Sys Rev Pharm 2020; 11(2): 309 – 316
A multifaceted review journal in the field of pharmacy
E-ISSN 0976-2779 P-ISSN 0975-8453

The Effect of Nitrogen, Phosphorus, and Potassium Fertilizer on the Yield and Quality of Sweet Potato (Ipomoea batatas L.) Clones in the Highlands of Indonesia

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Article History: Submitted: 28.11.2019 Revised: 15.01.2020 Accepted: 10.02.2020

ABSTRACT
Sweetener production in Indonesia decreased due to the unavailability of clones with high yield potential and site-specific. This research aims to assess the influence of nitrogen, phosphorus, and potassium fertilizer (NPK) in plants and the quality of sweet potato in the Indonesian highlands. The research was conducted at Syiah Kuala University Farm, Bener Festive (998 m above sea level), Aceh Province, Indonesia. Experiments It were performed using a completely random block design with factorial patterns. The results showed three factors 15:15:15 NPK doses (200, 300, and 400 kg • ha – 1) and seven Sweet potato lines (CIP-LSQ, CIP-287, CIP-GA, CIP-B9, CIP-440137, local Saree landrace, and the Antin I varieties). The highest tuber yield (32.51 t • ha – 1), coarse fat, crude fiber, Total glucose, and starch were found at a dose of NPK 400 kg ha – 1. The CIP-GA clone has the highest yield of the tuber (39.86 t • ha – 1), which does not differ significantly from the CIP-287 (37.13 t • ha – 1), but this clone has a biomass weight. The CIP-GA clone has The highest moisture conte coarse protein (3.91%), crude fiber (2.67%), and beta-carotene (6.24 • 100 g – 1) of those tested; However, it is also lower in total glucose has the lowest starch content.

Keywords: beta-carotene, biomass, clone, sweet potato, tuber yield

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DOI: 10.5530/srp.2020.2.48

INTRODUCTION

Sweet potato (Ipomoea batatas L.) is an important source of carbohydrates, beta-carotene, and ascorbic acid in Indonesia, where plants grown over a wide area ranging from the lowlands to the highlands. Plants are typically grown under less than ideal conditions where production of other crops is severely limited (Uwah et al., 2013). Tubers are used for diet diversification, animal feed, and as raw ingredients for industrial food production. As the Indonesian population has grown, the demand for food production has also increased. Unfortunately, the production of sweet potato in Indonesia decreased by 6.45%, from 2.169M t in 2016 to 2.029M t in 2017, while harvested area decreased by 10.60% from 123.6 ha in 2016 to 110.5 ha in 2015 (Kementerian Pertanian Republik Indonesia, 2019). In order to address these drops in production and harvested area, optimizing production of region-specific clones as well as the appropriate application rate of nitrogen, phosphorus, and potassium (NPK) fertilizer are effective options.

In the highlands, sweetpotatoes grown at altitudes of 700+ m above sea level (ASL) can produce high yield; however, they require a longer harvest period. Planting sweet potatoes at higher altitudes delays maturity and allows for prolonged photosynthesis. Junior et al. (2009) evaluated sweet potato clones grown at an altitude of 1250 m ASL and was harvested after seven months in Diamantina, Brazil. The results showed that the yield of tubers ranged from 22.0–45.4 t·ha−1. In a previous study, a total of 19 sweetpotato clones from The Center of International Potato-South-East Asia (CIP-SEA), Bogor, Indonesia, were studied with regards to their adaptability in the highlands of Bener Meriah (998 m ASL), Aceh Province. The sweet potato clones CIP-LSQ, CIP-287, CIP-GA, CIP-B9, and CIP-440137 produced higher tuber yields compared to other clones tested.

