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Nutrient Uptakes and N, P, K and Ca Utilization Rates of Some Plants Grown Under Greenhouse Conditions According to Farmer Practices

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ABSTRACT

In this study, it was aimed to determine the uptakes of N, P, K, Ca, Mg, Fe, Mn, Zn and Cu and utilization rates of N, P, K and Ca by cauliflower, lettuce, leek, onion and radish plants grown under greenhouse conditions depending on the farmer practices. For this reason, the breeding practices and fertilization program of the farmers were taken as the basis. The research was continued until the harvest period of each plant. According to the results of the analysis, significant differences (P<0.01) were found in examined parameters between the fertilized and non-fertilized treatments. Based on the nutrient uptake of the plants, it was seen that the radish plant removed the highest nutrient and the onion removed the least nutrient in both conditions. Considering the fertilizer nutrient utilization rates of plants as percentage for N, P, K, and Ca were 5.61, 4.31, 14.30, 75.30 for cauliflower; 11.39, 13.50, 38.70 and 22.31 for lettuce; 8.32, 8.06, 17.90, 43.0 for leek; 2.79, 2.50, 7.10, 41.80 for onion and 23.10, 33.83, 81.50 and 335 for radish plant. Although the applied fertilizers had a positive effect on the yield and nutrient concentrations of the plants, utilization rates were found to be quite low especially for N, P, and K. These results showed that these plants grown under greenhouse conditions according to farmer treatments were not fertilized properly.

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Sera Koşullarında Çifttçi Uygulamalarıyla Yetiştirilen Bazı Bitkilerin Besin Elementi Alımlarıyla N, P, K ve Ca Yararlanma Oranları

ÖZET

Bu çalışmada, çiftçi uygulamaları altında serada yetiştirilen karnabahar, marul, pırasa, soğan ve turp bitkilerinin N, P, K, Ca, Mg, Fe, Mn, Zn ve Cu alımlarıyla N, P, K ve Ca kullanım oranlarını belirlemek amaçlanmıştır. Bu nedenle, çiftiçilerin yetiştiricilik pratikleri ve gübreleme uygulamaları temel alınmıştır. Araştırma, her bitkinin hasat dönemine kadar sürdürülmüştür. Analiz sonuçlarına göre gübreli ve gübresiz uygulamalar arasında incelenen özellikler açısından istatistiksel olarak önemli farklar olduğu belirlenmiştir (P<0.01). Bitkilerin besin elementi alımlarına göre genel bir değerlendirme yapılırsa, her iki durumda da en fazla besin elementi alımının turp, en az besin maddesi alımının ise soğan tarafından gerçekleştiği görülmüştür. Gübrelerle uygulanan besin elementlerinden yararlanma oranları değerlendirildiğinde, bitkilerin N, P, K ve Ca'dan yararlanma oranlarının yüzde olarak karnabahar için sırasıyla 5.61, 4.31, 14.30 ve 75.30, marul için; 11.39, 13.50, 38.70 ve 22.30, pırasa için; 8.32, 8.06, 17.90 ve 43.0, soğan için; 2.79, 2.50, 7.10 ve 41.80, turp için; 23.10, 33.83, 81.50 ve 335.0 olduğu belirlenmiştir. Uygulanan gübreler, bitkilerin verim ve besin elementi içeriklerini olumlu etkilemiş olsa da, özellikle N, P ve K için yararlanma oranlarının oldukça düşük olduğu görülmüştür. Bu sonuçlar, sera koşullarında çiftiçi uygulamalarına göre yetiştirilen bu bitkilerin uygun gübrelenmediğini göstermektedir.

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INTRODUCTION

Due to the continuous increase in the world population, the need for food is increasing day by day while usable agricultural lands are decreasing. This situation shows that higher yield should be obtained from a unit area. The best and fast way to get higher yield is to use chemical fertilizers. Although chemical fertilizers are the most important inputs for these purposes, it should not be forgotten that their unconscious use can cause irreparable harms to the environment and soil. For this, the applied fertilizers must be taken by the plants without any loss. Therefore, the needs of the plants should be taken into account. Fertilizer utilization efficiency (FUE) is an indicator of how much of the applied fertilizer is used by plants. Although there are several descriptions for FUE in the literature, it is also used as fertilizer recovery rates by plants (Rakshit et al., 2015; Hawkesford et al., 2016). Appropriate fertilizer selection and the correct determination of the amount needed are important in terms of issues such as yield, quality, soil health and environmental impact (Ayoub, 1999). Otherwise, problems such as salinity, heavy metal accumulation, plant nutrient imbalance, nitrate and phosphate accumulation occur in the soils if over fertilization is made (Sönmez & Kaplan, 2004; Pradika et al., 2019). Excessive and unbalanced fertilization adversely affect the yield, amount and quality as well as the damage it causes to the environment (Tang et al., 2022). For the sustainability of soil fertility and prevention of environmental pollution, the applied fertilizers should have been used by plants in a large extent. Over and unbalanced fertilization are the most important environmental problems we faced in agricultural practices especially under greenhouse production (Engindeniz et al., 2010). In Antalya region, it was determined that 61% of the fertilizer used by farmers is in parallel with the amount of fertilizer used in the EU countries, but 39% of the farmers used fertilizer 10 times more than Turkey's average (Atılgan et al., 2007).

