Change in the Status of Secondary Macronutrient Levels in Soil with the Long-term Application of Chemical Fertilizers in *Allium ascalonicum* L. Plots in Lablare District, Uttaradit Province

Chattanong Podong* and Saisunee Junta

Department of Environmental Science, Faculty of Science and Technology, Uttaradit Rajabhat University, Muang, Uttaradit 53000, Thailand

* Corresponding author. E-mail address: Chattanong@hotmail.com

Received: 27 August 2019; Revised: 25 December 2019; Accepted: 16 January 2020; Available online: 27 April 2020

Abstract

The long-term use of chemical fertilizers has impacted the levels of secondary macronutrients in agricultural soils in which scallion (*Allium ascalonicum* L.) crop is grown in Fai Luang sub-district, Lablare District, Uttaradit Province. Accordingly, the objective of this study was to investigate the effects of chemical fertilizer and insecticide use on the content of secondary macronutrients - including calcium (Ca), magnesium (Mg), and sulfur (S) - in the soils from regional scallion plots. The investigation was conducted in 5 villages within the sub-district: Moo 1. Baan Chaing-Saen (Control), Moo 2. Baan Nam-Tum (T1, 50% NPK), Moo 5. Ban Thung-Eang (T2, 100% NPK), Moo 6 Ban Na-Pong (T3, 100% FYK), and Moo 9 Ban Wat Pa (T4, 50 % NPK + 50%FYM). For each of the villages, soil samples from 3 scallion plots were tested for the levels of secondary macronutrients. The total average for each secondary macronutrient levels represented the results. The results are concluded as follows: for the status of change for exchangeable Ca^+ average level, it was found that the exchangeable Ca^+ average level decreased after every post-harvest period, with the highest control treatment of 45.10% followed by T2 (15.21%), T1 (12.72%), T4 (3.15%) and T3 (2.25%); for the status of change for exchangeable Mg+ average level, it was found that the exchangeable Mg+ average level decreased after every post-harvest period, with the highest control treatment of 19.37%, followed by T2 (13.29%), T1 (7.41%) and T3 (0.38%), but T3 treatment not change status; and for the status of change for exchangeable S average level, it was found that the exchangeable S average level decreased after every post-harvest period, with the highest T3 treatment of 166.67%, followed by T4 (112.50%), T1 (16.67%), but S average level increased in T2 (53.33%) and control (14.29%).

Keywords: Chemical fertilizer, Long-term, *Allium ascalonicum* L., Secondary macronutrients, Uttaradit Province

Introduction

A large portion of the Thai population earns a living through agricultural practices. One of the economically significant crops in Thailand is the scallion (*Allium ascalonicum* L.). According to reviews on the production and export of the plant in Thailand, approximately 192,308 tons of scallions entered the market in 2014. In Uttaradit Province, scallion is intercropped with rice in an annual cycle; rice is grown once and scallion twice per year. Similarly, besides scallion, of which the whole plant is consumed, farmers might also cultivate shallots for their bulbs. The first cycle of scallion production begins early in the dry winter in January through February. In the rainy season, the cultivation cycle takes place in July and August. The process typically takes one month and 20 days from transplanting to harvest. Lablare District covers 4,595 rai (rai: A Thai measurement unit equivalent to 1,600 m^2) of total scallion planting area, with nearly 9,408-ton scallion exports in 2014 (Strategic Information Center, 2018). With continuous economic growth in the agriculture sector, farmers have adopted yield-enhancing methods to meet consumers' demands. One such approach involves chemical pesticides – some of which have been in use for many decades – to control weeds, insects, and diseases. Heavy metals are included in the ingredients in some chemical pesticides and fertilizers. Lablare District has been a large production base of scallion, serving rural families as one of the mainstays for their livelihood. Every year, scallion yields had been high and profitable. However, the situation deteriorated with the emergence of stunted growth in scallions, the symptoms of which included yellowed leaves, small bulbs and a high density of pests. The local farmers responded by applying agricultural chemicals in an attempt to revert poor performance to initial fertility rates. The consequential drawback of such practice involves an accumulation of excess chemicals, following their delivery, in soils and scallion crops. Particular regions might be more thoroughly affected due to the chemicals' diffusivity. Therefore, the application of agricultural chemicals leads to secondary macronutrient deficiency, impacting scallion lots and soil throughout the area.

These practices significantly contribute to the degradation of soil, an important source of support for all living creatures. Farmers adopt chemical fertilizers, composed almost entirely of primary macronutrients that can be immediately released for plant uptake. With abundant nutrients, the crops grow rapidly and high yield becomes common. Nevertheless, the prolonged application of agricultural chemicals causes an imbalance in the nutrient content of the soil. Always receiving additional primary macronutrients through fertilizers, the soil is gradually exhausted of its secondary macronutrients via harvested products and different mechanisms of soil erosion. Therefore, in the case of excessive use, chemical fertilizers lead to secondary macronutrient deficiency. The solution of directly adding depleted secondary macronutrients to the soil is not entirely effective, since the nutrients may be fixed or converted into forms unavailable for plant metabolic activities. Coupled with certain environmental limitations, soil-directed addition of secondary macronutrients is generally unsuccessful. Secondary macronutrients are important. Plants require less secondary macronutrients (Ca-Mg-S) than primary counterparts (N-P-K). In the past, the roles of secondary macronutrients were less obvious since many of these nutrients were naturally available. Nowadays, secondary macronutrient deficiency has become increasingly relevant, especially in areas with extensive supplementation of primary macronutrients. Secondary macronutrients are crucial for the physiological development of plants. Too much of added primary macronutrients in the soil causes macronutrient imbalance. Certain types of soil are particularly susceptible to macronutrient imbalance, including soil with high sand content, soil with high clay content, compacted soil, overly acidic or alkaline soil, and soil that is extensively employed for mono-cropping. Without replenishing the secondary macronutrients depleted through plant uptake, the effects will be manifested in successive crops. Some of the symptoms include slow growth, stunted shoots, undeveloped flowers and fruits, the premature dropping of fruits, and stunted roots. Obviously, secondary macronutrients play a crucial role in proper plant growth and crop yield. This leads us to study the content of secondary macronutrients – that is, calcium (Ca), magnesium (Mg), and sulfur (S) – in the sample of soils from regional scallion-growing areas. We aim to investigate both the direct and indirect effects of chemical fertilizers on the content of secondary macronutrients in soil. The results will be useful for identifying solutions to the problems related to the use of agricultural chemicals.

Methods and Materials

Methods

This study aims to investigate the content of secondary macronutrients for the soil in each scallion-growing area from each of the five sub-districts in Lablare District, Uttaradit Province.

