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Full Length Research Paper

Effect of potassium and phosphorus fertilization on green herb yield and some quality traits of *Thymus vulgaris* L.

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***Thymus vulgaris* L. (garden thyme) is a member of the Lamiaceae family and is an indigenous aromatic and medicinal plant of Europe and Asia. At present, it is cultivated majorly in North America, Europe and North Africa in a large scale due to its economic importance. *Thymus vulgaris* L. is not accepted as a native plant of Turkey though some taxon is existing. However, it is commercially grown. The objective of this study was to examine the effects of P and K fertilizations on green herb yield, some herb chemical constituents (N, P, K) and volatile (essential) oil of *Thymus vulgaris* L. in order to recommend a reliable nutrient management for commercial growers. Results showed that, yield generally increase in accordance with the increases in K and P fertilizer rates. The N and P contents of the herb were measured higher under P rich (P2) conditions (that is, 67.5 + 67.5 = 135 kg P_2O_5 ha^{-1} from 15:15:15 + Zn and phosphoric acid, respectively). The highest three volatile oil constituents (compound) of the herb were found as thymol, paracymen and carvacrol.**

Key words: Potassium (K), phosphorus (P), oil contents, volatile (essential) oil compound, thyme (*Thymus vulgaris* L.)

INTRODUCTION

Thymus vulgaris L. which is an aromatic and medicinal plant indigenous to Europe and Asia is a member of the Lamiaceae family. In recent years, it is widely cultivated in North America, Europe and North Africa due to its increasing economic importance (Bisset and Wichtl, 2001). *T. vulgaris* L. is not a native plant of Turkey but it is commercially grown. It is a bush crop, low-growing and perennial.

The genus Thymus has a long list of species like *Thymus citriodorus, Thymus herba-barona, Thymus pseudolanuginosus, Thymus serpyllum* and *Thymus vulgaris* etc. *T. vulgaris* L. is regarded as the main species species and used commercially. It is commonly called garden thyme which is used for culinary, medical and decorative purposes (Deans and Waterman, 1993; Kan et al., 2005).

The main active constituents of garden thyme are volatile oil (essential oils), mono-terpenes, flovanoids and tannins (Zeybek and Haksel, 2010). The volatile oils of *T. vulgaris* L. are characterized with prominent concentrations of thymol (44.4 to 58.1%), paracymen (9.1 to 28.5%), g-terpinen (6.9 to 18.9%) and carvacrol (2.4 to 4.2%) (Baranauskiene et al., 2003). Zeybek and Haksel (2010) reported that thyme, origanum and thymbra which are the members of Lamiacea family existing in the natural vegetation of Turkey and harvested for medical or culinary purposes are generally mixed by the producers due to their similar odors. On the other hand, Karık et al.

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(2007) indicated that the secondary metabolites specific to the aromatic and medicinal plants are mainly controlled genetically but are strongly affected by environmental influences. Some of the endemic medicinal herbs consumed or exported from Turkey are wild harvested. Wild harvest together with the above indicated "herb mixtures of similar odors" might end with low quality volatile oils. Moreover, balanced nutrition of the thyme plant has not been examined thoroughly until recently. It is claimed that in order to achieve standard crops and standard quality oil yields, the commercial thyme growers need to practice well managed cultivated production systems (Bayram, 2003). In this regard, the significance of N fertilization is related (Ceylan, 1996) to visible emphasis of N on vegetative growth and to herbage area increase which directly increases the total oil yield. Baranauskiene et al. (2003) state the disadvantages of excess N fertilization which often results with high leaf NO_3 concentrations. Palada et al. (1998) recommended 50 to 150 kg ha^{-1} N for *T. vulgaris* L. as a concluding remark to his N fertilization testing. The same author also reports the beneficial effects of cow manure and urea as N sources (Palada et al., 1995) which are generally practiced in two splits; in spring and after the first harvest. However, not much information is found on the efficient use of P and K fertilizers. Some growers apply P and K during the soil preparation in spring in the form of compound fertilizers. Ateia et al. (2009) claimed that the mixture of compost + sheep manure applied at 3:1 ratio give high essential oil yields.