Applying NPK fertilizer increases the total-N, available P, and available K in the soil as well as the levels and uptake of N, P, and K nutrients and plant yield. Tuber yield and chemical composition measured as moisture, ash, crude fat, crude protein, carbohydrate, crude fiber, starch, total glucose, protein and beta-carotene of highly productive sweet potato clones are expected to increase with NPK fertilizer application (Gibberson et al., 2017). Mukhtar et al. (2010) reported that the best growth and yield of sweet potatoes was obtained using a dosage of 450 kg·ha−1 NPK (15:15:15) fertilizer. Asawalam and Onwudike (2011) applied NPK of 200 kg·ha−1 along with cow dung at 1.9 t·ha−1, which resulted in improved soil properties, nutrient uptake, growth, and yield of sweet potato in Umudike, Nigeria. However, this differs from their recommended application of 0.9 t·ha−1 cow dung and 300 kg·ha−1 NPK fertilizer in Uturu, Nigeria, which indicates that fertilizer treatments require optimization for varying regions. Koodi et al. (2017) found that the application of NPK fertilizer (100:60:100) with vermi-compost level of 5 t·ha− 1 increased the growth, yield, and quality of tubers (starch, protein, and vitamin C content) in sweet potatoes. Furthermore, the chemical composition of sweet potato clones varies due to growing environmental factors such as type of climate, soil, and other factors (Bovell-Benjamin, 2007). Naz et al. (2011) found in their study on potatoes that the plant response to NPK fertilizer varied depending on variety, soil type, and geographical characteristics. Information on the optimum application rate of NPK fertilizer in sweet potatoes is limited, but several different NPK fertilizer compositions are commercially available. In order to determine appropriate fertilizer treatments, this study was conducted to evaluate the effects and interactions of NPK fertilizer (15:15:5) with several sweet potato clones on yield and quality of sweet potatoes grown in the Indonesian highlands.

MATERIALS AND METHODS

Experimental site

The study was conducted from March to August in 2016, at the University Farm, Universitas Syiah Kuala, Bener Meriah, Aceh Province, Indonesia (4°45'44"N and 96°44'48"E), at an altitude of 998 m ASL. Average rainfall from March to August was 137 mm·month^{-1}; the average number of rainy days was 8.7 days·month^{-1}; and the average temperature was 20°C (Meteorology, Climatology, and Geophysics Center).

The soil was analyzed at the Soil Laboratory, Bogor Agricultural University, Bogor, Indonesia. The type of soil at the study site was Andisol. The soil texture was sandy clay with a sand content of 51.12%, dust content of 25.97%, and clay content of 22.91%. The soil acidity at pH H_2O (1:1) was 5.34, indicating an acidic soil. Soil nutrients were measured, and their relative concentrations were determined. The soil make-up was: organic-C 4.02% (high), N-Total 0.30% (moderate), P_2O_5 15.0 ppm (low), available Ca^{2+} 3.58 me·100 g^{-1} (moderate), available Mg^{2+} 0.54 me·100 g^{-1} (low), available K^+ 0.14 me·100 g^{-1} (low), available Na^{2+} 0.09 me·100 g^{-1} (very low), and cation exchange capacity was measured as 17.38 me·100 g^{-1} (medium). The value of base saturation of 25.03% (low). The content of micro soil elements were: H^+ 0.20 at me·100 g^{-1} and Fe^{2+} 39.13, Cu^{2+} 0.81, Zn^{2+} 1.59, and Mn^{2+} 3.04 ppm. Al^{3+} was not measured. Soil with the nutrient status criteria as described is classified as soil with low fertility rates (Pusat Penelitian Tanah dan Agroklimat, 1993).

Planting materials

The plant material used in this research included five clones from CIP-SEA (CIP-LSQ, CIP-287, CIP-GA, CIP-B9, and CIP-440137), a local Saree clone, and the Antin I variety. CIP-LSQ and CIP-GA originated in Bogor, Indonesia, CIP-B9 originated in Kuningan, Indonesia, CIP-287 and CIP-440137 were breeding clones from Lima, Peru, the local Saree clones were from Aceh Besar, Indonesia, and Antin I was from the Nuts and Tuber Crops Research Center, Malang City, Indonesia. The clones were characterized according to their flesh color, where CIP-LSQ was classified as cream, CIP-287 and CIP-B9 as yellow, CIP-GA and Antin 1 as orange, the local Saree clone as pale orange, and CIP-440137 as white. Cuttings of 25 cm were taken from each sweet potato clone.