Study site and soil chemical properties

A long-term field experiment was established in 1989 on a Red yellow Podzolic soils classification (Soil Survey Staff, 2014). We conducted a survey in the region of interest, Fai Luang sub-district of Lablare District, to locate scallion-growing areas in five villages: Moo 1 Baan Chaing-Saen (Control), Moo 2 Baan Nam-Tum (T1), Moo 5 Ban Thung-Eang (T2), Moo 6 Ban Na-Pong (T3), and Moo 9 Ban Wat Pa (T4). Scallion cultivation has been practiced in the region for more than a decade. The locations of the scallion plots, from which the soil samples were collected, are shown in Table 1. The 5-year mean annual temperature of the site was 28.2 °C, while the lowest and highest mean monthly temperatures were 22.2 °C and 35.8 °C, respectively. The mean annual precipitation was 1,341 mm.

Table 1 The locations of the soil collection in Lablare District, Uttaradit Province

Soil Collection Location	Scallion Plot	Coordinates	Background of land usage
	Plot # 1	N 0609116, E 1955136	Started growing scallions in 2011
Control	Plot # 2	N 0609161, E 1955015	Started growing scallions in 2011
	Plot # 3	N 0609734, E 1953283	Started growing scallions in 2011
	Plot # 1	N 0609585, E 1955313	Started growing scallions in 2007
T1	Plot # 2	N 0609113, E 1955284	Started growing scallions in 2007
	Plot # 3	N 0609111, E 1955184	Started growing scallions in 2007
	Plot # 1	N 0609165, E 1953642	Started growing scallions in 2012
T2	Plot # 2	N 0609637, E 1953642	Started growing scallions in 2012
	Plot # 3	N 0609637, E 1953644	Started growing scallions in2012
	Plot # 1	N 0609762, E 1953261	Started growing scallions in 2002
T3	Plot # 2	N 0609710, E 1953306	Started growing scallions in 2002
	Plot # 3	N 0609734, E 1953283	Started growing scallions in 2002
	Plot # 1	N 0609657, E 1954483	Started growing scallions in 2002
T4	Plot # 2	N 0609675, E 1954590	Started growing scallions in 2002
	Plot # 3	N 0609699, E 1953452	Started growing scallions in 2002

Five treatments, including control (no fertilizer or manure application); 50% NPK (50% nitrogen, phosphorus and potassium); 100% NPK (100% nitrogen, phosphorus and potassium); FYK (farmyard manure alone) and NPK + FYM (nitrogen, phosphorus and potassium with manure). Each treatment had three replicates and 15 plots of 48 m^2 each arranged in random blocks. All the plots were under the scallion cultivation system. The doses of fertilizers were 16:8:8 $N/P_2O_5/K_2O$ kilogram per plots. The organic fertilizer was made from wheat straw, durian cake, and leaves after composting. The field was irrigated 2-3 times depending upon precipitation.

Table 2 Various physiochemical properties of long-term fertilizer experiment soils after 30 years of cropping

Soil Collection Location	Treatment	Sand (%)	Silt (%)	Clay (%)	EC (ms/cm)	OM (%)	pH
Control	(no fertilizer or manure application)	81	11	8	28.5	1.88	4.5
T1 (50% NPK)	nitrogen, phosphorus, and potassium	85	6	2	33.5	1.38	4.7
T2 (100% NPK)	nitrogen, phosphorus, and potassium	85	11	8	24.9	1.52	5.2
T3 (100% FYK)	farmyard manure alone	82	8	10	31.8	1.39	4.4
T4 (50 %NPK + 50%FYM)	nitrogen, phosphorus, and potassium with manure	84	12	96	33.9	1.76	4.9

Soil Collection

Each soil sample was collected from the top layer of soil, 0 – 15 cm from the surface. All of the samples were obtained from the scallion plots in the five villages aforementioned, from three plots in each village. All of the areas have been used for scallion cultivation for at least 5 consecutive years. Sample collection was done twice for each plot: the first time before cultivation, and the second time after harvesting. The soil samples were air-dried, ground and sifted through a 2mm sieve. The sieved samples were stored in plastic bags, to be analyzed for their secondary macronutrient content.

Analysis of Secondary Macronutrients

The content of calcium (Ca^+) and magnesium (Mg^+) available to plant in exchangeable forms was measured separately by using pH neutral (pH = 7) ammonium acetate solution, following the method of Jackson (1962). The measurement of extractable sulfur (S) content was carried out with the turbidimetric method of sulfate to convert it to barium sulfate $BaSO_4$. The white, opaque precipitate of barium sulfate $BaSO_4$ was formed by the precipitation reaction between sulfate and barium chloride solution.

Statistical Analysis

Statistical analysis of each data set obtained from the analysis included one-way ANOVA to measure sample variance. The comparison of means was done through the Tukey test and LSD test. Besides sample means and standard deviation, the maximum and minimum of each data set were calculated in case the data was statistically significant at a 95% confidence level.

Results

Change in the status of secondary macronutrient levels in soil with the long-term application of chemical fertilizers in *Allium ascalonicum* L. plots soils within Uttaradit Province was studied. The results are explained below.

Exchangeable Calcium (Ca^+) Content

The data of exchangeable Ca^+ levels in the soil samples from 3 scallion plots in control was analyzed. The average level before cultivation was 978 mg /kg, with the highest level of 1,339 mg /kg and the lowest level of 799 mg /kg. After the harvest, the average level changed to 674 mg /kg, with the highest level of 682 mg /kg and the lowest level of 668 mg /kg. In control, the pre-cultivation levels of soil exchangeable Ca^+ were higher than the post-harvest levels. After the addition of chemical fertilizers, the soil exchangeable Ca^+

levels decreased to 45.10 % on average, which is statistically significant at a 95% confidence level of pre-cultivation levels (Figure 1). T1 average level prior to cultivation was 762 mg /kg, with the highest level of 796 mg /kg and the lowest level of 685 mg /kg. After the harvest, the average level changed to 676 mg /kg, with the highest level of 796 mg /kg and the lowest level of 685 mg /kg. In T1, the pre-cultivation levels of soil exchangeable Ca^{+} were higher than the post-harvest levels. After the addition of chemical fertilizers 50% NPK, the soil exchangeable Ca^{+} levels decreased to 12.72 %, which is statistically significant at a 95% confidence level of pre-cultivation levels. T2 average level prior to cultivation was 762 mg /kg, with the highest level of 803 mg /kg and the lowest level of 685 mg /kg. After the harvest, the average level changed to 697 mg /kg, with the highest level of 796 mg /kg and the lowest level of 685 mg /kg. In T2, the pre-cultivation levels of soil exchangeable Ca^{+} were higher than the post-harvest levels. After the addition of chemical fertilizers 100% NPK, the soil exchangeable Ca^{+} levels decreased to 15.21 % , which is statistically significant at a 95% confidence level of pre-cultivation levels. T3 average level prior to cultivation was 727 mg /kg, with the highest level of 754 mg /kg and the lowest level of 707 mg /kg. After the harvest, the average level changed to 711 mg /kg, with the highest level of 717 mg /kg and the lowest level of 704 mg /kg. In T3, the pre-cultivation levels of soil exchangeable Ca^{+} were higher than the post-harvest levels. After the addition of farmyard manure alone at 100%, the soil exchangeable Ca^{+} levels decreased to 2.25 %, which is not statistically significant at 95% confidence level of pre-cultivation levels. T4 average level prior to cultivation was 721 mg /kg, with the highest level of 726 mg /kg and the lowest level of 716 mg /kg. After the harvest, the average level changed to 699 mg /kg, with the highest level of 712 mg /kg and the lowest level of 688 mg /kg. T4, the pre-cultivation levels of soil exchangeable Ca^{+} were higher than the post-harvest levels. After the addition of 50 % NPK + 50% farmyard manure, the soil exchangeable Ca^{+} levels decreased to 3.16 %, which is statistically significant at a 95% confidence level of pre-cultivation levels (Figure 1).

