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Yield and Profitability of Newly Recommended Sweetpotato (*Ipomoea batatas* (L.) Lam) NSIC Sp36 Variety as Affected by Planting Density

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ABSTRACT

Appropriate planting density is necessary to achieve high crop productivity. Hence, this study aimed to determine the optimum planting density and assess the profitability per hectare of NSIC's newly recommended sweetpotato variety. The treatments were as follows: T_{1}- 1.0 m x 0.50 m at two cuttings per hill, T_2-1.0 m x 0.25 m at one cutting per hill, T_3- 1.0 m x 0.25 m at two cuttings per hill, T_4-1.0m x 0.30m at one cutting per hill, and T_5-1.0 m x 0.30 m at two cuttings per hill. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The results revealed that sweetpotato planted at wider spacing of 1.0 m x 0.50 m at two cuttings per hill produced more primary lateral vines (7.13), bigger leaf area index (4.29), fresh herbage weight (21.22 tha^{-1}), and highest weight (g) of marketable roots per hill. On the other hand, planting density of 1.0 m x 0.25 m at one and two cuttings per hill obtained the highest weight of total root yield at 13.43 t ha^{-1} and 14.04 t ha^{-1} respectively. Likewise, sweetpotato grown in 1.0 m x 0.25 m at one cutting per hill obtained the highest gross margin of PhP160,240.00 ha^{-1} due to higher root yield and less cost of planting materials. This was followed by plants planted in 1.0 m x 0.25 m at two cuttings per hill with PhP159,702.00 ha^{-1}.

Keywords: Sweetpotato, plant spacing, planting density, productivity

INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L.) Lam) is a crop belonging to the family Convolvulaceae, cultivated for its enlarged edible roots. It is one of the most widely grown root crops cultivated throughout tropical and warm temperate regions (Demissew 2006). Sweetpotato, locally known as camote in the Philippines, is grown mainly for human consumption. The fleshy roots are typically boiled, fried, baked, or fed to livestock. Sweetpotato is a good source of energy and vitamins such as carotene, niacin, ascorbic acid, and thiamine (Islam, 2006). The storage roots are used as food, (Manal et al 2011) and raw materials for starch, catsup, jam, snack chips, beverage, and alcohol production (Nungo 2004). The tender leaves are also used as vegetables, while the vines as feed for livestock. The leaves contain about 8% sugar, 27% protein, 10% ash, and about 56mg carotene per 100 g dry matter (Nyiawung et al 2010).

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One of the major concerns of sweetpotato production the improvement of yield and quality of edible roots since the production of sweetpotato in the country could not meet the demand of the processing and fresh market, (Lirag & Estrella 2017) even though Sweetpotato production accounts for 102,941,357 metric tons worldwide, with Asia as the highest producer at 76.2% (Lirag 2019). In the Philippines, the production of sweetpotato in the second quarter of 2018 reached 154.31 thousand MT. However, in comparison to the yield from the previous quarter in 2017 (189, 000 MT), there was about 12% drop in yield (FAO 2019). This is mainly due to insufficient or non-adoption of proper cultural management practices and extreme weather conditions. However, this crop is easy to grow and can thrive in dry regions and typhoon belt areas. In fact, sweetpotato was used as a major source of food and livelihood by typhoon Haiyan victims in 2013-2014 (JL Bacusmo, personal communication , 2019) .

Several production constraints impede the full potential of sweetpotato production as a source of food and nutrition.

Crop scientists and agriculturists are working together to address these production constraints. Agronomists, in particular, have been developing the best cultural practices for sweetpotato cultivars; however, these are not based on specific varietal characteristics. One of the management practices involved sweetpotato production is the manipulation of planting density. Adjusting the planting distance and the number of plants per unit area influences the crop's growth and yield performance (Abdissa et al 2011). Generally, crops grown at wider spacing encourages better growth and development of the crops, (Yooyongwech et al 2014). However, weeds may grow between the rows that also lead to the competition of light, nutrients, and moisture. Thus, determining the optimum planting density of a particular crop may give the best of its yield potential. The general recommended plant spacing of sweetpotato is 1.0m x 0.25m, having a planting density of 40,000 plants per hectare (Ambi 2008).

