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EFFECT OF SPATIAL VARIABILITY ON FERTILISER REQUIREMENT OF OLIVE ORCHARD CULTIVATED FOR OIL PRODUCTION

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Abstract. Aim of this research is to determine effect of spatial variability of soil texture, pH, salt, and plant nutrient contents of soil and leaves on fertiliser requirement of an oil olive orchard which has 102 olive trees. Soil and leaf samples were taken from 29 locations to determine spatial variability. Soil texture, pH, salt, lime, organic matter, nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) amounts were determined from soil samples that were taken from 0–30 cm and 30–60 cm soil depths. N, P, K, Ca, Mg, Fe, Cu and Mn were determined from leaf samples. When results were evaluated, N, P, K, Ca and Cu contents had optimum values, but Fe, Mn and Zn were found in deficiency levels. Fertiliser requirements for variable rate fertilisation were between 0–0.76 kg/tree for N, 0–0.192 kg/tree for P, and 0–5.22 kg/tree for K. Fertiliser requirement for fixed rate was determined 0.75 kg/tree for nitrogen, 0.275 kg/tree for phosphorous and 1.5 kg/tree for potassium. Required N, P and K values converted to commercial fertiliser forms as urea, ammonium nitrate, and potassium sulphate and triple super phosphate.

Keywords: olive, precision farming, spatial variability, variable rate fertilisation.

AIMS AND BACKROUND

Precision farming applications is a new subject for olive growers. Spatial variability is key point to start precision farming. Variable rate applications based on spatial variability has been used for decreasing cost and environmental effect of agricultural inputs. Fertilisation of olive trees is important for high yield and good quality. Fertilisation of olive trees are carried out between January and March in

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temperate climate conditions. In more severe winter conditions, fertilisation can be completed in March or April. Phosphorous, potassium and half of the nitrogenous fertiliser are applied at first fertilisation. The remaining half of the nitrogenous fertiliser should be mixed to the soil once or twice depending on the irrigation situation during March or May. Phosphorous and nitrogenous fertiliser should be applied to the root depth. Applications made to the surface which are not buried in the soil are not effective and plants can not benefit from phosphorous fertilisers applied to surface[1]. A study to measure tree canopy size via ultrasonic sensors with position data recorded via GPS. Afterwards, a fertiliser application map was prepared depending on the canopy dimensions. A saving of about 38.48% was made in fertiliser cost via variable rate fertilisation[2]. A system that can make variable rate lime application was designed and manufactured. Coordinates are obtained via GPS in that system. Coordinates, machine forward speed and amount of lime to be applied for each point are sent to the computer in that system. The software automatically adjusts the lime amount to be applied depending on the position of the machine[3].

In the research, yield and soil mapping were carried out in 2007 and 2008 in a 9.1 ha commercial olive tree plantation for olive oil production. The field is planted in rows with about 1650 trees in total. The location of the sacks or group of closely placed sacks were identified using a commercial GPS (5 m resolution). In addition, 91 soil samples were taken at depth of 0–30 cm on a 30 m systematic sampling grid corresponding to a density of 10 soil samples per ha. The following soil parameters were measured: soil texture, organic matter, pH, P, NO_3–N, K, Mg, Zn, Mn, Fe, B and Ca contents[4]**.** Another study assessed the ability of thermal imaging to provide the spatial distribution and variability of tree water status in a commercial irrigated olive orchard, and described strategies and a procedure for choosing which individual trees best represent the orchard[5].

In this research, spatial variability of soil texture, pH, salt and some plant nutrients of soil (N, P, K, $CaCO_3$, Mg) were determined. Fertiliser requirements were calculated according to the leaf nutrient (N, P, K) contents in order to compare variable and fixed rate fertilisation scenarios. Olive has been widely growing for oil production in Turkey. Turkey is also one of the important producers for olive oil in the world. It is an important industry for Turkey. This study may help stakeholders of the olive oil industry.

