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Effect of kiln dust from a cement factory on growth of *Vicia faba* L.

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Abstract

This study was undertaken to study the effects of different amounts of kiln dust mixed with soil on the seed germination, plant growth, leaf area and water content of *Vicia faba* cv. Eresen. The reason for this was that cement kiln dust generated as a by-product from the cement factories is rich in potassium, sulfate and other compounds. This product becomes a serious problem when it comes in contact with water. The dust was collected from a cement factory located in Çanakkale. Various elements such as Al, Co, Mo, Ca, B, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, S, Se and Zn were determined both in soil as well as kiln dust. Kiln dust was mixed with soil in pots (20 cm diameter) to make seven different treatments varying from 15 to 105 g kiln dust kg^{-1} of soil. The experiment lasted for 4 months. Seeds of *V. faba* were sown in the pots filled with mixtures of preanalysed kiln dust and soil. Germination was high in the pots with a lower treatment of cement kiln dust. However, lower germination rates were observed in the pots mixed with the highest and the medium amounts of cement kiln dust. Plants growing in the soil including 15 g kiln dust showed better performance in length as compared to control. Leaf area increased with increase in cement kiln dust content up to 60 g kiln dust kg^{-1} of soil, but declined after 75 g kg^{-1}. Water content of leaves (mg cm^{-2} leaf area) was found to be constantly decreasing with respect to increasing cement kiln content in the pots. Differences between the averages were evaluated by Tukey test and results were found to be significant.

Key words

Cement kiln dust, *Vicia faba*, Plant growth, Air and soil pollution

Introduction

The location of an industrial plant is very important in terms of dispersion of air pollutants. The wastes coming from heavy industries affect both natural vegetation and agricultural areas in particular cultivated plants. If the region's meteorological conditions are not taken into consideration during industrial establishments, severe environmental problems can arise (Canpolat *et al.*, 2002). Cement kiln dusts (CKD) are a complex mixture of elements, including high levels of fluoride, magnesium, lead, cadmium, nickel, zinc, copper, beryllium and other compounds. In particular, the dust coming out of the chimneys falls on the surrounding plant cover, thus affecting their growth and survival. A lot of work has been done on the effects of cement factory kiln dust on natural vegetation as well as cultivated plants (Sheikh *et al.*, 1976; De Nevers, 2000; Iqbal and Shafiq, 2001). CKD is not only harmful to the terrestrial but also aquatic ecosystems, because of its toxicity and radioactive isotope properties. Many studies underline the negative effects of CKD on the plants in the long run. The studies undertaken on sunflower, saffron, wheat, aquatic plants and other plant communities revealed that CDK increases the mortality of these plants (Borka, 1980; Murray, 1981; Singh and Rao, 1981; Selahattin and Katircioglu, 1984; Lone, 2010; Serkan and Demirtas, 2010). An increase in calcium, magnesium, sodium and potassium and a decrease in nitrogen and phosphorus concentrations as well as leaf area index and dry matter of sorghum and blackgram species has been reported when CKD was applied to these plants between 10-100 g kg^{-1} at 10 g kg^{-1} intervals (Subha and Dakshinamoorthy, 2001). An increase in the growth of faba bean has been recorded at initial stages of application of lower fly-ash doses but nodulation decreases as the dose increases (Rai *et al.*, 2003).The studies carried out on the effects of CKD on hazelnut; one of the most important products from the Black sea region of Turkey; citrus from Mersin, leguminous plants from Erzurum-Askale, and olives from Izmir and Canakkale reveal that significant losses in the production have been recorded due to the dust falling falling on

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these plants (Sheikh *et al.*, 1976; Subha and Dakshinamoorthy, 2001; Bayhan *et al.*, 2002).

The work done on the aquatic plants also show that their diversity and numbers increase with the distance from the cement factory, but *Lemna minor, Ceratophyllum submersum* and *Potamogeton natans* have been observed to flourish well in the vicinity of cement factory (Serkan and Demirtas, 2010).

In the species like *Salicornia fruticosa, Halocnemum strobilaceum* and *Arthrocnemum galucum*, from the salt marshes of the Mediterranean, CKD has been observed to increase the mortality of young branches, reduce the height and cover. *A. galucum* has been observed to be the most sensitive to CKD. A considerable increase in the proline has been reported in *A. glauca* and in the soluble carbohydrates in *S. fruticosa* and *H. strobilaceum* (Migahid and El-Darier, 1995).

Since $CaCO_3$ is the active ingredient of CKD, no positive response has been recorded in the animals fed with CKD but no positive response was recorded (Noller *et al.*, 1980). An examination of the workers exposed to asbestos cement dust reveal a high percentage of polyclonal hypergammaglobulinemea as well as B cell hyperactivity in their serum (Doll *et al.*, 1983).