Planting, maintenance, and harvesting of sweet potatoes

Initial land preparation consisted of weed removal and soil cultivation. Mounds of 100 cm width, 40 cm height, and 225 cm length were made and spaced at a distance of 70 cm in the row and 50 cm between rows. Individual sweet potato cuttings were planted at a spacing of 30 cm in the mound at a depth of 5 cm. Cow dung was applied 7 days before planting with a dosage of 20 t·ha^{-1}. Inorganic fertilizer (15:15:15 NPK) was applied at dosages of 200, 300, and 400 kg·ha^{-1} with half the dose applied at seven days after planting (DAP) and the remaining half at 21 DAP. Replanting was done at the 14 DAP. Plants were watered as needed. Weed control, sprouting, and reversal of tendrils occurred at 28, 56 and 84 DAP. Sweet potato tubers were harvested at 126 DAP.

Data collection

Sweet potato growth, yield, and overall quantity of production were measured as fresh biomass weight·plant^{-1} (g), dry biomass weight·plant^{-1} (dried in an oven at 60°C for 72 hours) (g), total tuber weight·plant^{-1} (g), large tuber weight·plant $^{-1}$ (g), small tuber weight·plant^{-1} (g), number of large tubers·plant^{-1}, number of small tubers·plant^{-1}, total number of tubers·plant^{-1}, and tuber yield (t·ha^{-1}). Tubers of more than 200 g were considered as large tuber, while tubers of less than 200 g were considered small. To assess the quality attributes of the tubers, chemical tests were performed, which consisted of the percentage of moisture content, ash content, crude fat content, crude protein content, carbohydrate content, dry matter content, crude fiber content, total glucose content, starch content and beta-carotene content (mg·100 g^{-1}).

Chemical content analysis

Sample preparation for chemical content analyses were performed on sweet potato tubers at 3 days after harvesting. The sample was comprised of 7 tubers taken randomly from each treatment, which were then washed, peeled, and cut to a size of 2–3 mm using a grated knife. The tubers were then heated in an oven at 60°C for 5 hours. After the sliced tubers were removed from the oven, they were milled and sieved with a size 80 mesh sieve. The samples used for chemical testing were measured on a dry weight base and stored in plastic bags at –4°C (Dako et al., 2016).

The chemical analyses performed in this study were the standardized methods of the Association of Official Analytical Chemists Official (AOAC, 1995), except for carbohydrate, crude fiber, total glucose, and beta-carotene analyses. The chemical analyses and methods included: moisture and dry matter (oven method), ash (furnace method), crude fat (Soxhlet extraction method using ethyl ether as the extraction solvent), crude protein (Kjeldahl method), crude fiber (SNI 01-2891-1992) (Badan Standardisasi Nasional, 1992), and starch content (direct acid hydrolysis method). Carbohydrate levels (Bach et al., 2018) were determined by the difference method (100% – (% moisture + % ash + % crude fat + % crude protein), total glucose by the phenol sulfate method (Dubois et al., 1956), and beta-carotene by UV Spectrophotometric method using an UV-VIS Spectrophotometer (UV-1700). Chemical analyses were carried out at the Food Analysis Laboratory, Agricultural Faculty of Universitas Syiah Kuala, Indonesia.

Crude fiber analysis (SNI 01-2891-1992)

A 5g sample with fat removed by Soxhlet extraction was put into a 500 mL Erlenmeyer flask, and then diluted with 50 mL of 1.25% H_2SO_4 solution, and boiled for 30 minutes. After cooling, the sample was diluted with 3.25% NaOH up to 50 mL, then boiled again for 30 minutes. The sample was filtered with dried Whatman No. 41 filter paper of known weight. While hot, the material was filtered with a Buchner funnel. The used filter paper was then washed consecutively with 1.25% H_2SO_4, boiling water, and finally with 96% ethanol and then weighed. The filter paper and sample were dried in an oven at 105ºC for 20 minutes, then weighed and dried until reaching a constant weight. The paper and sample were then put into a crucible of known weight, which was put into a muffler furnace at 550ºC for 5 hours. The level of crude fiber was calculated using the formula:

$$\text{Crude fiber content (\%)} = \frac{\text{filter paper weight} + \text{fiber} - \text{filter paper weight}}{\text{sample weight (g)}} \text{ x } 100\%$$

Beta-carotene content (UV Spectrophotometric method)

The carotene content in each sample was estimated by acetone-petroleum ether extraction followed by spectrophotometric measurement (Shajib et al., 2013). The carotenoid was performed by grinding the processed sweet potato sample with a mortar and pestle, and filtering it through Whatman No. 41 filter paper. The petroleum eluent was adjusted to a specific volume and read at 450 nm in a spectrophotometer. The results were expressed in milligrams per 100 g of fresh weight (mg·100 g−1).

