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GROWTH AND YIELD PERFORMANCE OF *IPOMOEA BATATAS* AS INFLUENCED BY N-(N-BUTYL) THIOPHOSPHATE TRIAMIDE (NBPT) COATED UREA (NCU)

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Abstract: Sweet potato (*Ipomoea batatas* L.) has potential to overcome food security issues with world production covering an area of about 9.4 million hectares. However, the sweet potato supply has decreased over the years due to lack of mechanization in harvesting, cost increase of nitrogen (N) fertilizers and loss of nitrogen-based nutrients in the soil due to ammonia volatilization, mineralization and immobilization. Thus, N-(N-butyl) thiophosphate triamide (NBPT) is used with urea fertilizer to reduce the mineralization process and minimize nutrient loss. An experiment was conducted on the growth of sweet potatoes using the randomized complete block design (RCBD) with four replications. One treatment comprised 5 t/ha of chicken manure (+CM) with varying treatments of NBPT-coated urea (NCU), while the other used the same amounts of NCU, but without chicken manure (-CM). The treatments were labelled as follows: (**T1**) 96 kg N/ha urea+CM (farmer's practice), (**T2**) 0 kg N/ha NCU+CM, (**T3**) 57.6 kg N/ha NCU+CM, (**T4**) 76.8 kg N/ha NCU+CM, (**T5**) 96.8 kg N/ha NCU+CM, and (**T6**) 115.2 kg N/ha NCU+CM. For those without manure, the NCU treatments were: (**T7**) 96 kg N/ha urea–CM (farmer's practice), (**T8**) 0 kg N/ha NCU–CM, (**T9**) 57.6 kg N/ha NCU–CM, (**T10**) 76.8 kg N/ha NCU–CM, (**T11**) 96.8 kg N/ha NCU–CM, and (**T12**) 115.2 kg N/ha NCU–CM. The results showed T4-treated crops producing the highest fresh and dry weight of shoot, tuber fresh and dry weight, root to shoot ratio, tuber diameter and length, and yield. In conclusion, using T4 seems to be the most suitable top soil fertilization because of the delay in urea hydrolysis, besides producing more ammonium, nitrate and urea-N content that are readily taken up by crops.

Keywords: Keywords: Sweet potato, urea fertilizer, urea losses, NBPT coated urea.
Abbreviations: N-(N-butyl) thiophosphate triamide (NBPT), NBPT coated urea (NCU).

Introduction

Sweet potato (*Ipomoea batatas*) has gained the attention of farmers in the 1980s, but its production has decreased throughout the years. The decrease may be mostly attributed to the rainy season, which will wash away nitrogen-based nutrients (N) in the soil through leaching, nitrification, denitrification, volatilization, mineralization and immobilization. Therefore, the constant use of fertilizer will increase the cost of growing sweet potatoes, making it more unviable to grow if the problem persists. Farmers have noticed that using fertilizer with high N-based content such as urea may help keep the soil fertile for a longer time and reduce production cost (Miller & Cramer, 2004). Nitrogen is not readily available for plant uptake, as it needs to be fixed into ammonia and other nitrogenous compounds through the nitrogenase metabolism of soil bacteria like Azotobacter (diazotrophy), or the breakdown of urea. Among all essential nutrients, N is required by plants in the largest quantity. However, due to ineffective usage of fertilizer, the nutrients are easily lost from the soil system (Merigout *et al.*, 2008). Urea performance in soil depends on efficiency of urease activity as this enzyme catalyzes urea hydrolysis into ammonia and carbon dioxide (Watson *et al.,* 1994). Such process is purposely slowed down with the use of special pellets to ensure the constant availability of nutrients and prevent run-offs that may be harmful to the environment (Zaman *et al.*, 2008). Despite that, poor management of N fertilizers has affected sweet potato production worldwide from 1967 to 2009 (FAO, 2017). The lowest yield was recorded in 2001 (15,946 t/ha), which was 80% lower than the harvest in 1961 (FAO, 2017). This has caused farmers to lose interest in planting sweet potatoes and switch to crops that are cheaper to grow to maximise income.

Urea is a rich source of N for food production. However, it has several limitations, which are major contributors to the expenditure of agricultural production as well as environmental problems. Normal farmers' practice is to apply chicken manure (CM) or another organic product as basal fertilizer (apart from urea) to supply N nutrients to the soil for sweet potato production. With the current innovation in producing fertilizer, urease inhibitors have been developed to minimize N nutrient losses and maximize yield by increasing root uptake. This includes a stabiliser with N-(n-butyl) thiophosphoric triamide (NBPT) as the active ingredient, which has been developed to overcome loss of ammonia from urea by slowing down the urease activity in urea hydrolysis. The application of NBPT has been reported to give better response to the crop than commercial urea fertilizer alone (Cantarella *et al.*, 2018, Silva *et al.*, 2007). However, the amount of NBPT applied is still debatable. The best N recovery of wheat plants was found when 100 kg N/ha of urea+NBPT was applied, but the application of 90 kg N/ha showed better nitrogen use efficiency (NUE) (Fageria *et al.*, 2011). In the United States, various studies on using NBPT have been conducted and the results showed that it can contribute to an average increase of 0.89 t/ha in maize productivity (Silva *et al.*, 2007). Besides that, herbage growth and N response efficiency increased when NBPT fertilizer is applied on ryegrass (Dinesh *et al.*, 2012). In Malaysia, studies have discovered the use of NBPT with urea in sandy soil has potential in decreasing urease activity, hence slowing the rate of hydrolysis to less than 10% compared to urea alone (Magagula *et al.*, 2010). Delay in urea hydrolysis has resulted in a reduction of N nutrient losses, as well as increasing its uptake by the crop (Fageria *et al.*, 2011). Hence, this study is designed to evaluate the effectiveness of using different treatments of NBPT-coated urea (NCU) with and without CM on growth and yield of sweet potatoes.

