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Effects of Different Fertilizers with Potassium and Magnesium on the Yield and Quality of Potato

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Potato (*Solanum tuberosum* var. Granola) were grown in trials of 15.15.15, gypsum, kieserite, potassium sulphate, kalimagnesia and ammonium sulphate materials in two locations of Nevsehir and Nigde provinces in 2005 and 2006 years. According to the results, in every two years in all locations effects of fertilizers used on tuber yields, tuber size distribution, dry matter content of tuber and K, Mg and S contents of leaves were significant changing depend on the locations. An important relation between K, Mg and S nutrition of plant and tuber yields were found in all locations. In two years, tuber yields obtained in all locations increased changing ratios between 2.4 and 132.9 % by fertilizer treatments with K, Ca, Mg and S by the side of N and P according to control treatment contained only N and P. In every two years, in all locations the highest tuber yield was obtained by treatment 6 having CAN + DAP + kalimagnesia + urea fertilizers that were given 650 kg N, 120 kg K_2O, 68 kg S and 40 kg MgO per ha and treatment 5 having CAN + DAP + potassium sulphate + urea followed to this. At the same time, tuber yield having < 35 mm size decreased in ratio of 22.9 % as mean of all locations in treatment 6 according to control.

Key Words: Potato, Kalimagnesia, Kieserite, Yield, Quality.

INTRODUCTION

About 15 % of potato growing areas (187500 ha) of Turkey is in Nevsehir and 11 % is in Nigde provinces, so total 26 % is in these two province boundaries. 39 % of potato production of Turkey which produces about 5 million tons is supplied from these provinces[1]. In these provinces, potato was grown in slightly textured soils. As reported[2,3], lack of a nutrition such as N, K, Mg and Ca is seen due to inadequate decomposition of parent material, low organic matter and high leaching in these soils. It was

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determined that N and Ca were generally inadequate, P and Mg were optimum, K was sufficient in some varieties, insufficient in some of their and Mn was inadequate in some varieties and very high quantities in some of the soil and potato leaf samples taken from Nevsehir around[4]. In addition according to analysis results of 182 soil samples taken from potato growing fields of Nigde and Nevsehir provinces, pH was between 3.9 and 7.5, organic matter values ranged from 0.1 to 1.75 %, K and Ca were inadequate in 40 % of samples and Mg was insufficient in 65 % of them, were reported by Gezgin[5]. In potato growing soil, it must be applied balanced fertilization according to soil analysis result to obtain high yield and quality. It is found hardly that generally N and P by the side of K absorbed highly by the potato in the fertilization program of potato in Turkey[6]. Whereas it is necessary in addition to these elements Mg, S and Ca must be present in a balanced fertilization program for potato plant. Generally these elements are insufficient in the slightly textured soils where grown potato and this plant needs the more quantities of Mg, S and Ca according to a lot of plant. Potassium, Mg and S affect a lot of metabolic process such as photosynthesis, carbohydrate and protein metabolisms and Mg plays a part in energy transfer, in the activation of a lot of enzymes, in the absorbing of water by the way of organizing of osmotic pressure in the cell and cell growing. Owing to these metabolism, K, Mg and S are not only increase tuber weight and size in potato but also increase dry matter, protein, sugar, starch amount, stability of tuber colour and tolerance to disease of plant[7-10].

This study was done to determine effects of K, Mg and S applied by different sources on yield and yield components of potato (*Solanum tuberosum* var. Granola) grown in four different locations of Nevsehir and Nigde provinces in Turkey in 2004 and 2005 years.

EXPERIMENTAL

Field experiments were conducted out in two different lands (location 1, Hakan Göztepe; location 2, Recep Turhan) in Kaymakli town of Nevsehir province in the first year (2004) and in Özyayla village (location 1, Ali Ipek) of Derinkuyu District/Nevsehir province and in Divarli village (location 2, Cumali Akbay) found in Melendiz Plain of Nigde province in the second year (2005). Nutrition amounts and their sources (CAN, DAP, 15.15.15, gypsum, kieserite, potassium sulphate, kalimagnesia, ammonium sulphate) applied to potato plant grown in these experiments were given in Table-1.

Experimental areas take part in the east of Central Anatolia and are found on rough lands which are 1200 m of altitude at sea level.