In this study, it was aimed to determine the uptakes of N, P, K, Ca, Mg, Fe, Mn, Zn, and Cu by cauliflower, lettuce, leek, onion, and radish plants. It is also aimed to determine the utilization rates of N, P, K and Ca from the applied fertilizers under farmer practices.

MATERIALS and METODS

The experimental area

The experiment was carried out under greenhouse condition in Elmalı district of Antalya. Initial soil properties of the greenhouse are given in Table 1. As can be seen from there, the soil has a neutral pH and clay loam texture without salinity problem. Organic matter and $CaCO_3$ contents of soil are moderate. Plant available nutrient concentrations in the soil are sufficient, except Mn (Alpaslan et al., 1998).

Table 1. Some characteristics of the experimental soil
Çizelge 1. Deneme toprağının bazı özellikleri

Properties	Results	References
Texture	Clayey loamy	(Bouyoucos, 1936)
pH (saturation)	7.3	(Peech, 1965)
EC (saturation) (dS m^{-1})	0.7	
$CaCO_3$ (g kg^{-1})	64	(Allison & Moodie, 1965)
Organic matter (g kg^{-1})	21	(Walkley & Black, 1934)
Total N (g kg^{-1})	2.7	(Kacar, 1994)
Olsen P (mg kg^{-1})	67	(Olsen, 1954)
Exchangeable K (mg kg^{-1})	520	(Jackson, 1967)
Exchangeable Ca (mg kg^{-1})	3944	
Exchangeable Mg (mg kg^{-1})	482	
DTPA extractable Fe (mg kg^{-1})	9.1	(Lindsay & Norvell, 1978)
DTPA extractable Zn (mg kg^{-1})	5.8	
DTPA extractable Mn (mg kg^{-1})	4.8	
DTPA extractable Cu (mg kg^{-1})	10.5	

Plant materials

In the study, *Igloo* variety for cauliflower, *Yedikule* variety for lettuce, *İnegö*l92 variety for leeks *İri kırmızı* variety for radish and *Hazar* variety for onion were used.

Fertilizers

During the experiment, 12 different fertilizers were used and all fertilization program was prepared by the producer. Fertilizers used were: 15.15.15, 18.18.18, 16.8.24, 10.0.40, 20.10.20, mono ammonium phosphate (MAP, 12.61.0), mono potassium phosphate (MKP, 0-52-34), potassium nitrate (13-0-46), magnesium nitrate (10.0.0+15), calcium nitrate (15.5-0-0+26.5), nitric acid (55%) and urea (46%). The list of fertilizers and the total amount of each nutrient is given in Table 2. As it seen there, 28.7 kg N da^{-1}, 8.81 kg P da^{-1}, 16.8 kg K da^{-1}, 2.51 kg Ca da^{-1} and 0.09 kg Mg da^{-1} were used as fertilizer during the growing periods.

Table 2. List of the fertilizers and total nutrient amounts used for experiment
Çizelge 2. Denemede kullanılan gübreler ve toplam besin elementi miktarları

Fertilizers	Amount (kg da^{-1})	Pure nutrient amounts (kg da^{-1})				
		N	P	K	Ca	Mg
20.10.20	26.02	5.20	1.14	4.28		
18.18.18	18.37	3.31	1.45	2.74		
16.8.24	15.81	2.53	0.55	3.14		
10.0.40	5.10	0.51		1.69		
Calcium nitrate (15.5-0-0+26.5)	13.27	2.06			2.51	
MKP (0-52-34)	9.18		2.08	2.58		
Urea (46)	26.02	11.97				
MAP (12-61)	12.24	1.47	3.26			
Potassium nitrate (13-0-46)	4.59	0.60		1.74		
Magnesium nitrate (10-0-0+15)	1.02	0.10				0.09
Nitric acid (55 %)	2.04	0.19				
15.15.15	5.10	0.76	0.33	0.63		
Total amount of nutrients (kg da^{-1})		28.70	8.81	16.80	2.51	0.09

METHODS

Set up of the experiment

The experiment was carried out in greenhouse conditions in Antalya, Elmalı district. All plants were grown in the same greenhouse with the homogeneous conditions at the same time. The study was carried out in accordance with the farmer practices. Before plantings, the seeds of plants were sown in peat-mixed crates in March. The plants that became seedlings were planted in the greenhouse in April. Study was planned according to randomized parcel design with four replications. Each replication was arranged 4x5 m parcels as 4 rows for each crop. While row spacing was 100 cm for all plants, row in spacing was 7 cm for leeks and radishes, 33 cm for cauliflower, 20 cm for lettuce and 5 cm for onions. After experiment set up and the necessary soil preparations were made, all practices, fertilizations and records keeping were made by the farmer. Fertilization was made with the fertigation technique by drip irrigation and the fertilizer amounts used were recorded at each application.

Harvest

All plants were grown until the harvest time. Whole plants including roots were harvested and cleaned from the soil. After plants were washed with tap water they were weighted to receive a fresh yield amount. The leaf and tuber of the radish plant were evaluated separately. In order to determine the moisture contents of plants, 3 fresh plants from each replication were taken randomly and washed with pure water. After free water was removed from the plants, their fresh weight was measured. Then, they were divided into small parts and kept at 70°C until they reach a constant weight to determine moisture contents of plants. The moisture contents were used to convert fresh weights in to dry weights.