Materials and Methods

Land Preparation

A field experiment was conducted in Field 15, Faculty of Agriculture, Universiti Putra Malaysia, Serdang, Malaysia. Land was prepared by removing the weeds and ploughing the soil for a month before planting. After two weeks, 5 kg of ground magnesium limestone (GML) was applied per plot (5 ton/ha). A fence was erected around the farm to prevent animals from destroying the crops. Three days after GML application, the land was ploughed for the second time. The size of each plot was 4 m x 4 m, consisting of five raised beds in each plot. The size of each raised bed was 0.75 m x 4 m, and 16 cuttings were placed within one bed at a distance of 25 cm from each other (Figures 1 and 2). The plots were sprayed with a pre-emergence herbicide (glufosinate magnesium) at a dose of 1.8 L/ha before the shoots were transplanted onto the beds.

Soil physical and chemical properties for each experimental plot were analysed. Samples were collected from a depth of 20 cm. Initial characteristics, such as soil structure and pH were recorded before and after the liming process.

Figure 1: Land preparation

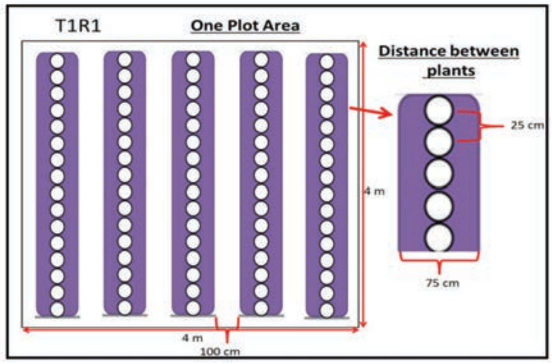

Figure 2: Mark the point of planting with the same distance between the plot points

Planting Materials

Sweet potato (*Ipomoea batatas* var. Anggun 1) cuttings were purchased from commercial farmers with a weight of 10-30 g for each cutting. The cuttings were in standard size between 25 to 30 cm in length, containing six to seven nodes from the terminal shoots, with the lower leaves removed to allow good root growth. The cuttings were treated overnight in fungicide solution (carbaryl 0.1%) before planting, or malathion 0.1% as a substitute. The cuttings were planted at a depth of 10 cm into the soil.

Experimental Design

The experiment was conducted using a randomized complete block design (RCBD). A total of 12 treatments were applied, depending on the amount and type of fertilizer. Each treatment was performed in four replicates. A total of 80 cuttings were used for each replicate. The experimental layout is presented in Figure 3.

