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Effect of Olive Vegetation Water (Mills) Application on Macronutrient Contents of Maize (*Zea mays* L.)

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Abstract: Olive vegetation water is a by-product obtained after the olive processing and is rich of nutrients and minerals. The impact of varying rates of olive vegetation water (0, 5, 15, 20, 25 and 30 g kg^{-1}) and Ca (0, 2.5 and 5.0%) doses on the soil fertility and the development of maize (cultivar Pioneer 31G98) were evaluated in present study. Statistically significant (at $P \leq 0.05$) relationships were obtained in terms of the doses of olive vegetation water, olive vegetation water + lime and lime in the evaluation of the results of soil and plant analyses. After the application of olive vegetation water + lime doses increased the total salt and organic material of the tested soils. The highest positive impacts of both olive vegetation water and lime treatment on $CaCO_3$ concentration were obtained at 15-20 g kg^{-1}, and 2.5% lime dose. The increasing olive vegetation water rates significantly ($P \leq 0.05$) increased the K uptake by the plants. In addition, application of 15-20 g kg^{-1} olive vegetation water caused positive effects on N, P, and K accumulation in maize.

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1. Introduction

Aydin is famous for being the homeland of olive and is located in the Aegean Region of Turkey. Olive and olive oil has been evaluated as an important nutrient and commercial product for ancient periods in the history. Turkey ranks 4th in the world with a total area of 0.826 m ha under the olive crop while the number of olive trees is estimated to be 145 million (FAO, 2013). Similarly, Turkey ranks 5th among the olive oil producing countries of the world (Tunalioglu, 2009a). Aydin is a potential area for producing olive with an area of 152.78 ha and olive production of 272.49 ton per year (Tunalioglu, 2009b).

Extraction of olive oil is great economic interest, however huge amount of solid or liquid wastes are great environmental concerns (Hachicha et al., 2006; Asfi et al., 2012). The by-products of olive are olive pomace, olive vegetation water (OVW) and the waste of pruning (Barbera et al., 2013). The waste of pruning in Turkey is utilized without modification. Olive pomace is the residue of olive which is left over from the pressing of olive in the olive factories. It contains 6-8% oil and 20-30% water. Generally, 35-40 kg olive pomace is obtained from a 100 kg of olive (Işıklı, 1986; Vincenzo, 2002). The oil obtained from olive pomace is used in soap industry, sugar factories, in the caldron of evaporation as removing foam, in the production of oil acid and also used as a fuel (Seferoğlu, 1997). The OVW is the dark red colored remain or by-product obtained after the olive processing for olive oil extraction. It contains fine particles of crushed olives, salts, fats, nitrogenous compounds, various carbohydrates, volatile acids, flesh and skin (Hachicha et al., 2006). It has acidic pH and is rich in organic matter as well as the P, K, and Mg nutrients (Püskülcü et al., 1995).

Agricultural wastes can be used as a plant nutrition and soil conditions (Seferoğlu et al., 2012). Olive oil solid wastes significantly increased both soil organic carbon content and aggregate stability (Kavdır and Killi, 2008).The OVW can be utilized as a plant nourishment substance because of its high nutrients and organic matter contents. In olive producing countries, the OVW is used fertilizer, applied in fodder fields, used for producing biogas and as stiff fuel (Ursinos, 1986; Barbera et al., 2013; Kokkora et al., 2015). Application of micro-filtered olive mill waste water had significant influence on quality parameters of maize kernel including ash, fiber, protein and starch contents. However maize yield and fat contents of maize kernel remained statistically similar (Kokkora et al., 2015).