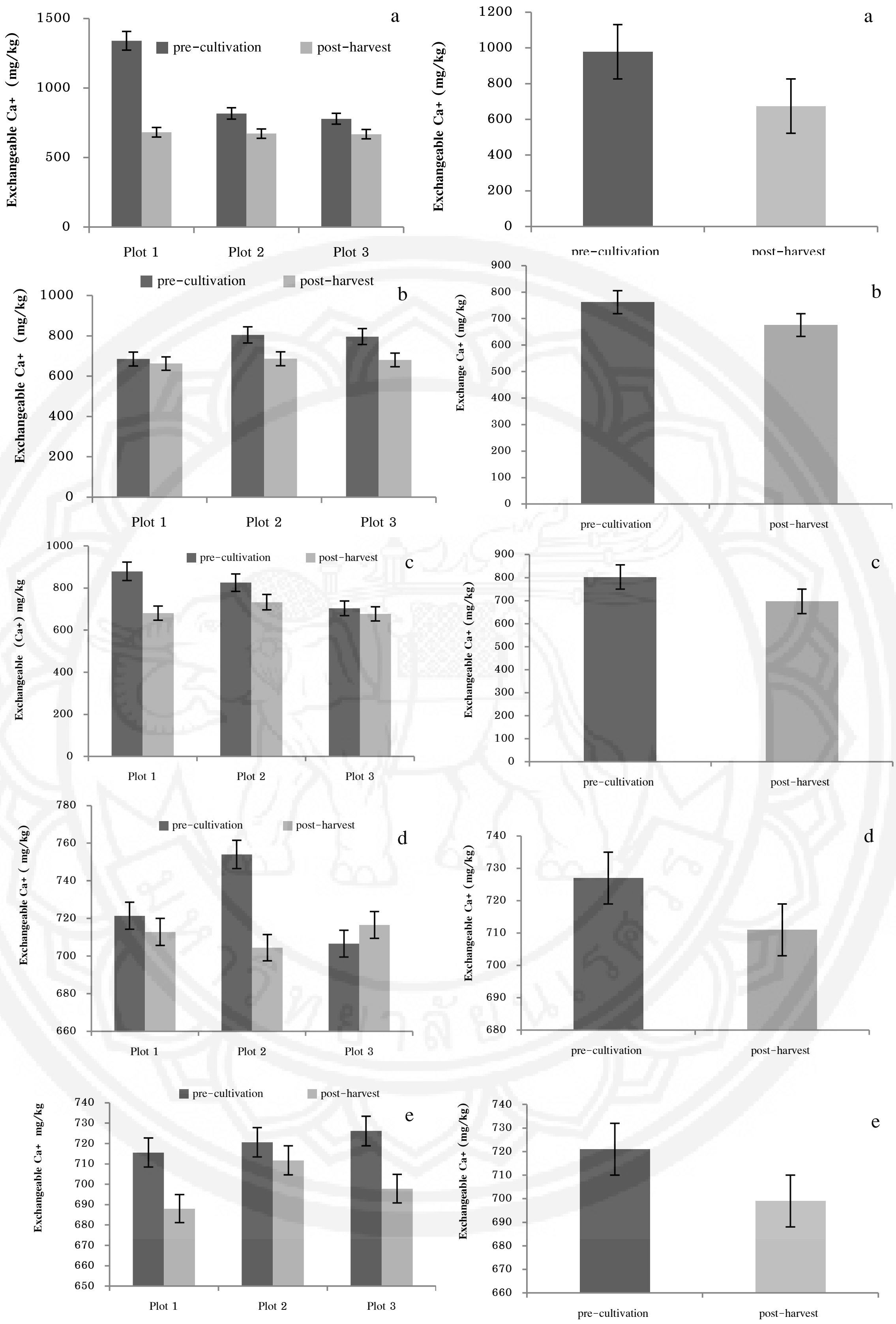
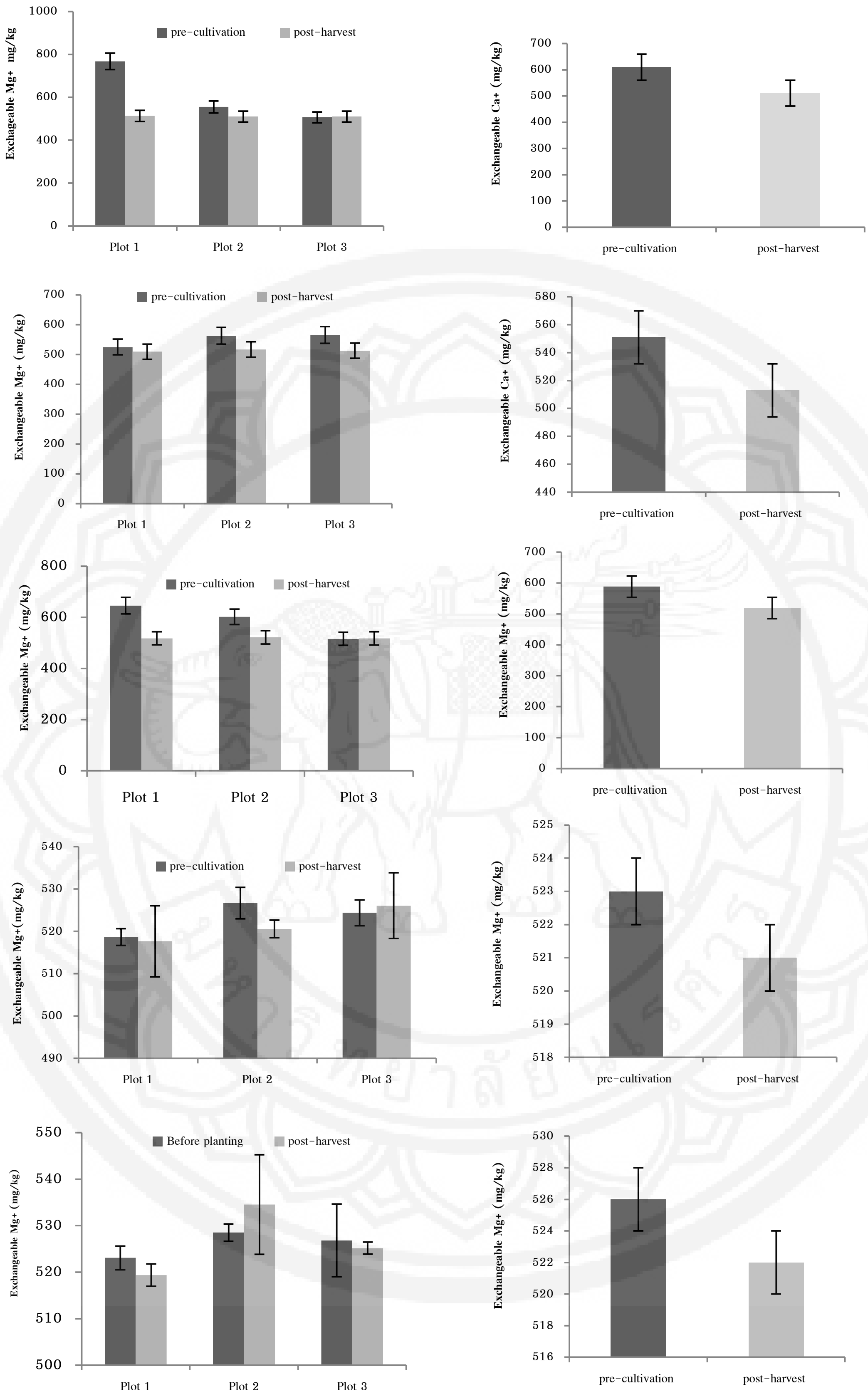