The chemical characteristics of soils also get effected if these are mixed with CKD. In general, there is an increase in the exchangeable soil Ca, K and Mg cations but the productivity of soils decreases in the vicinity of cement factories (Bayhan *et al.*, 2002). The work done around Ezine-Canakkale has shown the soils near the factory are rich in Ca, Na, K and Fe concentrations as compared to the average concentrations in the study area (Uysal *et al.*, 2003). However, it has been emphasized that seasonal meteorological parameters change concentrations of these elements (Uysal *et al.*, 2006). Present investigation focuses on the developmental behaviour of *Vicia faba* cv. Eresen plants, an important agricultural crop in Canakkale, when supplied with different concentrations of cement kiln dust.

Materials and Methods

In the present study, *Vicia faba* “Eresen” seed varieties were used. In this experiment, 8 new pots were set up and each was filled with 1 kg of soil. The soil used for the experiment was dried and then sieved using 2 mm sieve. Physical characteristics of soil and cement dust were determined at Çanakkale Onsekiz Mart University, Faculty of Agriculture Laboratory and chemical analysis of soil and cement dust was done at Selcuk University (Konya) Faculty of Agriculture Laboratory. Soil physical and chemical analyses (texture, pH, $CaCO_3$, conductivity) were determined according to the methods of Ozturk *et al.*, (1997). It was mixed up thoroughly with 15 g of cement kiln dust (CKD), other pots received 30, 45, 60, 75, 90 and 105 g of CKD, respectively. One pot was left as control (no cement kiln dust added). A total of 4 replicates were used for each pot. Seeds were sown in the pots in November. These were watered with 250 ml of normal tap water per pot in the beginning of the experiment. Cement kiln dust was collected from a cement factory situated nearly 40 km south of Canakkale.

Canakkale water supply has a pH value of 7.38 (slightly alkaline), electrical conductivity of 492 μS cm^{-1}, aluminum concentration of 89.78 μg l^{-1}, iron concentration of 4.95 μg l^{-1}, manganese concentration of 1.13 μg l^{-1}, chloride concentration of 26.64 mg l^{-1}, sulfate concentration of 161 mg l^{-1} and sodium concentration of 18.23 mg l^{-1}, respectivily.

First germination was recorded in the month of December and periodical observations were carried out up to March. The measurements on the plant height were recorded for the first time in January, and final measurements were taken in March. Plant leaf water content was determined by measuring fresh and dry weights (103°C) of leaves and differences in weights were noted.

Elemental analyses of soils and cement kiln dust was done by wet digestion procedure, using ICP-AES (Varian Liberty II AX Sequential). The instrument was calibrated with 0.1, 1.00, 10.00 and 25.00 mg l^{-1} concentrations using ICP multi-element standard solution VIII (Merck, 24 elements). Each measurement was done in triplicate and their averages were calculated (Roelandts, 1991). Each soil and cement kiln dust sample was digested by using HNO_3/H_2O_2 (2:1) acid mixture. The temperature at the time of digestion was set at 110°C for 50 min and then the samples were dissolved in 50 ml of 5% graded HNO_3. The procedure was repeated 3 times for each sample. The minerals and heavy metal concentrations were calculated based on standard deviation (SD) after treating three replicates of each sample (Roelandts, 1991). The data was subjected to analysis of variance (ANOVA) using MINITAB statistical program. The differences between the averages were evaluated by Tukey test.

Results and Discussion

Lowest germination was observed in pots treated with 90 g of CKD, but in the control pot germination was slightly higher than the pot treated with 105 g of CKD. In the case of pots with 45 g and 60 g of CKD the germination (95%) was same. The pots with 15 and 75 g of CKD showed higher germination (96.25%) compared to the control. Highest germination (98.75%) was recorded in the pot with 30 g cement kiln dust.

Similarly the fresh weight of plants in the pots containing 105 g CKD yielded the lowest weight (1.31 g); whereas both control and the pot with 15 g of CKD had highest fresh weight per plant (1.60 g). Similar results were obtained for dry weight. Control provided the highest dry weight per plant; whereas pot that had 90 and 105 g of CKD yielded the lowest dry weight per plant (Table 1).