Experimental design

This study consisted of two stages using a randomized completely block design in factorial pattern with three replications. The first study was conducted on the growth and yield of sweet potato plants (quantity) consisting of two treatments, NPK fertilizer (three levels: 200, 300, and 400 kg·ha−1) and clones (seven clones: CIP-LSQ, CIP-287, CIP-GA, CIP-B9, CIP-440137, local Saree clone, and Antin I). The second study was a chemical treatment analysis of the five higher productions sweet potato clones in the highlands (CIP-LSQ, CIP-287, CIP-GA, CIP-B9, and CIP-440137).

Statistical analysis

Statistical analyses of data were performed using an analysis of variance, and for treatments that showed a significant effect, an additional Duncan's New Multivariate Range Test at the level of 5% was performed. Data were analyzed using SPSS version 22.0. Chemical components were analyzed based on standard deviation.

RESULTS AND DISCUSSIONS

The effect of NPK fertilizer on yield and quality attributes of sweet potato tubers

The effects of the NPK level on the yield attributes are shown in Table 1. The results of the study showed that vegetative growth as reflected by fresh and dry biomass weight tend to be higher at an NPK application rate of 400 kg·ha−1, although there were no significant differences observed among the NPK fertilizer dosages. However, an application rate of 400 kg·ha−1 NPK did produce the highest yield, significantly increased total tuber weight, large tuber weight, the number of small tubers, total number of tubers, and potential yield. This is consistent with the study of Constantine (2016) that showed that yields and components of sweet potato yields increased linearly with the increasing dosages of NPK fertilizer up to 350 kg·ha−1.

The increase in growth and yield as affected by the increasing level of NPK fertilizer are caused by N, which is a component of proteins and nucleic acids (RNA and DNA). It plays an important role in photosynthetic activity and yield capacity and is one of the main stimulating factors in production (Hakmalipour and Darbandi, 2011). Nitrogen promotes vegetative growth, but cannot react without P and K as well as other essential nutrients. Phosphorus plays an important role in photosynthesis, respiration, energy storage and transfer, cell division and enlargement, promoting early root formation, and growth (Shukla et al., 2018), while K is essential for carbohydrate translocation, root growth, and is crucial in plant water intake (Romheld and Kirkby, 2010).

Table 1. The Effects of NPK level on the growth and yield attributes of sweetpotato

Parameters	NPK (kg·ha^{-1})		
	200	300	400
Fresh biomass weight plant^{-1} (g)	505.90	507.24	541.33
Dry biomass weight plant^{-1} (g)	84.82	85.05	94.11
Total tuber weight plant^{-1} (g)	329.24^a	341.29^b	406.38^c
Large tuber weight plant^{-1} (g)	153.43^a	165.48^b	203.71^c
Small tuber weight plant^{-1} (g)	178.74^a	175.10^a	213.24^b
Number of large tubers plant^{-1}	0.68^a	0.77^b	0.87^b
Number of small tubers plant^{-1}	1.92^a	1.88^a	2.27^b
Total number of tubers plant^{-1}	2.60^a	2.65^a	3.13^b
Tuber yield (t·ha^{-1})	26.34^a	27.30^b	32.51^c

Letters after each mean value in each row indicate differences at P<5% level according to DNMRT

