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Changes in the Vegetation Properties Depending on the Distance to an Industrial Facility: Example of Pumice Mining Dust

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ABSTRACT

Mining areas have become a major environmental problem for developing countries due to their undesirable effects of dust pollution and digging operations. The objective of this study was to examine the effect of dust emitted from pumice mining areas on canopy coverage, functional plant groups and seed bank, and growth performance of common plants in areas surrounding the mining. Canopy coverage increased with decreasing dust accumulation, while dust led to different effects on functional plant groups and seed bank. The height and the bunch of *Festuca ovina* L., the dominant plant species, increased with distance from the dust center. Dust emission on natural environment must be reduced by using appropriate technologies during operation to minimize its negative effects.

Keywords: Environmental problems, Growing properties, Mining areas, Seed bank.

INTRODUCTION

Rangelands are a major source of feed for both domestic and wild herbivores. However, rangelands supply different services beyond this such as wood, edible plants, water, minerals, biodiversity, recreation area, habitat for wildlife, etc. (Holechek *et al.,* 2011). However, these areas have been degraded mainly by overgrazing and the environmental pollutants originating from the byproducts of industrialization and urbanization. Mining not only directly affects the operation area's morphological, biological, and physiological structure, but also affects characteristics of the surrounding area by emitting dust (Farmer, 1993; Ulrichs *et al.,* 2008; Yan *et al.,* 2011). Thus, dust causes considerable economic, social, and physical damage around mining areas (Katare *et al.,* 2013; Tozer and Leys, 2013).

The pumice industry is important for Erzurum and its surroundings, and deposits lie mainly below rangelands in the province. A high amount of dust is emitted around during both the mining and manufacturing processes of pumice production. Although toxic pollutants are not emitted from pumice mining area, the emitted dust causes environmental pollution and damages plant communities by burning or sandblasting depending on particle size and distance from mining and manufacturing areas. Pumice mining airborne particle size varies between 1 nm and 100 μm (Graedel and Crutzen, 1994), and its dispersion distance varies depending on particle size (Ulrichs *et al.,* 2008; Yan *et al.,* 2011; Turner, 2013). Thus, the effects of dust on the environment change radially.

Research has generally focused on emission of phytotoxic pollutants, whereas there has been limited study on dust pollution originating from mining (Farmer, 1993; Tripathy *et al.,* 2013; Katare *et al.,* 2013). Dust particulates arise from various

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sources, with deposition near source due to gravity, but particles smaller than 10 µm can be transported by wind for several meters or kilometers depending on size (Turner, 2013; Zia-Khan *et al.,* 2015). The physical and chemical characteristics of particles vary with the origin (Tripathy *et al.,* 2013), and their negative or positive effects on plants vary depending on particle size and content (Cattle *et al.,* 2009; Tozer and Leys, 2013; Chaturvedi *et al.,* 2013). In general, the detrimental effect of dust increase as particle size decrease (Turner, 2013), dust particles can decrease stomatal openings (Chaturvedi *et al.,* 2013), reduce photosynthetic rate (Cook *et al.,* 1981; Zia-Khan *et al.,* 2015), and increase leaf temperature and transpiration (Davison and Blakemore, 1976). Deposition ratio, particulate size, chemical composition, plant species, and even the age and growth stage of the plant have been affected either positively or negatively by dust (Tozer and Leys, 2013; Chaturvedi *et al.,* 2013; Gao *et al.,* 2017).

The effects of dust-fall on plants change depending on plant morphology, age, species, leaf anatomy, and deposition amount and content (Tozer and Leys, 2013; Chaturvedi *et al.,* 2013). The plants affected by dust demonstrate reactions such as chlorophyll degradation, necrosis, and reduction in photosynthesis and plant growth (Chaturvedi *et al.,* 2013). Moreover, dust particulates accumulated on plant leaves decrease light, diffusive resistance, and increase water stress (Davison and Blakemore, 1976; Zia-Khan *et al.,* 2015). The light and gas exchange ratios decrease for dust-covered plant leaves. The plant species response to dust-coverage varies depending on leaf surface properties such as geometry, orientation, epidermal and cuticle properties (Zia-Khan *et al.,* 2015). As a consequence of different responses among plants, competitive ability changes, and species composition of natural plant cover may also change (Ulrichs *et al.,* 2008; Rai and Panda, 2014).