The mean plant height and germination were positively and significantly correlated at 5% confidence level (78.8%, $R_{critical}$=75.4%, α=5%). A similar situation was observed between mean plant height and fresh weights, these showed positive correlation, statistically significant at 5% confidence level (89.2%,

$R_{critical}$=75.4%, α=5%). Mean plant height and dry weight also showed positive correlation, statistically significant (83.6%, $R_{critical}$=75.4%, α=5%)). The wet and dry weight values too were correlated (79.5%, $R_{critical}$=75.4%, α=%) as expected. In January, the control pot yielded 11.60 cm plant height on average; whereas, 12.0 cm plant height was measured on the pot treated with 30 g of CKD and the lowest plant height (7.22 cm) was recorded in the pot treated with 90 g of CKD. Considering minimum plant height, the lowest plant height (6.08 cm) among replicates was found in the pot treated with 90 g of CKD and the highest plant height was recorded as 10.57 cm among the replicates of pot treated with 30 g of CKD. Considering maximum plant height, the lowest (9.00 cm) was determined in the pot including 90 g of CKD and the highest one (14.02 cm) was measured on the pot treated with 30 g of CKD. Average plant height in January is shown in (Table 2), where 30 g of CKD yielded the highest plant height among all treatments including control. The highest variance (7.25) in terms of plant height in January belonged to the 5th pot although control also had higher variance (6.44) compared to all pots with the exception of the 5th. The lowest variance (0.008) was seen in the 7th pot.

In March, average plant height in the control was 55.67 cm, the pot treated with 15 g of CKD showed an average plant height of 58.17 cm in March. In contrast to January results, when the pot treated with 30 g of CKD yielded the highest plant height, these results (based on March measurements) indicate that even slightly higher CKD affects *Vicia faba* in relation to the time period after germination. The pots treated with 90 and 105 g of CKD showed the lowest plant height in March (Table 1). The highest variance (32.6) in terms of plant height was observed in March, which was seen in the control pot followed by the 5th (10.8) and 6th (13.4) pots compared to other pots. The lowest variance (2.86) belonged to the 1st pot.

The lowest plant height (45.24 cm) among replicates was found in the pot treated with 90 g of CKD and the highest plant height was recorded as 56.48 cm among the replicates of pot treated with 15 g of CKD. As far the maximum plant height, the lowest (53.24 cm) was determined in the pot including 105 g of CKD and the highest (59.75 cm) in the pot treated with 15 g of CKD. On the other hand, maximum plant height in the control's was determined to be 63.14 cm (the highest of all). Average plant height in March showed that 15 g of CKD yielded the highest plant height among all treatments including control. While the pot treated with 30 g of CKD provided the best result in terms of average plant height in January, the pot treated with 15 g of CKD yielded highest average plant height (58.17 cm) in March. In terms of plant growth between January 5th and March 5th, 2004, the fastest growth (584%) was observed on the 1st pot despite the fact that control pot resulted in the lowest plant growth (380%) in 60 days. According to paired t-test (plant height measured on 5th of January and 5th of March, 2004), t was computed to be 48.18 that was larger than 1.895 ($t_{critical}$ for α=0.05 and d.f.=7) meaning that plant growth is statistically significant.

As regards the leaf measurements, the leaf area (LA) was computed using an equation developed by Peksen (2007) where leaf area (cm^2) of faba bean can be estimated with LA = 0.919 + 0.682LW, R^2 = 0.977; L being leaf length and W being leaf width (Peksen, 2007). It should be noted that a leaf has two sides. Raw results obtained after using the formula given above was multiplied by two in order to get the total leaf area. Leaf areas were computed as 10.28 cm^2 (for control), 10.41, 10.62, 10.83, 11.50, 11.05, 10.80 and 10.51 cm^2, from the 1st pot to the 7th pot, respectively. It is clear that the 4th pot resulted in larger leaves and leaf area decreased with increase in CKD quantity in the pots. It can be concluded that roughly 9 % or more CKD in soil effects the plant growth negatively. Final plant height (measured in March), germination percentage, fresh weight and dry weight values were lower in 90 and 105 g treatments than control and the pots treated with lower CKD quantity (Table 2).

The lowest average number of leaves was 12. It was recorded in the control plants and pots treated with 90 and 105 g of CKD, while the number was 13 leaves on average. In terms of the average length of the leaf, the pots treated with 60 and 75 g of CKD gave higher measurements than others including control (Table 2). In terms of leaf width, only the pot treated with 60 g of CKD provided the highest value.

It was also found that water content divided by leaf area decreased with respect to increase in CKD dose in the pots. For control, water content (as mg) cm^{-2} leaf area was 138. From the 1st pot to the 7th one, water content cm^{-2} leaf area was computed as 137, 123, 117, 116, 120, 116 and 111 mg cm^{-2}, respectively. Similar results were reported by Nanos and Ilias (2007). Further they reported that increase in cement dust cause a decrease in leaf water content of olive (*Olea europae* L.).