TABLE-1
FERTILIZERS USED IN THE POTATO EXPERIMENTS

Treat. No.	Nutrition/ha	Source	Treat. No.	Nutrition/ha	Source
1	150 kg N 120 kg P_2O_5 500 kg N	CAN, DAP DAP Urea	5	150 kg N 500 kg N 120 kg P_2O_5 120 kg K_2O 43 kg S	CAN, DAP Urea DAP P. Sulphate P. Sulphate
2	150 kg N 500 kg N 120 kg P_2O_5 120 kg K_2O	15:15:15, CAN Urea 15:15:15 15:15:15	6	150 kg N 500 kg N 120 kg P_2O_5 120 kg K_2O 68 kg S 40 kg MgO	CAN, DAP Urea DAP Kalimagnesia Kalimagnesia Kalimagnesia
3	150 kg N 500 kg N 120 kg P_2O_5 120 kg K_2O 43 kg S	15:15:15, CAN Urea 15:15:15 15:15:15 Gypsum	7	120 kg N 210 kg N 260 kg N 500 kg N 120 kg P_2O_5 120 kg K_2O 245 kg S	15.15.15 A. Sulphate CAN Urea 15.15.15 15.15.15 A. Sulphate
4	150 kg N 500 kg N 120 kg P_2O_5 120 kg K_2O 43 kg S 54 kg MgO	15:15:15, CAN Urea 15:15:15 15:15:15 Kieserite Kieserite			

Nevsehir and Nigde districts where experiments were conducted out were characterized by terrestrial climate having hot and arid in summers, cold and snowy in winters. According to average of long terms, mean yearly temperature is 16 ºC, mean yearly total precipitation is 429.4 mm. In the first year (2004), total precipitation between May and September which are potato growing season is 72.4 mm, while total precipitation is 104.7 mm between May and October in the second year (2005) (Table-2). Air temperatures (ºC) and air relative humidity values (%) as monthly means were given in relevant Table. The fact that precipitation and relative humidity in the second year are more and mean temperature is less than that of in the first year is better for potato growth.

Some physical and chemical properties of soils of experiment fields in every two years were presented in Table-3. As it seen in the Table, soils of experiment place are calcareous, slightly acid in location 2 of second year, moderate acid, low salt level, low organic matter and slightly textured according to the limits reported[11]. Available NO_3-N and P amounts are sufficient or quite high levels, while available S contents are insufficient

TABLE-2
CLIMATIC DATA BELONG TO POTATO EXPERIMENT AREAS

Years	Parameters	May	Jun	Jul	Aug	Sep	Oct	Mean
2004	Air temp. (ºC)	14.30	18.90	21.70	22.30	17.20	-	18.88
	Rel. humidity (%)	59.00	54.60	47.30	51.10	48.40	-	52.08
	Precipitation (mm)	28.10	27.40	15.00	1.90	0.00	-	Total 72.40
2005	Air temp. (ºC)	14.81	18.78	24.34	23.92	16.84	9.29	17.99
	Rel. humidity (%)	55.89	52.49	50.28	52.13	55.76	69.23	55.96
	Precipitation (mm)	29.50	7.00	0.50	7.00	30.80	29.90	Total 104.70

TABLE-3
SOIL ANALYSIS RESULTS OF POTATO EXPERIMENT FIELDS

Parameters	First year (2004)		Second year (2005)		Analysis methods[13]
	L1	L2	L1	L2	
pH (1:2.5 soil:water)	4.68	4.61	4.4	5.9	By pH meter
EC, μS/cm (1:5 s:w)	54.2	62.4	48	45	By EC meter
Org. matter (%)	1.0	1.3	1.45	0.56	Walkley-Black method
Lime (%)	1.75	2.75	4.83	4.02	Scheibler Calcimeter method
Clay (%)	12,4	18.4	10.60	10.60	Bouyoucos hydrometer (1951)
Silt (%)	2	20	12.00	10.00	Bouyoucos hydrometer (1951)
Sand (%)	85.6	61.6	77.40	79.40	Bouyoucos hydrometer (1951)
Texture class	Loamy sand	Sandy loam	Sandy loam	Sandy loam	-
NO_3-N (ppm)	490	352.8	244	60	Extraction with 2 N KCl
P (ppm)	44.7	30.8	83	38	$NaHCO_3$ method
K (ppm)	81.9	163.8	354	115	NH_4OAc extraction method
Ca (ppm)	468	804	457	1570	NH_4OAc extraction method
Mg (ppm)	126	189.6	92	132	NH_4OAc extraction method
Ca:Mg	2.2	2.5	3.0	7.1	-
Ca:K	11.1	9.6	2.5	2.7	-
K:Mg	0.2	0.3	1.2	0.3	-
S (ppm)	7.05	10.54	8.3	9.2	KH_2PO_4 extraction method

L = Location

in the soil samples of all locations. Available K amount is adequate in location 1 in the second year, is marginal in location 2 in the first year and is inadequate in the other locations. Both Mg and Ca amounts are in the insufficient level, while available Mg amount of the soils is marginal in the first year and Ca amount is also marginal in location 2 in the 2nd year[12,13].