EXPERIMENTAL

This research was carried out with an olive *(Oleaeuropae* cv. Ayvalik*)* orchard which has 102 trees (Fig. 1). There were no rows for trees because it was established by grafting of wild olive trees. Ayvalik cultivar is a common olive cultivar for oil production in Turkey.

Fig. 1. GPS positions of olive trees and soil/leaf sampling points

Soil samples were taken from 0–30 cm and 30–60 cm soil depths from 29 locations to determine spatial variability of soil texture, pH, salt, lime, organic matter, nitrogen (N), phosphorous (P), potassium (K), and calcium (Ca) amounts. N, P, K were determined from leaf samples. Spatial variability maps of plant nutrient elements and some soil characteristics such as texture, pH, salt, etc. were created.

The texture classes of the soil samples were determined according to the Bouyoucos Hydrometer method[6]. Soil pH (1:2.5 soil: pure water) were measured by glass electrode pH-meter[7]. Total nitrogen was determined by steam distillation (Kjeldahl) method. Useful phosphorous was determined according to the Olsen method. Organic content was determined according to the Walkley-Black method[8]. Cations (Ca^{2+}, Mg^{2+}, K^{+}) exchange capacity was determined by flame photometer. Salinity was measured by electrical conductivity device (1:2.5 soil:water)[9] and active lime analyses were carried out by Scheiblercalcimeter ($CaCO_3$) (Ref. 10). The B, Fe, Mn, Zn and Cu contents of the soil samples were determined via an ICP-OES device[11].

Olive leaf samples were collected from fully expanded mature leaves in pairs which were at the centre of each shoot. Shoots which were at a height of 1.5 and 2 m were selected for this purpose. Shoots were chosen from the north, south, east and west sides of each tree and 4 to 8 leaves were collected from each side[12].

Total nitrogen for the dry and wet burned leaf samples were determined by steam distillation (Kjeldahl) method whereas useful phosphor was determined by yellow colour method with spectrophotometer and other plant nutrient (Ca^{2+}, Mg^{2}, K^{+}, B, Fe, Mn, Zn, Cu) contents were determined by an ICP-OES device[13].

Each tree was harvested manually and yield was measured by weighing on a scale. After that yield map was created via Golden Surfer software.

Determination of nutrient requirement. Suggested pure N, P and K rates were determined from the literature. Fixed amounts of N, P and K were determined as the conventional fertilisers applications. Suggested rates were 0.75 kg/tree for N, 0.275 kg/tree for P (in form of P_2O_5) and 1.5 kg/tree for K (in form of K_2O).

Reference potassium amounts were given double the amount of nitrogen applied to the orchards as suggested according to the literature[14]. For the variable fertiliser applications, rates were calculated by the leaf analysis. A regression formula for each macro element (N, P and K) was formed by using minimum and maximum values from leaf analysis (Table 1).

Table 1. Regression equation for determining nutrient requirement

Nutrients	Equation	R^2
Nitrogen	$y = -0.7463x + 1.9925$	1
Phosphorus	$y = -1.5x + 0.65$	1
Potassium	$y = -0.6061x + 2.4424$	1

Optimum rates for N, P and K were obtained for fertilisers application rates by using a regression equation. K values in that region were high in soil and leaf analysis also indicated those results. So only, 10% of the required amount of K were applied for each tree, assuming maximum 10% of K could be uptake from the soil. Application rates for N, P and K were calculated from the commercial forms of the fertilisers. Half of required nitrogen was assumed that will be applied in form of urea (46% N) and other half will be applied in form of ammonium nitrate (33% N). Phosphorus was applied in form of triple super phosphate (42% P_2O_5) and potassium was applied in form of K_2SO_4 (51% K_2O). Fertiliser prescription maps for N, P and K were created by using developed agricultural inputs application software.

RESULTS AND DISCUSSION

Soil analysis. Soil textures of two sampling depths are given in Fig. 2. Orchard soil texture was mainly clay and clay loam. Soil analysis results which were taken from 0–0.3 and 0.3–0.6 m are given in Table 2.