The physical and chemical characteristics of soil and CKD are presented in table 3. The soil was sandy loam in texture with neutral pH (7.19) and electrical conductivity of 3.28 dS m^{-1}. The CKD was alkaline with high pH (12.50) and electrical conductivity (14.55 dS m^{-1}). Soil $CaCO_3$ level showed moderate values, while soil used for the experiments had low salt content. This indicates that when higher amounts of CKD are mixed with soil, salinity increases with time.

C, H, O, N, P, S, K, Ca and Mg are the macro nutrients, whereas Fe, Mn, Cu, Zn, B, Mo and Cl are the micro-nutrients neccessary for the growth and development of plants. On the other hand Al, Cd, Cr, Pb, Ni, and Se produce toxic effects on plants, if their enrichment takes place in the soil (Kacar and Katkat, 2009). The elemental analysis data on CKD and soils is presentd in Table 4.

Control soil and CKD, when examined together, showed some enrichment in macro-and micro-nutrient elements in terms of Ca, Co, Cu, K, Mo, Na and S. CKD leads to an increase in such elements when used effectively in soil if it is not rich in terms of macro and micro nutrients. On the other hand, others (such as

Fe, Mg, P, etc.) were found more in parent soil compared to that in CKD. Al, Cd, and Pb, which were found elevated in parent soil than in the CKD, are known to be toxic elements. For this reason, it is better to eliminate these from the soil by using additive materials such as CKD. Se, Mo, and Ni were moderately higher in CKD than in the soil. However, according to the Turkish soil pollution control standards (Anonymous, 2001), soils become toxic if Se, Mo and Ni are above 5, 10 and 75 mg kg^{-1} (if soil pH > 6), respectively. CKD Se level is a concern since both cement dust and soil contain more selenium than lawfully allowed in Turkey.

One of the important problems in the CKD is its Co content which is listed under soil pollution factors according to the Turkish soil pollution control legislation (Anonymous, 2001). Although some plants need 4 to 40 mg kg^{-1} Co in soil, but different plants have different sensitivity levels depending on their growth requirements and physiological specifications. Maximum Co concentration in soil must be less than 20 mg kg^{-1} (Anonymous, 2001). As such, less than three quarters of CKD should be used with the soil if agriculture is a concern under similar conditions. Cu and K can be evaluated as being in acceptable limits if CKD and soil mix are prepared carefully. Although Pb in both soil and CKD are below the standard (Anonymous, 2001), but a careful mix and application is recommended when CKD is thought to be used in agricultural practices. The amount of Al in soil was 47.14 mg kg^{-1}, whereas it was low in CKD (29.52 mg kg^{-1}). The amount of Al needed for the plant growth should not exceed 1 mg kg^{-1} in the soil. Iron is used by plants and its concentration in the soil was higher than that in CKD. Average levels of Fe in the soil are approximately 38000 mg kg^{-1}. The cultivated soils need 120 to 2400 mg kg^{-1} of Mg on an average basis. The Mg levels in the soil and CKD lie between these values, however, the plant type is a critical factor that should be considered before applied to the soil. The Mn level of soils varied between 600 and 1000 mg kg^{-1}. The Mn level (551 mg kg^{-1}) in the soil was very close to these figures. Therefore, CKD should not be used in high amounts. The Na in CKD was twice more than that in the soil. The Na content in the Turkish soils on an average is around 6300 mg kg^{-1} (between 1000 and 10000 mg kg^{-1}). The minimum level (1000 mg kg^{-1}) in the CKD could be problematic in terms of Na concentration. Salt sensitive plants should not be used when CKD is added to the soil for agricultural activities. The P content in the Turkish soils varied between 146-2800 mg kg^{-1}, however it is lower in the CKD. The S levels in the soil was found to be 400 mg kg^{-1}. However, CKD had S content of more than 1000 mg kg^{-1}. Humid regions have 100-1500 mg kg^{-1} S content in the soil. Canakkale is located in a semiarid region. Agricultural areas have an average Zn concentration of 100-300 mg kg^{-1} (Kacar, 2009; Kacar and Katkat, 2009), but CKD contained only 37 mg kg^{-1} of Zn. As such, the soil can be accepted to be agriculturally rich in Zn concentration since it had approximately 109 mg kg^{-1}.