As indicated in Table 1, the application of NPK in the range of 200–400 kg·ha− 1 in this study produced tubers in the range of 2.60–3.13 tubers·plant−1 and a total tuber weight between 329.24–406.38 g·plant−1 (weight potential yield range is 26.34–32.51 t·ha−1). According to Rubatzky and Yamaguchi (1997), sweet potato plants usually produce 4–10 tubers of 100–400 g. Akpaninyang et al. (2013) reported that the average tuber weight obtained from a 400 kg·ha−1 application was 12.49 t·ha−1, much higher than the weight of the control. The application of NPK fertilizer has also been reported to increase the growth, tuber yield, P, K, and Ca content in sweet potato leaves and tubers (Agbede, 2010; Kareem, 2013; and Mu'azu 2016). The recommended application rate for sweet potato cultivation is 100–200 kg·ha−1 of urea, 100 kg·ha− 1 of TSP, and KCl (Kementerian Pertanian, 2012). In this study, the 400 kg·ha−1 application of NPK fertilizer was equivalent to 130 kg·ha−1 of urea fertilizer (46% N), 130 kg·ha−1 of TSP (46% P2O5), and 100 kg·ha−1 of KCl (60% K2O).

Table 2. The effects of NPK fertilizer application on sweet potato quality attributes

Quality attributes	NPK (kg·ha^{-1})		
	200	300	400
Moisture (%)	64.41 ± 2.62	63.96 ± 2.94	64.44 ± 3.30
Ash (%)	0.90 ± 0.05^a	1.06 ± 0.12^b	1.24 ± 0.10^b
Crude fat (%)	0.81 ± 0.14^a	1.12 ± 0.09^b	1.21 ± 0.15^c

Crude protein (%)	3.27 ± 0.70	3.19 ± 0.54	3.13 ± 0.43
Carbohydrate (%)	30.86 ± 2.94	30.72 ± 3.65	29.62 ± 3.47
Dry matter (%)	35.59 ± 2.62	36.04 ± 2.94	35.56 ± 3.30
Crude fiber (%)	2.31± 0.25^{a}	2.39 ± 0.23^{a}	2.49 ± 0.21^{b}
Total glucose (%)	3.08 ± 0.26^{a}	3.16 ± 0.25^{a}	3.27 ± 0.20^{b}
Starch (%)	20.75 ± 2.21^{a}	21.74 ± 2.06^{b}	22.71 ± 1.67^{c}
Beta-carotene (mg·100g^{-1})	3.10 ± 2.00^{a}	3.55 ± 2.05^{b}	3.34 ± 1.96^{a}

Plus or minus values indicate the standard deviation, and letters after each mean value in each row indicate differences at P<5% level according to DNMRT

The effects of NPK fertilizer application on sweet potato quality attributes are listed in Table 2, including ash content, crude fat, crude fiber, total glucose, and starch, which were highest at NPK 400 k· ha−1. The application of NPK ranging from 200 to 400 kg·ha−1 in this study resulted in ash levels ranging from 0.90%–1.24%, crude fat from 0.81%–1.21%, crude fiber from 2.31%–2.49%, total glucose from 3.08%–3.27%, starch from 20.75%–22.71%, and beta-carotene from 3.10–3.55 mg·100 g−1. Moreover, in this study all traits increased significantly as NPK fertilizer application rates approached 400 kg·ha−1, except for beta-carotene. Typically, NPK fertilizer levels have been reported to increase beta-carotene, protein, and other composition in some sweet potato varieties (Gibberson et al., 2017). Eleiwa et al. (2012) found that the beta-carotene of potatoes treated with NPK (120:80:100) sprayed six times every 15 days during the vegetative period, increased up to an application rate of 300 kg·ha−1 but subsequently decreased with NPK doses of more than 300 kg·ha−1. As expected, the protein and carbohydrate levels decreased with an increasing level of NPK fertilizer, although statistically not significant, while total glucose increased significantly. Chemical components such as total glucose, total soluble solids, carbohydrates, starch, and carotene content have also been shown to increase with the application of P (P2O5) fertilizer (El-Sayed et al., 2011; Razzak et al., 2013). In their research, Mitiku and Teka (2017) also found a higher range of fat and lower range of fiber of 1.25%–1.52% and 1.04%–1.16%, respectively, in two sweet potato varieties released in Ethiopia, and Ukom et al. (2009) found that crude fiber decreased with an increasing level of N. Given these results, chemical composition seems to vary widely and be highly dependent on a combination of environmental factors.