Figure 1 Exchangeable Ca^{+} content in scallion plots for (a) Control; (b) T1; (c) T2; (d) T3 and (e) T4, in Lablare District, Uttaradit Province

Exchangeable Magnesium (Mg^+) Content

The data for exchangeable Mg^+ levels in the soil samples from 3 scallion plots in control were analyzed. The average level prior to cultivation was 610 mg /kg, with the highest level of 768 mg /kg and the lowest level of 507 mg /kg. After the harvest, the average level changed to 511 mg /kg, with the highest level of 514 mg /kg and the lowest level of 510 mg /kg. For control, the pre-cultivation levels of soil exchangeable Mg^+ were higher than the post-harvest levels. After harvest, the soil exchangeable Mg^+ levels decreased to 19.37 %, which is statistically significant at a 95% confidence level of pre-cultivation levels. T1 average level prior to cultivation was 551 mg /kg, with the highest level of 566 mg /kg and the lowest level of 525 mg /kg. After the harvest, the average level changed to 513 mg /kg, with the highest level of 566 mg /kg and the lowest level of 513 mg /kg. In T1, the pre-cultivation levels of soil exchangeable Mg^+ were higher than the post-harvest levels. After the addition of chemical fertilizers 50% NPK, the soil exchangeable Mg^+ levels decreased to 7.41 %, which is statistically significant at a 95% confidence level of pre-cultivation levels. T2 average level prior to cultivation was 588 mg /kg, with the highest level of 645 mg /kg and the lowest level of 516 mg /kg. After the harvest, the average level changed to 519 mg /kg, with the highest level of 522 mg / kg and the lowest level of 517 mg / kg. In T2, the pre-cultivation levels of soil exchangeable Mg^+ were higher than the post-harvest levels. After the addition of chemical fertilizers 100% NPK, the soil exchangeable Mg^+ levels decreased to 13.29 %, which is statistically significant at a 95% confidence level of pre-cultivation levels. T3 average level prior to cultivation was 523 mg / kg, with the highest level of 527 mg /kg and the lowest level of 519 mg /kg. After the harvest, the average level changed to 521 mg /kg, with the highest level of 526 mg /kg and the lowest level of 518 mg /kg. In T3, the pre-cultivation levels of soil exchangeable Mg^+ were higher than the post-harvest levels. After the addition of farmyard manure alone 100%, the soil exchangeable Mg^+ levels decreased to 0.38 %, which is not statistically significant at a 95% confidence level of pre-cultivation levels. T4 average level prior to cultivation was 526 mg /kg, with the highest level of 529 mg /kg and the lowest level of 523 mg /kg. After the harvest, the average level changed to 526 mg /kg, with the highest level of 535 mg /kg and the lowest level of 519 mg /kg. In T4, the pre-cultivation levels of soil exchangeable Mg^+ were higher than the post-harvest levels. After the addition of 50 % NPK + 50% FYM, the soil exchangeable Mg^+ levels do not change (Figure 2).



a

Figure 2 Exchangeable Mg^{+} content in scallion plots ı a a) control; (b) T1; (c) T2; (d) T3 and (e) T4, in L a e District, Uttaradit Province

Extractable Sulfur (S) Content

The data for extractable S levels in the soil samples from 3 scallion plots in control were analyzed. The average level prior to cultivation was 0.06 mg /kg, with the highest level of 0.06 mg /kg and the lowest level of 0.05 mg /kg. After the harvest, the average level changed to 0.07 mg /kg, with the highest level of 0.09 mg /kg and the lowest level of 0.06 mg /kg. For control, the pre-cultivation levels of soil extractable S were lower than the post-harvest levels. After the addition of post-harvest, the soil extractable S levels increased to 14.29 %, which is not statistically significant at a 95% confidence level of pre-cultivation levels. T1 average level prior to cultivation was 0.07 mg /kg, with the highest level of 0.08 mg /kg and the lowest level of 0.06 mg /kg. After the harvest, the average level changed to 0.06 mg /kg, with the highest level of 0.06 mg /kg and the lowest level of 0.06 mg /kg. In T1, the pre-cultivation levels of soil extractable S were higher than the post-harvest levels. After the addition of chemical fertilizers NPK 50%, the soil extractable S levels decreased to 16.67 %, which is not statistically significant at a 95% confidence level of pre-cultivation levels. T2 average level prior to cultivation was 0.07 mg /kg, with the highest level of 0.08 mg /kg and the lowest level of 0.07 mg /kg. After the harvest, the average level changed to 0.15 mg /kg, with the highest level of 0.3 mg /kg and the lowest level of 0.06 mg /kg. In T2, the pre-cultivation levels of soil extractable S were higher than the post-harvest levels. After the addition of chemical fertilizers NPK 100%, the soil extractable S levels increased to 53.35 %, which is statistically significant at a 95% confidence level of pre-cultivation levels. T3 average level prior to cultivation was 0.08 mg /kg, with the highest level of 0.08 mg /kg and the lowest level of 0.07 mg /kg. After the harvest, the average level changed to 0.03 mg /kg, with the highest level of 0.03 mg /kg and the lowest level of 0.03 mg /kg. In T3, the pre-cultivation levels of soil extractable S were higher than the post-harvest levels. After the addition of farmyard manure alone 100%, the soil extractable S levels decreased to 166.67%, which is statistically significant at a 95% confidence level of pre-cultivation levels. T4 average level prior to cultivation was 0.17 mg /kg, with the highest level of 0.34 mg /kg and the lowest level of 0.09 mg /kg. After the harvest, the average level changed to 0.08 mg /kg, with the highest level of 0.14 mg /kg and the lowest level of 0.04 mg /kg. In T4, the pre-cultivation levels of soil extractable S were higher than the post-harvest levels. After the addition of 50 % NPK + 50% FYM, the soil extractable S levels decreased to 112.50 % , which is statistically significant at a 95% confidence level of pre-cultivation levels (Figure 3).