Plant analysis procedures

Dried plants were grinded and 0.5 g was weighted for dry digestion at 550 °C for P, K, Ca, Mg, Fe, Zn, Mn and Cu analysis. While vanadomolybdate yellow color method was used for P determination; K, Ca, Mg, Fe, Zn, Mn and Cu measurements were made using atomic absorption spectrophotometer (Jones, 1991). Nitrogen concentration was determined according to the Kjeldahl method (Bremner, 1965). Nutrient analysis was performed on whole plant (root+obove ground parts together) except radish. The leaf and tuber of the radish were analyzed separately.

Nutrient utilization rates

The amount of nutrients that the plants removed from each plot was obtained by multiplying the dry weights of the plants with the nutrient concentrations, then converted to area (da). In order to determine the nutrient utilization rates, the difference between the nutrients taken by the plants from the soil in the fertilized and non-fertilized plots was calculated and proportioned to the applied fertilizer. Nutrient

utilization rates were calculated only for N, P, K, and Ca. For other elements, only the amounts taken from the soil were determined because they were not applied as fertilizers.

For example (N), N utilization rate was calculated by comparing the total N removal to applied N doses as described in the following equations given by Erdal et al. (2006).

NU (kg da^{-1}) = DM × NC

NUF (kg da^{-1}) = NU_1 - NU_0

NUR (%) = NUF × 100/NF

Where NU is N uptake (kg da^{-1}), DM is oven dry matter (kg da^{-1}), NC is N concentration (g kg^{-1}), NUF is N uptake from fertilizer (kg da^{-1}), NU_1 is N uptake from fertilized plots (kg da^{-1}), NU_0 is N uptake from control plots (kg da^{-1}), NUR is N utilization rates (%), and NF is N application dosage with fertilizer (kg da^{-1})

Statistical analysis

Analysis of variance (ANOVA) followed by Tukey test was performed using Minitab 19 package program (https://www.minitab.com/en-us/products/minitab/free-trial/).

RESULTS

Nutrient utilization rates from the applied fertilizers

Nitrogen uptakes and N utilization rates (NUR) of plants were given in Table 3. As indicated there, yields, N concentrations and N uptakes of all plants were affected by the N fertilization. Fresh yield values of cauliflower, lettuce, leek, onion, radish tuber and radish leaf increased from 1564 to 1745 kg, 3169 to 3645 kg, 2105 to 2302 kg, 1034 to 1136 kg, 3383 to 3565 and 1999 to 2204 kg respectively.

Table 3. Nitrogen uptake and nitrogen utilization rates of plants
Çizelge 3. Azot alımı ve bitkilerin azottan yararlanma oranları

Applied N (kg da^{-1})	Fresh weight (kg da^{-1})		Dry weight (kg da^{-1})		N Concentration (g kg^{-1})		N uptake (kg da^{-1})		NUF (kg da^{-1})		NUR (%)
					Cauliflower						
28.71	1745 ±65a*		153 ±6a		39.2 ±0.3a		6.00 ±0.26a		1.61		5.61
0	1564 ±108b		124 ±9b		35.4 ±0.4b		4.39 ±0.05b				
					Lettuce						
28.71	3645 ±128a		242 ±9a		36.4 ±0.5a		8.81 ±0.42a		3.27		11.39
0	3169 ±184b		173 ±10b		32.0 ±0.7b		5.54 ±0.11b				
					Leek						
28.71	2302 ±98a		224 ±7a		27.0 ±0.9a		6.05 ±0.47a		2.39		8.32
0	2105b±66b		177 ±6b		20.7 ±0.3b		3.66 ±0.05b				
					Onion						
28.71	1136 ±41b		83 ±3a		28.2 ±0.7a		2.34 ±0.14a		0.80		2.79
0	1034 ±43b		64 ±3b		24.0±0.2b		1.54 ±0.01b				
					Radish						
	L	T	L	T	L	T	L	T	L	T	Total
28.71	2204 ±75a	3565±114a	372±13a	241 ±8a	41.8 ±0.6a	27.6 ±0.5a	15.6 ±0.7a	6.65 ±0.32a	4.8	1.83	23.1
0	1999 ±95b	3383 ±138b	289 ±11b	184 ±8b	37.2 ±0.5b	26.2 ±0.3b	10.8 ±0.14b	4.82 ±0.06b			

*: There is no significant differences between the values sharing the same letters in the same column (P<0.01). L: leaf, T: tuber

Similarly, N concentrations of plants increased from 35.4 to 39.2 g kg^{-1} in cauliflower, 32.0 to 36.4 g kg^{-1} in lettuce, 20.7 to 27.0 g kg^{-1} in leek, 24.0 to 28.2 g kg^{-1} in onion, 37.2 to 41.8 g kg^{-1} in radish leaf and 26.2 to 27.6 g kg^{-1} in radish tuber. The amounts of N taken from the soil under fertilized and non-fertilized conditions were 6 and 4.39 kg da^{-1} for cauliflower, 8.81 and 5.54 kg da^{-1} for lettuce, 6.05 and 3.66 kg da^{-1} for leek, 2.34 and 1.54 kg da^{-1} for onion 15.6 and 10.8 kg da^{-1} for radish leaf and 6.65 and 4.82 for radish tuber. Depending on the given values, N uptake from fertilizers (NUF) was calculated as 1.61, 3.27, 2.39, 0.80 and 6.63 (4.8+1.83) kg da^{-1} for cauliflower, lettuce, leek, onion and radish, respectively. When the NUF was compared to the applied N amount, it can be seen that the NUR of cauliflower, lettuce, leek, onion and radish plants are 5.61, 11.39, 8.32, 2.79 and 23.1 %, respectively.