In the experiment of location 1 in first year, planting and first fertilization in May 25, 2004, hoeing and second fertilization in July 06, 2004 were realized. On the other hand 50 893 tubers per ha were used in the planting. Leaf sampling was done on July 27, 2004 meeting to flowering period and harvest was realized on October 14, 2004. In addition, in the experiment of location 1, planting and first fertilization in May 13, 2004, hoeing and second fertilization on June 30, 2004 were realized. On the other hand 50 893 tubers per ha were used in the planting. Leaf sampling was done on July 27, 2004 and harvest was realized on October 4, 2004. In every two locations, during the planting insecticide (Cruiser) and fungicide (Rizolex-T + Sancozeb) were used for tubers and in the vegetation period herbicide (Lexone), fungicide (Ridomil Gold) and insecticide (Karate + Zeon) were used for green parts of the plants.

In the experiment of location 1 in second year, planting and first fertilization on May 12, 2005, hoeing and second fertilization on July 01, 2005 were realized. First germination occurred on July 11, 2005. Tuber forming also started on June 29, 2005. On the other hand 228 tubers per plot and 50 893 tubers per ha were used in the planting. Leaf sampling was done on July 28, 2005 meeting to flowering period and harvest was realized on October 28, 2005. In addition, in the experiment of location 2, planting and first fertilization on May 13, 2005, hoeing and second fertilization on July 03, 2005 were realized. First germination occurred on July 15, 2005. Tuber forming also started on June 30, 2005. On the other hand 228 tubers per plot and 50 893 tubers per ha were used in the planting. Leaf sampling was done on July 28, 2005 and harvest was realized on October 28, 2005.

Leaf samples were taken as leaves between 3rd and 6th leaves from tip in flowering period in the dates given above and carried in paper bags to laboratory of Soil Department, Faculty of Agriculture, University of Selcuk. After cleaned they were dried in 70 ºC for 48 h. Then these specimens were grinded in plant mill covered tungsten. 0.5 g sample grinded was weighted and digested in concentrated HNO_3 by microwave system (CEM, Mars 5). Potassium, Mg and S concentrations in the solution obtained were determined by ICP-AES (Varian, Vista Axiel Simultaneous)[14].

Field experiment were planned according to randomized plots factorial experimental design. 35 Plots from seven different treatments with five replications where using fertilizers (Table-1) were prepared in locations 1 and 2. Plot dimensions were 5.6 m × 8.0 m (44.8 m^2) in planting. In the planting, rows distance and row on intervals were organized as 70 and 28 cm, respectively. One each row in sides were not taken in harvest, six row were taken in the middle, 0.25 m parts of beginning and last of plots were not harvested, lines having 7.5 m long tall in the middle were harvested by hand. Plot dimensions were 4.2 m × 7.5 m (31.5 m^2) in the harvest. The cleaned potato tuber specimens were carried to store in the bags immediately and their weights were determined according to < 35 mm, 35-55 mm and > 55 mm size distributions. Tuber yields in the plot were translated to t ha^{-1}. In addition tuber samples were taken from the plots depend on their size distributions and were transferred to the laboratory. After cleaning they were cut by stainless steel knife, 5 g was weighed and their dry matter contents were determined drying in the 105 ºC for 6 h[15]. In addition certain part of tuber specimens cut after dried in the 70 ºC was grinded and their K, Mg and S contents were determined like in leaf samples. Then in each treatment, dry matter yield obtained by multiplying tuber yield with dry matter content was multiplied with K, Mg and S contents. K, Mg and S amounts taken up by tuber from the soil (kg ha^{-1}) were evaluated. Four number were taken into account putting out one each number turning from mean of five replicates to determine effects of treatments on tuber yield in statistical analysis.

In the experiments, all of the P, K, Mg and S were applied in the planting time, 1/5 of N was also given in the planting time and rest of the N was added to soil as urea and CAN form in the tuber forming period.

