Thai Environmental Engineering Journal Vol. 35 No. 2 (2021) : 29-37
www.eeat.or.th

Yield Response and Soil Nutrient Change of Sweet Potato Varieties to Different Fertilization Treatments

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Abstract

The experimental study was for the field trials of yield response and soil nutrient change of sweet potato varieties to different fertilization treatment conducted at the highland agricultural development station under the royal initiative, Ban Pa Kha, Kamphaeng Phet, Thailand. The objectives of this research are to compare yield weight and soil nutrient change of sweet potato under different fertilizer uses. Trials were planted in 4 months by using two species of sweet potato (A) sweet potato cultivars Okinawan (*Ipomoea batatas var.* batatas), and (B) Native sweet potato (*Ipomoea batatas L.* Lam.). The result show that yield of sweet potato (A) was significantly lower than that sweet potato (B). The maximum yield weight was sweet potato (B) in plot 3 (0.96 Kg/Tree), using 150 kg of compost fertilizer and the yield weight of sweet potato (A) show the lowest yield weight in the plot 4 (0.27 Kg/Tree), which was the control plot with natural condition. The chemical fertilizer formula (N13-P13-K21) used in the sweet potato cultivation by Hmong hill tribe farmers were lower quantity of K and P, while the amount of N in such formula used was suitable to the growing needs. However, the studies have also shown that sweet potato is unsuitable for upstream cultivation due to their high uptake of soil nutrients., which could cause soil deterioration.

Keywords : Sweet potato; Highland agriculture cultivation; Soil nutrient

Introduction

The sweet potato (*Ipomoea batatas* L. Lam) produces high root yields per unit of area even on poor soil [1, 2]. However, the sweet potato crops take up large amounts of nutrients from the soil [3]. Although sweet potato crop is easy to cultivate, it has some production and economic constraints. Yields remain poor on account of low fertility status of the over-cropped soils, while post-harvest losses and low market prices [1]. Considering the uptake and removal of nutrients by the sweet potato are relatively high [4], nutrients supplement in an appropriate and balanced way becomes necessary to attain the full production potential of sweet potato [5]. The study performed at the highland agricultural development station under the Royal Initiative, Ban Pa Kha, Kamphaeng Phet, Thailand (PKhS). Monocultural agriculture of the Hmong hill tribe was patterned with varying factors such as seasons, diseases, plants, and pests.

Biven et al., 2009 suggests that adding organic matter to soil can improve soil quality stability and reduce erosion and erosion problems. The sweet potatoes use large amount of soil nutrients. Long-term cultivation of sweet potatoes resulted in lower yields due to the change in soil quality. Inappropriately, the high quantity and continuous use of chemical fertilizers can affect soil quality. Using compost or manure is one method that can help produce better yields of the sweet potatoes and to maintain soil quality. A study of the use of cow manure to enhance the sweet potatoes production in Nigeria, showed that cow manure was used at a rate of 3 tons per hectare was best for better sweet potato yields without altering soil properties [6-8].

PKhS has encouraged the Hmong hill tribes to plant sweet potatoes instead of corn farming which taken large area. However, encouraging Hmong hill tribe to grow sweet potatoes may contribute to the rapid deterioration of the soil. In addition, the use of large amounts of chemical fertilizers affects upstream areas.

The objective of the field trials conducted at PKhS was to compare yield weight and soil nutrient change of sweet potato in different fertilizer uses. This study result could guide for decision making on agricultural promotion of PKhS.

Material and Methods

1. Study Area

Pa Kha is the village located in the forest conservation area, Klong Wang Chao National Park. The Hmong hill tribe has settled and called by the name of the Hmong village leader "Mr. Yee" which was appointed as the headman later. Pa Kha in the past was difficult to access. One-way entry route is difficult for transportation. Most of the population had engaged in shifting cultivation. This shifting agriculture is a system of farming for hill tribe farmers who grow opium as an economic crop. The farmers will select the primary forest plantation area for each occupation of the land [9]. For this reason, PKhS was initiated according to Her Majesty Queen Sirikit's initiative with the purposes (1) to be a source of knowledge dissemination by promoting agriculture career for local tribe, (2) to improve the quality of life, and (3) to create awareness in the conservation of natural resources, forests, and environment for the country. PKhS is the last Royal Initiative Project. The main duties are operating the conservation of natural resources and enhancing the dissemination of agricultural knowledge on the basis of using less area - high income approach. (Fig. 1)