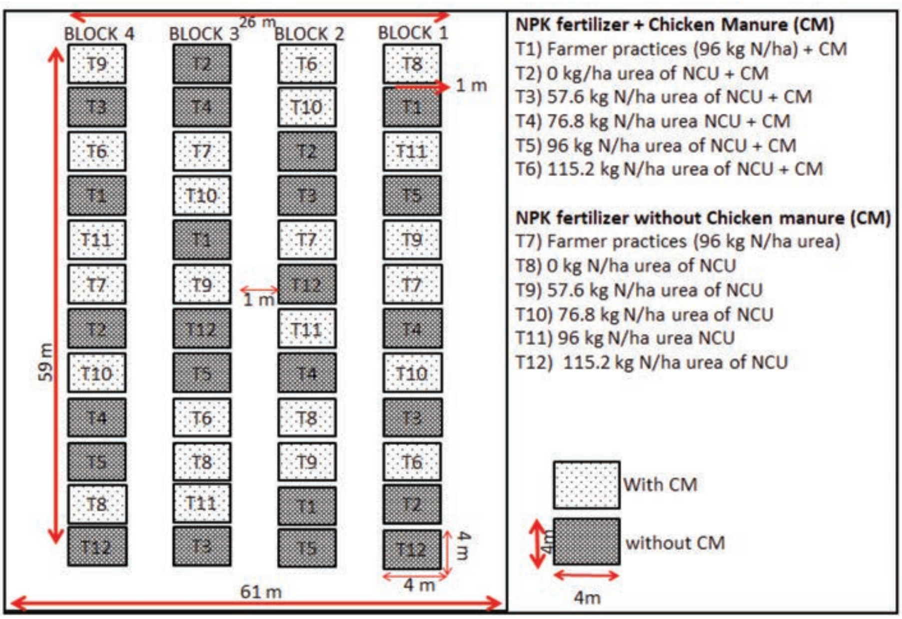

Figure 3: The experiment layout

Fertilization and Treatments

The urea (46% N) fertilizer was used according to farmer's practice (which served as a control). A solution containing Agrotain® NBPT (Koch International, Wichita, KN, USA) was the source of NCU treatment and CM was used as base fertilizer. The NCU was prepared in the Chemical Process Engineering Laboratory 2 at the Faculty Engineering, UPM, by spraying a standard volume of NBPT (3 ml) with 1 kg of urea and blending them in a SOLTEQ rotary drum for five minutes at constant speed (55 rpm) and angle (45°) as recommended by the manufacturer. This fertilizer was dried and kept in store at room temperature.

Basic fertilizer treatment of 800 kg/ha ($12N_2$:$12P_2O_2$:$17K_2O$), which was recommended by the Malaysian Agriculture Research and Development Institute (MARDI), was applied as a positive control. Sweet potato cuttings were grown in five treatments of NCU [0 kg N/ha (0%), 57.6 kg N/ha (60%), 76.8 kg N/ha (80%), 96 kg N/ha (100%) and 115.2 kg N/ha (120 %)]. The cuttings were also grown in soil amended with and without chicken manure, resulting in an overall of 12 treatments with four replications. The fertilizer was applied at three-week intervals. The treatments with chicken manure were labelled as **T1**: 96 kg N/ha urea+CM (farmer's practice), **T2**: 0 kg N/ha NCU+CM, **T3**: 57.6 kg N/ha NCU+CM, **T4**: 76.8 kg N/ha NCU+CM, **T5**: 96.8 kg N/ha NCU+CM, and **T6**: 115.2 kg N/ha NCU+CM. The treatments without CM were labelled as **T7**: 96 kg N/ha urea–CM (farmer's practice), **T8**: 0 kg N/ha NCU– CM, **T9**: 57.6 kg N/ha NCU–CM, **T10**: 76.8 kg N/ha NCU–CM, **T11**: 96 kg N/ha NCU–CM, and **T12**: 115.2 kg N/ha NCU–CM.

A single type of fertilizer in the form of urea, the Triple Super Phosphate (TSP) and Muriate of Potash (MOP), respectively, to provide N, phosphorous (P) and potassium (K) commonly referred as NPK were used. The NPK fertilizer was applied as a side dressing just after seven days of planting. Thus, each plot had the same proportion of P and K nutrients, but different amounts of N nutrients that were applied according to each treatment. The experiment was conducted within three months and two weeks.

Data Collection

Fresh and Dry Weight of Shoot and Tuber

Measurement on plant growth, including shoot fresh weight (SFW) and shoot dry weight (SDW), were measured at 26 days after planting (DAP) (labelled as S1), 52 DAP (S2), 78 DAP (S3) and 120 DAP (S4). Meanwhile, tuber fresh weight (TFW) and tuber dry weight (TDW) were only recorded at S3 and S4. All plants were harvested, cleaned and segregated into top and bottom parts of the sweet potato plants. Fresh weight of the plant parts was recorded immediately. The plant parts were then dried at 70°C for two days before recording their dry weight. Both parameters were expressed in ton/ha.

Nitrogen Uptake in Shoot and Tuber

The ashing method was used to determine total N content in the leaves and tuber. Dried sample (0.5 g) was placed on a crucible before being burned in furnace between 550°C and 660°C for seven to eight hours. A total of 2 ml of concentrated hydrochloric acid (HCl) was added on the samples on the hot plate, and they were allowed to dry and cool down. Then 10 ml of 20% nitric acid (HNO_3) was added on the samples and placed in a water bath (80°C) for 45 minutes. The solution was transferred into volumetric flasks before being sent for analysis (Merigout *et al.*, 2008). The total nitrogen reading was expressed in percentage (%). Nitrogen uptake by the shoot (NUS) and tuber (NUT) could be calculated using Equation 1.

$$N_2 \text{ uptake} = \text{Yield x } [(\text{total N in shoot or tuber})/100] \quad (1)$$

The N_2 uptake was expressed in kg/ha.

Nitrogen Use Efficiency

The formula to calculate nitrogen use efficiency (NUE) is stated in Equation 2.

$$NUE = [(\text{N uptake by plant with N fertilizer application - N uptake by plant without N fertilizer application})/96] \times 100\% \quad (2)$$

The amount of N applied is represented by the number 96 (Merigout *et al.*, 2008). The reading of NUE was expressed in percentage (%).

Total Yield

Total yield (TY) of sweet potatoes was determined based on a quadrant size of 3 m x 3 m according to Equation 3.

$$Total\ yield\ (ton/ha) = \frac{Fresh\ weight\ sample}{1000} \times total\ crop\ area \quad (3)$$

Statistical Analysis

All data were subjected to One-Way Analysis of Variance (ANOVA), followed by the LSD post-hoc test to determine if there were significant differences between the fertilizer treatments ($P<0.05$). The analysis was performed using the Statistical Analysis System Version 9.4 software (SAS Institute, Cary, NC, USA).