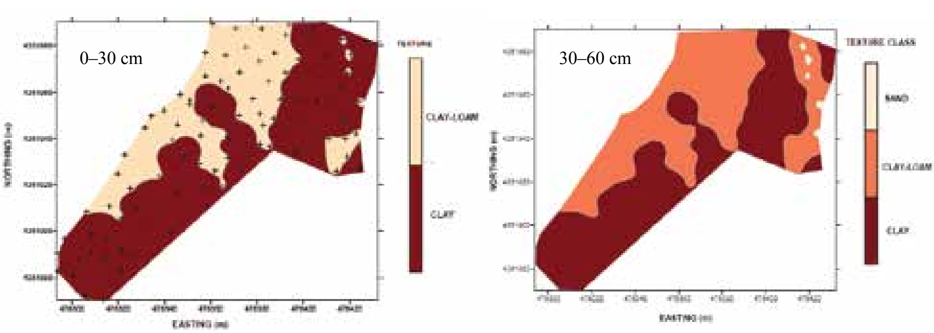

Fig. 2. Soil texture for two different sampling depths

Table 2. Soil analysis

Parameter	Depth (m)	Mean	Min.	Max.	SD	CV (%)
pH (1/2.5)	0.0–0.3	7.59	7.11	8.31	0.34	4.46
	0.3–0.6	7.59	6.95	8.25	0.36	4.73
Lime ($CaCO_3$) (%)	0.0–0.3	5.65	0.00	16.56	4.11	72.72
	0.3–0.6	5.81	0.00	18.78	5.20	89.54
Organic matter (%)	0.0–0.3	2.08	1.03	3.39	0.72	34.64
	0.3–0.6	1.22	0.43	2.19	0.48	39.26
N (%)	0.0–0.3	0.09	0.02	0.20	0.04	48.36
	0.3–0.6	0.06	0.01	0.14	0.03	48.31
P (ppm)	0.0–0.3	1.20	0.62	3.10	0.51	42.73
	0.3–0.6	1.20	0.62	3.10	0.51	42.73
K (ppm)	0.0–0.3	45.17	33.60	69.90	8.82	19.52
	0.3–0.6	33.31	22.50	48.60	6.06	18.20

Spatial variability of N, P, K, organic matter, pH, salt, Ca, lime and Mg of the soil samples for 0–0.3 m sampling depth are given in Fig. 3.

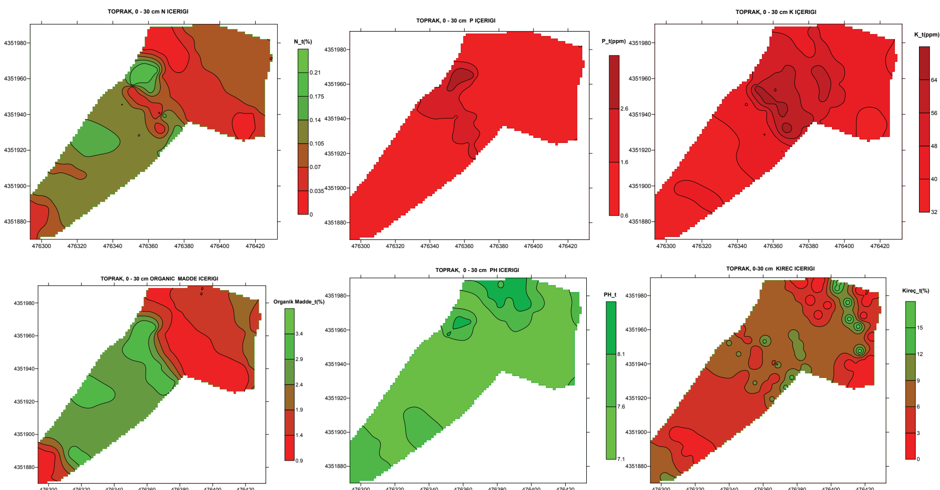

Fig. 3. Spatial variability of N, P, K, organic matter, pH, lime for 0–30 cm

Spatial variability of N, P, K, organic matter, pH, salt, Ca, lime and Mg of the soil samples for 0.3–0.6 m sampling depth are given in Fig. 4.