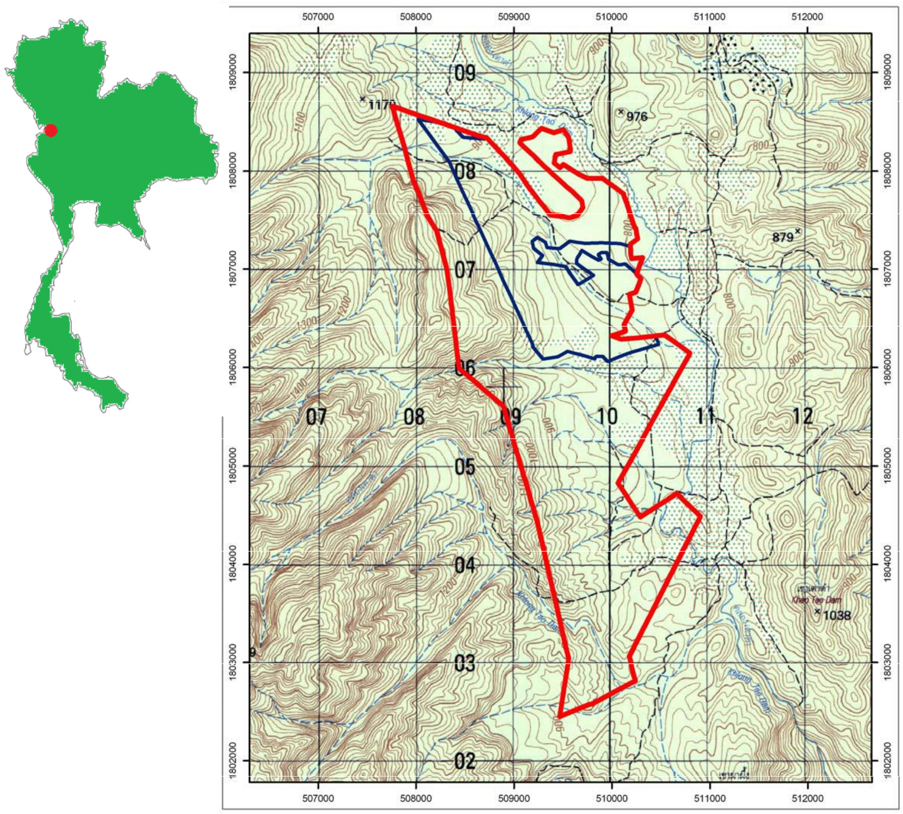

Fig. 1 Study area the red line show boundary of Pa Kha project area of and the blue line show PKhS
Source: Kamphang-phet land development station, 2019

2. Study plots

This study was conducted in four plots (2.5 m x 10 m) at PKhS (Elevation 950 m.s.l, Longitude 99.09E and Latitude 16.33N) (Fig. 2), Trials were planted in late December 2019 and harvested early April 2020, 4 months. Two species of sweet potato were used for this experiment: (A) sweet potato cultivars Okinawan (*Ipomoea batatas* var. batatas), and (B) Native sweet potato (*Ipomoea batatas* L. Lam.). Soil preparation before planting is shown in Fig. 2.