Results and Discussion

Shoot Fresh Weight

Figure 1 shows there were significant effects of different N nutrient treatments on sweet potato SFW. SFW increased with an increase in plant age. Crops treated with T4 (76.8 kg/ha NCU+CM) showed the highest result across all sampling times, and the increases were 27.2% at S1, 12.5% at S2, 43.4% at S3 and 58.2% at S4 compared to control (T1). However, at S2, there were no significant differences between T3, T5 and T10. Crops treated with T8 (0 kg/ha NCU-CM) consistently showed the lowest results, where the increases were 6.8% at S1, 4.9% at S2, and 31.9% at S3 as compared to control (T7). However, at S3, there was no significant difference between T8, T2 and T12. Meanwhile, T11 (96 kg/ha NCU-CM) and T12 (115.2 kg/ha NCU-CM) showed significantly low effect at S4 compared with other sampling times.

Biomass was an important feature to quantify the performance of plant growth. This was in line with other studies that found sweet potatoes treated with 8 t/ha of NCU-CM had the highest SFW result compared with control, 10 t/ha NCU-MCU and other treatments without CM (Yeng *et al.*, 2012). The sweet potato was a fastidious crop that needed optimal nutrition to grow to marketable size. Monitoring the growth of the plant's aerial parts was vital because they produced photoassimilates, which would be channelled down to tubers in the roots for storage (Chen *et al.*, 2008). Macronutrients and micronutrients were essentially important for plant growth and could increase crop yield. The use of CM in fertilizer applications could help to improve soil structure and nutrient uptake (Magagula *et al.*, 2010). CM could increase soil density, water holding capacity and infiltration, conductivity and porosity (Niassy & Diarra, 2012). Optimizing the amount of fertilizer was important to improve NUE and nitrogen fixation in sweet potato roots. Thus, improper usage of fertilizer would cause a decrease in NUE, leading to stunted growth, crop toxicity and a waste of resources (Kareem, 2013). Integration of organic and inorganic fertilizers was a rational strategy for efficient use of scarce resources to increase and sustain crop yields, besides maintaining soil fertility (Lu *et al.*, 1989; Norton *et al.*, 2013). According to Patidar *et al.* (2017), sweet potato growth parameters like plant height, number of leaves and tuber quantity could be improved with the use of NCU. The study found that the best results in all parameters on plants that were treated with 100% recommended doses of fertilizer (RDF) coated with 5% Naem cake. The SFW results in Figure 4 concurred with those observed by Patidar *et al.* (2017).

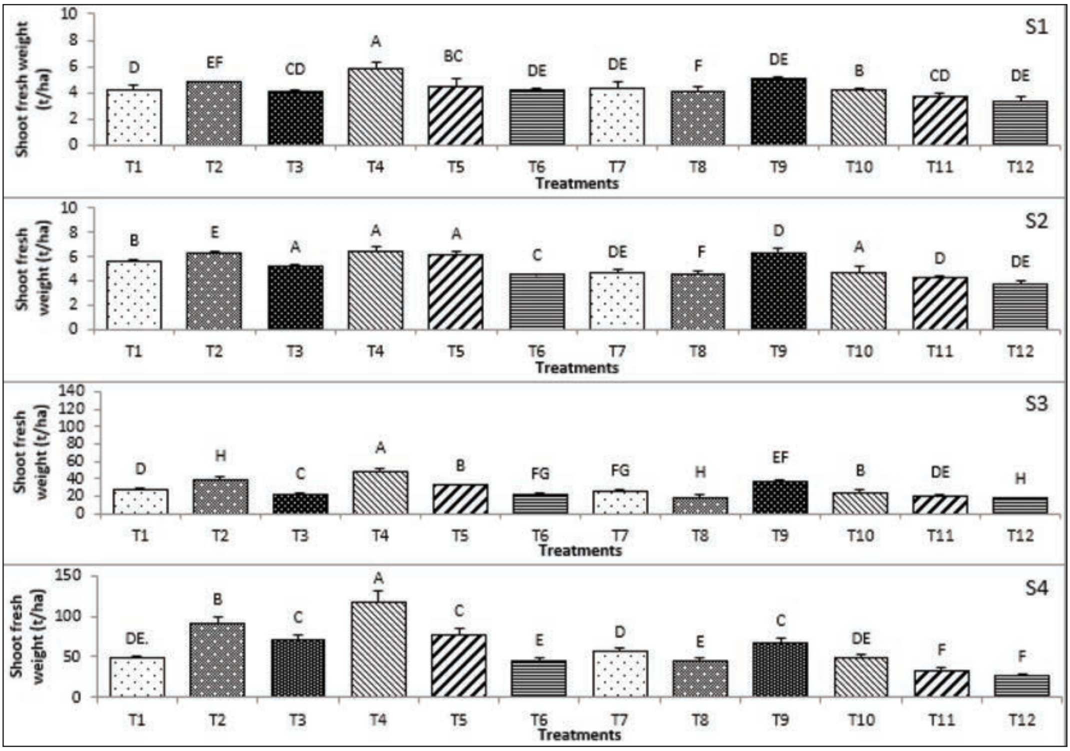

Figure 4: Effect of different fertilizer treatments on shoot fresh weight (t/ha) of sweet potatoes at (S1) 26 DAP, (S2) 52 DAP, (S3) 78 DAP and (S4) 120 DAP. P<0.05 LSD mean values with the same letter within each harvesting time are not significantly different at P<0.05 by the least significant difference (LSD)