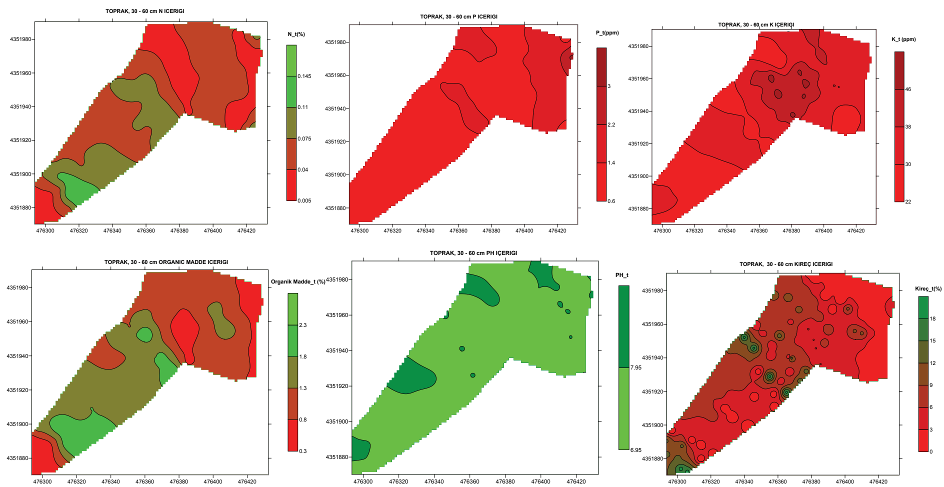

Fig. 4. Spatial variability of N, P, K, organic matter, pH, lime and Mg for 30–60 cm

Measured parameters from soil samples and their classification are given in Table 3.

Table 3. Distribution of parameters from orchard soil and their classification

Parameter	Classification	Soil sampling depth (cm)			
		0–30	30–60	0–30	30–60
		number of samples		range of measured values	
pH	7.5–8.5 (light alkaline)	15	18	7.11–8.31	6.95–8.25
	6.5–7.5 (neutral)	14	11		
Active lime (%)	15–25 (very high)	1	2	0–16.56	0–18.78
	5–15 (high)	14	13		
	1–5 (moderate)	8	8		
	0–1 (low)	6	6		
Organic matter (%)	3–4 (good)	4	0	1.03–3.39	0.43–2.19
	2–3 (moderate)	10	3		
	1–2 (low)	15	15		
	0–1 (very low)	0	11		
N (%)	0.17–0.32 (high)	1	0	0.02–0.20	0.01–0.14
	0.09–0.17 (moderate)	12	6		
	0.045–0.09 (low)	12	14		
	<0.045 (very low)	4	9		
P (ppm)	2.5–8.0 (low)	1	1	0.62–3.10	0.62–3.10
	<2.5 (very low)	28	28		
K (ppm)	50–140 (low)	7	0	33.60–69.90	22.50–48.60
	<50 very low	22	29		

Leaf analyses. The analysis results for the leaf samples are given in Table 4, whereas those for N, P and K – in Fig. 5.

Table 4. Leaf analysis for variable rate part of the olive orchard

Nutrient	Mean	Min.	Max.	Standard deviation	CV (%)
N (%)	1.64	1.33	2.88	0.26	15.91
P (%)	0.25	0.20	0.34	0.03	11.83
K (%)	1.26	0.73	2.38	0.36	28.68

