African Journal of Agricultural Research Vol. 7(6), pp. 937-942, 12 February, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1015
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Instantaneous evaluation of nitrate, ammonium, phosphorus and potassium pools in greenhouse soils in Antalya Province of Turkey

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Accepted 5 January, 2012

Nitrogen, phosphorus and potassium are the main components determining yield and quality of intensive agricultural production particularly at undercover production, however; excessive fertilization has some environmental and economical consequences. The aim of this study was to investigate surplus amount of fertilizers at the harvest stage of the greenhouse soils in Antalya Province. Therefore, soil samples were collected from 57 representative greenhouses to determine their mineral nitrogen, available phosphorus and potassium along with organic matter contents. The results revealed that soil from 30% of greenhouses had nitrate values of 30 to 35 kg da^{-1}. Ammonium values were considerably low compared to nitrate values; the highest ammonium value was nearly 6 to 7 times lower than the highest nitrate. The highest distribution according to ammonium content was found as 46% with the value of <1 kg da^{-1}. This result indicates that nitrate is the more preferred mineral nitrogen source than ammonium in the study area. One tenth of greenhouses had low P content, whereas the rest of the greenhouses had sufficient amount of P. Potassium content of the analyzed soil samples are classified either as "very low" or "low". On the other hand, over the half of the greenhouses have sufficient or even higher amount of organic matter. This study clearly shows that the greenhouses usually contain sufficient quantities of macro nutrients even at the harvest stage of the plants. This implies that the farmers may postpone the fertilization for a longer time if they consider the nutrient budget and status of soil nutrients. However, farmers in Turkey are not generally considering nutrients existence in the soil before applying fertilizer.

Key words: Greenhouse, mineral nitrogen, available phosphorus, available potassium, Antalya.

INTRODUCTION

Undercover vegetable farming in the Mediterranean coast of Turkey is very well established with a wide range of vegetables being produced in Antalya Province. Similar to all Mediterranean coasts, Antalya Province has favorable daylight period, air moisture content and temperature (Sevgican, 1989; Asri et al., 2008). Thus, soils in many agricultural areas of the Antalya Province have been heavily fertilized with artificial fertilizers during the last decades. As a result, the amount of plant-available nutrients generally exceeds plant demands. Heavy applications of artificial and organic fertilizers are lead to increase soil phosphorus and nitrogen, which often reach ground or surface water and causes eutrophication. Most soil fertility studies represent the high correlation between nutrients and plant growth, therefore macro and micro nutrients have been increasingly used in agricultural areas without considering nutrient pools of soil.

In greenhouses, soil nutrients, including nitrate, accumulate in the topsoil within a relatively short period of time because fertilizer cannot be removed from the soil

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Table 1. Standard classification of P, K and soil organic matter concentrations (Alpaslan et al., 2005).

Nutrient	Very low	Low	Sufficient	High	Very high
P (mg kg^{-1})	< 2.5	2.5-8	8-25	25-80	> 80
K (mg kg^{-1})	< 50	50-140	140-370	370-1000	> 1000
Organic matter (%)	< 1	1-2	2-3	3-4	> 4

Table 2. Minimum, maximum and average values for nitrate, ammonium, phosphorus, potassium and organic matter contents (n: 57).

Measurement	NO_3^--N (kg da^{-1})	NH_4^+-N (kg da^{-1})	Mineral N* (kg da^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Organic matter (%)
Minimum	3.0	0.1	3.2	5.1	9.5	0.6
Maximum	33.9	19.7	52.2	17.2	108.9	5.0
Average	22.8	1.8	24.5	11.7	36.0	2.2
Standard deviation**	9.0	2.7	10.0	2.5	19.0	0.8

*Mineral N is the sum of NO_3^--N and NH_4^+-N. ** Standard deviation.