Phosphorus concentrations, uptakes and P utilization rates (PUR) of different vegetable crops are given in Table 4. The P concentrations of plants in P-treated conditions were higher than the plants grown in non-fertilized conditions. Additionally, P uptakes of plants under fertilized conditions were significantly higher comparing to control groups. While cauliflower, lettuce, leek, onion and radish (L+T) removed 1.42, 2.59, 1.86, 0.52 and 6.88 kg P da^{-1} under fertilized conditions, they took 1.04, 1.40, 1.15, 0.30 and 3.90 kg

P da^{-1}, respectively. When the amount of P taken from the fertilizer (PUF) was examined, it was seen that there were significant differences between plants. While the highest P uptake was realized by the radish plant with 2.98 kg da^{-1}, the lowest P uptake was realized by the onion plant with 0.22 kg da^{-1}. Similar to PUF, PUR varied with the plants. While the radish used the highest fertilizer P (33.83 %), lettuce plant followed this with 13.50 %. After these two plants, the leek took the 3rd line with 8.06 % in terms of PUR. Onion and cauliflower were the plants using the lowest fertilizer P with the rates of 2.50 and 4.31 percent.

Potassium concentrations of vegetables grown under fertilized and non-fertilized conditions significantly differed from each other (Table 5). The K concentrations of cauliflower, lettuce, leek, onion, radish leaves and radish tuber were determined as 52-45, 74-66, 43-38, 39-31, 68 -58 and 68-61 g kg^{-1} under fertilized and non-fertilized conditions, respectively. Again, in the same order, plants grown in fertilized and non-fertilized conditions removed 8.0-5.6, 17.9-11.4, 9.7-6.7, 3.2-2.0 and 41.7-28.0 kg K da^{-1} from the soil. According to the calculations based on the K difference taken by the plants in the fertilized and unfertilized conditions, it was seen that cauliflower, lettuce, leek, onion, radish plants recovered 2.4, 6.5, 3.0, 1.2 and 13.7 kg da^{-1} of the applied fertilizer, respectively. K utilization rates (KUR) of cauliflower, lettuce, leek, onion, radish from fertilizer was found as 14.3, 38.7, 17.9, 7.7 and 81.5 %, respectively.

Table 4. Phosphorus uptake and phosphorus utilization rates of plants
Çizelge 4. Bitkilerin fosfor alımı ve fosfordan yararlanma oranları

Applied P (kg da^{-1})	Dry weight (kg da^{-1})	P concentration (g kg^{-1})	P uptake (kg da^{-1})	PUF (kg da^{-1})	PUR (%)
		Cauliflower			
8.81	153 ±6a*	9.3 ±0.6a	1.42 ±0.04a	0.38	4.31
0	124 ±9b	8.4 ±0.4b	1.04 ±0.01b		
		Lettuce			
8.81	242 ±9a	10.7 ±1a	2.59 ±0.37a	1.19	13.50
0	173 ±10b	8.1 ±0.7b	1.40 ±0.12b		
		Leek			
8.81	224 ±9a	8.3 ±0.6a	1.86 ±0.20a	0.71	8.06
0	177 ±6b	6.5 ±0.5b	1.15 ±0.09b		
		Onion			
8.81	83 ±3a	6.3 ±0.3a	0.52 ±0.04a	0.22	2.50
0	64 ±3b	4.7 ±0.3b	0.30 ±0.02b		
		Radish			

	L	T	L	T	L	T	L	T	Total
8.81	372 ±12a	241 ±7a	12.2 ±0.6a	9.7 ±1a	4.54 ±0.4a	2.34 ±0.3a	1.82	1.16	33.83
0	289 ±10b	184 ±7b	9.4 ±0.8b	6.4 ±0.5b	2.72 ±0.2b	1.18 ±0.1b			

*: There is no significant differences between the values sharing the same letters in the same column (P<0.01). L: leaf, T: tuber

As other nutrients, Ca concentrations and uptakes of plants were higher under fertilized conditions. While Ca concentrations of cauliflower, lettuce, leek, onion, radish leaf and radish tuber were 48.7, 4.6, 16.3, 34.6, 28.7 and 27.7 g kg^{-1} under fertilized conditions, they were measured as 44.8, 3.2, 14.5, 28.5, 16.06 and 22.6 g kg^{-1} under control conditions (Table 6). Looking at the differences in Ca uptakes of plants between fertilized and control plots, it was seen that the radish plant received the highest amount of Ca from fertilizer (CaUF, 8.4 kg da^{-1} in total, L+T) which is 3.3 times higher than applied Ca. While Ca uptakes of other plants varied between 0.56 (lettuce) and 1.89 (cauliflower) kg da^{-1}, Ca utilization rates (CaUR) were between 22.3 and 75.3%.