Shoot Dry Weight

SDW is proportionally related to SFW. Figure 5 shows the effects of different treatments of NCU of SDW. T4 treatment consistently showed the highest SDW among other treatments from S1 to S4, which increased by 29.6% at S1, 13.8% (S2), 40.5% (S3) and 52.4% (S4) compared to control (T1). However, at S2, the SDW of T4 crops had no significant difference between T3, T5 and T10 while at S3, the SDW was similar to those with T5 and T10 treatments. T8 SDW was consistently the lowest at all harvesting times (S1-S4).

Basic fertilizers, N, P and K are the essential nutrient which helps to improves yield and quality of sweet potatoes (Westermann, 2005). Sufficient nutrient with a conducive environment plays a major role in improving the fresh vines and tuber growth had proved that integrating organic and inorganic fertilizers could bring a significant effect on plant growth compared to untreated plants (Desire *et al.*, 2017; Zewide *et al.*, 2012). The highest plant dry weight (480.06 g/plant) and tuber yield (18.66 t/ha) was reported with the use of integrated fertilizers, whereas the lowest weight (62.54 g/plant) and tuber yield (2.11 t/ha) were recorded in control treatments. Inorganic fertilizers had been shown to increase plant growth through enhancement of the N, P and K uptake (Norton *et al.*, 2013). The SDW results of this study were in line with Li *et al.* (2011) which proved that optimum N supply is the keys to maximize the shoot and tuber growth at the highest amount (Desire *et al.*, 2017). Environmental issues such as N leaching could influence the nutrient's availability in the soil, thus limiting plant size and tuber production.

Studies had found that dry matter could increase with the use of more fertilizer. However, any increase from the optimum treatment

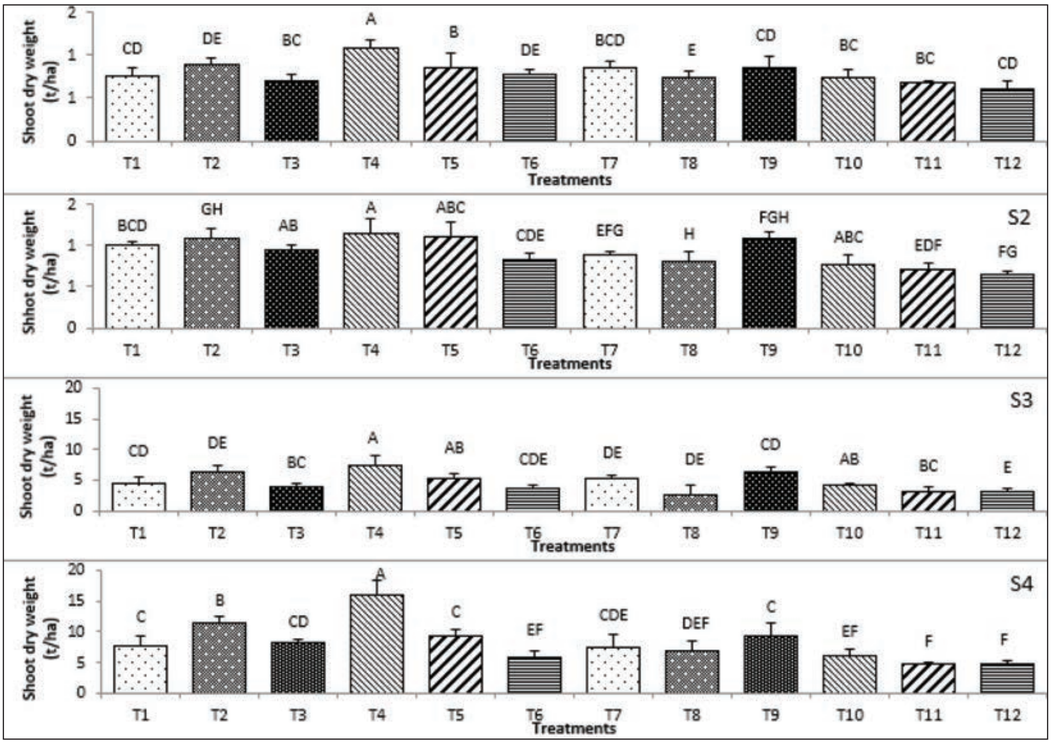

Figure 5: Effect of different fertilizer treatments on shoot dry weight (t/ha) of sweet potatoes at 26 DAP (S1), 52 DAP (S2), 78 DAP (S3) and 120 DAP (S4). Mean values with the same letters at each harvesting time are not significantly different

had been observed to degrade dry matter accumulation in corn (Schwab & Murdock, 2014). Among all treatments in the study, polymer-coated urea showed the highest value of dry matter and grain yield, as well as total N and N uptake compared to control. Another study on paddy reported that the maximum dry matter accumulation in the crop was at 60% NPK treatment, while 0% NPK and 100% NPK less in dry matted of paddy (Deng *et al.,* 2017).