3. Experimental design and treatments

The experimental design used a completely randomized design (CRD). Biochar with either compost or chemical fertilizers were mixed with soil to prepare the substrates for the two species of sweet potato growth. The treatments were according to suitable rate of compost at 2,000 kg per 1,600 m^2 and chemical fertilizers at 75 kg per 1,600 m^2 [10]. (Fig 3) Each experimental plot was 2.5m x 10m. In each plot planted two species of sweet potato (A) sweet potato cultivars Okinawan (*Ipomoea batatas* var. batatas), and (B) Native sweet potato (*Ipomoea batatas L*. Lam.) as shown in Fig. 3. Plot 1 (A) and Plot 1 (B) contained only chemical fertilizer (N13-P13-K21). Plot 2 (A) and Plot 2 (B) contained 100 kg compost and 5 kg Biochar. Plot 3 (A) and Plot 3 (B) contained only compost fertilizer 150 kg. Plot 4 (A) and Plot 4 (B) as the control with natural soil. The experiment was terminated 150 days after planting. Harvesting of the underground biomass took place at the end of the experiment. Soil samples were collected from each plot at the beginning and the end of the experiment for chemical analysis.

Fig. 2 Soil preparation before planting

Plot-1 50(A) 0.5kg chemical fertilizers x 2 time (N13-P13-K21)	Plot-2 50(A) 100kg compost 5kg Biochar x 2 time	Plot-3 50(A) 150kg compost x 2 time	Plot-4 50(A) Control
Plot-1 50(B) 0.5kg chemical fertilizers (N13-P13-K21) x 2 time	Plot- 2 50(B) 100kg compost 5kg Biochar x 2 time	Plot-3 50(B) 150kg compost x 2 time	Plot-4 50(B) Control

Fig. 3 The treatments in each 2.5m x 10m experimental plot, in each plot planted two species of sweet potato (A) sweet potato cultivars Okinawan (*Ipomoea batatas* var. batatas), and (B) Native sweet potato (*Ipomoea batatas* L. Lam.)

4. Soil nutrient analysis

Surface soil samples were collected by composite sampling; a technique that combines several discrete samples collected from a body of material into a single homogenized sample for the purpose of analysis. The objective of composite soil sampling is to represent the average conditions in the sampled body of material [11-12]. Chemical analyses in three main soil nutrients; (1) soil total N (TN) contents were determined according to the Kjeldahl method [13], (2) available P (avlP) contents were extracted using Bray II solution (0.03 N NH_4F, 0.1 N HCl) as an extract, and (3) the extracted P contents were measured colorimetrically with a spectrophotometer (Hitachi U-2000) based on the reaction with ammonium molybdate and the development of molybdenum blue color [14]. The available K (avlK) contents were extracted using 1 M NH_4OAc solution (pH 7.0); the extracted K contents were also measured colorimetrically with a spectrophotometer (Flame Photometer BWB-XP) [15].

5. Statistical treatments

To examine the effects of soil nutrient change of sweet potato varieties to different fertilization treatment, two-sample tests were used, and statistical significance was determined with the Pearson product-moment correlation coefficient ($p < 0.05$). The statistical treatments were conducted with MINITAB (ver. 17, Kozo Keikaku Engineering Inc., Tokyo, Japan)

Results and Discussion

1. Yield Response

Yield of sweet potato varieties to different fertilization treatment are shown in Table 1. Sweet potato yield weight of (A) was significantly lower than that of (B). In both 4 plots, the maximum yield weight was (B) in plot 3 (48kg/50plants), which was a plot using only 150Kg of compost. Notably, the yield weight of sweet potato (A) had the lowest yield weight in the plot 4, which was the control plot without any fertilizers, implying that sweet potato need fertilizer either organic or chemical type.

The results of two-sample testing between the yield weights of sweet potato (A) and (B) under four different fertilization treatments, showed that sweet potato (A) and (B) grown were statistically significant different yield weight per plot, except sweet potato B in Plot 1 and Plot 2 (Table 2).

2. Soil nutrient analysis

The soil Chemical analyses of three main soil nutrients; soil total N (TN) (%), available P (avlP) (mg/kg), and (3) available K (avlK) (mg/kg) of the site before experimentation are shown in Table 3.

The amounts of avlK, avlP, were significantly higher in the pre-field trial than in the post-field trial (Fig. 3) However, and TN was lower in the post-field trial than in the pre-field trial (Fig 4). The study of growth and yield response of sweet potato (*Ipomoea batatas* (L.) Lam) varieties to different rates of potassium fertilizer in Calabar, Nigeria which shows that potassium fertilizer application at 120 to 160 kg/ha appeared appropriately for optimum yield for sweet potato in the study area and is therefore recommended [16].