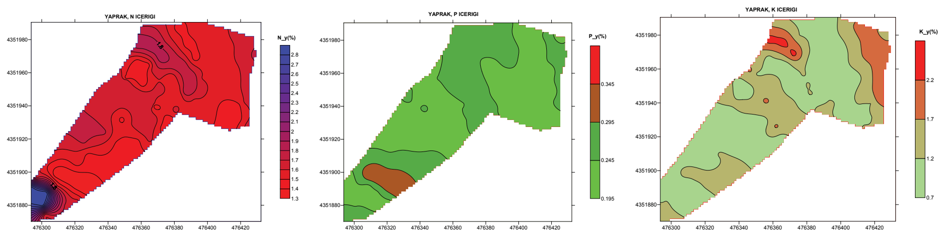

Fig. 5. Spatial variation of N, P and K for leaf samples

Table 5. Distribution of parameters from orchard soil and their classification

Plant nutrient content	Classification	Number of samples	Range of measured values (%)
N (%)	>2.55 (toxic)	1	1.32–2.88
	1.5–2 (optimum)	22	
	<1.4 (deficient)	6	
P (%)	>0.34 (toxic)	1	0.203–0.338
	0.1–0.3 (optimum)	28	
	<0.05 (deficient)	0	
K (%)	>1.65 (toxic)	4	0.73–2.38
	1.01–1.65 (higher than optimum)	18	
	0.8–1.0 (optimum)	5	
	0.4–0.8 (lower than optimum)	2	
	<0.4 (deficient)	0	

Yield. Ayvalik cultivar oil olives were harvested by hand when they reached harvest maturity and harvested olives from each tree were weighed (Table 6). Yield values are given in Table 6 for the year 2012, whereas the yield map is given in Fig. 6.

Table 6. Olive yield data

Year	2012
Number of tree	101
Total production (kg)	2498.00
Mean (kg/tree)	24.73
Minimum (kg/tree)	0.00
Maximum(kg/tree)	104.00
Standard deviation (kg/tree)	18.29
Coefficient of variation (%)	73.95

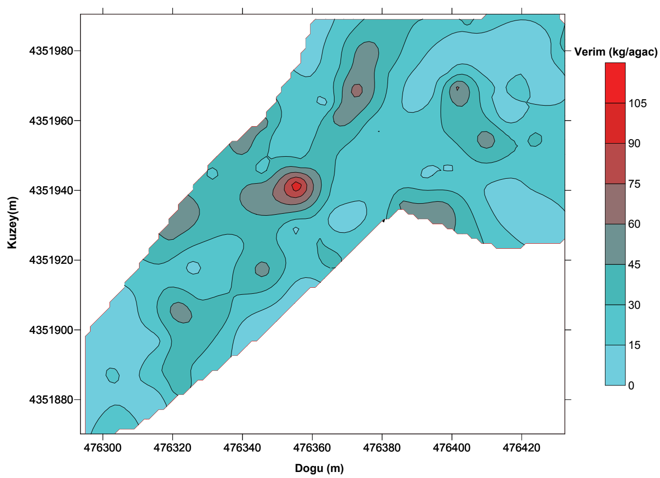

Fig. 6. Yield map of the orchard for 2012

When the values obtained for the 2012 year Ayvalik cultivar olive orchard were examined, it was determined that total production was 2498.0 kg for the 102 trees. Average yield per tree was 24.63 kg. There was a big variability for yield. It can be seen from table that coefficient of variation (CV) was 73.95 %.

Variable rate and fixed rate fertilisation scenarios. According to the leaf analyses N, P and K requirements were calculated for fixed rate and variable rate fertilisation scenarios by using the methodology in experimental.

Nitrogen was applied in form urea (46% N) for the first nitrogen application and ammonium nitrate (33% N) for the second nitrogen application. Phosphorus was applied triple super phosphate (42 % P_2O_5) form. Potassium was given K_2SO_4 (51% K_2O) form. For the fixed rate fertilisation scenario, 0.75 kg (N), 0.275 kg (P_2O_5) and 1.5 kg (K_2O) per tree were applied. Total fertiliser requirements for fixed rate applications were determined for the whole orchard in commercial form. They were calculated 82.34 kg for urea, 114.77 kg for ammonium nitrate, 66.13 kg triple super phosphate and 29.71 kg K_2SO_4.