Tuber Fresh Weight and Tuber Dry Weight

The major constraints in maximizing tuber yield are inadequate and imbalanced nutrients in the soil, which could limit the growth of sweet potatoes (Awgchew *et al.*, 2017). Table 1 showed there were significant ($P<0.05$) effects of CM and NCU treatment on TFW and TDW at S4, while there were no significant effects at S3. The results showed that CM application could significantly ($P<0.05$) increase TFW and TDW of sweet potatoes by 34.03% and 28.57% respectively, compared with treatments without CM at S4.

From Table 1, 76.8 kg N/ha of NCU (with and without CM treatment) showed significantly higher ($P<0.05$) TFW and TDW at S4 compared with other treatments. Tuber production did not increase with increasing treatment of fertilizer (Ayoola *et al.*, 2002). In fact, Table 1 shows that TFW and TDW had significantly decreased by about 38% and 48.31% respectively, as NCU treatments increased. Excessive urea in soil could impede tuber growth, yield and quality of sweet potatoes as it might shorten the tuber bulking period, reduce specific gravity and delay maturity (Alam *et al.*, 2017). Meanwhile, the farmer's practice of 96 kg N/ha showed no significant difference of TFW and TDW at S4 between 0 kg N/ha and 115.2 kg N/ha of NCU. These findings were in line with Awgchew *et al.* (2017) who stated that different fertilizer

Table 1: Effects of CM application and different treatments of NCU fertilizer on tuber fresh weight (TFW) and tuber dry weight (TDW) of sweet potatoes at 104 DAP (S3) and 120 DAP (S4), N_2 uptake by shoot and tuber as well as NUE (%) of sweet potatoes at 120 DAP

Treatment	TFW (g)		TDW (g)		NU (Kg/ha)		NUE (%)
Chicken Manure	S3	S4	S3	S4	Shoot	Tuber	
CM	3.60a	11.58a	0.69a	1.80a	22.11a	11.38a	14.11a
NoCM	2.67a	8.64b	0.49a	1.40b	15.04b	8.31b	8.62b
LSD $_{P<0.05}$	1.14NS	1.10***	0.22NS	0.25*	2.72***	1.33***	2.77***
Treatment (kg/ha)							
96 (urea)	3.08ab	8.38c	0.56ab	1.38bc	16.08c	9.58c	6.95c
0 (NCU)	2.06b	6.92c	0.41b	1.18c	10.24d	4.71d	NIL
58 (NCU)	3.19ab	10.58b	0.53ab	1.76b	18.27c	10.26bc	14.01b
77 (NCU)	4.39a	14.71a	0.85a	2.34a	29.65a	13.97a	19.03a
96 (NCU)	3.57ab	12.08b	0.68ab	1.77b	23.34b	12.17ab	11.83b
115 (NCU)	2.51ab	7.98c	0.49ab	1.26c	13.87cd	8.41c	5.01c
LSD $_{P<0.05}$	1.98NS	1.91***	0.39NS	0.43***	4.71***	2.31	4.38***
CM x N Treatment	NS	NS	NS	NS	NS	0.096*	NS

$P<0.05$ with n=48. * and *** indicate significant differences at $P<0.05$ and $P<0.001$ and NS = not significant

treatments had a significant impact on tuber production and NUE at 184 kg/ha as compared to other treatments (0, 46, 92 and 230 kg/ha). In that study, the application of 184 kg/ha of urea increased the tuber weight by 96.71 % compared with control. According to Awgchew *et al.* (2017), tuber production did not increase with increasing NCU amounts.