Table1: Physical and chemical properties of the soil used in the experiment

Attribute		Soil	OVW
Texture	-	Sandy	-
pH	-	7.92	6.4
Total salt (%)		0.0011	0.97
Organic matter	%	0.27	15.78
Na	%	0.019	1.95
P	mg kg^{-1}	0.6	167
K	mg kg^{-1}	53.4	3245
Ca	mg kg^{-1}	2270	1082
Mg	mg kg^{-1}	124	1435
Na	mg kg^{-1}	42	287
Fe	mg kg^{-1}	11	578
Zn	mg kg^{-1}	0.8	72
Mn	mg kg^{-1}	3.7	175
Cu	mg kg^{-1}	0.1	30
B	mg kg^{-1}	0.13	32

OVW is olive vegetation water

The high organic matter, low pH and enriched with nutrients (N, K, P, Mg) make OVW suitable fertilizer benefiting the plants as well as improving the soil condition (Püskülcü et al., 1995; Barbera et al., 2013). Seferoğlu et al. (2001) suggested the use of OVW as fertilizer. According to an estimate, 1 m^3 of OVW contains 3.5–11 kg K_2O, 0.6–2.0 kg P_2O_5 and 0.15–0.5 kg Mg (Acunaz, 1987; Püskülcü et al., 1995). In the same studies, it was confirmed that OVW had high nutrient contents and could be used as organic fertilizer with an annual application rate of 30-100 m^3 ha^{-1}.

If the OVW is to be added to the soil purely, it should be incorporated in soil 2-3 months before planting, particularly for annual crop plants (Ursinos, 1981). Addition of lime to soil can have various type effects on the soil properties. For example, several researchers have reported that addition of lime can remove the negative effects of phenolic compounds in soil (Püskülcü et al., 1995; Durucan and Gördük, 2002). Similarly, another study reported that application of lime could alleviate the cadmium toxicity in the soil (Bolan et al., 2003). Other positive effects of liming on soil may include improvement in soil aggregation and organic matter, and enhanced crop yields (Haynes and Naidu, 1998). Therefore, the main aim of the present study was to use OVW as a fertilizer and neutralize the negative effects of OVW on the soil through use of lime.

2. Materials and Methods

The experiment was done in the pots kept in the plastic greenhouse (average temperature 25 ± 2 ºC, relative humidity 65 ± 5 %) at Soil Science and Plant Nutrition Department, Adnan Menderes University Aydin, Turkey. The maize cultivar Pioneer 31G98 was used as a test crop. The treatments included seven different doses oil processing waste (0, 5, 10, 15, 20, 25 and 30 g OVW per kg of soil) and three different doses of lime (0, 2.5and 5%). The treatments were applied immediately before the sowing of maize (*Zea mays* L.) crop in the pots. The materials (lime and OVW) for respective treatments were weighed and mixed in the soil of the relevant pots, and the maize seeds were sown. The experiment was done in two consecutive years i.e., 2005 and 2006. The experiments had three replications in each year. The years had non-significant effect therefore, the data over the years was pooled in statistical analysis so the analyzed data had 6 replications in total.

Table 2: Effect of varying rates OVW and $CaCO_3$ on N (%) and P (%) contents in maize shoots.

	Mg (%)				Na (%)			
OVW (g kg^{-1})	**0 % $CaCO_3$**	**2.5 % $CaCO_3$**	**5.0 % $CaCO_3$**	**Mean**	**0 % $CaCO_3$**	**2.5 % $CaCO_3$**	**5.0 % $CaCO_3$**	**Mean**
0	0.99	1.33	1.50	1.27 **bc**	0.13	0.13	0.12	0.13 **c**
5	1.00	1.19	1.37	1.19 **c**	0.21	0.17	0.20	0.19 **ab**
10	1.33	1.35	1.59	1.42 **ab**	0.28	0.23	0.26	0.26 **a**
15	1.44	1.50	1.67	1.54 **a**	0.24	0.27	0.31	0.27 **a**
20	1.69	1.35	1.57	1.54 **a**	0.25	0.21	0.24	0.23 **a**
25	1.19	1.04	1.20	1.14 **c**	0.20	0.13	0.17	0.17 **bc**
30	1.35	1.08	1.07	1.17 **c**	0.12	0.14	0.15	0.14 **c**
Mean	1.28 **b**	1.26 **b**	1.42 **a**	1.32	0.20	0.18	0.21	0.20
*** SE OVW**		**0.06**				**0.01**		
***SE Lime**		**0.04**				NS		
SE OVW*Lime		NS				NS		