Amount of nutrient requirements for variable rate application are given in Table 7.

Total fertiliser requirements for variable rate fertilisation scenario were determined for the whole orchard in commercial form. They were calculated 85.07 kg for urea, 118.69 kg for ammonium nitrate, 67.75 kg triple super phosphate and 33.28 kg K_2SO_4.

Table 7. Nutrient requirements for variable rate application in olive orchard (kg/tree)

Number of trees	N	P_2O_5	K_2O	1st nitrogen as urea	2nd nitrogen as $(NH_4)(NO_3)$	P_2O_5 as TSP	K_2O as K_2SO_4
1–2–3	0.79	0.23	1.70	0.86	1.20	0.54	1.00
4–5–6–7	0.00	0.29	1.72	0.00	0.00	0.70	1.35
11–12	0.78	0.29	1.85	0.85	1.18	0.70	0.72
13–14–8–9	0.73	0.32	1.92	0.79	1.11	0.75	1.50
15–16–17–18	1.00	0.14	1.64	1.09	1.52	0.34	1.28
19–20–21	0.83	0.27	1.85	0.90	1.26	0.64	1.09
22–23–24	0.91	0.24	1.70	0.99	1.37	0.58	1.00
25–26–27–28	0.71	0.33	1.82	0.77	1.08	0.78	1.43
29–30–31–32	0.89	0.28	1.75	0.97	1.36	0.68	1.37
33–34–35	0.77	0.28	1.65	0.84	1.17	0.66	0.97
36–37–38–39	0.78	0.33	1.84	0.85	1.19	0.79	1.44
40–41–42	0.76	0.32	1.36	0.82	1.15	0.77	0.80
43–44–45–46	0.73	0.29	1.60	0.79	1.11	0.70	1.25
47–48–49–50	0.91	0.25	1.56	0.99	1.38	0.60	1.22
51–52–53	0.90	0.28	1.79	0.98	1.36	0.65	1.05
54–55–56	0.76	0.21	1.99	0.83	1.15	0.50	1.17
57–58–59–60	0.87	0.28	1.68	0.94	1.31	0.65	1.32
61–62–63	0.59	0.28	1.00	0.64	0.89	0.67	0.59
64–65–66–67	0.75	0.27	1.70	0.81	1.13	0.64	1.34
68–69–70	0.65	0.34	2.00	0.71	0.99	0.80	1.18
71–72–73–74	0.80	0.30	1.73	0.87	1.22	0.71	1.35
75–76–77	0.91	0.22	1.79	0.98	1.37	0.53	1.06
78–79–80–81	0.83	0.27	1.86	0.91	1.26	0.64	1.46
82–83–84	0.81	0.31	1.81	0.88	1.23	0.73	1.06
85–86–87–88	0.90	0.31	1.71	0.98	1.37	0.75	1.34
89–90–91–92–93–94	0.82	0.34	1.48	0.90	1.25	0.82	1.74
95–96–97–98–99	0.78	0.27	1.22	0.85	1.18	0.64	1.20
100–101	0.76	0.31	1.67	0.82	1.15	0.75	0.66
102	0.71	0.26	1.69	0.77	1.08	0.62	0.33
Total (kg)	78.26	28.43	169.73	85.15	118.69	67.75	33.28
CV (%)	25.20	18.61	16.11				

CONCLUSIONS

Turkey is among the first 5 countries in terms of olive plantation, and olive cultivation occurs in regions with Mediterranean climate in Turkey. The average rainfall is annually 700 mm and approximately 85% of annual rain falls between November-March in a period of five months[15]. In this research, fixed rate and variable rate scenarios were compared by using soil and leaf analyses. Difference between variable rate and fixed rate fertiliser application was not so much but there is variability due to trees positions. According to the literature, amount of the fertiliser affects shape, quality and yield of the olives and consequently olive oil[16,17]. If farmers want to get more money from their production they should consider spatial variability of nutrients, yield determined in this research for an olive orchard cultivated for olive oil production.