There are several NSIC recommended sweetpotato varieties released in the Philippines. One of these is NSIC Sp36, previously named UPL Sp17, developed by the Institute of Plant Breeding, University of the Philippines Los Baños, Laguna. This newly released NSIC sweetpotato variety is generally adapted to all kinds of soil in the Philippines. It is also a good material for processed products requiring high starch and high dry matter content. This variety is moderately resistant to sweetpotato scab fungi and moderately susceptible to sweetpotato weevil. It is a non-spreading or bushy type of sweetpotato variety. Thus, correct plant population per hectare needs to be established to attain its potential yield. This study aimed to evaluate the performance, determine the proper planting density, and assess the profitability of sweetpotato production per hectare using this NSIC Sp36 variety.

MATERIALS AND METHODS

An area of Umingan clay loam soil (FAO 2013) was used as the experimental area. This experiment was located at the Agronomy Experimental Area, College of Agriculture and Food Science, Visayas State University, Visca, Baybay City, Leyte, Philippines. The experimental area has the GPS coordinates of 10°44' 59.8668” N, 124°47' 38.1264” E. A total area of 312 m^2 was plowed and harrowed twice at weekly intervals using a tractor-drawn implement to pulverize, clean and level the soil, and to remove weeds. After the last harrowing, furrows were made at a distance of 1.0 m apart. Ten (10) soil samples, 20 cm deep, were collected randomly from the experimental field using a soil auger. The soil samples were composited, air-dried, pulverized, sieved (2-mm wire mesh), and placed in properly labeled bags. The samples were brought to the Department of Agriculture Regional Soils Laboratory, Magsaysay Blvd., Tacloban City. These were analyzed for pH (potentiometric method at 1:2.5 soil-water ratio), % organic matter (Modified Walkley-Black method), total N (Kjeldahl method), available phosphorus (Olsen's method), exchangeable potassium (ammonium acetate extraction, pH 7.0), and quantified by atomic absorption spectrophotometer. Final soil samples were collected randomly from each treatment plot after harvest for analysis. They were composited, processed, and analyzed for the same soil parameters mentioned above. The treatments were designated as follows: T_1= 1.0 m x 0.50 m at 2 cuttings hill^{-1} (farmers practice), T_2= 1.0 m x 0.25 m at 1 cutting hill^{-1}, T_3 = 1.0 m x 0.25 m at 2 cuttings hill^{-1}, T_4= 1.0 m x 0.30 m at 1 cutting hill^{-1}, and T_5= 1.0 m x 0.30 m at 2 cuttings hill^{-1}. The experimental area was laid out in Randomized Complete Block Design (RCBD) with three replications. Each treatment plot measured 4.0 m x 4.0 m (16 m^2). Replication and treatment plots were separated by 1m and 0.50 m alleyways, respectively, to facilitate farm operations and data gathering.

Sweetpotato (NSIC Sp36) cuttings were procured from the Philippine Rootcrop Research and Training Center, Visayas State University, Visca, Baybay City, Leyte. The terminal cuttings about 25-35 cm in length were taken from the mature vines with at least five nodes. The cuttings were bundled and placed under a shady place near the experimental site a day before planting to prevent dehydration. The cuttings were planted at a depth of 20 cm, allowing the 5-15 cm of the vine above the soil surface. Hand weeding was done using a bolo to control weeds. The first hand-weeding operation was done three weeks after planting and spot weeding was done a week later. Hilling up was done after weeding to loosen the soil and facilitate root development. A drainage canal was constructed around the experimental area and between replications to drain excess water during rainy days and to irrigate water during dry periods. Application of complete fertilizer at 45-45-45 kg ha^{-1} N, P_2O_5, K_2O was done one week after planting. This was applied in between the plants by digging holes and the fertilizers were placed and covered with layers of soil. Each treatment plot was applied with 0.51 kg complete fertilizer or 45-45-45 kg ha^{-1} N, P_2O_5, K_2O. No spraying of chemical pesticides was done since damage from pests` infestation such as scab and weevil were very minimal. Harvesting at 120 days after planting was done in all treatment plots. All sample plants within the harvestable area were harvested. This was done by digging the soil using a bolo after cutting the vines at the base. The harvestable areas of Treatments 1, 2, and 3, and 4 and 5 were 6.0 m^2, 7.0 m^2, and 6.8 m^2. Extra care was observed during harvesting to minimize the damage of fleshy roots. Harvested fleshy roots were cleaned, air-dried, classified into marketable and non-marketable roots, and then weighed.