Table 7 shows the nutrient utilization rates for N, P, K and Ca of all plants comparatively. As seen there, the plant with the highest nutrient utilization rates was radish with the use of 23.10 % of the nitrogen fertilizer given. This was followed by lettuce, which utilized about 11.39 % of fertilizer nitrogen. The plant that benefited least from the applied fertilizer nitrogen was onion. Similar trends were observed for other nutrients as well. When a ranking was made by looking at the utilization rates of the applied N, P and K fertilizers, it was seen that the order was radish>lettuce>leek>cauliflower>onion.

Magnesium, Fe, Mn and Cu uptakes of the crops

Nutrient concentrations and removals of crops under fertilized and non-fertilized conditions are given in Table 8. Results showed that Mg, Fe, Mn, Zn and Cu concentrations and uptakes of plants under fertilized conditions were significantly higher when compared to non-fertilized conditions.

Table 5. Potassium uptake and potassium utilization rates of plants
Çizelge 5. Bitkilerin potasyum alımı ve potasyumdan yararlanma oranları

Applied K (kg da^{-1})	Fresh weight (kg da^{-1})		Dry weight (kg da^{-1})		K concentration (g kg^{-1})		K Uptake (kg da^{-1})		KUF (kg da^{-1})		KUR (%)
Cauliflower											
16.80	1745 ±65a*		153 ±10a		52 ±5a		8.0 ±0.4a		2.4		14.3
0	1564 ±107b		124 ±9b		45 ±5b		5.6 ±0.4b				
Lettuce											
16.80	3645 ±128a		242 ±10a		74 ±8a		17.9 ±0.9a		6.5		38.7
0	3169 ±184b		173 ±10b		66 ±6b		11.4 ±0.3b				
Leek											
16.80	2302 ±98a		224 ±10a		43 ±5a		9.7 ±0.7a		3.0		17.9
0	2105 ±66b		177 ±6b		38 ±4b		6.7 ±0.7b				
Onion											
16.80	1136 ±41a		83 ±3a		39 ±2a		3.2 ±0.3a		1.2		7.1
0	1034 ±43b		64 ±3b		31 ±2b		2.0 ±0.1b				
Radish											
	L	T	L	T	L	T	L	T	L	T	Total
16.80	2204 ±74a	3565 ±114a	372 ±13	241 ±8a	68 ±6a	68 ±5a	25.3 ±2a	16.4 ±3a	8.5	5.2	81.5
0	1999 ±94b	3383 ±138b	289 ±11b	184 ±8b	58 ±7b	61 ±8b	16.8 ±2b	11.2 ±3b			

*: There is no significant differences between the values sharing the same letters in the same column (P<0.01). L: leaf, T: tuber

Table 6. Calcium uptake and calcium utilization rates of plants
Çizelge 6. Bitkilerin kalsiyum alımı ve kalsiyumdan yararlanma oranları

Applied Ca (kg da^{-1})	Fresh weight (kg da^{-1})		Dry weight (kg da^{-1})		Ca conc. (g kg^{-1})		Ca uptake (kg da^{-1})		CaUF (kg da^{-1})		CaUR (%)
Cauliflower											
2.51	1745 ±65a*		153 ±6a		48.7 ±8a		7.45 ±0.4a		1.89		75.3
0	1564 ±108b		124 ±8b		44.8 ±3b		5.56 ±0.3b				
Lettuce											
2.51	3645 ±128a		242 ±8a		4.6±0.3a		1.11 ±0.1a		0.56		22.3
0	3169 ±184b		173 ±10b		3.2 ±0.2b		0.55 ±0.04b				
Leek											
2.51	2302 ±98a		224 ±9a		16.3 ±0.6a		3.65 ±0.3a		1.08		43.0
0	2105 ±66b		177 ±5b		14.5 ±0.3b		2.57 ±0.1b				
Onion											
2.51	1136 ±42a		83 ±3a		34.6 ±1a		2.87 ±0.2a		1.05		41.8
0	1034 ±43b		64 ±3b		28.5 ±1b		1.82 ±0.1b				
Radish											
	L	T	L	T	L	T	L	T	L	T	Total
2.51	2204 ±74a	3565 ±114a	372 ±13a	241 ±7a	28.7±1.5a	27.7 ±1a	10.7 ±0.9a	6.7 ±0.51a	5.9	2.5	335
0	1999 ±94b	3383 ±138b	289 ±11b	184 ±7b	16.0 ±0.7b	22.6 ±0.8b	4.8 ±0.2b	4.2 ±0.14b			

*: There is no significant differences between the values sharing the same letters in the same column (P<0.01).
L: leaf, T: tuber

Çizelge 7. Comparing the plants in terms of nutrient utilization rates
Çizelge 7 Bitkilerin besin elementlerinden yararlanma oranlarına göre karşılaştırılması

Plants	Nutrient utilization rates (%)			
	N	P	K	Ca
Cauliflower	5.61 ±0.6d*	4.31 ±0.9d	14.3 ±2.2d	75.3 ±9b
Lettuce	11.39 ±1.4b	13.50 ±4.1b	38.7 ±5.1b	22.3 ±7e
Leek	8.32 ±1.6c	8.06 ±2.3c	17.9 ±3.9c	43.0 ±7c
Onion	2.79 ±0.4e	2.50 ±0.9e	7.1 ±1.6e	41.8 ±8d
Radish (L+T)	23.10 ±3.7a	33.83 ±6.0a	81.5 ±12a	335.0 ±15a
Means	10.2	12.4	32.1	104.7