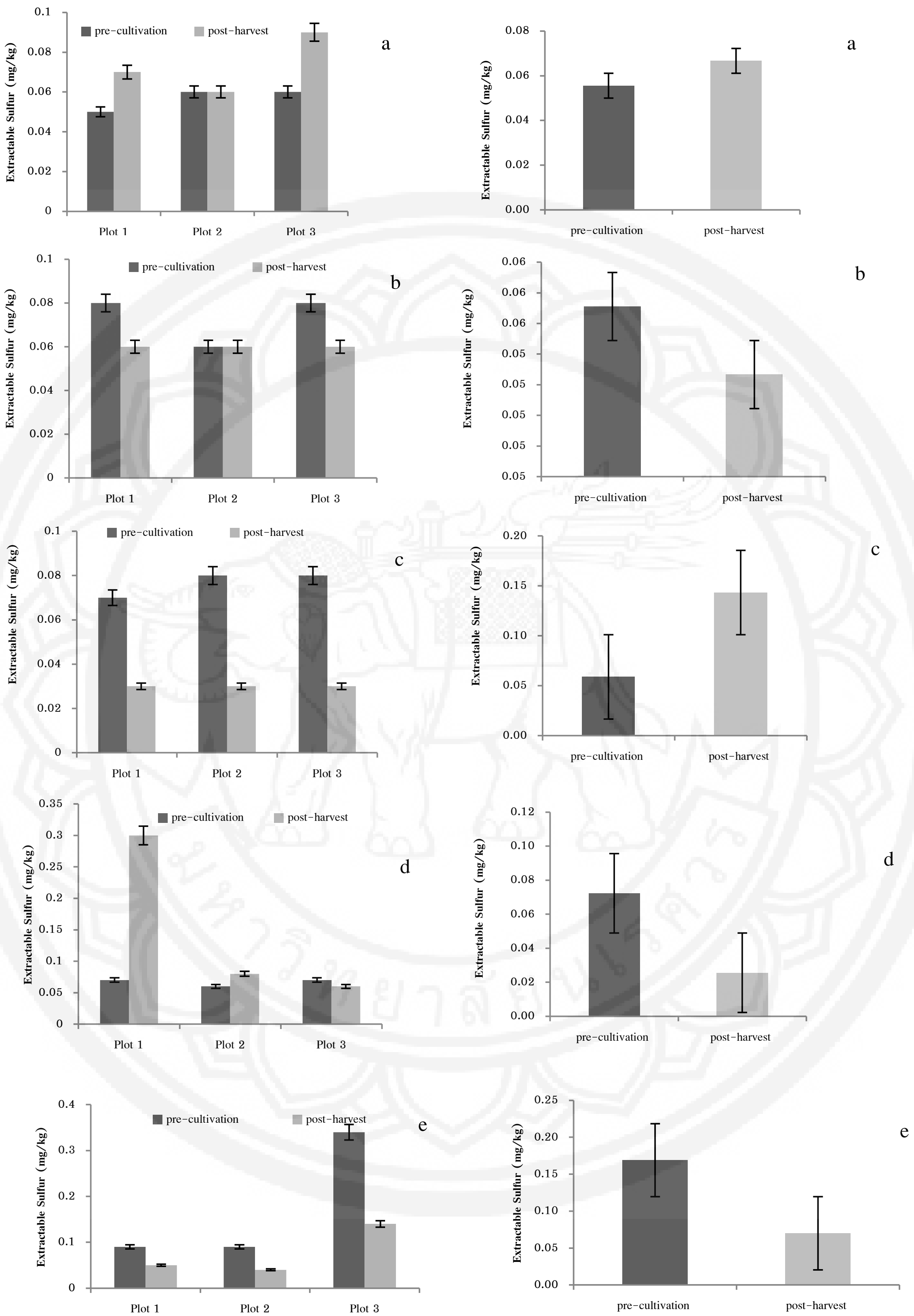


Figure 3 Extractable S content in scallion plots for (a) Control; (b) T1; (c) T2; (d) T3 and (e) T4, in Lablare District, Uttaradit Province

The data for average exchangeable Ca^+ level prior to cultivation of all treatments was the lowest level of control and statistically significant at 95% confidence level, the results status level of average exchangeable Ca+ in the control treatment. It was significantly higher than other treatments at 95% confidence level. After the harvest, the average exchangeable Ca + amount showed that the T1 treatment did not have a statistically significant difference at 95% with the control unit, as in Figure 4 and Table 3.

For the status of change for exchangeable Ca+ average level, it was found that the exchangeable Ca + average level decreased after every post-harvest period, with the highest control treatment of 45.10%, followed by T2 (15.21%), T1 (12.72%), T4 (3.15%) and T3 (2.25%), as shown in Table 4.