Whereas OVW = Olive vegetation water, SE = Standard error, NS = Non-significant. The numbers not sharing a letter in common differ significantly at $p \leqslant 0.05$, n = 3. Means for each parameter are the average of two-year data (2005 and 2006).

The results of chemical and physical analyses of the soil and OVW used in the experiment are given in Table 1. The same soil and OVW source were used for the experimentation in either of the years, hence, Table 1 contains single value for each soil or OVW character.

In present study, a total of 63 pots (width of 29.5 cm and a depth of 25 cm, containing 12 kg soil per pot). Fifteen seeds were planted in each pot, and after the germination, the number of seedlings was maintained to 3 in each pot and uprooted plants were crushed and mixed into the respective pot. In order to perform plant tissue analysis, plant leaves were collected when they were fully expanded. Leaves were washed with distilled water in the laboratory then dried at the temperature of 65-70 °C for 48 h in an oven. Later, the leaves were ground before analysis. K, Ca and Na elements were measured by means of fresh burning (Perchloric and nitric acid mixture at 1/4 ratio) by using Flame Photometer (PFP7, JENWAY, Bibby Scientific Limited, Staffordshire, United Kingdom). Mg was measured by using Atomic Spectrophotometer (Varian, Spectra AA-220FS System, Midland, ON, Canada) according to the method of Kacar (2008). The detection limit was considered as 1 ppm while quantification limit was considered as 100 as described by (Bataglia et al., 1983).

The collected data were analyzed by applying Duncan's Multiple Range Test (DMRT) at $p \leqslant 0.05$, using SPSS statistical software version 20. The treatments were grouped according to the significant differences among them.

3. Results and Discussion

Analysis of pooled data indicated that data did not differ among the years; hence, we have analyzed and presented data averaged over the years. In present study, the application of oil processing waste (OVW) and lime improved the N and P uptake by the maize plants (Table 2). The highest N uptake was recorded for 15 and 20 g OVW followed by 10 g OVW. Further increase in the OVW levels decreased the N uptake by maize plants. Similarly, the highest P uptake by maize plants was noted for 10, 15 and 20 g OVW followed by 5 g OVW while the maize plants in control and 30 g OVW pots had the minimum P uptake. The years' and OVW's × lime interaction's effects were statistically non-significant on the N and P contents of maize leaves (Table 2). In consonance with the present study, Püskülcü et al. (1995) also determined that the application of OVW to olive plants increases their N and K contents. Higher doses of OVW help to improve the P contents of soil and its uptake by plants (Anac et al. 1993). The high P contents of OVW was sufficient to provide P enough for growth of wheat crop without need of additional P from the fertilizer application (Seferoglu and Kılıç, 2002). Chen at al. (1996) applied waste water and animal dung as fertilizer to the plants and as a result the N concentration in the plant was increased.

This increase was 20% higher for the water than animal dung. Seferoğlu and Kılıç (2002) reported that application of liquid (0-50-100 t ha^{-1}) and solid (0-40-50-60, t ha^{-1}) OVW's doses as well as OVW+NP improved the leaves' N content in wheat plants. This increase was similar for OVW and the NP fertilizer.