Data Gathered

The agronomic parameters evaluated were the following:(1) length of main vines (cm) and (2) leaf area index (LAI). The LAI was computed using the following formula:

$$LAI = \frac{\text{Total leaf area (TLA)}}{\text{Area of the quadrat } (2500cm^2)}$$

where:
TLA= [length x width x correction factor (0.58)]

The correction factor was determined by using 100 leaves taken randomly from the experiment area. The longest and the broadest portions of the leaf were traced in a paper and weighed (Wt). Out of this traced paper, the rectangular shape and the leaf's actual shape were cut and weighed (At). The correction factor was derived from the traced paper's weight in its actual leaf shape divided by the weight of paper in its rectangular shape. This represents the longest and widest portion of leaves as follows:

CF= Wt (g) / At (g)

where:

CF = correction factor

(CF 0.58) established by Beltran and Cagasan (2019)

Wt = weight of the traced leaf paper representing the most extended and broadest parts of the leaf.

At = weight of the leaf paper after being cut with the actual shape of the leaf.

Moreover, the number of primary lateral vines per hill was evaluated, and the fresh weight of herbage (t ha^{-1}) was obtained using the formula:

$$\text{Herbage weight } (t\ ha^{-1}) = \frac{\text{Herbage weight (kg/plot)}}{\text{Harvestable Area } (m^2)} \times \frac{10{,}000\ m^2\ ha^{-1}}{1{,}000\ kg\ t^{-1}}$$

The yield and yield components, such as the number and weight of marketable and non-marketable roots/hill and t ha^{-1} were obtained by weighing the marketable and non-marketable roots separately from the harvestable area. These were converted into tha^{-1} using the formula:

$$\text{Root Yield } (t\ ha^{-1}) = \frac{\text{Root Yield (kg/plot)}}{\text{Harvestable Area } (m^2)} \times \frac{10{,}000\ m^2\ ha^{-1}}{1{,}000\ kg\ t^{-1}}$$

Moreover, total root yield (t ha^{-1}) was determined by adding the marketable and non-marketable root yield (t ha^{-1}) obtained in each treatment plot while harvest index (HI was determined using the formula:

$$HI = \frac{\text{Fresh wt. of fleshy roots of 5 sample hills (g)}}{\text{Fresh wt. of fleshy roots of 5 sample hills (g) + fresh herbage wt. of 5 sample hills (g)}}$$

Other parameters were also gathered, such as profitability and meteorological data. Profitability was obtained using this formula: Gross margin=Gross income – Total variable cost.

Analysis of variance (ANOVA) was done using Statistical Analysis Software (SAS version 6.12). A comparison of means was made using the Honestly Significant Difference (HSD) test.

RESULTS AND DISCUSSION

Chemical Soil Properties

The initial soil analysis revealed that the experimental area had a pH of 5.91 with 1.20% organic matter (OM), 60.20 mg kg^{-1} extractable phosphorus, and 0.67 (cmol kg^{-1}) exchangeable potassium (Table 2). These results indicated that the soil was moderately acidic with deficient organic matter but had very high phosphorus and potassium content (Landon 1991). The final analysis showed a slight increase in soil pH and decreased organic matter, extractable phosphorus, and exchangeable potassium of the soil after harvest. The decrease in OM, phosphorus, and exchangeable potassium content can be attributed to crop removal or utilization by sweetpotato plants during its growth and development (Coolong et al 2012).

Agronomic Characteristics

The data on agronomic characteristics of sweetpotato as affected by plant density is presented in Table 3. The results showed that the number of primary lateral vines, LAI, and fresh herbage yield (t ha^{-1}) were significantly affected by plant density. These results revealed that plants grown in 1.0 m x 0.50 m spacing at two cuttings per hill produced themost number of primary lateral vines (7.13) and the heaviest herbage weight (27.22 t ha^{-1}) than the rest of the treatments. On the contrary, plants grown in 1.0 m x 0.25 m spacing at one and two cuttings per hill produced the lowest number of primary lateral vines (3.90 & 4.27) and smallest LAI (2.50 and 3.09). These results indicated that the more primary lateral vines produced, the heavier the herbage weight (t ha^{-1}). This confirmed the findings of Zamil et al (2010 in Semaw 2014) that sweetpotato with more primary lateral vines per hill had significantly high fresh herbage weight (t ha^{-1}). At the same time, Ambi (2008) mentioned that increasing the number of plant population at plant spacing of 0.75 m by 0.25 m increases the fresh herbage weight per hectare in sweetpotato production but no significant differences were noted in tuber yield (tha^{-1}) among the treatments studied.