Rangeland plant communities are highly sensitive to changing environmental conditions because plant species respond differently (Gibbens *et al.,* 2005; Han *et al.,* 2008). Krippelova (1982) showed that, around magnesite factory in Czechoslovakia, common species such as *Lolium perenne*, *Polygonum aviculare*, *Poa annua* decreased, and *Puccinellia distans*, *Chenopodium glaucum*, and *Agropyron repens* became dominant after the factory was established. According to Farmer (1993), Sree Rangasamy *et al.* (1973) reported that only nine plant species grew near a cement factory, whereas 54 species were recorded in the broader area in southern India. Dust also affects the soil's physical, chemical, and microbial properties, and alters its nutrient content (Tripathy *et al.,* 2013). Where particulate matter is deposited, plant growth and botanical composition, flora, fauna, and vegetation are affected. This situation also affects seed bank (soil seed content) abundance and composition (Godefroid *et al.,* 2006; Chaideftou *et al.,* 2009). Rangeland seed banks are seriously affected by botanical composition, which is strongly affected by the environmental condition (Bakoglu *et al.,* 2009; Ozaslan Parlak *et al.,* 2011; Erkovan *et al.,* 2013; Koc *et al.,* 2013).

The objective of this study was to determine the changes of the effects of dust pollution on canopy coverage, botanical composition, and soil seed bank density and composition depend on distance from a pumice mining area of the high altitude rangelands in the eastern Anatolia region of Turkey.

MATERIALS AND METHODS

Site Description

This study was conducted at the pumice mining and processing area, the Pasinler District of Erzurum Province in eastern Anatolia, Turkey during 2015 and 2016. The elevation is about 1,750 m, and the area is characterized by a harsh climate with a long extremely cold winter, and a cool, short dry summer. Mean annual temperature is 5.2°C, total annual precipitation of 428 mm, mostly occurring in September to May, and mean relative humidity of 66.4%. During 2015 and 2016, average temperatures were 7.4 and 5.5°C, total annual precipitation was 506 and 441 mm, and relative humidity of 61 and 66%, respectively (Table 1).

The plots, 100×100 m size, were established in four lines, two of which lied southwest and the others lied in southeast directions from the dust-emitting centre (Figure 1). Positions of plots were arranged by considering the main wind direction and the flow speed in May, June, July and August in northwest and southeast directions, and 2.1, 2.2, 1.8, 2.0 Bofor, respectively (Gecit, 2002). Every plot consisted of four replications. Thereafter, four sampling units were selected for vegetation survey and seed bank examination based on distance from the dust-emitting centre. Sampling occurred at four plots in every line, considering distance from the emitting centre, which were 0-500, 500-1,000, 1,000-1,500 and 1,500-2,000 m from the mining centre and the processing area. Sampling areas had been protected from grazing since mining operations were initiated, which was approximately 10 years prior to the present research.

In order to describe the main soil properties, four composite soil samples were taken from the plots at 0-20 cm depth, at the beginning of the experiment. The analyses were done at laboratory of Department of Soil Science, Faculty of Agriculture, Ataturk University, based on the methods described in Soil Survey Laboratory Staff (1992) and

Table 1. Monthly precipitation, temperature and relative humidity of the experimental years (2015 and 2016) and long-term average (1990-2016).

	Total precipitation (mm)			Mean air temperature (°C)			Mean relative humidity (%)		
	2015	2016	LT	2015	2016	LT	2015	2016	LT
January	26.1	17.8	16.2	-6.0	-9.4	-10.5	76.2	82.7	79.1
February	34.0	25.0	20.1	-4.5	-4.9	-9.1	80.4	84.1	78.8
March	37.9	26.4	33.9	0.2	1.1	-2.3	70.2	70.5	75.1
April	88.6	39.4	57.0	5.3	7.1	5.5	61.6	58.9	67.3
May	81.5	64.8	66.2	10.6	10.5	10.5	63.8	65.9	64.3
June	28.5	88.6	42.6	17.0	14.7	14.9	50.3	63.7	59.0
July	5.8	17.8	23.4	21.2	19.9	19.2	40.3	53.7	52.8
August	38.8	17.4	15.7	21.2	20.9	19.6	42.8	44.0	49.0
September	3.9	76.2	21.4	18.3	12.5	13.9	39.2	57.4	51.8
October	131.3	18.6	49.6	9.4	7.7	7.7	69.7	64.0	65.9
November	15.4	21.8	27.0	2.8	-1.7	-0.2	60.5	71.6	73.6
December	15.1	27.4	22.2	-6.5	-11.4	-7.2	77.7	80.3	79.9
Total/Mean	506.9	441.2	428.1	7.4	5.5	5.2	61.1	66.4	66.4