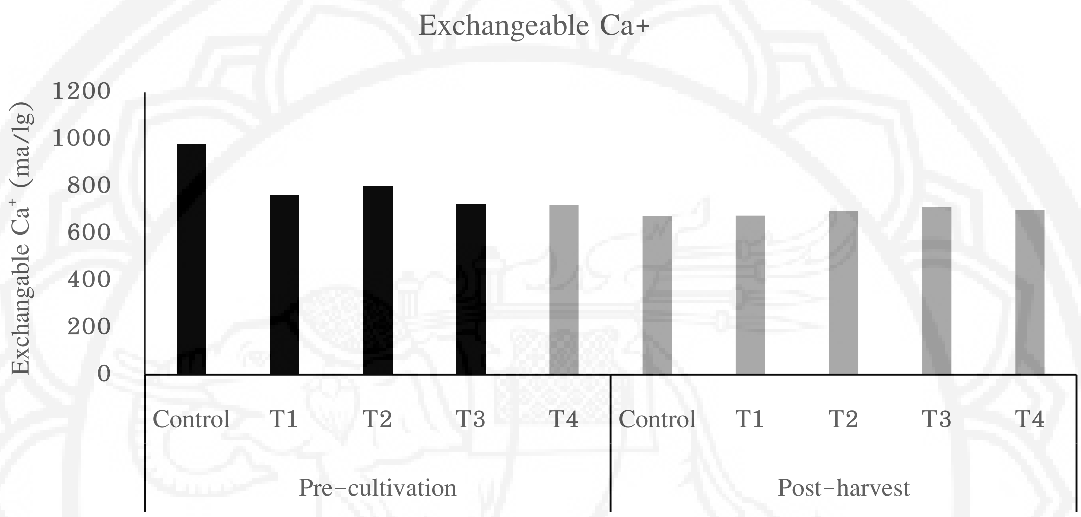


Figure 4 Exchangeable Ca+ content in scallion plots compare between Control, T1, T2, T3 and T4, in Lablare District, Uttaradit Province

The data for average exchangeable magnesium level prior to cultivation of all treatments was the lowest level of control and statistically significant at a 95% confidence level, the results status level of average exchangeable Mg^+ in the control treatment. It was significantly higher than other treatments at a 95% confidence level. For post-harvest, the average exchangeable Mg^+ amount showed that the T1 and T2 treatment set did not have a statistically significant difference at 95% with the control unit, as seen in Figure 5 and Table 3.

For the status of change for exchangeable Mg^+ average level, it was found that the exchangeable Mg^+ average level decreased after every post-harvest period, with the highest control treatment of 19.37%, followed by T2 (13.29%), T1 (7.41%) and T3 (0.38%). However, T3 treatment did not change status, as shown in Table 4.

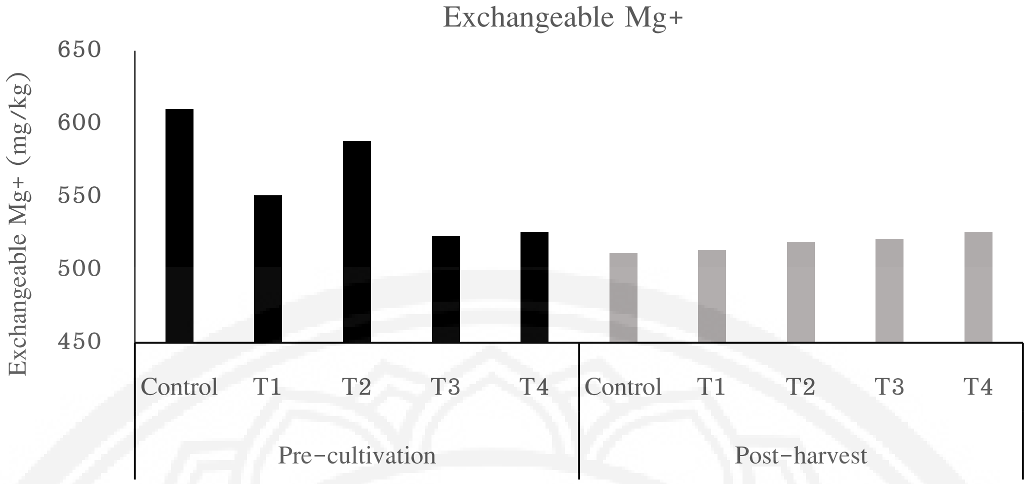


Figure 5 Exchangeable Magnesium (Mg+) Content in scallion plots comparing Control, T1, T2, T3 and T4, in Lablare District, Uttaradit Province

The data for average extractable sulfur level prior to cultivation all treatment was the lowest level of control, but not statistically significant at a 95% confidence level. The results status level of average exchangeable S in the control treatment was not significantly higher than other treatments at a 95% confidence level. Post-harvest, the average exchangeable S amount showed that the T1 T3 and T4 treatment set did not have a statistically significant difference at 95% with the control unit, as shown in Figure 5 and Table 3.

For the status of change exchangeable S average level, it was found that the exchangeable S average level decreased after every post-harvest period, with the highest T3 treatment of 166.67% , followed by T4 (112.50%), T1 (16.67%), but S average level increased in T2 (53.33%) and control (14.29%), as seen in Table 4.

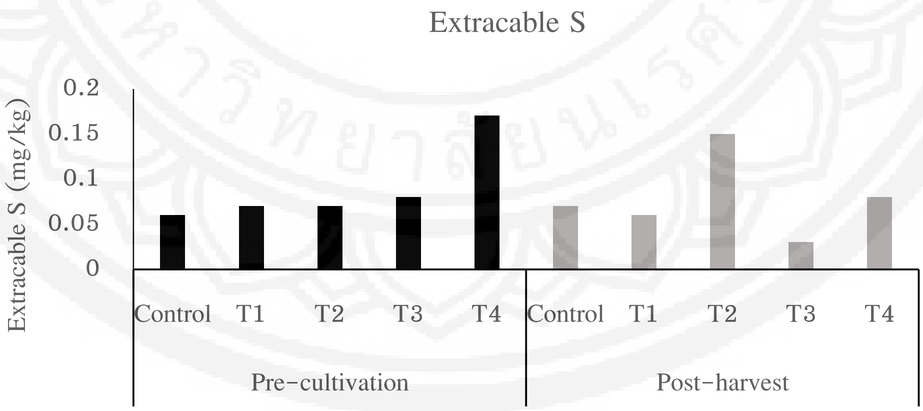


Figure 6 Extractable Sulfur (S) Content in scallion plots comparing between Control, T1, T2, T3 and T4, in Lablare District, Uttaradit Province

Table 3 Statistical analysis of secondary macronutrient levels in scallion plots comparing between Control, T1, T2, T3 and T4, in Lablare District, Uttaradit Province

	Pre-cultivation (mg/kg)					**Post-harvest (mg/kg)**				
	Control	T1	T2	T3	T4	Control	T1	T2	T3	T4
Ca	978^{d}	762^{b}	803^{c}	727^{a}	721^{a}	674^{eb}	676^{eb}	697^{f}	711^{ga}	699^{hf}
P (F test)		*	*	*	*		NS	*	*	*
Mg	610^{d}	551^{b}	588^{c}	523^{a}	526^{a}	511^{e}	513^{e}	519^{e}	521^{fa}	526^{fa}
P (F test)		*	*	*	*		NS	NS	*	*
S	0.06^{a}	0.07^{a}	0.07^{a}	0.08^{a}	0.17^{b}	0.07^{a}	0.06^{a}	0.15^{b}	0.03^{a}	0.08^{a}
P (F test)		NS	NS	NS	*		NS	*	NS	NS