The effect of different clones on the yield and quality attributes of sweet potato tubers

Fresh and dry biomass weights of sweet potato plants are listed in Table 3, and the highest weights were those of clone CIP-B9. In terms of fresh biomass weight, CIP-B9 was significantly different from CIP-287 and CIP-GA, but it was not significantly different from CIP-LSQ and Antin I. In terms of dry biomass weight. CIP-B9 was significantly different from CIP-287, CIP-GA, and the local Saree clone, but not significantly different from the CIP-LSQ, CIP-440137 clones, and Antin I variety. The difference between the clones with regards to the vegetative portion of the plant was most likely caused by differences in genotype among the plants and environmental influences.

Table 3. The effects of clones type on the growth and yield attributes of some sweetpotato

Parameters	Sweetpotato Clones						
	CIP-LSQ	CIP-287	CIP-GA	CIP-B9	CIP-440137	Local Saree	Antin 1
Fresh biomass weight plant^{-1} (g)	570.22^{bc}	391.11^{a}	420.67^{a}	638.89^{c}	559.33^{b}	529.11^{b}	517.78^{bc}
Dry biomass weight plant^{-1} (g)	99.17^{b}	73.69^{a}	73.88^{a}	106.03^{b}	105.16^{b}	78.42^{a}	79.58^{a}
Total tubers weight plant^{-1} (g)	315.56^{b}	464.11^{c}	498.22^{c}	348.67^{b}	325.78^{b}	239.56^{a}	320.89^{b}
Large tuber weight plant^{-1} (g)	148.67^{bc}	219.11^{d}	285.11^{e}	185.56^{c}	143.44^{b}	78.67^{a}	158.89^{b}
Small tuber weight plant^{-1} (g)	157.11^{a}	242.78^{d}	190.44^{c}	167.56^{abc}	190.44^{c}	160.22^{a}	182.61^{bc}
Number of large tubers plant^{-1}	0.69^{bc}	0.91^{d}	1.22^{e}	0.91^{cd}	0.67^{bc}	0.38^{a}	0.84^{bc}
Number of small tubers plant^{-1}	1.71^{ab}	2.67^{d}	2.00^{c}	1.79^{ab}	2.29^{abc}	1.74^{a}	1.99^{abc}
Total number of tubers plant^{-1}	2.09^{ab}	3.58^{c}	3.52^{c}	2.64^{b}	2.67^{b}	2.42^{a}	2.63^{b}
Tuber yield (t·ha^{-1})	25.24^{b}	37.13^{c}	39.86^{c}	27.89^{b}	26.06^{b}	19.16^{a}	25.67^{b}

Letters after each mean value in each row indicate differences at P<5% level according to DNMRT

The low production of tubers in clones with high biomass weight, was likely caused by an accumulation of assimilate in vegetative tissues as opposed to tuber formation. Van Vugt and Franke (2018) compared six sweet potato varieties at seven locations in Malawi and obtained similar results where Zondeni and Anaakwanire varieties produced large quantities of biomass, but had lower yield (the average yield of fresh tubers ranged from 18 to 32

$t \cdot ha^{-1}$). Likewise, Minantyorini and Setyowati (2016), varieties with the highest biomass weight (1617 $g \cdot plant^{-1}$) had the lowest tuber weight of 433.0 $g \cdot plant^{-1}$, number of $tubers \cdot plant^{-1}$ of 2.0, and ratio of biomass to $weight \cdot tuber^{-1}$ of 3.73. This ratio indicates that it is less efficient in producing tubers.