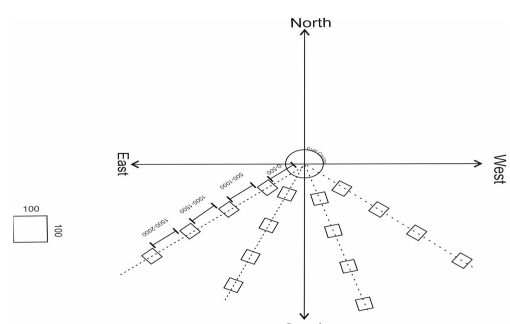

Figure 1. Experimental designs of vegetation survey and seed bank examination based on distance from the dust emitting centre.

the results were summarized as follow. In soil samples, texture classes were sandy-loam at 0-500, 500-1,000 , and 1,000-1,500 m distance from thee emitting centre, and sandy clay loam at 1,500-2,000 m. Soil pH was slightly alkaline at the plot 0-500 and 500-1,000 m, neutral at the 1,000-1,500 m plot, and it was slightly acidic in the 1,500-2,000 m plot. While soil organic matter content changed between 2.0 and 5.2%, soil aggregate stability changed 60.67-88.43% among the plots. Electrical conductivity changed between 97.6 and 220.1 mS cm^{-1}. Soils of the experimental plots were poor in plant-available phosphorus but rich in plant-available potassium.

In order to describe the main properties of dust, composite dust samples were collected from plant surfaces in every sampling units and placed in iron trays, thereafter, dust content and particulate size, were analysed using a wavelength dispersive x-ray fluorescence spectrometer, WDXRFS of ZSX 1000 of Rigaku firm and laser particle size analyser SALD-3001 at laboratory of department of Physical Science, Faculty of Science, Ataturk University. According to analysis results, average C, O, Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Mn, Fe, Rb, Zr and Pd content of the dust were 2.09, 49.55, 1.02, 0.23, 8.72, 30.40, 0.02, 0.04, 0.05, 5.43, 1.30, 0.13, 0.04, 0.94, 0.01, 0.02 and 0.03 %, respectively. Particulate size in the distance from emitting centre 0-500, 500-1,000, 1,000-1,500 and 1,500-2,000 m were less than or equal to 10 µm, 2.5-10 µm, less than 2.5 µm and more than or equal 0.1 µm, respectively. The dust accumulation were 0-500, 500-1,000, 1,000-1,500 and 1,500-2,000 m about 8-10, 5-8, 2-6 and 1-2 g m^{-2}, respectively.

Study area vegetation was short grass steppe, and the dominant plant was sheep fescue (*F. ovina*). Other common species were Annual Grasses (AG) *Bromus japonicus, Bromus tectorum,* Perennial Grasses (PG) *Bromus tomentellus, Bromus variegatus, Koeleria cristata, Phleum montanum, Stipa lagascea, Thinopyrum intermedium,* Perennial Legumes (PL) *Astragalus microcephalus, Lotus corniculatus, Medicago papillosa,* Annual Other Families (AOF) *Alyssum desertorum, Alyssum murale, Galium aparine, Minuartia anatolica,* Perennial Other Families (POF) *Achillae millefolium, Artemisia spicigera, Euphorbia virgata, Helichrysum arenarium, Hypericum scabrum, Teucrium polium, Thymus parviflorus, Ziziphora capitata.*

Canopy Coverage and Botanical Composition

In each sampling unit, 5 transect line with 100 m length were established considering the main wind direction for vegetation survey, and the transects were sampled at 1 m intervals in every line. Vegetation sampling was conducted in late June or early July in both years when common species were flowering, using a modified wheel-point method (Koc and Cakal, 2004). Canopy coverage was calculated as the ratio of total plants recorded versus the number of sampling point and botanical composition was calculated (Gokkus *et al.,* 2011). Species composition was grouped into the categories listed above for statistical analysis.

Soil Seed Bank Density

Ten soil cores (10 cm diameter×6 cm deep) were collected at 50 m intervals along each transect at every sampling plot during the summer (mid-August) in both years. Each sample was stored in a cloth-bag after removal of gravel, litter, and roots. Samples were air-dried and stored in the dark at 4 °C up until the following March. Seed banks were determined using a germination method commonly used for field surveys (Pugnaire and Lazaro, 2000). For germination, soil cores were spread on a plastic tray (25 cm diameter and 6 cm deep) to a depth of approximately 2 cm. Trays were placed in a greenhouse under semi-controlled conditions (temperature 20^{o}C dark/30°C light (12-hour cycle)), and watered once or twice daily with tap water to maintain a moist surface, for 90 days (Sternberg *et al.,* 2003). Emerging seedlings were counted as soon as identified and recorded and thereafter removed from the tray during the experimental period.

Plant Measurements

Plant height and bunch diameter of dominant species, sheep fescue (*F. ovina*), was recorded in all plots by measuring 20 plants (5 plants in every replication unit) were selected in every plots and their height and bunch diameter were measured.