*: There is no significant differences between the values sharing the same letters in the same column (P<0.01). L: leaf, T: tuber

Table 8. Comparing the Mg, Fe, Mn, Zn and Cu concentrations and uptakes of plants under fertilized and non-fertilized conditions
Çizelge 8. Bitkilerin gübreli ve gübresiz koşullardaki Mg, Fe, Mn, Zn ve Cu konsantrasyonları ve alımlarının karşılaştırılması

Fertili-zation	Dry weight (kg da^{-1})	Mg conc. (g kg^{-1})	Mg upt. (kg da^{-1})	Fe conc. (mg kg^{-1})	Fe uptake (g da^{-1})	Mn conc. (mg kg^{-1})	Mn uptake (g da^{-1})	Zn conc. (mg kg^{-1})	Zn uptake (g da^{-1})	Cu conc. (mg kg^{-1})	Cu uptake (g da^{-1})
					Cauliflower						
+	153 ±5.7a*	6.4 ±0.3a	0.98 ±0.06a	190 ±3.8a	29 ±1.6a	154 ±4.5a	24 ±1.5a	44 ±2.7a	6.7 ±0.6a	10.4 ±1.3a	1.6 ±0.3a
-	124 ±8.5b	4.4 ±0.1b	0.55 ±0.02b	169 ±1.7b	21 ±0.2b	137 ±1.7b	17 ±0.2b	31 ±1.4b	3.8 ±0.2b	5.5 ±0.8b	0.7 ±0.1b
					Lettuce						
+	242 ±8.5a	4.8 ±0.6a	1.16 ±0.19a	264 ±13.0a	64 ±5.2a	126 ±9.1a	30 ±3.2a	28 ±3.3a	6.8 ±0.7a	14.2 ±1.6a	3.4 ±0.5a
-	173 ±10.0b	3.6 ±0.3b	0.62 ±0.06b	229 ±10.4b	40 ±1.8b	106 ±5.0b	18 ±0.8b	19 ±0.7b	3.3 ±0.1b	5.4 ±0.7b	0.9 ±0.1b
					Leek						
+	224 ±9.5a	3.9 ±0.3a	0.89 ±0.11a	137 ±4.5a	31 ±2.3a	66 ±7.0a	15 ±2.1a	22 ±2.3a	4.9 ±0.7a	8.5 ±1.1a	1.9 ±0.3a
-	177 ±5.5b	3.2 ±0.1b	0.57 ±0.03b	120 ±2.5b	21 ±0.4b	44 ±2.3b	8 ±0.4b	15 ±0.7b	2.7 ±0.1b	5.8 ±0.3b	1.0 ±0.1b
					Onion						
+	83 ±3.0a	5.4 ±0.4a	4.4 ±0.05a	88 ±4.1a	7.3 ±0.5a	73 ±1.9a	6 ±0.4a	29±1.4a	2.4 ±0.2a	15.4 ±0.9a	1.3 ±0.1a
-	64 ±2.6b	3.7 ±0.3b	0.24 ±0.03b	68 ±1.5b	4.4 ±0.1b	60 ±0.9b	4 ±0.6b	23 ±0.7b	1.5 ±0.1b	9.6 ±0.8b	0.6 ±0.1b
					Radish						
	L T	L T	L T	L T	L T	L T	L T	L T	L T	L T	L T
+	372±12a 241±7a	4.5±0.4a 4.7± 0.1a	1.7 ± 0.2a 1.1 ± 0.1a	269± 23a 80 ± 3a	100± 11a 19 ± 1.3a	136 ± 9a 33 ± 3.4a	51 ± 4.8a 8 ± 1.5a	30 ± 2.8a 41 ± 2.6a	11 ± 1.4a 9 ± 0.9a	15.4 ± 1.3a 12 ± 1.6a	5.7 ± 0.7a 2.8 ± 0.5a
-	289±10b 184± 7b	3.4 ± 0.4b 4.1 ± 0.1b	1.0 ± 0.1b 0.8 ± .02b	198± 7b 63± 2b	57 ± 2b 12 ± 0.4b	105 ± 8b 21 ± 0.6b	30 ± 2.4b 4± 0.11b	20 ± 1.5b 29 ± 1.6b	6 ± 0.4b 6± 0.1b	9.0± 0.4b 8 ± 0.8b	2.6 ± 0.1b 1.5 ± 0.2b

*: There is no significant differences between the values sharing the same letters in the same column (P<0.01). L: leaf, T: tuber

Comparing the plants in terms of nutrient concentrations, nutrient uptakes and fertilizer use efficiencies

Comparing with the nutrient concentrations of crops, it can be seen that there was a significant difference between the plants under both fertilized and non-fertilized conditions (Table 9). The highest nutrients measured under non-fertilized conditions were in the leaves of radish plant for N and P, the highest value for K and Fe were measured in lettuce, the highest Ca, Mg, Mn and Zn values were measured in cauliflower, the highest Cu was measured in onion plant. Similarly, the highest nutrient concentrations of crops under fertilized conditions followed the same order as in non-fertilized condition. Furthermore, the lowest nutrients under both conditions were found to be similar except for Cu.