Kalimagnesia fertilizer used in the field experiments is a granule potassium-magnesium sulphate fertilizer. It contains 30 % K_2O (25 % K), 10 % MgO (6 % Mg) and 42.5 % SO_3 (17 % S). On the other hand kieserite fertilizer is a granule magnesium sulphate fertilizer soluble in water contains 27 % MgO (16.3 % Mg) and 55 % SO_3 (22 % S). Minitab and Mstat packet programs were used in the statistical analysis of data obtained from the research.

RESULTS AND DISCUSSION

Effect of fertilizers on the tuber yields (t ha^{-1}) were statistically significant ($p < 0.01$) in every two years in all locations. The effect of them on the dry matter contents (%) of tuber were significant ($p < 0.01$ and $p < 0.05$) in the first year in two locations. It was significant ($p < 0.01$ and $p < 0.05$) in the second year in location 1 and was significant in location 2 according to variance analysis of data obtained from potato experiments. These potato experiments were conducted by applying different fertilizers in Central Anatolia, in Kaymakli town and Özyayla village of Derinkuyu attached to Nevsehir and Divarli village of Nigde Province in 2004 and 2005 years (Table-4).

In every year, in all locations, total potato yields were significantly increased by the fertilizer applications having K, Ca, Mg and S by the side of N and P according to control having only N and P. The increasing ranged from 2.4 to 23.6 % in the first year, in location 1 and varied from 4.5 to

TABLE-4
VARIANCE ANALYSIS RESULTS RELEVANT POTATO TUBER YIELDS

				Mean of square				
Year	Loc	Variance sources	DF	< 35 mm	35-55 mm	> 55 mm	Total yield (t/ha)	Dry matter (%)
2004	1	Fertilizer	6	13.138‡	20.064‡	43.036‡	55.689‡	15.211†
		Error	21	0.769	1.395	0.930	5.246	4.291
	2	Fertilizer	6	4.6097‡	26.088‡	53.200‡	130.31‡	21.445‡
		Error	21	0.1009	0.273	0.100	0.56	2.551
2005	1	Fertilizer	6	12.839‡	587.23‡	48.725‡	971.90‡	3.191†
		Error	21	0.599	2.87	0.400	2.73	1.213
	2	Fertilizer	6	13.753‡	969.92‡	82.807‡	1600.5‡	1.109
		Error	21	0.106	1.48	0.155	2.20	1.261

38.5 % in location 2, in the second year. They ranged from 3.8 to 109.3 % in location 1 and varied from 14.0 to 132.9 % in location 2. In every two years, in all locations, the highest yield were obtained by treatment 6 (CAN + DAP + kalimagnesia + urea) supplying 650 kg N, 120 kg P_2O_5, 120 kg K_2O, 68 kg S and 40 kg MgO per ha and this treatment was followed by the treatment 5 (CAN + DAP + potassium sulphate + urea). The least increasing tuber yield was got by treatment 2 (15.15.15 compose + CAN + urea) and treatment 7 which is traditional fertilization in experiment districts according to control depending on years and locations (Tables 1 and 5). In all locations treatment 6 and 5 (difference between these treatments was significant in the first year in location 2 and in the second year in location 1) caused to the highest yield formed group 1, treatments 3 and 4 formed group 2, treatments 7 and 2 formed group 3 and treatment 1 (control) formed final group according to Duncan test except some exceptions (Table-5).

Small tuber is not desired in the production of potato, especially crisps potato. Effects of fertilizer applications on the tuber size were generally positive. According to < 35 mm tuber yield obtained by control, yield was increased by the treatment 4 in the first year in location 1 in the rate of 4 % and yield was increased by the other treatment 7 in location 2 in the rate of 19.5 %, yield was decreased by the other treatments in the rates changing between 3.8 and 34.2 %. On the other hand, in the second year, while < 35 mm tuber yield increased 44.1 and 9.7 % with the treatments 3 and 5 in location 1, 156.9 and 15.9 % in location 2, it decreased in rates changing between 8.1 and 41.7 % with the other treatments. In every two years in all locations both 35-55 mm and > 55 mm tuber amounts significantly increased with the different fertilizer applications according to control. In the first year, > 55 mm tuber yield was obtained in location 1 (13.35 t ha^{-1}) 285.0 % and in location 2 (13.39 t ha^{-1}) 340.5 %, in the second year in

TABLE-5
EFFECTS OF VARIOUS FERTILIZERS ON THE POTATO TUBER YIELDS IN DIFFERENT LOCATIONS† AND DUNCAN GROUPS OF MEAN TOTAL YIELD VALUES‡