Statistical Analyses

An arc-sin transformation was applied to all plant canopy, botanical composition, and seed bank composition data. All statistical analyses were performed based on the general linear model using the Statview software package (SAS Institute 1998). Means were separated using Bonferroni/Dunn Multiple Range Test.

RESULTS

Canopy Coverage and Functional Plant Groups

Mean canopy coverage was significantly (P< 0.0060) higher in 2015 (57.7%) than 2016 (52.7%) (Table 2). Significant differences (P< 0.0001) were recorded among the distance from emitting center for canopy coverage, which increased linearly with distance from the dust emission center. Increases beyond 1,000 m (500-1,000 m) did not vary statistically (Table 2). The canopy coverage ratio showed a different trend among the distance from emitting center. While canopy coverage increased at 0-500 m in the second year compared to the first year, it did not change significantly at 500-1,000 m between years and decreased significantly in 1,000-1,500 and 1,500-2,000 m in the second year (Figure 2). This different trend caused significant interaction between year x distance.

An overall contribution of Annual Grasses

Table 2. Canopy coverage and functional plant groups' frequency on the experimental area's rangeland plant cover (%).[a]

	Canopy coverage	AG	PG	PL	AOF	POF
Year (Y)						
2015	57.7 A	4.2 B	33.6 A	7.4	11.8 B	49.6
2016	52.7 B	8.0 A	18.9 B	9.6	17.6 A	47.2
Distance (D)						
0-500	31.1 C	6.3	23.0 B	6.9 B	14.5 B	54.5 A
500-1000	53.1 B	4.3	21.4 B	2.5 B	22.0 A	51.5 B
1000-1500	66.5 A	7.1	29.1 A	13.3 A	13.8 B	42.6 C
1500-2000	69.9 A	6.8	31.5 A	11.2 A	8.9 C	45.0 C
Average	55.2	6.1	26.3	8.5	14.7	48.4
Y	**	**	***	ns	***	ns
D	***	ns	***	***	***	***
Y×D	***	ns	**	ns	ns	ns

[a] Values followed by capital in a column shows significantly differences at P< 0.05, P< 0.1 and P< 0.01 levels, respectively, using Bonferroni/Dunn multiple range test. ns: Not significant at P< 0.05, P< 0.1 and P< 0.01. Statistical Difference at P< 0.05; ** P< 0.1, and *** P< 0.01.