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REFERENCES

1. I .H. GUÇDEMIR: Turkey Fertiliser and Fertilisation Guide. 5th ed. T. C. Ministry of Agriculture and Rural Affairs, General Directorate of Agricultural Researches, Directorate of Soil and Fertiliser Research Institute, General Publication No 231, Technical Publications No T-69, Ankara, 2006.
2. Q. U. ZAMAN, A. W. SCHUMANN, W. M. MILLER: Variable Rate Nitrogen Application in Florida Citrus Based on Ultrasonically Sensed Tree Size. Appl Eng Agri, **21** (3), 331 (2007).
3. D. G. P. CERRI, L. A. BALASTREIRE, J. R. AMARAL: Development of a Variable Rate Lime Application System. In: Proceedings of the World Congress of Computers in Agriculture and Natural Resources, 2002, 238–243.
4. S. FOUNTAS, K. AGGELOPOULOU, C. BOULOULIS, G. D. NANOS, D. WULFSOHN, T. A. GEMTOS, M. GALANIS: Site-specific Management in an Olive Tree Plantation. Precision 832 Agriculture. **12**, 179 (2011).
5. N. AGAM, E. SEGAL, A. PEETERS, A. LEVI, A. DAG, U. YERMIYAHU, A. BEN-GAL: Spatial Distribution of Water Status in Irrigated Olive Orchards by Thermal Imaging. Precision Agric, **15**, 346 (2014).
6. A. TÜZÜNER: Soil and Water Analysis Laboratories Handbook. T.C. Ministry of Agriculture and Rural Affairs, Rural Affair General Directory, Ankara, 1990, 61–73.
7. F. BAYRAKLI: Soil and Plant Analysis. Ondokuz Mayis University, Faculty of Agriculture, 1986, 77–79.
8. T. GREWELING, M. PEECH: Chemical Soil Tests. Cornell Univ. Agric. Exp. Stn. Bull. No 960, USA, 1960.
9. M. T. SAĞLAM: Soil and Water Chemical Analysis Methods. Tekirdag. N.K.Ü. Agricultural Faculty Publication No 2, Supplementary Course Book No 2, 2008, 1–154.
10. I. GEDIKOĞLU: Laboratory Analysis Methods Used in the Determination of Soil Efficacy. KHGM, Sanliurfa Research Institute Direct, Spring. General Publication No 55, Technical Publication No 11, 1990, 22–27.

11. B. KACAR: Soil Analysis. Extended 2nd ed. Nobel Publishing Distribution Ltd. Ști, Ankara, 2009, 209–269.
12. B. KACAR, A. V. KATKAT: Fertilisers and Fertilisation Technique. 2nd ed. Nobel Publication No 1119, Series of Science and Biology Publications, Ankara. 2007, p. 234.
13. B. KACAR, A. INAL: Plant Analysis. Nobel Publication Distribution Ltd. Şti, Ankara, 2008, 145–503, 816–855.
14. HAIFA Group: Nutritional Recommendations for Olive, http://www.haifa-group.com/files/Guides/Olive_Booklet.pdf, Access date: 04.05.2017(2012).
15. M. T. ESETLILI, F. OZEN, Y. KURUCU, U. KAYA: Agroecological Aspect of Olive Cultivation. J Environ Prot Ecol, **15** (4), 1810 (2014).
16. A. MORALES-SILLERO, H. RAPOPORT, JE. FERNÁNDEZ, A. TRONCOSO: Olive Fruit Pulp and Pit Growth under Differing Nutrient Supply. Sci Hortic, **117**,182 (2008).
17. R. EREL, A. DAG, A. BEN-GAL, A. SCHWARTZ, U. YERMIYAHU: Flowering and Fruit Set of Olive Trees in Response to Nitrogen, Phosphorus, and Potassium. J Am Soc Hortıc Sci, **133**, 639 (2008).

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