Removed nutrients from the soil by different crops were given in Table 10. The highest nutrient uptakes was realized by the radish plant. On the other hand, it was determined that the least nutrient uptakes were realized by the onion plant, except for Ca under non-fertilized conditions. In both conditions, lettuce was the second plant that removed the highest nutrients with a general evaluation.

Çizelge 9. Comparing the nutrient concentrations of plants under non-fertilized and fertilized conditions
Çizelge 9. Gübresiz ve gübreli koşullarda bitkilerin besin elementi konsantrasyonlarının karşılaştırılması

Plants *(Bitkiler)*	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	(g kg^{-1})					(mg kg^{-1})			
Non fertilized condition									
Cauliflower	35.4 ±0.4b*	8.4±0.4b	45 ±5d	44.8 ±3a	4.4 ±0.1a	169±1.7c	137 ±1.7a	31 ±1.4a	5.5 ±0.8d
Lettuce	32.0 ±0.7c	8.1±0.7c	66 ±6a	3.2 ±0.2f	3.6 ±0.3d	229 ±10.4a	106 ±5.0b	19 ±0.7e	5.4 ±0.7d
Leek	20.7 ±0.3f	6.5±0.5d	38 ±6e	14.5 ±0.3e	3.2 ±0.1f	120 ±2.5d	44±2.3e	15±0.7f	5.8 ±0.3d
Onion	24.0 ±0.2e	4.7±0.3f	31 ±2f	28.5 ±1b	3.7 ±0.3c	68±1.5e	60 ±0.9d	23 ±0.7c	9.6 ±0.8a
Radish leaf	37.2 ±0.5a	9.4±0.8a	58 ±7c	16.0 ±0.7d	3.4 ±0.4e	198±7b	105 ±8.2c	20±1.4d	9.0 ±0.3b
Radish tuber	26.2 ±0.3d	6.4±0.5e	61 ±8b	22.6 ±0.8c	4.1 ±0.1b	63±2f	21±0.6f	29±1.6b	8.2 ±0.8c
Fertilized condition									
Cauliflower	39.2 ±0.3b	9.3±0.6bc	52 ±5c	48.7 ±8a	6.4 ±0.3a	190 ±3.8b	154 ±4.5a	44 ±2.7a	10.4 ±1.35c
Lettuce	36.4 ±0.5c	10.7±1ab	74 ±8a	4.6 ±0.3e	4.8 ±0.6bc	264 ±13.0a	126 ±9.1b	28 ±3.3b	14.2 ±1.65ab
Leek	27.0 ±0.9d	8.3±0.6c	43 ±5d	16.3 ±0.6d	3.9 ±0.3c	137±4.5c	66±7.1c	22 ±2.3c	8.5 ±1.19c
Onion	28.2 ±0.7d	6.3±0.3d	39 ±2e	34.6 ±1b	5.4 ±0.4b	88±4.1d	73±1.9c	29 ±1.4b	15.4 ±0.99a
Radish leaf	41.8 ±0.6a	12.2±0.6a	68 ±6b	28.7 ±1.5	4.5 ±0.4bc	269 ±23.5a	136 ±9.0b	30 ±2.8b	15.4 ±1.26a
Radish tuber	27.6 ±0.5d	9.7±1bc	68 ±5b	27.7c ±1c	4.7 ±0.1bc	80±3d	33 ±3.4d	41 ±2.6a	12.0 ±1.61bc

*: There is no significant differences between the values sharing the same letters in the same column (P<0.01).
L: leaf, T: tuber

Table 10. Comparing the nutrient uptakes of crops under non-fertilized and fertilized conditions
Çizelge 10. Bitkilerin gübresiz ve gübreli koşullardaki besin elementi alımlarının karşılaştırılması

Plants *(Bitkiler)*	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	(kg da^{-1})					(g da^{-1})			
Non fertilized conditions									
Cauliflower	4.39 ±0.05c**	1.04 ±0.01d	5.6 ±0.4d	5.56 ±0.3b	0.55 ±0.02d	21.0 ±0.2d	17 ±0.2c	3.8 ±0.2b	0.7 ±0.1d
Lettuce	5.54 ±0.11b	1.40 ±0.12b	11.4 ±0.3b	0.55 ±0.04e	0.62 ±0.06b	40.0 ±1.8b	18 ±0.8	3.3 ±0.1c	0.9 ±0.1b
Leek	3.66 ±0.05d	1.15 ±0.09c	6.7 ±0.7c	2.57 ±0.1c	0.57 ±0.03c	21.0 ±0.4c	8±0.4d	2.7 ±0.1d	1.0 ±0.1c
Onion	1.54 ±0.01e	0.30 ±0.02e	2.0 ±0.1e	1.82 ±0.1d	0.24 ±0.03e	4.4 ±0.1e	4±0.6e	1.5 ±0.1e	0.6 ±0.1e
Radish (L+T)	15.62 ±0.20a	3.90 ±0.34a	28±4.0a	9.00±0.3a	1.73 ±0.13a	69.0 ±2.5a	34 ±2.5a	12.0 ±0.5a	4.1 ±0.3a
Fertilized conditions									
Cauliflower	6.00 ±0.26d	1.42 ±0.04d	8.0 ±0.4d	7.45 ±0.4b	0.98 ±0.06d	29 ±1.6d	24 ±1.53c	6.7 ±0.6b	1.6 ±0.3d
Lettuce	8.81 ±0.42b	2.59 ±0.37b	17.9 ±0.9b	1.11 ±0.1e	1.16 ±0.19b	64 ±5.2b	30 ±3.2b	6.8 ±0.7c	3.4±0.5
Leek	6.05 ±0.47c	1.86 ±0.20c	9.7 ±0.7c	3.65 ±0.3c	0.87 ±0.11c	31 ±2.3c	15 ±2.1d	4.9 ±0.7d	1.9 ±0.3c
Onion	2.34 ±0.14e	0.52 ±0.04e	3.2 ±0.3e	2.87 ±0.2d	0.45 ±0.05e	7.3 ±0.5e	6±0.4e	2.4 ±0.2e	1.3 ±0.1e
Radish (L+T)	22.25 ±1.06a	6.88 ±0.70a	41.7 ±2.0a	17.4 ±1.4a	2.80 ±0.26a	119 ±13a	59 ±6.3a	20 ±2.3a	8.5 ±1.1a