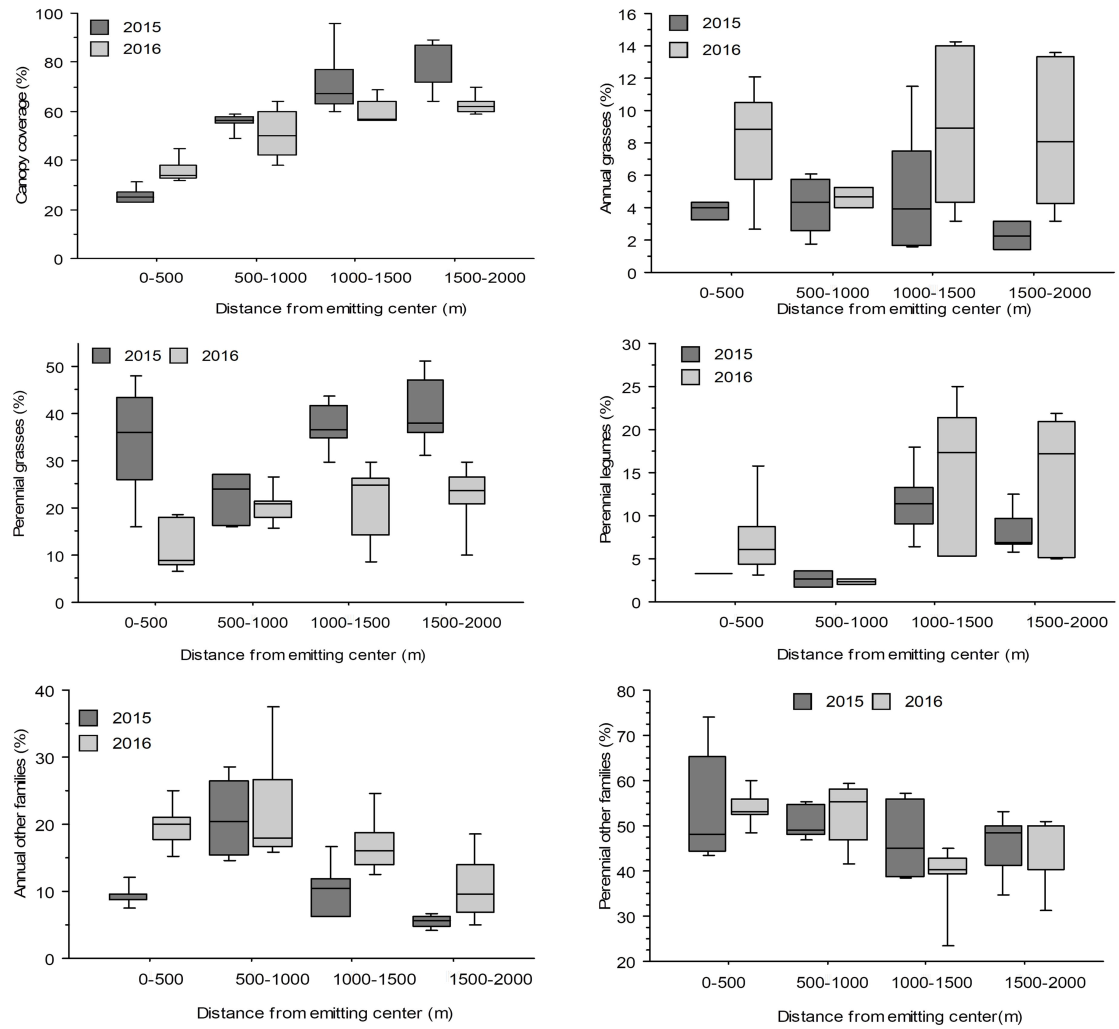

Figure 2. Variation of canopy coverage, functional groups (Annual grasses, Perennial grasses, Perennial legumes, Annual other families and Perennial other families) with aboveground vegetation distance from dust center.

(AG) to plant cover was 6.1% and was significantly influenced by year (Table 2), being significantly (P< 0.0005) higher in the second year. There were no significant changes in AG contribution to plant cover as distance from dust emission centre increased.

There was a strong effect of year, distance, and their interaction on Perennial Grasses (PG) ratio (P< 0.0001) (Table 2). PG ratio was higher in 2015 (33.6%) than in 2016 (18.9%) (Table 2; Figure 2). Also, the PG ratio was highest at 1,500-2,000 m plots (31.5%) than the others. While the PG ratio did not change significantly at 500-1,000 m between years, it was higher at the other distance from emitting centre in the first year.

There was no significant effect for years (P< 0.0537), but a significant effect for distances (P< 0.0001) for the Perennial Legumes (PL) ratio. Also, the two-way interaction was not significant (P< 0.5748) for the PL ratio, which was higher at 1000-

1500 and 1500-2000 m than closer plots (Table 2).

The average ratio of Annual Other Families (AOF) of the years and the distances showed a significant difference (P< 0.0001), but two-way interactions were not significant (P< 0.0572). AOF ratio was higher in 2016 than 2015, and it was higher in 500-1000 m (22.0%) compared to the other distances from emitting center (Table 2).

The ratio of Perennial Other Families (POF) was affected by distance from the center, declining until 1,000-1,500 m and increasing thereafter (Table 2).

Soil Seed Bank Density

Total seed density in the seed bank did not change significantly between years, but it changed significantly among distance from emitting center (Table 3). Year by distance interaction for total seed density was insignificant (Table 3 and Figure 3). As the distance from the emission center increased, seed number per m^2 increased (Table 3).

Average AG seed number was not affected by year or distance, and there was no significant interaction (Table 3; Figure 3).

There was a strong effect of years (P< 0.0164) and distance (P< 0.0440) on soil seed bank density of PG, but their interaction was not significant (P< 0.6753). Soil seed bank density of PG was 290.2 seed m^{-2} in 2015 and 481.4 m^{-2} in 2016 and it increased regularly away from the emission center. Soil seed bank densities of PG were 227.3, 261.9, 485.7, and 568.3 m^{-2} for the distance from emitting center 0-500, 500-1,000, 1,000-1,500 and 1,500-2,000 m, respectively (Table 3 and Figure 3).

Legumes content in soil seed banks was lower and unevenly distributed in the experimental area, therefore, legumes added forbs groups considering their life span. The effect of the year (P< 0.1918) and two-way interaction (P< 0.9869) on AOF was not significant but the distance (P< 0.0001) effect was significant. It was approximately 569.9 AOF seed per m^2 in the experimental area (Table 3) and it varied (263.5 and 1252.4 seed m^{-2}) greatly among the distance from emitting center (Table 3; Figure 3).

An average seed number of POF in the seed bank was 689.0 and it did not change statistically depending on years, but increased significantly (P< 0.0001) in line with increasing distance from dust emitting center in the area (Table 3). Since POF seed number increases in the seed banks showed a similar trend based on distance from dust emitting center in both years, years by distance interaction was not significant.