The objective of this study was to recommend a reliable nutrient management for commercial garden thyme growers by examining the effects of different rates of P and K fertilizations on green herb yield (leaf + stalk + flower), some herb nutrients (N, P, K) and volatile oil contents.

MATERIALS AND METHODS

A fertilization experiment was conducted in a one-year old and drip irrigated garden thyme plantation of Kütaş Company situated in Salihli-İzmir-Turkey where Mediterranean climatic conditions prevail. In the springs of the two successive seasons 2006 and 2007, experiments were laid out in the same plots in randomized blocks design with four replications. Each treatment parcel was $14m^2$ and the on and between rows of plants were 35 × 20 cm respectively. Every year, N, P_2O_5 and K_2O were applied to all treatment parcels at constant amounts by incorporating 450 kg ha^{-1} 15:15:15 + Zn early in the springs as starter fertilization. In accordance with the objective of this study, four different rates of potassium (control [K1], 100[K2], 200[K3] and 300[K4] kg K_2O ha^{-1}) and two different rates of phosphorus (P1= 67.5kg P_2O_5 from 15:15:15 + Zn fertilizer and P2=67.5+67.5=135 kg P_2O_5 ha^{-1} from 15:15:15+Zn and phosphoric acid, respectively) formed the treatments of this current study. The specified doses of K and P were enhanced by applying potassium sulphate and phosphoric acid.

In the first year of this study, a soil sample was taken from the experimental site and analyzed for its physical and chemical properties (Kacar, 1995). The soil was sandy loam in texture, slightly alkaline in reaction, low in organic matter, high in $CaCO_3$ and had no salt problem. It was poor in N, P, K, Mg and rich in Ca (Table 1). Green herb yields were harvested on 17th of July, 29th of August and 30th of November in the first season. In the second season, the harvest dates were 25th of May, 6th of August and 14th of September.

Total yield was determined and the herbs were air dried under shade and examined for their nutrient elements (N, P, K). Total nitrogen was analyzed by Kjeldahl method. For other analysis, plant samples were wet digested. In the extracts, K was determined by flame photometrically and P by spectrophotometry (Kacar, 1972).

Volatile oils were analyzed only in the second year and the dried plant material was subjected to hydro distillation for 3 h using a Clevenger type apparatus. The volatile oil compounds were determined with Gas Chromatography-Mass Spectrometer (Toncer et al., 2009).

All the statistical analyses were done on a completely randomized design with four replications. The data obtained was subjected to analysis of variance (ANOVA) and the mean differences were compared by LSD tests.

RESULTS

Green herb yields were found generally higher in the second year of the experiment in all of the treatments. Each year, yield response to the enhanced K and P fertilizations were found positive and statistically significant at 1% level. The interaction effect of P and K fertilizations on yield was not found significant in the first year where as was determined significant in the second year (Table 2). In this context, the highest yield was obtained in the highest rate of K (300 kg K_2O $ha^{-1)}$ and P (135 kg P_2O_5 ha^{-1}) fertilizations.

Nutrient elements (N, P and K) of the green herb were also analyzed in both of the study years. Results of the statistical analyses showed that the herb N, P and K contents were significantly higher under enriched-higher P2 soil conditions and effect of K fertilization in this regard (Table 3) was not important. On the other hand, in the first and second years of this study, statistically significant interaction effects of P and K fertilizations were determined on the N and P contents of the herb respectively.

The herb oil was examined only in the second year of the experimentation. Positive effects of K fertilization was determined on oil, oil increased by the increases of K doses particularly under low P conditions (P1). In this regard, results revealed that the first three volatile oil components of thyme are thymol, paracymen and carvacrol (Table 4). According to the variance of analysis, the main effects of the tested K and P fertilizers on these components were generally statistically significant (1%). Especially in the higher, that is, enriched P2 status of the field during the season, all of the oil components were positively affected and increased at 1% significance. In the case of K fertilization, the effects were positively significant only for thymol and paracymen (1%) and the highest amounts were found at 100 kg ha^{-1} K_2O under the second rate of P in most cases.