Treatment	Tuber size (mm)	First year (2004)				Second year (2005)			
		Yield (t/ha)	Variation (%)	Yield (t/ha)	Variation (%)	Yield (t/ha)	Variation (%)	Yield (t/ha)	Variation (%)
1	<35	10.19	-	7.22	-	6.57	-	5.80	-
	35-55	32.85	-	30.38	-	30.43	-	29.04	-
	>55	3.47	-	3.04	-	2.26	-	1.61	-
	Total	**46.51b**	**-**	**40.65e**	**-**	**39.26e**	**-**	**36.45f**	**-**
2	<35	8.93	-12.4	5.71	-20.9	5.30	-19.3	5.33	-8.1
	35-55	37.23	13.3	32.33	6.4	33.00	8.4	33.72	16.1
	>55	5.98	72.3	4.45	46.4	2.44	8.0	2.49	54.7
	Total	**52.14a**	**12.1**	**42.49d**	**4.5**	**40.75e**	**3.8**	**41.55e**	**14.0**
3	<35	8.77	-13.9	6.02	-16.6	9.47	44.1	9.16	156.9
	35-55	37.17	13.2	32.47	6.9	44.25	45.4	44.14	52.0
	>55	6.80	95.9	6.50	113.8	5.46	141.6	3.35	108.1
	Total	**52.73a**	**13.4**	**44.99c**	**10.7**	**59.18c**	**50.7**	**56.65b**	**55.4**
4	<35	10.60	4.0	6.25	-9.9	5.74	-12.6	4.00	-31.0
	35-55	37.23	13.3	33.39	9.9	48.10	58.1	40.91	40.9
	>55	6.88	98.3	5.70	87.	5.00	121.2	4.44	175.8
	Total	**54.70a**	**17.6**	**45.34c**	**11.5**	**58.85c**	**49.9**	**49.35c**	**35.4**
5	<35	6.80	-33.3	5.27	-27.0	7.21	9.7	6.72	15.9
	35-55	38.32	16.7	36.88	21.4	52.76	73.4	68.04	134.3
	>55	9.38	170.3	9.07	198.4	5.58	146.9	9.24	473.9
	Total	**54.58a**	**17.4**	**51.21b**	**26.0**	**65.56b**	**67.0**	**84.00a**	**130.4**
6	<35	6.71	-34.2	5.84	-19.1	5.33	-18.9	4.67	-19.5
	35-55	37.41	13.9	37.06	22.0	64.13	110.7	65.79	126.5
	>55	13.36	285.0	13.39	340.5	12.73	463.3	14.44	796.9
	Total	**54.47a**	**23.6**	**56.29a**	**38.5**	**82.19a**	**109.3**	**84.90a**	**132.9**
7	<35	9.80	-3.8	8.63	19.5	3.83	-41.7	3.83	-34.0
	35-55	33.07	0.7	32.90	8.3	35.24	15.8	35.36	21.8
	>55	4.77	37.5	4.52	48.7	4.70	108.0	4.59	185.1
	Total	**47.64b**	**2.4**	**46.05c**	**13.3**	**43.77d**	**11.5**	**43.78d**	**20.1**
LSD p<0.05	3.368	-	1.100	-	2.430	-	2.181	-	-

†=Values are average of 4 replications. ‡=Separately Duncan test were done for each location and difference between values shown with same letter is insignificant in 0.05 significant level, statistically.

location 1, (12.73 t ha^{-1}) 463.3 % and in location 2 (14.44 t ha^{-1}) 796.9 % by treatment 6 (CAN + DAP + kalimagnesia + urea) and then treatment 5 (CAN + DAP + potassium sulphate + urea) according to control (Table-5).

Effects of different fertilizers on the dry matter contents of tuber were given in Table-6. It was seen from the Table that the highest dry matter content was obtained by control treatment (CAN + DAP + urea) in the first year 23.17 % in location 1 and 23.52 % in location 2, by treatment 4 (CAN + 15.15.15 + urea + kieserite) in the second year 19.44 % in location 1 and 19.22 % in location 2. Tuber dry matter content decreased in the rates ranging from 1.95 to 26.19 % with the other treatments according to control in the first year in every two locations. Large differences among the treatments were not found in terms of dry matter content by treatment 7 with decreasing of 20.67 % in the first year in location 1, 26.19 % in location 2 and 6.9 % in the second year in location 1 according to control (Table-6).