Table 3. Changes of seed banks and sheep fescue, which is dominate plant, plant height and bunch size depending on years and dust emitting center in the experimental area.[a]

	Total	AG	PG	AOF	POF	Height	Bunch
Year (Y)							
2015	1388.7	206.7	290.2 B	539.0	690.7	32.3	5.5
2016	1628.6	221.9	481.4 A	600.8	687.2	32.5	5.9
Distance (D)							
0-500	607.0 C	200.3	227.3 B	263.5 B	256.3 B	22.9 C	2.1 C
500-1000	1044.2 B	155.0	261.9 B	444.9 B	456.8 B	31.1 B	2.8 C
1000-1500	1481.8 B	165.3	485.7 A	318.9 B	939.8 A	31.0 B	6.4 B
1500-2000	2901.6 A	336.6	568.3 A	1252.4 A	1103.0 A	44.6 A	11.5 A
Average	1508.6	214.3	385.8	569.9	689.0	32.4	5.7
Y	ns	ns	*	ns	ns	ns	ns
D	***	ns	*	***	***	***	***
YxD	ns	ns	ns	ns	ns	ns	ns

[a] Values followed by capital in a column shows significantly differences at P< 0.05, P< 0.1 and P< 0.01 levels, respectively, using Bonferroni/Dunn multiple range test. ns: Not significant at P< 0.05, P< 0.1 and P< 0.01. Statistical Difference at P< 0.05; ** P< 0.1, and *** P< 0.01.