Table 1. Soil properties of the experimental site.

Depth (cm)	Soil texture	pH	Soluble salts (%)	Organic matter (%)	$CaCO_3$ (%)
0-20	Sandy loam	7.46	0.047	0.98	20.95
20-40	Sandy loam	7.69	< 0.02	0.62	26.78

Depth (cm)	Total-N (%)	Available elements(mg kg^{-1})				
		P	K	Ca	Mg	Na
0-20	0.07	1.18	118	3240	23	95
20-40	0.03	1.48	59	3360	24	143

P: Water extractable; K, Ca, Mg, Na: NH_4AOC Extractable.

Table 2. Effect of K and P fertilization on green herb yield (kg/ha^{-1}) for 2006 and 2007 seasons.

K Rate	Green herb yield (kg ha^{-1})					
	First season (2006)			Second season (2007)		
	P1	P2	Mean	P1	P2	Mean
K1	15000	15100	15050^{b}	26290^{aA}	26300 ^{bA}	26295^{b}
K2	16000	15775	15888^{b}	26300^{aA}	26400 ^{bA}	26350^{b}
K3	16500	16500	16500^{ab}	26300^{aB}	26800^{aA}	26550^{a}
K4	17000	20275	18638^{a}	26400^{aB}	27000^{aA}	26700^{a}
Mean	16125	16913		26322.5	26625	
$K_{(LSD)}$		2296**			188**	
$P_{(LSD)}$		ns			132.9**	
$KxP_{(LSD)}$		ns			265.87**	

K1=Control K2=100 K3=200 K4=300, (K_2O kg ha^{-1}); P1=67.5kg P2=135, (P_2O_5kg ha^{-1}). Means in the same column followed by different small letters are significantly different (p≤0.01). Means in the same line followed by different capital letters are significantly different (p≤0.01).

DISCUSSION

The data of this study showed that P and K fertilizations positively affect the developments in *T. vulgaris* L., its yield as well as its quality as a medicinal and herbaceous plant. Among many plant growth factors, the nutritional requirements of the crops are considered to be the most important factor. Generally the growth, development, yield and the quality of herbs are affected by genetic background; however, environment and the cultural practices are as well important (Karık, et al., 2007). It is well known that P is an essential element in reproductive and vegetative growth and flower number can increase by the increased P applications (Mengel and Kirkby, 2001). Phosphorus also has many other cellular functions in plants and affects the primary and secondary metabolites. Therefore, P fertilization in medicinal herbs is strongly recommended especially in cites with low available soil P (Marschner, 1995).

Similarly, it is also very well known that K fertilizers improve growth parameters and yield quality (Mengel and Kirkby, 2001). Potassium fertilizers proved its role in plant metabolism, carbohydrate synthesis, water transport in xylem, cell elongation. Singh (2001) reported that addition of K resulted with higher herb yields.

In this current study, green herb yield, some of the herb nutrient elements like N, P, K and some important volatile oil compounds positively responded to P and K fertilizer treatments. The dominant oil compound was found as thymol and was followed by paracymen and carvacrol. The highest herbal yield was determined in 300 kg K_2O ha^{-1} (K4) + 135 kg P_2O_5 ha^{-1} (P2) treatment in both of the study seasons. In this regard, results showed that an additional side dressed P fertilization (67.5 kg P_2O_5 ha^{-1}) during the season always increased the yield as well as the herb N and P contents positively. On the other hand, it is worth reporting that this specified highest yield obtained from the 300 kg K_2O ha^{-1} + 135 kg P_2O_5 ha^{-1} treatment statistically did not vary from the yield of the treatment parcel of 200 kg K_2O ha^{-1} + 67.5 kg P_2O_5 ha^{-1}.

Thymol as the dominant volatile oil was measured highest in the 100 K_2O ha^{-1} + 135 kg P_2O_5 ha^{-1} treatment and the thymol content of this indicated parcel was statistically similar with the thymol contents of all other treatment parcels. Paracymen was also found highest in 100 kg K_2O ha^{-1}+135 kg P_2O_5 ha^{-1} specified treatment.

Carvacrol was positively affected only by the second rate of P fertilization.