TABLE-6
EFFECTS OF VARIOUS FERTILIZERS ON THE DRY MATTER RATIOS OF POTATO TUBERS† AND DUNCAN GROUPS OF MEAN DRY MATTER VALUES‡

Treatment	First year (2004)				Second year (2004)			
	Location 1		Location 2		Location 1		Location 2	
	Dry matter (%)	Variation (%)	Dry matter (%)	Variation (%)	Dry matter (%)	Variation (%)	Dry matter (%)	Variation (%)
1	23.17a	-	23.52a	-	18.25abc	-	18.78a	-
2	23.12a	-2.16	23.04a	-2.04	17.56bc	-3.78	18.17a	-3.25
3	23.05a	-5.18	22.65a	-3.70	18.93ab	3.73	17.87a	-4.84
4	22.35ab	-3.54	23.06a	-1.95	19.44a	6.52	19.22a	2.34
5	20.00bc	-13.68	22.70a	-3.49	18.90ab	3.56	19.17a	2.08
6	19.98bc	-13.77	19.59b	-16.71	17.59bc	-3.62	19.01a	1.22
7	18.38c	-20.67	17.36b	-26.19	16.99c	-6.90	18.34a	-2.34
Min.	18.38	-	17.36	-	16.99	-	17.87	-
Max.	23.17	-	23.52	-	19.44	-	19.22	-
LSD; p<0.05	3.046	-	2.349	-	1.620	-	1.651	-

†=Values are average of 4 replications. ‡=Separately Duncan test were done for each location and difference between values shown with same letter is insignificant in 0.05 significant level, statistically.

Contents of K, Mg and S of potato leaves taken from experiment plots were given in Table-7. It was seen in the Table, in every two years in all locations the contents of K, Mg and S of leaves were found generally as the lowest level in control (treatment 1). The K contents of leaf increased as 9.8 and 23.5 % in the first year in every two locations and in the rates ranged from 0.7 to 9.4 % in the second year in location 1 with the other treatments having 120 kg K_2O ha^{-1} according to control which is not containing potassium. The highest K content of leaf (3.70 % in location 1; 3.78 % in location 2) was found in the treatment 5 (CAN + DAP + potassium sulphate + urea). The more Mg contents of leaf were obtained by the treatments 4 (0.37-0.39 %) and 5 (0.37-0.41 %) having Mg in every two years in all locations according to the other treatments. Treatments 4 and 5 presented significantly differences between year and locations in terms of Mg contents of potato leaves. The S contents of leaves increased in the rates ranged from 5 to 27 % by the other treatments having S according to control and treatment 2 which is not have sulphur with some disharmonies in every two locations, in every two years in all locations. Significantly differences between year and locations were not found in the treatments 3, 4, 5, 6 and 7 which are having S in terms of S contents of the leaves (Table-7).

They were determined statistically significant positive correlations (in location 1, r = 0.673**, r = 0.455*, r = 0.547**; in location 2, r = 0.649**, r = 0.373*, r = 0.610**) between K, Mg and S amounts of potato leaf and total tuber yields in the first year in every two locations. However, a statistically significant positive correlation (r = 0.622**) was also determined between Mg contents of leaves and total tuber yield in the second year in only location 2. The significant negative correlations (first year in location 1 r = -0.436*, in location 2 r = -0.373*, second year in location 2 r = -0.364*) were found between S contents of the leaves and dry matter amounts of tuber in every two years, except the location 1 in the second year.

Amounts (kg ha^{-1}) of K, Mg and S absorbed from the soil by potato tubers were presented in Table-8. It is seen in the Table, amounts of elements in question absorbed from the soil by tuber changed significantly depend on treatment, year and locations. The amounts of K, Mg and S taken up from the soil by tuber were the lowest level by treatment 7 in the first year in every two locations. The lowest amounts of K, Mg and S absorbed from the soil were obtained from treatments 7, 1 and 2 except some exceptions in the second year in every two locations. However, amounts of K, Mg and S absorbed from the soil by tuber were more in treatments 5 and 6 than the others. In every two years, in all locations except some exceptions generally treatments 5 and 6 formed first group, treatments 3 and 4 formed second group, treatments 1, 2 and 7 formed third group in terms of amounts of K, Mg and S absorbed from the soil by tuber according to Duncan test (Table-8).