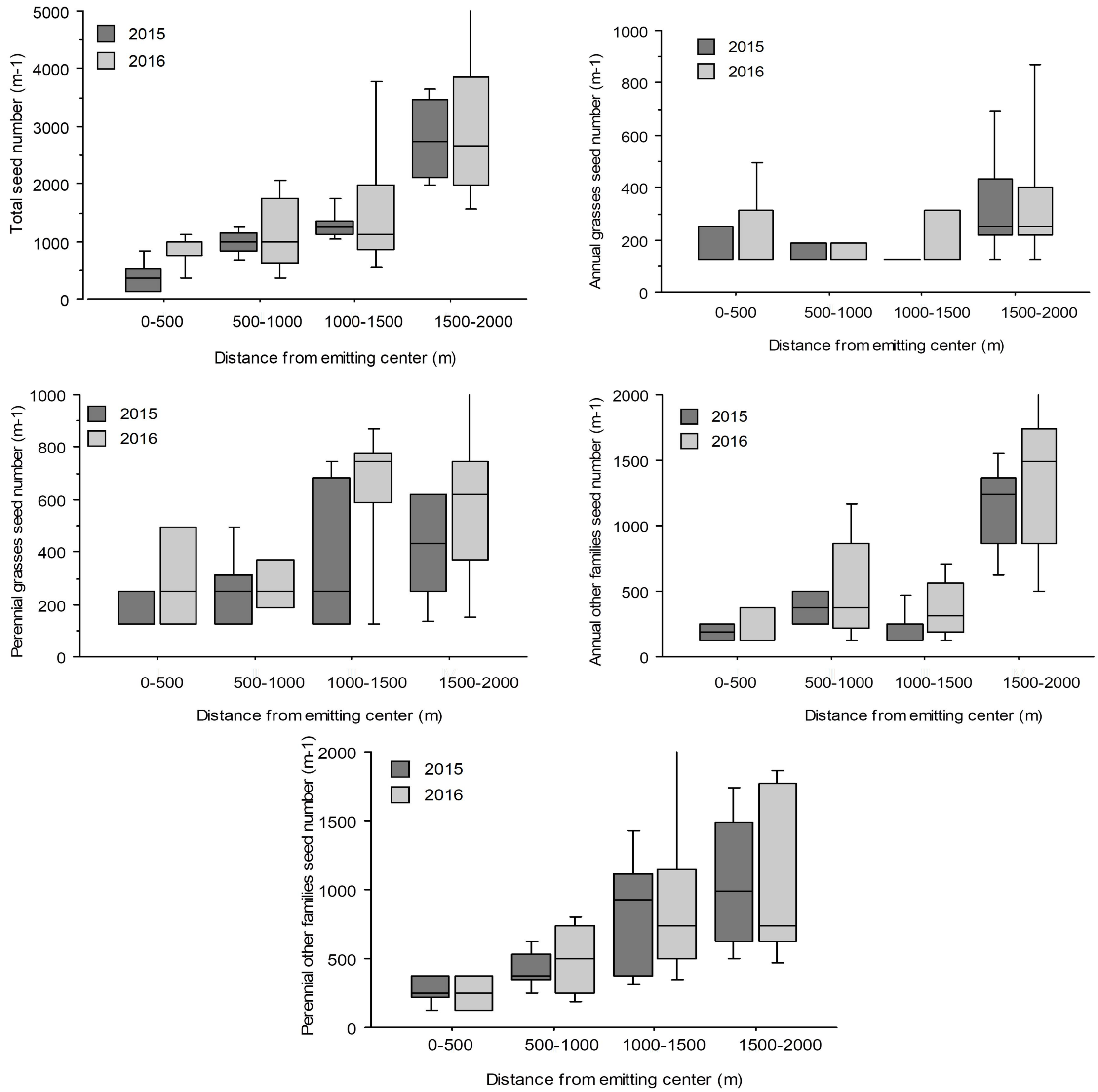

Figure 3. Variation of functional groups (Total, Annual grasses, Perennial grasses, Annual other families and Perennial other families seed number) with soil seed bank density distance from dust center.

Dominant Plant Height and Bunch Size

Dust significantly suppressed plant vitality, the changes in plant height, and bunch size of sheep fescue (Table 3). This decreasing trend was similar in both years with respect to both plant height and bunch size (Figure 4).

DISCUSSION

Canopy Coverage

Stress factors have different effects on plants depending on their physiological and morphological properties. In general, as the influence of stress factor increases, plant mortality increases (Ulrichs *et al.,* 2008;

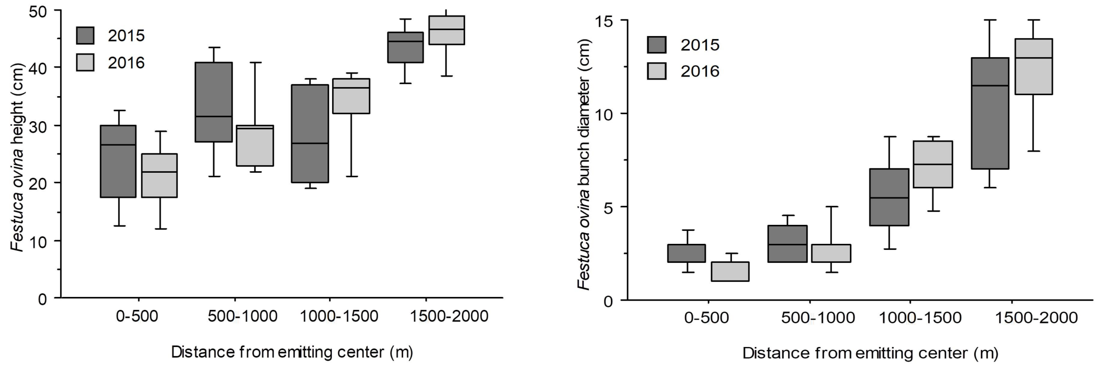

Figure 4. Variation of *F. ovina* height and bunch diameter with distance from the dust center.

Katare *et al.,* 2013). As the stress factor influence decrease depending on increasing with distance from the dust-emitting center, plant longevity increase (Wang, 2004; Li *et al.,* 2011; Yan *et al.,* 2011), consequently, canopy coverage increased as the distance increased. The differences between years may be a consequence of differences in prevailing climatic conditions, with precipitation patterns different between years, particularly the latter months. Higher April precipitation in 2015 must probably have washed leaf surfaces and decreased dust accumulation at the beginning of the growing season. Distance from 0-500 m plots received more dust, and precipitation was perhaps insufficient to remove all dust deposition from leaves, so, leading to a year x distance interaction.

Species Groups

The plants are differentially affected by dust deposition (Ulrichs *et al.,* 2008). Thus, functional plant groups exhibited different responses to dust deposition, modified by different years and distance from the dust-emitting center. The contribution of annual plants into botanical composition was higher in the second year. This situation could be related to the climatic condition, because June and July in the second year received more precipitation. This situation supports survival of annual plants seedling, consequently, their contribution to botanical composition increased. Similar results were also reported by Hegazy (1996) and Singh (2006). Annual grasses frequency was not affected by distance from the emission center, whereas annual plant species belonging to the other families were affected significantly. This situation mainly originated from the plant composition of the plots 500-1000 m because this plot canopy had quite higher annual plants of the other family (Table 2). Lower perennial grass contribution to botanical composition in this plot may responsible for this stuation because perennial grasses that suppress the other plants under favorable condition (Erkovan et al., 2011).