Shoot and Tuber Nitrogen Uptake

There was no significant interaction between CM application and different NCU treatments on NUS, but it was significant in NUT. From Table 1, the highest NUT was recorded at 76.8 kg N/ha NCU, which increased by 31.4%, but there were no more significant differences with subsequent increases of fertiliser treatment. The lowest NUT was recorded at 0 kg N/ha NCU, which was lower by 50.8% as compared to control. At 96 kg N/ha NCU, the NUT started to decrease by 12.9% compared to 76.8 kg N/ha NCU (highest). This NUS and NUT results in this study was in agreement with those reported by Montanez *et al.* (1996). The values between NUT and NUS were not much different and they ranged from 11% to 22% which were similar to Montanez *et al.* (1996). Meanwhile, comparison of mean values showed there were significant differences between treatments of fertilizer in NUS. Table 1 shows significant effects of NUS with different fertilizer applications. The highest NUS was recorded at 76.8 kg N/ha NCU, which increased by 45.8% as compared to control (96 kg N/ha urea). While the lowest NUS was recorded at 0 kg N/ha NCU, which decreased by 36.3% but there was no significant difference with 115.2 kg N/ha NCU (13.7%) as compared to control treatment. At 96 kg N/ha NCU, N uptake by shoot started to reduce by 21.3%, which concurred with other observations stating that marketable sweet potato yield could be negatively affected by increasing amounts of fertilizer treatment. This also corresponded with studies showing more growth on the shoots (upper part) compared to tuber (lower part) (Hartemink *et al.*, 2000; Montanez *et al.*, 1996). Based on their results, the highest marketable sweet potato yield was recorded at 400 kg N/ha treatment, while the lowest was 100 kg N/ha. These results were affected by N uptake in both parts of the sweet potato plant, as it increased with increasing N uptake up to optimum rate that needed by plants and decreased by 37.86%, 14.56% and 55.34% as it received excessive N treatment (200 kg N/ha, 300 kg N/ha and 400 kg N/ha) respectively as compared to 100 kg N/ha.

Nitrogen Use Efficiency

Maximum yield of plants might be achieved with maximum N uptake. If the N availability in soil is insufficient, the plants would start to show symptoms on their leaves, stem and roots. With urea fertilization, the most critical part was the percentage of N fertilizer that could be taken up from 100% application. Based on previous studies, N uptake in shoots and tuber showed significant effects on NUE of sweet potatoes as the plant grew better with sufficient N fertilizer in the soil (Montanez *et al.*, 1996). Another study found that 4 t/ha of urea showed the highest reading of NUE among all treatments (0 t/ha, 2 t/ha, 6 t/ha and 8 t/ha) (Islam *et al.*, 2013). According to their results, the P and K use efficiency would influence N uptake as well.

Urea deficiency in soil could hinder vegetative and reproductive growth, as well as tuber production, which resulted in yield loss (Gerik *et al.*, 1994). Thus, pH testing of the soil must be conducted as an indicator to ensure that nutrients in soil were sufficient for plant uptake. The pH was recorded before (4.19) and after (5.40) the liming process, together with soil composition analysis: sand (43.07%), silt (10.41%) and clay (47.49%), mineral N contents (12.53 µg/g NH^{4+}-N and 5.01 µg/g NO_3—N). Soil nutrient contents were 0.11% N, 0.89% P, 29.15 mg/kg K, 70.68 mg/kg Ca and 10.03 mg/kg Mg. Application of 76.8 kg N/ha NCU showed significantly higher ($P<0.05$) NUE in the crop as compared to control (19.03%) and other treatments, while the lowest NUE was recorded with 115.2 kg N/ha NCU treatment. However, there were no significant differences between 96 kg N/ha FP and 115.2 kg N/ha NCU. NUE could be one of the ways to determine the growth performance of plants in terms of increased SDW and decreased root dry weight (Walker *et al.*, 1989).

Yield

Figure 7 showed there was significant interaction between fertilizer treatments and CM application on TY of sweet potatoes (t/ha). TY was explained as total returns during harvest, which was related to SFW, TFW and N uptake in shoots and tuber. In this experiment, T4 (76.8 kg N/ha NCU+CM) produced the highest TY

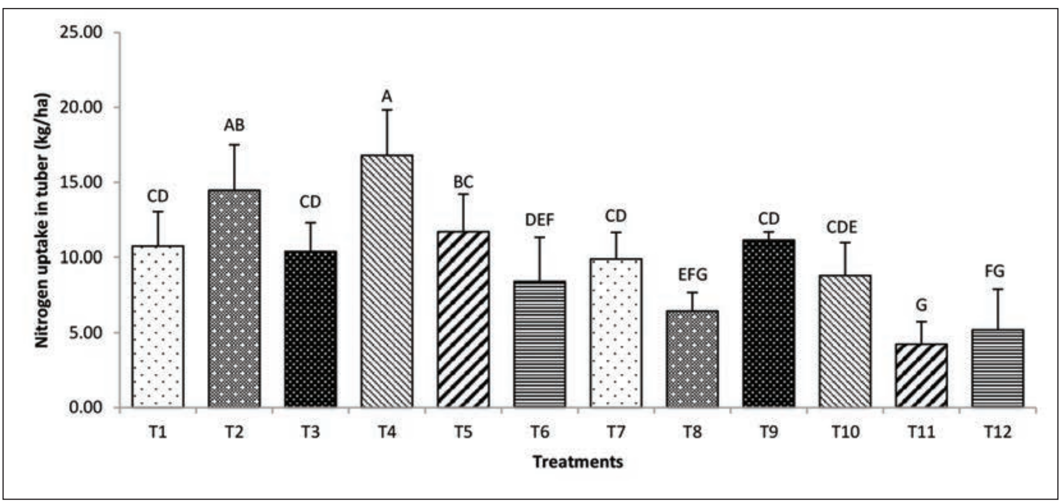

Figure 6: Effect of different fertilizer treatments on nitrogen uptake in tuber (kg/ha) of sweet potatoes. P<0.05 LSD Mean values with the same letter within each harvesting time are not significantly different at P<0.05 by the least significant difference (LSD)