Means followed by the same letter in a row are not significantly different from one another based on the Tukey Test at $p \leq 0.05$, *=significant, NS=Not significant for control of treatment

Table 4 Status of secondary macronutrient levels in scallion plots comparing between Control, T1, T2, T3 and T4, in Lablare District, Uttaradit Province

	Status of secondary macronutrient level (mg/kg)					**Percentage of status change (%)**				
	Control	**T1**	**T2**	**T3**	**T4**	**Control**	**T1**	**T2**	**T3**	**T4**
Ca*	- 304	- 86	- 106	- 16	- 22	- 45.10	- 12.72	- 15.21	- 2.25	- 3.15
Mg*	- 99	- 38	- 69	- 2	0	- 19.37	- 7.41	- 13.29	- 0.38	0.00
S	+ 0.01	- 0.01	+ 0.08	- 0.05	- 0.09	+ 14.29	- 16.67	+ 53.33	- 166.67	- 112.50

Status of secondary macronutrient level (+) increase, (-) decrease

Discussion

From five villages in the Fai Luang sub-district of Lablare District, Uttaradit Province, the total average of exchangeable calcium levels in soils prior to scallion cultivation was 798 mg/kg. After the harvest, the total average of the calcium levels was 692 mg/kg. When the two values are compared, it is apparent that the pre-cultivation soil calcium content exceeds the post-harvest content. The difference might originate from the plant uptake of calcium for growth. Another possible reason is the delivery of agricultural chemicals, including chemical fertilizers. According to the standard range of useful calcium content in the soil, as outlined by the Land Development Department (2010), the levels of exchangeable calcium both pre-cultivation and post-harvest fell into the low range, 400 - 1,000 mg/kg. Calcium is a secondary macronutrient that plants require in a relatively high quantity, although less than those of primary macronutrients. Generally, it is readily available to plants in abundance within soils. An indispensable nutrient of plant, calcium is involved in various mechanisms of plant growth. Its functions at the cellular level include, for example, component strengthening of the plant's cell walls; a preserving agent of plant chromosomes; a functioning component in cell division; an ingredient of many enzymatic mechanisms. Calcium also promotes root development, pollination, and germination (Wijit, 2009). Particularly crucial to young plants, one symptom of calcium deficiency is the browning and eventual death of leaves, although this is rare (Silva & Uchida, 2000). This study examined the status of change exchangeable Ca^+ average level, which found that the exchangeable Ca^+ average level decreased after every post-harvest period, with the highest control treatment of 45.10%, followed by T2 (15.21%), T1 (12.72%), T4 (3.15%) and T3 (2.25%). The content of magnesium in the scallion plots' soils from the five villages in the Fai Luang sub-district of Lablare District, Uttaradit Province, averaged 560 mg/ kg before scallion cultivation. The total average magnesium content changed to 518 mg/ kg after harvesting. The pre-cultivation magnesium levels clearly average to a higher value compared to the total average of the post-harvest magnesium levels. The scallion uptake of magnesium and subsequent removal of the scallions during harvest likely causes such decline. The application of agricultural chemicals, including chemical fertilizers, is a probable contributory factor. Compared to the standard range of useful magnesium levels in soil from the Land Development Department (2010), the levels of exchangeable magnesium both pre-cultivation and post-harvest were high since they were in the range of 360 - 960 mg/kg. Magnesium is a component of chlorophyll, which has important functions in plant photosynthesis. It is also involved in some metabolic pathways, such as starch synthesis and nucleic acid synthesis. In addition, magnesium catalyzes enzymes involved in cellular respiration and carbohydrate metabolism. Another role of magnesium is the uptake and transportation of phosphorus, and the facilitation of sugar transportation (Wijit, 2009). In the scallion plots' soils from control, T1, T2, T3 and T4 of Fai Luang sub-district, Lablare District, Uttaradit Province, the total average of the extractable sulfur level was, before scallion cultivation, 0.09 mg/kg. After the harvest, the averaged extractable sulfur level changed to 0.08 mg/ kg. Comparing the two values, it becomes obvious that the averaged extractable sulfur before scallion cultivation is greater than the total average of the post-harvest sulfur content. The decrease likely comes from the depletion through scallion uptake for growth. The application of agricultural chemicals, including chemical fertilizers, might also be a reason for the difference. This study examined the status of change exchangeable Mg+ average level, which found that the exchangeable Mg+ average level decreased after every post-harvest period, with the highest control treatment of 19.37%, followed by T2 (13.29%), T1 (7.41%) and T3 (0.38%), but T3 treatment did not change.

In light of the standard range of soil sulfur levels developed by the Land Development Department (2010), the levels of extractable sulfur were very low, within <5 mg/kg range, for both pre-cultivation and post-harvest values. Sulfur is involved in energy transfer pathways. It is also a component of the amino acids and proteins that function in the syntheses of vitamins, biotin, thiamine, and coenzyme A. Sulfur also indirectly affects the synthesis of chlorophyll and cell division in meristems, providing stability to cell structure. Additionally, it facilitates the synthesis of lipids (Wijit, 2009). This study examined the status of change exchangeable S average level, which found that the exchangeable S average level decreased after every post-harvest period, with the highest T3 treatment of 166.67%, followed by T4 (112.50%), T1 (16.67%), but S average level increased in T2 (53.33%) and control (14.29%). In this way, N and S interactions are positively related and should be managed together. No response to S additions will occur if N is limiting plant growth. Similarly, an optimal S level maximizes the effect of N fertilization on yield (Figure 3), although actual N uptake in the plant does not change (Rasmussen & Kresge, 1975). Secondary nutrients are no less essential to plant growth than the primary nutrients: N, P, and K. The mineralogy of Montana and Wyoming soils generally maintain high levels of available Ca and Mg. Because plants require relatively small amounts of these nutrients and leaching is minor, Ca and Mg deficiencies are rare in this region; the accumulation of Ca and Mg salts are actually a more common problem. Although deficiencies of S are also relatively infrequent, sustained cropping with few if any inputs may cause yields to be limited by S. Sulfur plays a major role in both yield and quality for most crops and considerably improves the effectiveness of N, P, and K fertilization. Effective management of S includes fertilization and leaving maximum amounts of post-harvest residues on-site, ensuring the best use of this limited nutrient 'pool'. Significant yield and protein responses to S fertilizers have been documented throughout the region for a variety of crops. Soil and tissue testing are useful in diagnosing nutrient deficiencies and managing for them before significant yield losses occur. Understanding the cycling of secondary nutrients in the soil can also help producers predict where deficiencies are most likely to occur (Nathan, Clain, & Jeff, 2002).