In the second experimental year, while PG decrease, forbs (PL and POF) increased. This situation probably originated from climatic differences between the years because more precipitation in the second growing season, probably, caused washing dust deposition from leaves of forbs and decreased dust side-effect and, consequently, forbs vigor increased. These results cause increase in forbs frequency in the botanical composition in the second year because broad and hairless leaves suffer more from dust deposition compared to grasses leaves (Tripathy *et al.,* 2013).

The adverse effects of dust deposition on perennial plants can be more pronounced compared to the annuals (Hegazy, 1996; Singh, 2006). Thus, perennial plants increased in the botanical composition because of decreased dust deposition in line with distance from dust emitting center. Although there were no significant differences in perennial grasses frequency in the second experimental year among the distance from emitting center, except for 0-500 m plots, it increased linearly in the first year in line with increased distance from dust emitting center (Figure 2). This situation probably originated from climatic differences between years.

Significant changes in both plant height and bunch size of sheep's fescue were recorded with increasing distance from the dust-emitting center. With higher distance from the dust emitting center, both plant height and bunch size increased significantly. These results confirm that dust causes a negative effect on plant vigor, which decreases as distance increase from dust emitting center (Table 2). Dust deposition has been recorded to decrease stomatal openings, reduce the photosynthetic rate, and increase leaf temperature and transpiration (Joshi and Swami, 2009; Chaturvedi *et al.,* 2013; Rai and Panda, 2014; Zia-Khan *et al.,* 2015).

The total seed number in the seed bank increased with distance from the dust-emitting center (Table 3). This situation is probably related to the negative effect of dust deposition on plant vigor, because dust deposition is a major stress source in the experimental area. The detrimental effect of dust deposition decreases away from the dust-emitting center (Hegazy, 1996; Fakhry and Migahid, 2011), and plant vigor increases. These situations cause an increase in seed production (Hegazy, 1996).

Except for annual grasses, seed number of all plant groups per unit area increased with increasing distance from the center, as did total seed number. This situation could be related to the effect of dust deposition on plant vigor because healthy plants produce more seeds (Hegazy, 1996; Fakhry and Migahid, 2011; Koc *et al.,* 2013). Annual grasses grow and complete their life span during the rainy period in the season and this condition decreases the side effect of the dust because rain removes deposited dust (Hegazy, 1996; Fakhry and Migahid, 2011). Therefore, annual grass seed production may be less affected by the emitted dust compared to the other plant groups. This explanation may contribute to why annual grasses frequency was higher around dust emitting center. Although years by distance interaction on perennial grasses seed number, the higher perennial seed number at the 1000-1500 and 1500-2000 m plots in the second experimental year caused statistically differences between years with respect to perennial grass seed number (data not presented). The growing season of second year received more precipitation, which may alleviate dust stress and the plants produce more seeds.

CONCLUSIONS

Even though, there is strong correlation between wind velocity and dust carrying, the deposition amount of dust dramatically decrease from emitting center distance increase. The amount of dust carried by the wind decreases with increasing distance from the emitting center. Both vegetation and seed banks were negatively affected by emitted dust. These effects were more pronounced in areas close to the emitting center. Plant vigority, density, and diversity are negatively affected in areas close to the dust emitting center. This situation will cause loss of biodiversity and decrease the rangeland carrying capacity. Further research on the effect of dust on individual plant species is necessary to determine those plants suitable for restoration of dust-affected areas. Above all, there is urgent need to use environmentally friendly technology in mining areas to save environment and sustainable use of natural resources.

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تغییرات ترکیب پوشش گیاهی در فواصل مختلف از یک مرکز صنعتی: نمونه ای از گرد و غبار معدن پوکه

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چکیده

مناطق دارای معدن به دلیل اثرات نامطلوب آلودگی گرد و غبار و عملیات حفاری به یک مشکل زیست محیطی بزرگ برای کشورهای در حال توسعه تبدیل شده است. هدف این پژوهش بررسی اثر گرد و غبار ساطع شده از مناطق معدن پوکه بر تاج پوشش گیاهان، گروه های گیاهی (functional plant groups) و ذخیره بذر در خاک و عملکرد رشد گیاهان رایج در مناطق اطراف معدن بود. تاج پوشش گیاه با کاهش تجمع گرد و غبار افزایش یافت، در حالی که گرد و غبار منجر به اثرات متفاوتی بر گروه های گیاهی و ذخیره بذر در خاک شد. ارتفاع و دسته گونه *Festuca ovina* L.، گونه غالب گیاهی، با افزایش فاصله از کانون گرد و غبار افزایش یافت. با استفاده از فناوری های مناسب در حین بهره برداری، انتشار گرد و غبار در محیط طبیعی باید کاهش یابد تا اثرات منفی آن به حداقل برسد.