Total tuber weight, total number of tubers, and tuber yield are also shown in Table 3. The CIP-GA clone was not significantly different from the CIP-287 clone. The CIP-LSQ and CIP 440137 clones had a tuber weight that was not significantly different from Antin1, but was still higher than the Saree clone. Total tuber weight found in this study ranged from 239.56–498.22 $g \cdot plant^{-1}$, which is consistent with Yildirim et al. (2011), who examined 13 sweet potato genotypes in Turkey that had yields between 210.5–621.8 $g \cdot plant^{-1}$. The tuber yield of the CIP-287 and CIP-GA clones obtained were high at 37.13 and 39.86 $t \cdot ha^{-1}$, respectively. The average yield of sweet potato tubers tested on various cultivation technologies in several cultivars and several years in Poland averaged 31.18 $t \cdot ha^{-1}$ and was high (Marczak et al., 2018). This yield was higher than the yield of sweet potatoes grown in nine locations in China that had an average of 36.7 $t \cdot ha^{-1}$ (Jian-wei et al., 2001). Uwah et al. (2013) also found that tuber yields varied from 20.8–25.5 $t \cdot ha^{-1}$. CIP-287 and CIP-GA clones showed higher tubers yield compared to the local Saree clone and Antin I variety. The CIP-LSQ, CIP-B9, and CIP-440137 clones did not differ significantly from Antin I, but they were higher than the Saree clone when harvested at 4.5 months. Larger tubers weight (more than 200 g), the total number of tubers, and the total weight of tubers increased when harvesting age was above 4 months, while medium, small, and unmarketable weight tubers decreased in weight when harvested at 4.5 months (Minantyorini and Setyowati, 2016). The CIP-GA clone from Bogor, Indonesia, and the CIP-287 from CIP Lima, Peru, showed the highest yield of 39.86 and 37.13 $t \cdot ha^{-1}$, respectively. These clones are best suited to the experimental environment and have the potential for production in the highlands in Bener Meriah, Aceh Province, Indonesia.

The influence of clone types on the quality attributes of some sweet potatoes is shown in Table 4. CIP-GA clones had the highest moisture content, crude protein, and beta-carotene; however, CIP-GA also had the lowest carbohydrates, dry matter, and crude fiber. This is in line with the results of Dako et al. (2016), where three colors of sweet potato tuber flesh were analyzed using the AOAC method. Orange fleshy tubers were evaluated for several traits, including moisture (74.84%), protein (2.48%), fat (1.12%), fiber (3.83%), and ash content (4.33%) and found to be the highest, while yellow tubers had lower fat and ash content. Tubers with orange color are rich in beta-carotene (Kammona et al., 2015), as was found in CIP-GA.

Table 4. The effects of clone types on the quality attributes of some sweetpotatoes

Quality attributes	Sweetpotato Clones				
	CIP-LSQ	CIP-287	CIP-GA	CIP-B9	CIP-440137
Moisture (%)	63.92 ± 1.63^{a}	63.79 ± 0.30^{a}	69.46 ± 0.63^{b}	63.02 ± 1.49^{a}	61.15 ± 0.47^{a}
Ash (%)	1.01 ± 0.12	1.09 ± 0.21	1.11 ± 0.19	0.98 ± 0.09	1.13 ± 0.15
Crude fat (%)	0.94 ± 0.12^{a}	0.98 ± 0.11^{a}	1.24 ± 0.18^{b}	0.94 ± 0.27^{a}	1.13 ± 0.20^{a}
Crude protein (%)	2.72 ± 0.24^{ab}	2.47 ± 0.20^{a}	3.91 ± 0.35^{c}	3.46 ± 0.03^{c}	3.44 ± 0.06^{bc}
Carbohydrate (%)	31.99 ± 1.82^{b}	31.28 ± 0.76^{b}	24.11 ± 1.01^{a}	31.47 ± 0.96^{b}	33.15 ± 0.87^{b}
Dry matter (%)	36.08 ± 1.63^{b}	36.21 ± 0.30^{b}	30.54 ± 0.63^{a}	36.98 ± 1.49^{b}	38.85 ± 0.47^{b}
Crude fiber (%)	2.04 ± 0.09^{a}	2.31 ± 0.11^{ab}	2.67 ± 0.11^{b}	2.38 ± 0.13^{ab}	2.59 ± 0.02^{b}
Total glucose (%)	3.47 ± 0.07^{c}	3.22 ± 0.07^{bc}	3.00 ± 0.03^{ab}	3.35 ± 0.09^{bc}	2.83 ± 0.18^{a}
Starch (%)	20.57 ± 0.86^{b}	22.46 ± 1.25^{c}	18.55 ± 1.13^{a}	23.01 ± 0.52^{d}	24.07 ± 0.39^{e}
Beta-carotene ($mg \cdot 100g^{-1}$)	1.47 ± 0.17^{a}	4.33 ± 0.15^{b}	6.24 ± 0.11^{c}	4.33 ± 0.53^{b}	0.75 ± 0.18^{a}