Conclusion and Suggestions

There is compelling evidence that organic fertilizer increases crop yield if it is applied to provide additional nutrients on the basis of inorganic fertilizer application (Dawe et al., 2003; Jiang et al., 2006). Organic fertilizers not only provide macronutrients that are otherwise provided by chemical fertilizer, but also have other benefits such as providing micronutrients (Li et al., 2007), and improving soil chemical and physical properties by increasing soil organic matter (Fraser, Haynes, & Williams, 1994; Bhandari et al., 2002). However, its effect on crop yield is inconsistent when it is used as an alternative nutrient source for chemical fertilizers. The investigation of secondary macronutrient contents in the three plots of scallion from each of the five villages in the Fai Luang sub-district, Lablare District in Uttaradit Province reveals the levels of secondary macronutrients in the regional soil samples. The average values for each macronutrient have been calculated and shown herein. The average of exchangeable calcium content was 798 mg/kg prior to scallion cultivation and 692 mg/kg after harvest. The averages were low (within 400 - 1,000 mg/kg) in comparison to the standard range of exchangeable calcium levels in the soil. Magnesium's averaged content was 560 mg/kg prior to cultivation, and the averaged value became 518 mg/kg after harvest. Compared to the standard range of exchangeable magnesium levels in soil, both values were high (within 360 - 960 mg/kg). The extractable sulfur levels in the soils before scallion cultivation averaged to 0.09 mg/kg, and after the harvest changed to 0.08 mg/kg. Apparently, the levels of all secondary macronutrients after the harvest of scallion were lowered from the pre-cultivation levels. The main mechanism that causes such decline has to do with the extensive, prolonged practice of scallion growing, which depletes substantial portions of the secondary macronutrients in harvested products. Since cultivation is carried out multiple times annually, the effect is intensified. The loss of secondary macronutrients also involves the chemical fertilizers and other agricultural chemicals, which deplete the soil of microorganisms which actively take part in the biogeochemical cycles of secondary macronutrients, naturally restoring the supplies of these important nutrients. The plant's requirement of each nutrient is very specific since each of the essential nutrients has important functions in metabolic activities (Yongyut, 2008). A survey indicates that the ranges of secondary macronutrient in soil throughout Uttaradit Province are: 112.5 - 2,925 ppm of calcium (the average of 953.27 ppm); 40 - 790 ppm of magnesium (the average of

312.85 ppm); 7.5 – 125 ppm of sulfur (the average of 36.37 ppm) (Kanjana, 1981). A study on the interactions of calcium with other nutrients shows that calcium enhances the uptake of phosphorus and potassium within a specific range of ion concentrations in nutrient solution containing phosphorus. The uptake of plants in the nutrient solution drops with statistical significance when calcium concentration increases (Ishizuka & Tanaka, 1960). Similarly, the uptakes of K and Mg affect the decrease but the uptake-inhibiting property of calcium is greater (Kawasaki, 1995). A study by Teerapat (2007) found pesticide residues in soil samples, including some organophosphate compounds and weed-killing paraquat.

Acknowledgments

This study was funded by a scholarship from Uttaradit Rajabhat University. We would like to express our gratitude for the scallion-growing farmers who assisted us throughout the process of data collection.

References

Bhandari, A. L., Ladha, J. K., Pathak, H., Padre, A. T., Dawe, D., & Gupta, R. K. (2002). Yield and soil nutrient changes in a long-term rice-wheat rotation in India. *Soil Science Society of America Journal, 66*(1), 162-170.

Dawe, D., Dobermann, A., Ladha, J. K., Yadav, R. L., Bao, L., & Gupta, R. K. (2003). Do organic amendments improve yield trends and profitability in intensive rice systems? *Field Crops Research, 83*(12), 191-213.

Fraser, P. M., Haynes, R. J., & Williams, P.H. (1994). Effects of pasture improvement and intensive cultivation on microbial biomass, enzyme activities, and the composition and size of earthworm populations. *Biology and Fertility of Soils, 17*(3), 185-190.

Ishizuka, Y., & Tanaka, A. (1960). Studies on the Metabolism of Nutritional Elements in Rice Plants. *Journal of the Science of Soil and Manure, 31*, 491-494.

Jackson, M. L. (1962). *Soil Chemical Analysis.* London: Constable and Co. Ltd.

Jiang, D., Hengsdijk, H., Dai, T. B., de Boer, W., Qi, J., & Cao, W. X. (2006). Long-term effects of manure and inorganic fertilizers on yield and soil fertility for a winter wheat maize system in Jiangsu, China. *Pedosphere, 16*(1), 25-32.

Kanjana, L. (1981). *Study of soil fertility in Uttaradit Province.* Bangkok: Department of Agriculture, Chemical Research Group, Agricultural, and Industrial Waste Materials Division.

Kawasaki, T. (1995). Metabolism and Physiology of Calcium and Magnesium. In T. Matsuo, K. Kumazawa, R. Ishii, K. Ishihara, & H. Hirata (Eds.), *Food and Agricultural Policy Research Center.* (pp. 412-419). Tokyo: Japan.

Land Development Department. (2010). *Manual of soil analysis and chemical analysis.* Retrieved From www.ldd.go.th/PMQA/2553/Manual/OSD-03.Pdf

Li, B.Y., Zhou, D. M., Cang, L., Zhang, H. L., Fan X. H., & Qin, S. W. (2007) Soil micronutrient availability to crops as affected by long-term inorganic and organic fertilizer applications. *Soil and Tillage Research, 96*(1-2), 166-173.

Nathan, K., Clain, J., & Jeff, J. (2002). *Secondary macronutrient: cycling, testing and fertilizer recommendations*. Bozeman, Montana: Nutrient management module No.6. Montana State University Publisher.

Rasmussen, P. E., & Kresge, P. O. (1986). *Plant Response to Sulfur in the Western United States*. In M. A. Tabatabai, (Ed.), *Sulfur in Agriculture Agron. Monogr. 27. ASA, CSSA, and SSSA* (pp. 357-374). USA: Madison, WI.

Silva, J. A., & Uchida, R. (2000). *Plant Nutrient Management in Hawaii's Soils.* Retrieved from https://www.ctahr.hawaii.edu/oc/freepubs/pdf/pnm0.pdf

Strategic Information Center. (2018). *Fertilizers and agricultural chemicals. National Statistical Office.* Retrieved from http://www.nic.go.th/gsic/uploadfile/Chemical.pdf

Soil Survey Staff. (2014). *Keys to Soil Taxonomy* (12th Ed.). U. S.: Government Printing Office, Washington, D.C.

Teerapat, S. (2007). *Participatory learning in reducing health and environmental impacts from chemical use and changing chemical behavior.* Mahasarakham University, Thailand.

Yongyut, S. (2009). *Plant Nutrient.* Bangkok: Kasetsart University Publisher.

Wijit, W. (2009). *Nutrition with crop production.* Bangkok: VB Book center Publisher.