Table 3. Effect of K and P fertilization on N, P and K contents (%) for 2006 and 2007 seasons.

K Rate	(%)																	
	N						P						K					
	First season (2006)			Second season (2007)			First season (2006)			Second season (2007)			First season (2006)			Second season (2007)		
	P1	P2	Mean	P1	P2	Mean	P1	P2	Mean	P1	P2	Mean	P1	P2	Mean	P1	P2	Mean
K1	2.60^{aB}	2.73^{bA}	2.67^{b}	1.89	2.05	26295^{b}	0.24	0.24	0.24	0.18^{bA}	0.20^{cA}	0.19^{b}	3.06	2.98	3.02	1.84	2.05	1.95
K2	2.46^{bB}	2.63^{cA}	2.54^{c}	1.96	2.14	26350^{b}	0.21	0.24	0.23	0.21^{aA}	0.23^{bA}	0.22^{a}	3.15	3.11	3.13	1.95	2.14	2.04
K3	2.55^{abB}	2.66^{bcA}	2.60^{bc}	1.87	2.07	26550^{a}	0.23	0.26	0.25	0.21^{aB}	0.25^{abA}	0.23^{a}	3.08	3.00	3.04	1.89	2.07	1.98
K4	2.63^{aB}	2.92^{aA}	2.77^{a}	2.11	2.09	26700^{a}	0.24	0.23	0.24	0.21^{aB}	0.26^{aA}	0.23^{a}	3.27	2.99	3.13	2.11	2.08	2.10
Mean	2.56^{B}	2.73^{A}		1.96B	2.09A		0.23B	0.24A		0.20^{B}	0.23^{A}		3.14	3.02		1.95B	2.08A	
$K_{(LSD)}$		0.089**			ns			ns			0.017**			ns			ns	
$P_{(LSD)}$		0.063**			0.119*			0.013*			0.012**			ns			0.118**	
$KxP_{(LSD)}$		0.092*			ns			ns			0.018*			ns			ns	

Means in the same column followed by different small letters are significantly different (p≤0.01).

Table 4. Total oil (%) and volatile oils compounds (%) of garden thyme as a function of K and P fertilization.

K Rate	Total oil (%)			Thymol			Paracymen			Carvacrol		
	P1	P2	Mean	P1	P2	Mean	P1	P2	Mean	P1	P2	Mean
K1	2.22^{a}	2.33^{a}	2.27	36.24^{bB}	46.90^{cA}	41.57^{b}	18.51^{b}	25.90^{b}	22.21^{b}	3.37	4.59	3.98
K2	2.27^{a}	1.90^{ab}	2.09	44.74^{aB}	53.30^{aA}	49.02^{a}	19.84^{ab}	27.71^{a}	23.77^{a}	3.66	4.83	4.24
K3	2.31^{a}	1.73^{b}	2.02	46.20^{aB}	50.64^{bA}	48.42^{a}	20.93^{a}	22.37^{c}	21.65^{b}	3.79	4.95	4.37
K4	2.44^{a}	1.55^{b}	2.00	44.83^{aB}	51.99^{abA}	48.41^{a}	18.79^{b}	24.98^{b}	21.88^{b}	3.44	5.08	4.26
Mean	2.31^{A}	1.88^{B}		43.00^{B}	50.71^{A}		19.52^{B}	25.24^{A}		3.56^{B}	4.86^{A}	
$K_{(LSD)}$		ns			2.275**			1.464**			ns	
$P_{(LSD)}$		0.219**			3.217**			1.035**			0.346**	
$KxP_{(LSD)}$		0.438**			1.608**			1.521**			ns	

Means in the same column followed by different small letters are significantly different (p≤0.01).

Conclusion

It can be concluded that if the herb yield and the finaltotal thymol, paracymen and carvacrol yields are evaluated together and weighed and ranked according to the treatments, we can reach the conclusion that if economically viable 200 kg K_2O and 135 kg P_2O_5 per hectare could be recommended for about 26800 kg of green herb yield ha^{-1}. In case N fertilization is necessary according to soil testing, recommendations should be followed.

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