by rainfall (Lee et al., 2011). Yu et al. (2010) reported the utilization rate of N and P_2O_5 to be 24 and 8%, respectively. Surplus nitrate (Ge et al., 2010; Lee et al., 2011) and phosphorus (Delgado and Torrent, 1997; Yuan et al., 2011) contamination of surface and groundwater is an increasing problem in many agricultural areas throughout the world. Mikayilov and Acar (1998) reported high correlation (P>0.001) between the mineral fertilizer input and contaminations of water resources. The estimation of plant available nutrients has become important for farmers and environmental agencies, because it can help them to use existing soil P reserves, therefore, it can prevent economic losses and environmental impacts (Delgado and Torrent, 1997). Organic farming which does not use artificial fertilizers and pesticides also resulted in significantly higher amount soluble organic nitrogen compared with soils under conventional farming (Ge et al., 2010). On the other hand organic and inorganic fertilizer amendments have resulted changes in microbial activity in soils that influence plant growth and disease development. Mineral nutrition can exert a profound effect on disease development, with fertilizer application increasing or decreasing development of diseases caused by different pathogens (Walters and Bingham, 2007). In support of this finding, nitrogen has been found to enhance especially the epidemic development of several bio trophic fungal diseases (Olesen et al., 2003) whereas in general, elements P and K tend to improve plant health (Reuveni and Reuveni, 1998).

The aim of this study was therefore to evaluate nitrate (NO_3), ammonium (NH_4), phosphorus (P), potassium (K) and organic matter contents of soils at representative independent greenhouses to represent a surplus amount of plant-available nutrients. The greenhouses were selected to encompass a wide range of undercover producers in Antalya region.

MATERIALS AND METHODS

The samples from topsoil (0 to 20 cm) were collected from randomly selected representative 57 greenhouses in the Antalya Province. Three years or older greenhouses were selected considering their locations to represent a wide range of undercover producers. As selecting criteria the cover material, plants or size of greenhouses were not taken into account. The soils were sampled once when the harvest of crops was performed. Samples were taken according to the procedure given by Jackson (1985). Three sub-samples were taken from each greenhouse and sub-samples mixed thoroughly, a few drops of toluene dripped over the samples to prevent nitrogen transformation. Soils then transported to Suleyman Demirel University, Soil Science Department (Isparta, Turkey) and sieved from 2 mm sieve. Soils were analyzed to determine their NO_3^--N, NH_4^+-N, available P, available K and organic matter contents according to the methods described by Fabig et al. (1978), Anonymous (1983), Olsen (1954), Kacar (1995) and Schlichting and Blume (1966). Table 1

The obtained P, K and organic matter values were classified according to the values presented by Alpaslan et al. (2005). Mineral ammonium and nitrate values were classified for 1 to 5 kg da^{-1} and 5 to 35 kg da^{-1} (5 units increasing step size). These values were compared to the nitrogen requirement of tomato cultivation in greenhouse which is widely cultivated in this region.

RESULTS AND DISCUSSION

In the present investigation, mineral nitrogen, available P and K contents of soil and soil organic matter percentage was determined for 57 independent greenhouses. The values observed are presented in Table 2 for minimum, maximum and average values. All values obtained (Table 2) were greatly fluctuating among the greenhouses.

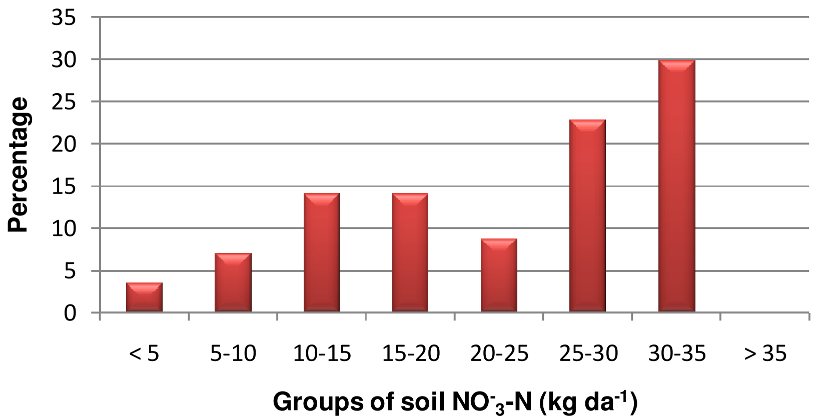

Figure 1. Distribution of greenhouses as percentages depending on NO^-_3-N values.