Table 3: Effect of varying rates of OVW and $CaCO_3$ on K (%) and plant Ca (%) contents in maize shoots

	Mg (%)				**Na (%)**			
OVW (g kg^{-1})	**0 % $CaCO_3$**	**2.5 % $CaCO_3$**	**5.0 % $CaCO_3$**	**Mean**	**0 % $CaCO_3$**	**2.5 % $CaCO_3$**	**5.0 % $CaCO_3$**	**Mean**
0	4.17 **d**	4.57 **b**	3.96 **d**	4.23 **c**	3.04	2.80	2.38	2.74
5	5.63 **b**	5.45 **a**	4.62 **c**	5.23 **b**	3.29	2.13	1.86	2.43
10	5.76 **abc**	5.62 **a**	5.23 **b**	5.54 **a**	3.23	2.15	1.74	2.37
15	5.48 **c**	5.90 **a**	5.83 **a**	5.74 **a**	2.19	2.03	2.33	2.18
20	5.68 **ab**	5.79 **a**	5.58 **ab**	5.68 **a**	3.01	1.57	2.30	2.29
25	5.98 **a**	5.54 **a**	5.52 **ab**	5.68 **a**	2.41	2.13	2.18	2.24
30	5.96 **a**	5.49 **a**	5.95 **a**	5.80 **a**	2.59	2.15	1.90	2.21
Mean	5.52 **a**	5.48 **a**	5.24 **b**	5.41	2.82 **a**	2.14 **b**	2.10 **b**	2.35
*** SE OVW**		0.101				NS		
***SE Lime**		0.066				0.15		
SE OVW*Lime		0.066				0.15		

Whereas OVW = Olive vegetation water, SE = Standard error, NS = Non-significant. The numbers not sharing a letter in common differ significantly at $p \leqslant 0.05$, n =3 for each year; Means for each parameter are the average of two-year (2005 and 2006) data.

Application of olive oil solid waste at the rate of 8% has significantly increased soil total organic N contents (Kavdır and Killi, 2008). The maize leaves P contents were significantly increased with increasing the OVW rates up to 20 g and then declined at higher rates of OVW. The reason may be the changes in pH levels and its effect on soil nutrient availability (Levi et al. 1992). Seferoglu et al. (2012) reported that application of OVW first lowered the soil pH, and then increased it to its original levels during the late crop growth stages. However, the effect of lime was not significant on the P contents of the maize leaves. Püskülcü et al. (1995) has determined similar results on olive plant and Seferoğlu and Kılıç (2002)described similar results on wheat plant. The main and interactive effects of OVW and $CaCO_3$ application were statistically significant on the K (%) of the maize leaves (Table 3).

The doses of increasing OVW have increased the K content of plants under the conditions where lime is not applied. The lowest K contents were recorded for control (0 g) OVW while highest K contents were recorded for 25 and 30 g OVW (Table 3). Using $CaCO_3$ at 2.5% increased the K contents of maize leaves similarly for all the doses of OVW compared with the control.

At 5.0% $CaCO_3$ applications, the K content of leaves increased with the increasing OVW doses being highest at 30 g kg^{-1} dose which was statistically similar with 15 g OVW dose. The K contents of leaves had significantly decreased with increasing the lime doses (Table 3). Hermosa (1984) has determined in one of his studies that OVW application makes plant rich in terms of potassium. Similar results has been reported by Seferoğlu and Kılıç (2002) on wheat and on olive plant by Püskülcü et al. (1995).

The results indicated the OVW doses did not significantly affected the Ca contents of maize leaves (Table 3). However, the lime application negatively affected the leaves' Ca contents (Table 3). Similarly, the effect of OVW × lime interaction on the plants' Ca content was non-significant (Table 3). The results of Ca become visible with time therefore, the non-significant effects of Ca are thought to be the less time span of plant growth. Seferoğlu and Kılıç (2002) have concluded in their study regarding OVW that Ca contents of wheat leaves can increase only in liquid OVW + NP treatment. They also determined that it is not effective when applied in other forms. In another research work, OVW cake was applied at three rates viz. 1.5, 3.0, and 4.5 t ha^{-1} (Aydın et al., 2001). This OVW application positively affected the soil pH, organic matter, N, P, K and Mg, but this had no effect on soil Ca concentrations. Püskülcü et al. (1995) has determined similar results in the study on olive. Anac (1993) has obtained similar results in a study on maize.