*: There is no significant differences between the values sharing the same letters in the same column (P<0.01). L: leaf, T: tuber

DISCUSSION

Results of this study indicated that fertilization resulted in increases in yield of whole plants comparing to non-fertilized conditions even about all nutrients were sufficient. This can be due to readily availability and immediate and fast contribution of chemical fertilizers nutrients to plants until they receive soil nutrients (Havlin et al., 2016). Results also

indicated that nutrient concentrations and uptakes were significantly different between the crops. This was well documented in previous studies that plants take different amount of nutrients even they grow under the same conditions due to their genotypically different adaptation mechanism (Kucukyumuk & Erdal, 2011; Nazlı & Erdal, 2019; Sun et al., 2020). Relating to nutrient concentrations and uptakes, plants showed great differences in terms of nutrient use efficiencies (Baligar et al., 2001). In general, it was seen that N, P and K utilization rates from fertilizers are low when compared to different plants under different conditions (Hesterman et al., 1987; Raun & Johnson, 1999; Erdal et al., 2006; Şahin, 2016; Dhillon et al., 2019). Previous studies implied that fertilizer utilization rates were low, and overall fertilizer use rates are about or lower than 50 % for N, less than 10 % for P, and about 40 % for K (Baligar & Bennett 1986a,b). Lower utilization rateswas related to leaching and run-off, gaseous losses, fixation by soil, and use of inefficient nutrient absorbing/utilizing plant species or cultivars. Şahin (2016) indicated that the fertilizer utilization rate of the plants was around 50-60% depending on the type of fertilizer, application method and plant type. Loses of nutrients from the soil can be the other important reason for lower nutrient use efficiencies of plants especially for N fertilizers. Ladha et al. (2005) reported that fertilizer N-use efficiency of crops was 30 to 50% and the rest of N either remains in the soil or it is lost from the soil. In previous studies it was reported that recovery from the applied phosphorus fertilizers rarely exceeded 25% and this rate was mostly 10-15% (Johnston et al., 2014; Roberts & Johnston 2015). Results on fertilizer use efficiencies showed that, all plants recovered quite below N, and only P recovery by radish plant was close to average values indicated in previous values. Only K use from fertilizer by radish plant was over the values given by literature. This may be explained with higher nutrient demand of this plant (Zhang et al., 2019). Contrary to low N, P and K recovery, calcium utilization rates from fertilizers were quite high. Even over 100% in radish plant. This can be explained by that the radish plant plant took higher Ca from the soil than applied by fertilizers. The biggest reason for lower N, P and K use efficiencies was excessive and unbalanced fertilization (Atılgan et al., 2007; Zhang et al., 2019). In a study conducted by Engindeniz et al. (2010) 40.8% of farmers stated that they determined the type and amount of fertilizer according to the dealer's recommendation, and 31.2% of them determined according to their own knowledge and experience. Another important reason why the nutrient utilization rates of plants were very low was the excessive amount of fertilizer used in greenhouses. The problems caused by excessive use of fertilizers in greenhouse conditions in the Antalya region were expressed in previous studies (Anaç & Eryüce 2003, Tüzel et al. 2005).

CONCLUSION and RECOMMENDATIONS

As conclusion, plants under greenhouse conditions growing with farmer fertilization programme were not be able to use all fertilizer nutrients. There might be several reasons for this. First of all, the producers make the same fertilization for all plants, regardless of the needs of each other. Another reason for this may be the use of fertilizers above the plant need due to the concern of obtaining higher yields. Another reason might be nutrient accumulation in the soil which preventing the nutrient utilization rates from the applied fertilizers. Unnecessary and wrong fertilizer recommendations of fertilizer dealers due to commercial concerns are thought to be the another reasons for the low nutrient utilization rates from fertilizers. In order to prevent this situation, it is necessary to make fertilization recommendations considering plant needs. Fertilization recommendations should be made based on soil and plant analysis. Not applying the same fertilization program to different plants is important in preventing unnecessary fertilizer consumption. Beriefly, in order to increase the rate of nutrient utilization from fertlilizer by plants, it is necessary to apply the appropriate fertilizer at the appropriate time, in the appropriate amount and with the appropriate method.

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The authors of the article declare that there is no conflict of interest between them.

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