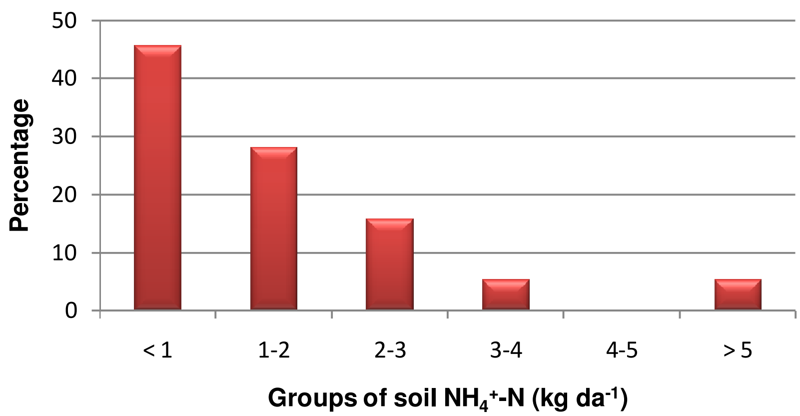

Figure 2. Distribution of greenhouses as percentages depending on NH_4^+-N values.

Considerable higher amount of mineral nitrogen were determined, whereas mineral nitrogen was mainly consisted of nitrate. Considering total mineral nitrogen requirement of tomato plant, determined mineral nitrogen amount was adequate, even higher than yearly mineral nitrogen allowance of the plant. Regarding the phosphorus concentrations, observed lowest concentration was 5.1 mg kg^{-1} which is classified as “low” according to Alpaslan et al. (2005) while the highest concentration classified as “sufficient” with 17.2 mg kg^{-1}.

In the terms of K content; even the highest value was lower than 140 mg kg^{-1}, thus determined K concentration was classified as either “very low” or “low”. Organic matter contents of soils have a great distribution. The lowest value was 0.6% whereas the highest was 5%. Mean value of organic matter content was found 2.2% and classified as “sufficient”. Distribution of greenhouses as percentages depending on nitrate, ammonium and mineral nitrogen (nitrate+ammonium) values are given Figures 1, 2 and 3, respectively. The results revealed that 30% of greenhouses’ soil has nitrate values of 30 to 35 kg per da. Ammonium values were considerable low comparing to nitrate values; the highest ammonium value is nearly 6 to 7 times lower than the highest nitrate. The highest distribution according to ammonium content was found as 46% with the value of <1 kg da^{-1}. This result indicates that, nitrate is a more preferred mineral nitrogen source than ammonium. More than 30 kg da^{-1} of total mineral nitrogen was determined in over 45% of the greenhouses’ soils. It is well known that nitrogenous fertilizers should not be applied in one time instead, it should be divide into at least two, even more equal portions. If the nitrogen requirement is satisfied in 4 equal parts, that means the mineral nitrogen concentration of the greenhouse should be 10 to 12 kg da^{-1} at any moment of sampling time. Therefore determined mineral nitrogen contents are considerable high compared to plant requirement.

Nitrate is highly soluble in the water, thus it moves along with the water in a soil. Nitrate ions (NO_3^-) are negatively charged, thus they are not retained by clay minerals which are naturally negative charged in high soil

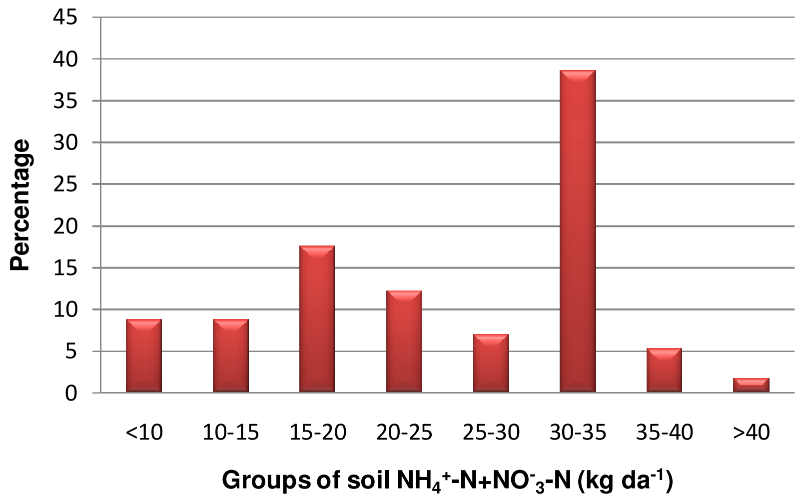

Figure 3. Distribution of greenhouses as percentages depending on mineral nitrogen (sum of NO^-_3-N and NH_4^+-N).