In addition significant positive ($p < 0.01$) correlations (in first year in location 1 r = 0.479**, r = 0.479**, r = 0.551**; in location 2 r = 0.603**, r = 0.522**, r = 0.536**; in second year in location 1 r = 0.948**, r = 0.962**, r = 0.928**; in location 2 r = 0.973**, r = 0.979**, r = 0.980**, respectively) were statistically determined between amounts of K, Mg and S taken up from the soil by potato tuber and total tuber yields.

TABLE-7
EFFECTS OF DIFFERENT FERTILIZATIONS ON THE K, Mg AND S CONTENTS OF POTATO LEAVES TAKEN FLOWERING PERIOD† AND DUNCAN GROUPS AMONG THESE VALUES‡

Treatment	First year (2004)						Second year (2005)					
	K		Mg		S		K		Mg		S	
	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
1	3.02c	3.06c	0.34b	0.37ab	0.31c	0.31c	2.98b	3.03ab	0.37ab	0.32c	0.37c	0.39c
2	3.50ab	3.42b	0.37a	0.36b	0.32c	0.31c	3.25a	2.97b	0.37ab	0.38ab	0.42b	0.43abc
3	3.50ab	3.42b	0.37a	0.37ab	0.37b	0.37ab	3.26a	3.09ab	0.35b	0.37b	0.46a	0.45ab
4	3.62a	3.66a	0.39a	0.37ab	0.38ab	0.38a	3.15ab	3.04ab	0.39a	0.38ab	0.41b	0.40bc
5	3.70a	3.78a	0.37a	0.37ab	0.37b	0.36b	3.00b	3.00ab	0.37ab	0.40ab	0.47a	0.47a
6	3.61ab	3.63a	0.38a	0.39a	0.39a	0.38a	3.14ab	3.09ab	0.37ab	0.41a	0.39bc	0.38c
7	3.40b	3.36b	0.37a	0.36b	0.37b	0.37ab	3.15ab	3.24a	0.36ab	0.39ab	0.42b	0.43abc
Min.	3.02	3.06	0.34	0.36	0.31	0.31	2.98	2.97	0.35	0.32	0.37	0.38
Max.	3.70	3.78	0.39	0.39	0.39	0.38	3.26	3.24	0.39	0.41	0.47	0.47
LSD,p<0.05	0.206	0.183	0.0236	0.0241	0.0187	0.0197	0.229	0.263	0.0301	0.0304	0.038	0.0557

TABLE-8
EFFECTS OF DIFFERENT FERTILIZATIONS ON THE K, Mg AND S CONTENTS† ABSORBED BY POTATO TUBERS AND DUNCAN GROUPS AMONG THESE VALUES‡

Treatment	First year (2004)						Second year (2005)					
	K		Mg		S		K		Mg		S	
	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
1	235.68bcd	179.17c	14.54ab	12.99bc	13.60	12.72cd	115.91d	112.62d	8.36c	7.31d	14.50d	12.87de
2	280.41ab	184.55c	15.53ab	11.62cd	15.79	11.62d	114.01d	138.33c	8.30c	8.50cd	12.59de	13.86d
3	268.81abc	210.98ab	16.58a	13.16bc	14.19	13.25bcd	174.21c	180.90b	13.00b	11.52b	22.58b	17.40b
4	283.72a	192.53bc	16.11ab	13.41b	15.20	14.74abc	200.38b	168.69b	14.42b	9.70c	18.26c	15.07c
5	224.54cd	229.10a	13.96b	15.58a	14.96	16.52a	200.76b	271.23a	14.25b	18.53a	20.72b	26.78a
6	239.14abcd	222.21a	14.72ab	14.49ab	14.68	14.99ab	235.43a	281.14a	18.42a	17.78a	27.33a	26.19a
7	195.48d	156.45d	11.23c	10.84d	11.78	11.13d	125.39d	132.71cd	8.71c	8.63c	12.19e	12.54e
Min.	195.48	156.45	11.23	10.84	11.78	11.13	114.01	112.62	8.3	7.31	12.19	12.54
Max.	283.72	229.10	16.58	15.58	15.79	16.52	235.43	281.14	18.42	18.53	27.33	26.78
LSD p<0.05	45.31	21.60	2.489	1.626	2.689	2.177	17.80	20.00	1.438	1.348	1.940	1.149

L = Location; †=Values are average of 4 replications. ‡=Separately Duncan test were done for each location and difference between values shown with same letter is insignificant in 0.05 significant level, statistically.

