به هم خوردن لایه‌های مختلف خاک و ناپایداری خاک در اطراف معادن با شکست مواجه می‌شود. روش‌های جدید اصلاح مراتع مبتنی بر استفاده از رهیافت‌های زیستی و غیرزیستی (زئولیت، سوپر جاذب و میکوریزا) ممکن است به استقرار گیاهان در اراضی حوالی معادن متروکه کمک کند. این تحقیق با هدف بررسی امکان بهبود استقرار اولیه و رشد گیاه مرتعی *Agropyron desertorum* (Fisch. ex Link) Schult. در اراضی معدن کاوی شده آلوده به فلزات سنگین انجام شد. ابتدا در گلخانه گیاهچه‌ها از سینی کشت به گلدان‌های کاغذی منتقل شدند و پس از گذشت دو ماه گلدان‌ها در عرصه نیمه خشک اراضی کارخانه سیمان شرق مشهد با میکوریزا (*Glomus intraradices*)، زئولیت و سوپر جاذب و به صورت شاهد ترکیب و در قالب طرح بلوک کامل تصادفی با چهار تکرار در سال ۹۵-۱۳۹۴ کشت شدند. گیاهان فقط یکبار در زمان کشت آبیاری شدند. در این تحقیق درصد استقرار، ارتفاع بوته، درصد تلقیح میکوریزا با ریشه گیاه *A. desertorum* و وزن خشک اندام هوایی و ریشه گیاه اندازه‌گیری شد. نتایج نشان داد تیمارهای میکوریزا، زئولیت و سوپر جاذب موجب بهبود استقرار اولیه گیاهچه‌ها (۵۰، ۴۲ و ۲۵ درصد) و افزایش وزن خشک ریشه به ترتیب (۶۲، ۷۲ و ۱۵ درصد) نسبت به تیمار شاهد شدند. همچنین کاربرد تیمارهای میکوریزا و زئولیت به ترتیب موجب افزایش ارتفاع (۴۴ و ۴۲ درصد)، افزایش وزن خشک اندام هوایی (۵۱ و ۶۱ درصد) و وزن خشک کل گیاه (۵۴ و ۶۶ درصد) نسبت به تیمار شاهد شدند. نتایج نشان داد که تیمارهای زئولیت و میکوریزا بیشترین تاثیر را بر افزایش استقرار اولیه و بهبود خصوصیات رشدی گیاه *A. desertorum* داشتند و می‌توان از آنها جهت استقرار اولیه گیاهان در اراضی آلوده به فلزات سنگین منطقه معدن کاوی شده کارخانه سیمان شرق مشهد در منطقه نیمه‌خشک واقع شده‌اند استفاده نمود.

کلمات کلیدی: فلزات سنگین، تلقیح، استقرار گیاهچه