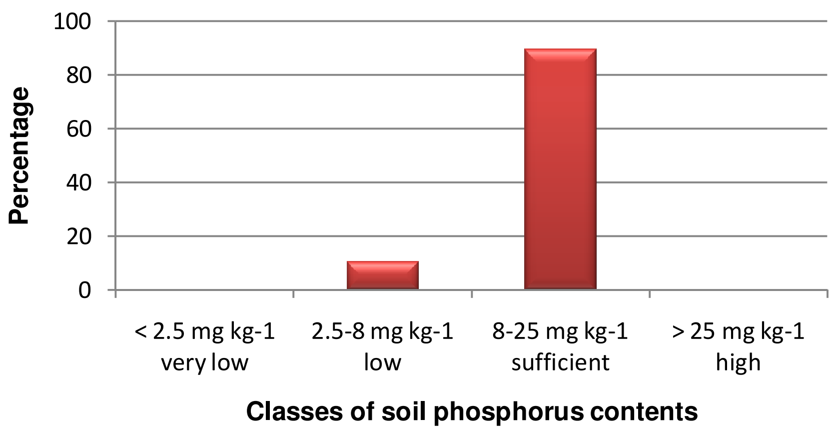

Figure 4. Distribution of greenhouses as percentages depending on phosphorus values.

pH. The negative charge of clay minerals protects ammonium ions (NH_4^+) therefore nitrate or nitrite are the more risky mineral nitrogen forms to reach surface or ground water. In addition, excessive amounts of nitrate inputs could lead to increase accumulation of nitrate ions on commonly eaten vegetables especially lettuces. Nitrates can be converted to nitrites in the gut and saliva; afterwards they can combine readily with natural amines in some foods to form highly carcinogenic chemicals called nitrosamines (Alcicek and Baslar, 1995). Moreover, when the pores in soil are filled with water, partial pressure of oxygen reduces, a group of soil bacteria called facultative anaerobes substitute nitrates for oxygen during respiration. In the case of bacteria use, nitrates as a substitute for oxygen, they reduce nitrates to greenhouse-gas through a process called denitrification (Benckiser et al., 1995).

Consequently, due to the determined mineral nitrogen, which is considerably higher, the aforementioned hazardous effect had to be considered. The number of greenhouses as percentage depending on phosphorus amount is presented in Figure 4. Classification units were obtained from Alpaslan et al. (2005). Results revealed that 11% of greenhouses had "low" P content, whereas the rest of the greenhouses had "sufficient". Although there is no greenhouse distribution in the classes of "very low", "high" and "very high", no evidence was observed proving that the farmers considered the soil available phosphorus budget. It seems to be high fixation rate of phosphorus regulating soil-available phosphorus pool. When phosphorus is supplied sufficiently in water environment, it would commonly enhance algal growth rate, causing eutrophication (Yuan et al., 2011). Luckily, the soil phosphorus is highly active against calcium ions,

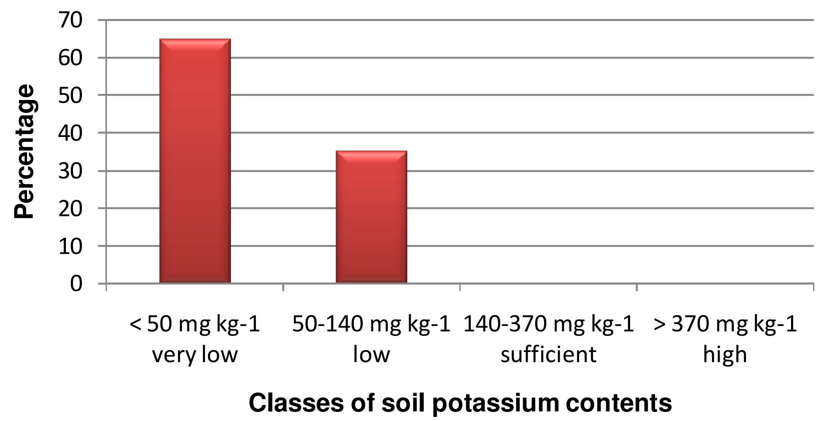

Figure 5. Distribution of greenhouses as percentages depending on potassium values.