On the other hand significant positive correlations (first year in location 1 r = 0.872**, r = 0.862**, r = 0.695**; in location 2 r = 0.449*, r = 0.506**, r = 0.409*; second year in location 1 r = 0.407*, respectively) between amounts of K, Mg and S absorbed from the soil by tuber and dry matter contents of tuber, were found. Relations between amounts of K, Mg and S taken up from the soil and dry matter contents of tuber were positive but statistically insignificant determined in the second year in location 2.

The correlation between amounts of K, Mg and S absorbed from the soil by potato tuber and contents of K, Mg and S of leaves changed depend on year, location and element. Generally, significant positive correlations were found between amount of same element taken up from the soil by tuber and their contents in the leaf.

The effects of different fertilizer applications on the tuber yields obtained in all locations were determined as statistically significant (Table-4). In addition according to Duncan test, in terms of tuber yield except some exceptions treatments 6 and 5 (difference between these treatments was significant in the first year in location 2 and in the second year in location 1) formed group 1, treatments 3 and 4 formed group 2, treatments 7 and 2 formed group 3 and control (treatment 1) formed final group (Table-5) and differences among the groups were found statistically significant. This situation may be resulted by increasing the tuber yields and sizes by fertilizer applications containing K, Ca, Mg and S in the side of N and P according to control supplying only N and P (Table-5). The soils belong to experiment places did not contain sufficient available K, Mg, Ca and S amounts or balance among was not suitable (Table-3). According to limits reported[12] in terms of sufficient nutrition of plants must be available (extractable with NH_4OAc) K, Ca and Mg amounts in soil at least 109.2, 1150 and 159.6 ppm. Available S amount to plant must be at least 10 ppm SO_4[16]. However it was reported that CEC of soil must be filled up about 65-85 % by Ca, 6-12 % by Mg and 3-5 % by K to absorbing by plants sufficiently[17]. In the same way, it was reported that Ca, Mg and K saturations must be 60, 10 and 5 %, respectively, ideal rates among changeable amounts Ca:K = 12, Ca:Mg = 6 and K:Mg = 0.5 around in the side of these elements found adequately in the soil for K, Ca, Mg absorbing sufficiently of plants[18]. In addition it was informed that rate between extractable with ammonium acetate (available to plant) K and Mg amounts in soil (K/Mg as me/100 g) must be 2:1 and 5:1 to absorb K and Mg from the soil by plants depend on plant species[17,19]. On the other hand it was reported that would obtained increasing in important levels in crop yields and K contents by K fertilization, if K:Mg rate is 1 or < 1 according to extractable amounts from the soil[19]. As a matter of fact K, Mg and S contents of the leaves increased as K, Mg and S increase with fertilizers applied into soil

(Table-7). The amounts of these elements absorbed by tuber increased significantly according to control (Table-8) may be resulted from these elements were not sufficient in experimental soils. In addition to the report[20], finding of statistically significant correlations between tuber yield and K, Mg and S contents of leaves and K, Mg and S taken up from the soil by tuber supported increasing occurred in the tuber yield by different fertilizer applications. In present studies, the fact that the lowest tuber yield was obtained in treatments 2 and 7 after control may be resulted from supplying of only K in addition N and P with these treatments and this K is KCl form (15.15.15 compose contains 12.5 % Cl^-) and high amounts of N applying with treatment 7. The fact that treatments 3 and 4 increased tuber yield. According to treatments 2 and 7 may be resulted from 50 kg Ca/ha and S with treatment 3 and Mg and S supplying with treatment 4 although K sources supplied with these treatments was same treatment 2 and 7. The fact that obtaining of the more total tuber yield and > 35 mm size tuber yield with the treatment 6 and 5 may be resulted from K, Mg and S amounts applied with these treatments and K sources was potassium sulphate in the side of K:Mg ratio. According to studies performed[21] potato plants that received sulphate had a higher tuber/shoot ratio and their tubers had a higher dry matter and starch content than those that received chloride because the translocation of assimilates as impaired at high Cl^- levels. The effect of K_2SO_4 as a fertilizer is also said to be better than that of KCl, particularly when large to very large amounts are used shortly before planting.

As reported[6] more of K suplied by fertilizers may result in different fertilizer applications on the tuber yield, potato took up more K than the other from the soil. According to analysis results (Table-7), in the leaf samples taken in the flowering time, K and Mg contents were insufficient according to limits (K: 6-8 and Mg: 0.7-1.0 %) reported[22] in every two years in all treatments. In the same way K contents of the leaves were adequate according to the limits (K: 5-6.6 and Mg: 0.25-0.80 %) reported[2] in every two years in all treatments. Mg contents of the leaves were sufficient.

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