The application of lime significantly increased the Mg contents of maize leaves compared with the control, however, the effect of OVW doses and OVW × lime interaction was non-significant on maize leaves Mg contents (Table 4). Püskülcü et al. (1995) reported that OVW had no effect on leaves' Mg content. Similarly Ursinos (1986) concluded that OVW contains some organic compounds, high level K, and noticeable amounts N, P and Mg. Therefore OVW fertilizations on soil improves physical and chemical properties and water holding capacity of soil.

Table 4: Effect of varying rates of OVW and $CaCO_3$ on Mg (%) and plant Na (%) contents in maize shoots.

	Mg (%)				Na (%)			
OVW (g kg^{-1})	**0 % $CaCO_3$**	**2.5 % $CaCO_3$**	**5.0 % $CaCO_3$**	**Mean**	**0 % $CaCO_3$**	**2.5 % $CaCO_3$**	**5.0 % $CaCO_3$**	**Mean**
0	20.43	24.30	19.26	21.33	0.048	0.048	0.058	0.051 **c**
5	16.76	21.79	21.10	19.88	0.061	0.053	0.060	0.058 **c**
10	10.62	14.81	20.48	15.30	0.070	0.073	0.083	0.075 **bc**
15	13.52	25.89	25.94	21.78	0.103	0.093	0.135	0.110 **a**
20	15.53	19.81	22.27	19.20	0.076	0.066	0.123	0.088 **ab**
25	20.98	18.63	20.81	20.14	0.086	0.068	0.160	0.105 **ab**
30	19.47	12.88	16.07	16.14	0.090	0.080	0.150	0.107 **ab**
Mean	16.76 **b**	19.73**a**	20.85**a**	19.11	0.076 **b**	0.069 **b**	0.110 **a**	0.085
*** SE OVW**	NS				0.010			
***SE Lime**	1.16				0.006			
SE OVW*Lime	NS				NS			

Whereas OVW = Olive vegetation water, SE = Standard error, NS = Non-significant. The numbers not sharing a letter in common differ significantly at $p \leqslant 0.05$, n = 3 for each year. Means for each parameter are the average of two-year (2005 and 2006) data.

Previous studies also report a non-significant effect of OVW on Mg contents of plants (Şahin, 2013). Interestingly, many articles have been reported that OVW applications as a fertilizer has appositive effect on crop production in agriculture (Hermosa, 1983; Ursinos, 1986; Acunaz, 1987; Levi et al., 1989; Timur and Ozturk, 1997) including maize (Kokkora et al., 2015; Belaqziz et al., 2016). The application of OVW and lime significantly increased the Na uptake of maize leaves (Table 4). The highest Na contents in maize leaves were recorded for 15 g OVW while 20, 25 and 30 g OVW were at par with 15 g OVW (Table 4). The highest Na contents in maize leaves were recorded for 5.0% lime (Table 4). This can be attributed to the high Na content of OVW, for example, Seferoglu (2011) has reported that fababean had highest Na concentration in plants after OVW application of OVW at 20 t ha^{-1}.

4. Conclusion

Olive vegetation water considerably improved the essential nutrients uptake by the maize plants. The highest N and P uptake by maize plants was obtained by applying OVW at 10-20 g kg^{-1} of soil. The uptake of K was increased gradually with increased OVW application rates. However, OVW did not affect the Ca and Mg uptake of maize plants. Similarly, the lime affected the N and Na uptake of maize plants. The highest N and Na uptake by maize plant was possible when lime was applied at 5.0% and 2.5%, respectively. Hence, the application of OVW at 15-20 g kg^{-1} with $CaCO_3$ at 2.5% may be the most suitable treatment for improving the nutrients uptake.

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