According to the soil and CKD analysis, soil was sandy-loam in texture, moderately calcareous and nonsaline. However, CKD was strongly alkaline, moderately calcareous and saline. If CKD mixed with soil increases the final product becomes alkaline, calcium content increases and salt levels increase. More than 15 g of CKD in one kg of mix adversely affects the growth of *Vicia faba* cv. Eresen. The toxic effects of Cr, Ni, and Se can be seen if CKD rich in such elements is used in the soil (Kacar, 2009). Initially extra K, P and S elements in soil augment plant yield, but S alongwith Ca and Mg become inhibitive for the plant yield. The micronutrients like Fe, Mn, Cu and Zn result in an increase in the plant growth, however plants are effected negatively by B and Mo. Moreover, Na and Co produce a positive effect on the plant growth in the beginning at the start but later they produce negative affects on the plant yield (Kacar and Katkat, 2009).

Vicia faba showed best growth pattern at 15 g of CKD mixed with 1 kg soil, but for better results 5 g CKD intervals should be used. This will allow to have a better understanding of useful dose in terms of CKD. Although the results presented here are the first attempt, these findings can be used as reference for more detailed studies. CKD can be used as fertilizer as long as it is used carefully within optimum amount. It should be emphasized that the amount of CKD used in soil is crucially

Table - 1: Effect of cement kiln dust (CKD) on plant height, wet and dry weight of *V. faba*

Treatment (g)	Mean plant height (cm)		Wet weight (g $plant^{-1}$)	Dry weight(g $plant^{-1}$)
	Jan, 2004	March, 2004	March, 2004	
Control	11.60±2.54	55.67±5.71	1.60	0.18
15	8.51±1.85	58.17±1.69	1.60	0.17
30	12.00±1.58	55.38±2.88	1.46	0.15
45	10.90±0.79	53.36±2.40	1.43	0.16
60	9.77±1.26	54.24±3.07	1.50	0.17
75	9.59±3.20	52.48±3.29	1.48	0.15
90	7.22±1.31	49.29±3.66	1.38	0.13
105	9.29±0.06	50.03±2.74	1.31	0.14
Average	9.85±0.83	53.58±1.54		

Values are mean of three replicates ±SD

Table - 2: Effect of CKD on number of leaves and leaf area in *V. faba* after 4 months of sowing

Treatment (g)	Number of leaves	Leaf measurement (cm) Leaf width	Leaf length
Control	12.0±3.10	3.21±3.86	1.93±0.96
15	13.0±1.26	3.24±1.26	1.94±1.26
30	13.0±2.06	3.25±2.63	1.98±1.63
45	13.0±2.83	3.28±3.42	2.01±1.00
60	13.0±1.50	3.44±0.96	2.06±1.63
75	13.0±4.90	3.28±1.91	2.06±1.51
90	12.0±3.77	3.27±1.71	2.01±1.52
105	12.0±3.27	3.21±1.91	1.98±1.88

Values are mean of three replicates ±SD

Table - 3: Physico-chemical properties of soil and cement kiln dust

Material	Textural classification				pH	$CaCO_3$ (%)	Electrical
	Percent clay	Percent silt	Percent sand	Texture			conductivity (dS m^{-1})
Soil	11.04	22	66.96	Sandy-loam	7.19	5.04	3.28
Cement dust	-	-	-	-	12.50	8.24	14.55

Table - 4: Analysis of metal in soil and cement kiln dust of Turkey

Element (mg kg^{-1})	Soil	Cement dust	Enrichment based on soil (%)	Standard of Turkish soil pollution Directive* (pH>6) (mg kg^{-1})
Al	47.14	29.52	-	-
B	45.03	44.35	-	-
Ca	17460	100770	477	-
Cd	0.53	0.31	-	3
Cr	32.29	34.04	5.42	100
Co	0.05	27.45	549	20
Cu	34.30	91.13	166	140
Fe	13030	8830	-	-
K	7780	12680	63	-
Mg	3790	2610	-	-
Mn	551.2	156.2	-	-
Mo	1.18	2.18	85	10
Na	995	1750	75	-
Ni	25.38	25.84	1.81	75
P	1420	130	-	-
Pb	32.55	6.18	-	300
S	400	1090	169	-
Se	5.35	8.13	52	5
Zn	108.76	36.84	-	300

* (Anonymous, 2001)

important. According to ShengGao and Zhu (2004) more than 10% of fly ash significantly interfers with the soil characteristics. In this study, more than 6% CKD in soils reduced the growth faba bean in terms of leaf area and more than 7.5% decrease germination.

Canakkale Cement Factory is said to emit excessive CKD in the environment. No doubt useful amounts (such as 1.5%) can augment fertility of soils and growth of natural and cultivated plants, but an effective filter system for the cement production plants is a must. The plant type and soil characteristics are the most important critical factors for such applications.

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