of sweet potatoes, which increased by 26.4%. However, the analysis of variance showed there were no significant differences between T4 and T5 (96 kg N/ha NCU+CM), which increased by 18.1% as compared to control treatments (T1). Based on a previous study, the combination of poultry manure with inorganic fertilizer gave extra benefits in terms of improved crop yield, soil fertility and lower production cost (Yeng *et al.*, 2012). Similar results had been observed in maize (Ayoola *et al.*, 2002; Chung *et al.*, 2000; Dapaah *et al.*, 2009; Olutayo *et al.*, 2005, rice (Satyanarayana *et al.*, 2002) and sorghum (Bayu *et al.*, 2006).

Meanwhile, the lowest TY was reported between two treatments, which were T8 (0 kg N/ha NCU) and T12 (115.2 kg/ha NCU), showing a decrease of about 61.1% and 45.8%, respectively, compared to control. Other studies had found the same results (Hartemink *et al.*, 2000). According to Hartemink *et al.* (2000), the highest TY of sweet potatoes was reported at 70% and 80% of N treatment with compost, which increased yield by 35.7% and 36.7%, respectively. Similarly, a study on the effect of different fertilizer treatments on sweet potato yield was carried out by Phillips *et al.* (2005). Their findings demonstrated that excessive urea in the soil would lead to a decrease in the production of sweet potatoes. Applying too much urea could lead to increased soil acidity, which would hinder the conversion of ammonia to nitrates needed by the plants. According to another study, a high amount of fertilizer could maximize leaf growth and tuber production, but, once the N needs were satisfied, any additional fertilizer would be used on leaf growth only (Nikolajsen *et al.*, 2020). Additionally, they reported that any extension of fertilizer application would induce K deficiency and limit tuber yield at the expense of leaf growth.

Conclusion

This study showed that sweet potatoes grown with highest amount of fertilizer at 115.2 kg N/ha NCU (T6 & T12) was able to promote similar result as the crop that received 96 kg N/ha NCU (T1 & T7). Sweet potato production would subsequently decrease with increased amounts of fertilizer used. Application of 76.8 kg N/ha NCU (T4 & T10) produced the highest reading in all parameters. However, 96 kg N/ha NCU (T5 & T11) showed there were same effect on shoot

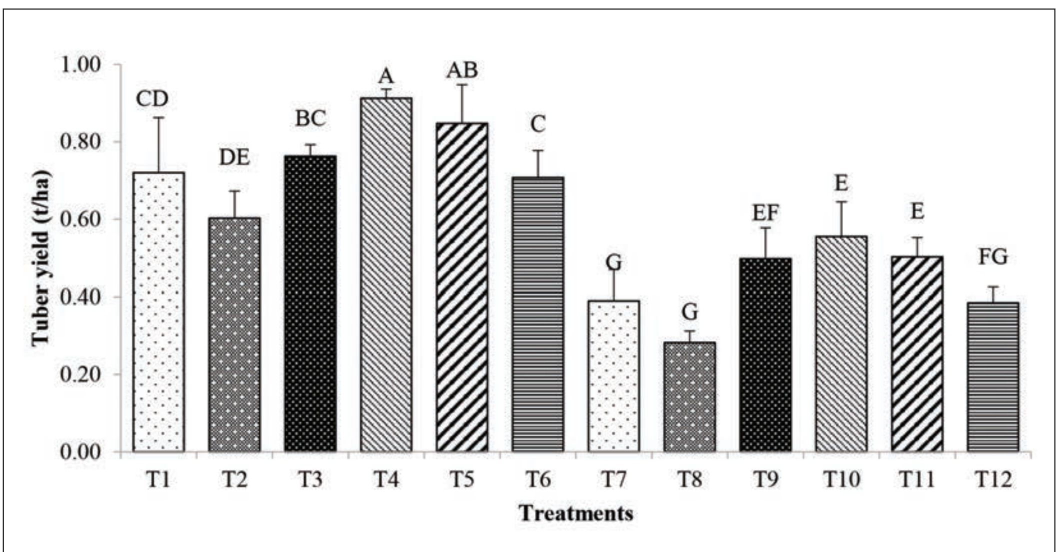

Figure 7: Effect of different N fertilizer rate on yield (t/ha) of sweet potatoes at 120 DAP (S4). Mean values with the same letters are not significantly different

fresh weight (SFW), tuber fresh weight (TFW), tuber dry weight (TDW), N uptake by tuber (NUT) and yield. In conclusion, 76.8 kg N/ha NCU with or without CM (T4 & T10) might be recommended for sweet potato production. The rate was about 19.2% less than farmers practice, thus it would help farmers in reducing their production cost, increasing NUE and obtaining higher yield. Reduction in fertilizer application was very important for food security because it could create a sustainable production system and avoid excessive use that cause environmental pollution.

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