In this study we found that the amount of 0.5 Kg of 21% K fertilizer (0.42 kg/100 m^2) was applied to the 2.5 m x 10 m experimental plot, which was 3.5 times than recommended rate of 0.12 kg/100 m^2, according to Uwah et al (2013). It also shows that the amount of K in the soil was still significantly reduced ($P < 0.05$, $R^2 = 0.67$), possibly due to the slope of the terrain that caused leaching. Therefore, K fertilization under this study site conditions required a higher level than 0.42 kg/100 m^2 (6.72 kg/rai).

For the TN study, sweet potato crops take up large amounts of nitrogen. In low fertility soils the addition N increases the sweet potato yield [17]. Compost fertilizer might be an alternative method for improving soil quality and supplying nutrients to the sweet potato. Fernandes et al. (2020) emphasise the N application rates promoted a greater increase in the biomass of the storage root and nutrient uptake. In the sweet potatoes unfertilized with green manure, high rates of N (greater than 1.20 kg/100 m^2) must be applied to obtain the utmost biomass of the storage root. In this study, N fertilizer was applied to was applied to 2.5 m x 10 m experimental plot at a rate of only 0.18 kg/100 m^2. Overall results of N in the pre-field trial and post-field trial were not statistically significant. The study showed that the amount of N fertilizer used in this experiment was 5.56 times less than in the studies of Fernandes et al. (2020). Therefore, the amount of N fertilizer used in the area was suitable (Fig. 4).

Table 1 Descriptive statistics show of 2 species of 50 plants of sweet potato (A) and (B) cultivation

Plot	Total (Kg)	Mean	St Dev	Minimum	Maximum
1A	33.15	0.66	0.21	0.20	1.15
1B	38.45	0.77	0.29	0.30	1.90
2A	16.60	0.33	0.12	0.10	0.75
2B	36.95	0.74	0.27	0.30	1.50
3A	23.21	0.46	0.20	0.05	0.90
3B	***48.00***	0.96	0.37	0.15	1.70
4A	***16.00***	0.34	0.36	0.10	0.50
4B	37.40	0.47	0.21	0.10	0.90

Table 2 T-Value of Two-sample test A

	Plot 1 A	plot 2 A	plot 3 A
plot 2 A	9.73**		
plot 3 A	4.89**	-4.03**	
plot 4 A	11.84**	2.64**	6.04**

T-Value of Two-sample test B

	Plot 1 B	plot 2 B	plot 3 B
plot 2 B	0.54^{NS}		
plot 3 B	-2.88**	3.40**	
plot 4 B	11.44**	5.58**	8.17**

Table 3 Chemical properties of the Experimental plots (0-15 cm) pre and post field trial

Plot	TN (%)		avlP (mg/kg)		avlK (mg/kg)	
	pre	post	pre	post	pre	Post
1	0.11	0.17	71.84	14.47	174.00	157.00
2	0.13	0.60	75.31	5.52	238.00	73.00
3	0.14	0.15	80.30	8.21	224.00	97.03
4	0.13	0.04	75.33	8.07	313.00	65.53