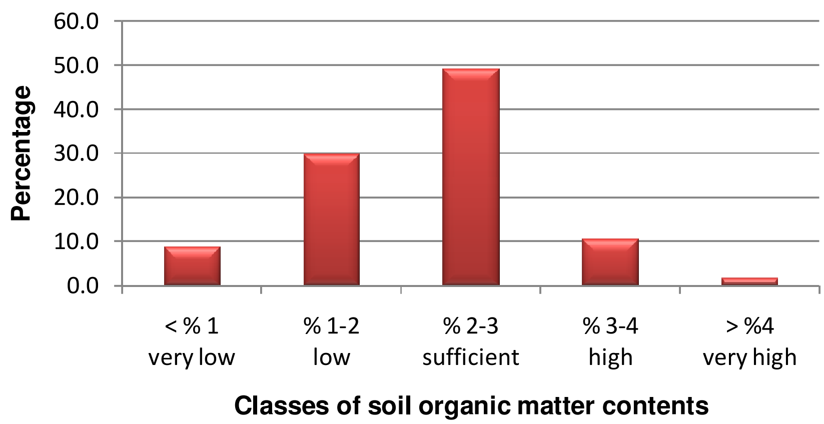

Figure 6. Distribution of greenhouses as percentages depending on organic matter contents of soil.

clay minerals and organic components in soil to form relatively insoluble substances. Similar to soil nitrate, inorganic phosphorus is also negatively charged in most soils, however; phosphorus does not behave like nitrate, because of its particular chemistry. Phosphorus reacts readily with positively charged iron and aluminum in acidic soils whereas calcium and magnesium ions in alkaline soils, therefore phosphorus is considered fixed or tied up being converting to insoluble complexes. Consequently, in order to overcome high fixation rate of phosphorus, farmers are using mineral phosphorous fertilizer regularly without considering the existing available phosphorus in the soil.

The number of greenhouses as percentage depending on potassium amount is presented in Figure 5. Potassium content of the analyzed soil samples are classified as either "very low" or "low". This result is not in accordance with the literature. High and very high rate of potassium levels reported by Sonmez et al. (1999), Ari et al. (2002), Ozkan et al. (2008). Our results revealed that potassium fertilizers are used much less than those nitrogenous or phosphorous fertilizers. Therefore, low residual potassium level was determined in the soils of greenhouses observed. The number of greenhouses as percentage depending on organic matter contents of soil is presented in Figure 6. The comparison of the organic matter content of the analyzed soil samples with the limits are given in Figure 1. Results presented in Figure 1 showed that over half of the greenhouses have sufficient or even higher organic matter contents. Although, 4% and higher organic matter are classified as “very high”; there is no toxic limit for organic matter. Thus, the excess of organic matter should be considered as an advantage. In accordance with our results, Alagoz et al. (2006) reported high organic matter at almost half of the greenhouses sampled in Antalya region.

Conclusions

The idea behind this paper was to prove the findings of questionnaire study carried out by Atilgan et al. (2007). In this questionnaire, farmers mentioned about their huge amount of fertilizer usage, which seems to be too much to be true, therefore soil samples from 57 greenhouses collected after harvest to determine residual nutrients in soil. Unfortunately, results revealed in this paper proved the excess amount of mineral fertilizer usage. This study clearly represents the greenhouses, which usually contain sufficient quantities of macro nutrients even at the harvest stage of the plants. That means the farmers may postpone the fertilization for a long time, if they considered the nutrient budget and soil nutrient status.

However, farmers in Turkey are not even aware of the nutrients existence in the soil. Tuzel et al. (1992) reported that 70 to 80% of the greenhouse producers were applying fertilizer without making any soil nutritional analyzes. Similarly, Atilgan et al. (2007) reported that the cultivation area and yield were the only criteria which the farmers take into account in Antalya region. This study also showed that farmers never considered the possible environmental problems. In some cases, farmers believed that the input of fertilizer was low, and used more fertilizer which made excess dose of chemical fertilizer (Yu et al., 2010). Improper fertilization leads to deterioration of soil quality and other related environmental program (Yu et al., 2010). The best method to prevent soil pollution and protect sustainability is to ensure the fertilizer inputs based on soil nutritional analyzes in irrigated agriculture and intensive cultivation areas such as greenhouse (Guo et al., 2006). Organic farming is not the approach for overcoming environmental impacts caused by fertilization, due to the organic farming which also results significantly in higher amount of soil soluble organic nitrogen (Ge et al., 2010). Nevertheless, it is necessary to apply more organic manure to balance the soil nutrient budget and improve the utilization rate of fertilizers.

Consequently, it is crucial to set up an environment-friendly nutrient program. Therefore, (1) farmers should be encouraged or even forced to make the analyses to determine the soil nutrient pool, subsequently fertilizer program should be arranged considering existing nutrients in soil, (2) training programs should be organized through agricultural agencies to introduce the environmental and economic effects of overdose fertilization to the farmers.

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