Letters after each mean value in each row indicate differences at P<5% level according to DNMRT

The range of ash content (0.98%–1.13%), crude fat (0.94%–1.24%), dry matter (30.54%–38.85%), crude fiber (2.04%–2.67%), and starch (18.55%–24.07%) of the five sweet potato clones studied are shown in Table 4. Omodamiro et al. (2013) examined the chemical content of 15 sweet potato genotypes using the AOAC method and determined ash content (0.50%–1.52%), fat content (1.02%–1.72%), dry matter weight (28.87%–40.90%), crude fiber (0.67%–2.00%), and starch (13.16%–22.90%). These results are in the range of the results of this study, except for the higher levels of starch and crude fiber. The results of this study also found a total glucose level in yellow tubers that was higher than in orange tubers, while the highest protein content was found in orange tubers. The CIP-LSQ, CIP-287, and CIP-B9 clones with yellow tubers were found to have the highest total glucose levels, and the orange CIP-GA clones was highest in beta-carotene. The differences in the chemical composition of sweet potatoes tubers in several clones studied appear to have a strong genetic basis.

The CIP-GA clone with orange tuber flesh had the highest levels of moisture content (69.46%), crude fat (1.24%), crude protein (3.91%), crude fiber (2.67%), and beta-carotene (6.24 $mg \cdot 100g^{-1}$), but the lowest level of starch (18.55%) (Table 4). This is consistent with Tomlins et al. (2012). Meanwhile, the CIP-GA clone had the lowest levels of carbohydrates and dry matter. Clones with low carbohydrate and dry matter content are also low in starch content (Zhang et al. 2002). Most cultivars with high water content had low dry matter, but high in fiber level. This occurs because water binds to the hydrogen groups in fiber and is not easily released due to the complex fiber structure and hydrophilicity. Dako et al. (2016) also found that orange fleshy tubers had the highest moisture (74.84%), ash (4.33%), fat (1.12%), protein (2.48%), and fiber content (3.83%), while yellow tubers were lower in fat and ash content. Sweet potatoes with orange flesh tend to have a low carbohydrate content, but high protein, crude fiber, and beta-carotene content, as in BARI SP4 and BARI SP 8 varieties (Alam et al., 2016). This is similar to the qualities of the CIP-GA clone with orange flesh.

CONCLUSIONS

The highest sweet potato tuber yield (32.51 t·ha−1) and desirable quality attributes (crude fat, crude fiber, total glucose, and starch) occurred at an NPK fertilizer application rate of 400 kg·ha−1. Higher tuber yields were found in CIP-GA (39.86 t·ha−1) and CIP-287 (37.13 t·ha−1) clones, which also had the lowest biomass weight. The CIP-GA clone had the highest moisture content (69.46%), crude fat, crude protein (3.91%), crude fiber (2.67%), and beta-carotene (6.24 mg·100 g−1), but was the lowest in carbohydrate, dry matter, and starch (18.55%). The CIP-LSQ, CIP-287, and CIP-B9 clones were higher in total carbohydrate and total glucose levels. The CIP-287, CIP-B9, and CIP-440137 clones had a higher starch content. The interaction among NPK fertilizer application rates and clones did not significantly affect yield and quality of sweet potato tubers. Given these results, sweet potato production, marketable yields, and quality in the highlands of Indonesia may benefit from an increase in applied NPK. However, clones would need to be carefully selected based on the desired end product. Further work needs to be carried out on value-added products of the CIP-GA clone prior to upscaling production.

ACKNOWLEDGMENTS

The author would like to thank the financial support provided by the Ministry of Research, Technology and Higher Education of Indonesia in the project research “Penelitian Hibah Bersaing” (Competitive Grants) year 2016 with contract number 79/UN11.2/PP/SP3/2016.

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