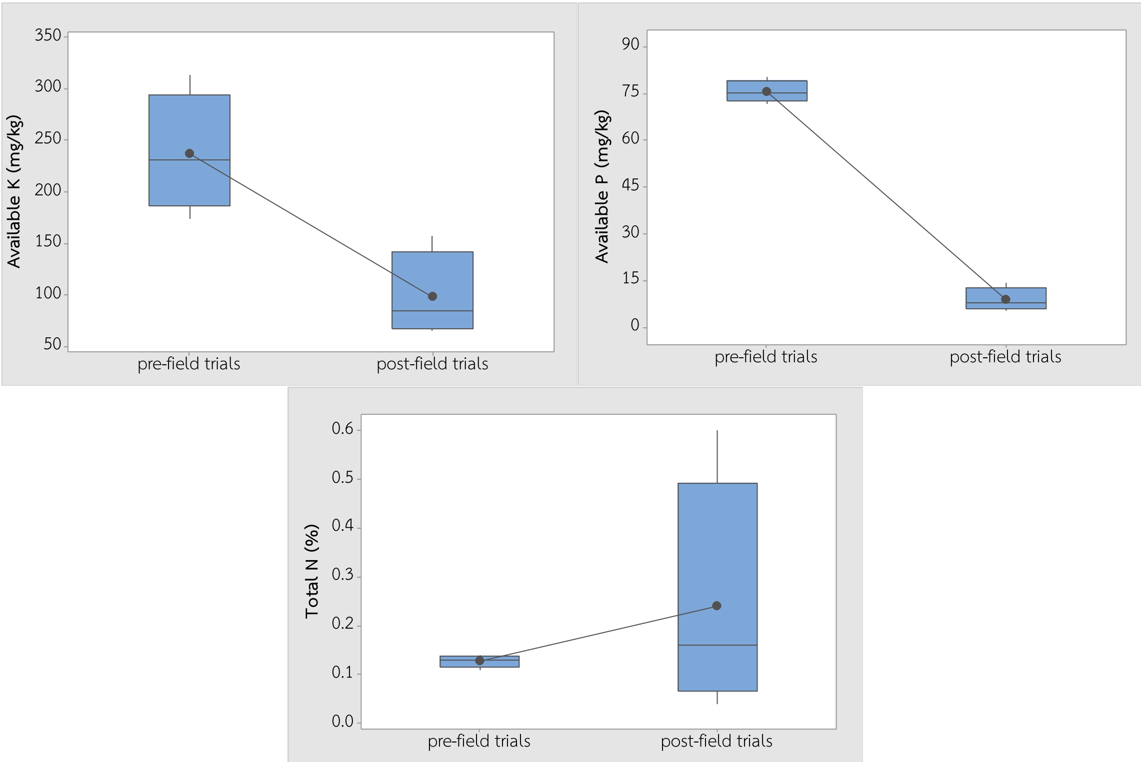

Fig. 4 Boxplot of soil nutrient (Total N (%), Available P (mg/kg), and Available P (mg/kg) change between pre-field trials and post-field trials of sweet potato planting

Sated et al. (2011) report that the increasing of applied phosphorus rate from 15 kg up to 45 kg significantly increased main stem length, canopy dry weight, total chlorophyll, and carotenoids as well as total and product yield, dry matter percentage of tuber root and tuber root weight and diameter [18]. While Dumbuya et al. found that highest growth and yield were observed from the 60 kg/10,000 m^2 treatment [19]. In this study we found that the amount of 0.5 Kg of 13% P fertilizer (0.31 kg/100 m^2) was applied to 2.5 m x 10 m experimental plot, which is 0.5 times than recommended rate of 0.60 kg/100 m^2. The result indicated that the amount of K in the soil is still significantly reduced ($P< 0.05$, $R^2=0.98$).

Therefore, chemical fertilizers formula N13-P13-K21 showed 3.5 times higher of nutrient K and 0.5 times nutrient P less than recommend rate in the previous research. It was found that Post-field trial, the avlK and avlP content decreased significantly.

From General Linear Model of TN (%), avlK (mg/kg), and avlK (mg/kg) was not statistically significant between each experiment plot. The addition of biochar in the sweet potato experiment plots showed no significant difference on sweet potato yield.

Conclusions

Yield of sweet potato (A) was significantly lower than that of (B). The maximum yield weight was (B) in plot 3 (48 kg/50 plants) and the yield weight of (A) show the lowest yield weight in the plot 4 (16.00 kg/50 plants). Sufficient compost can make high yields and maintain soil nutrient quality. The amount of K from the fertilizer formula (N13-P13-K21) used in sweet potato cultivation by the Hmong hill tribe farmers still in lower quantity required of both of (A) ad (B) which corresponded to the amount of P while the amount of N in the formulation used was well suited to the growing needs. However, the studies have also shown that sweet potato is unsuitable for upstream cultivation due to their high uptake of soil nutrients, which could possibly cause soil deterioration.

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