Table 2. Results of soil analyses before planting and after harvesting of sweetpotato as affected by planting density

Treatment	pH	Organic matter (%)	Extractable P (mg kg^{-1})	Exchangeable K (cmol kg^{-1})
Initial Analysis	5.91	1.20	60.20	0.67
Final Analysis				
T_1-1.0 m x 0.50 m at 2 cuttingshill^{-1}	6.68	0.96	42.73	0.46
T_2-1.0 m x 0.25 m at 1 cutting hill^{-1}	5.75	1.15	38.68	0.55
T_3-1.0 m x 0.25 m at 2 cuttings hill^{-1}	6.64	1.16	32.25	0.58
T_4-1.0 m x 0.30 m at 1 cutting hill^{-1}	6.26	1.05	48.69	0.50
T_5-1.0 m x 0.30 m at 2 cuttings hill^{-1}	6.06	1.12	55.31	0.57
Mean	6.27	1.10	43.53	0.53

Table 3. Agronomic characteristics of sweetpotato as affected by planting density

Treatment	Length of Main Vines (cm)	Number of Primary Lateral Vines	Leaf Area Index (LAI)	Fresh Herbage Yield (t ha^{-1})
T_1-1.0 m x 0.50 m at 2 cuttings hill^{-1}	314.87	7.13^{a}	4.29^{a}	21.22^{a}
T_2-1.0 m x 0.25 m at 1 cutting hill^{-1}	343.47	3.90^{c}	2.50^{c}	15.28^{b}
T_3-1.0 m x 0.25 m at 2 cuttings hill^{-1}	313.03	4.27^{c}	3.09^{bc}	17.04^{b}
T_4-1.0 m x 0.30 m at 1 cutting hill^{-1}	326.85	5.20^{bc}	3.70^{ab}	18.60^{b}
T_5-1.0 m x 0.30 m at 2 cuttings hill^{-1}	317.07	5.60^{b}	3.69^{ab}	18.52^{b}
Mean	323.06	26.10	3.45	16.132
CV (%)	19.43	15.27	6.56	10.94

In a column, means followed by the same letters and without letters are not significantly different at 5% level, HSD

The wider spacing of 1.0 m x 0.50 m and 1.0 m x 0.30 m obtained comparably higher leaf area indices than the plants in closer spacing. This result can be attributed to healthier and bigger plant leaves in wider spacing due to less competition for nutrients, light, space, and water between plants. Sarcol and Cagasan (2016) also found that a higher leaf area index was obtained in sweetpotato planted at wider spacing than closer spacing.

Yield, Yield Components and Harvest Index

The data on yield, yield components, and harvest index of sweetpotato as affected by plant density is presented in Table 4. The results showed that plant density did not significantly affect most of the yield, yield components, and harvest index of sweetpotato except on the weight of marketable roots per hill and marketable yield (tha^{-1}) and total root yield (tha^{-1}). The heaviest marketable roots per hill (516.67g) were obtained when sweetpotato was planted at 1.0 m x 0.50 m (wider spacing) compared to plants spaced at 1. 0 m between rows x 0.25 m or closer spacing regardless of the number of cuttings per hill. This result can be attributed to the competition for sunlight, nutrients, water, and space, which affected the plant's ability to produce bigger and heavier roots (Alvin et al 2007).

Table 4. Yield and yield components and harvest index of sweetpotato as affected by planting distance

Treatment	Number of Roots per Hill		Root Weight per Hill (g)		Root Yield (t ha^{-1})		Total Root Yield (tha^{-1})	Harvest Index (HI)
	Marketable	Non-marketable	Marketable	Non-marketable	Marketable	Non-marketable		
T_1	3.20	1.67	516.67a	80.00	10.12a	1.33	11.45b	0.43
T_2	3.00	1.90	298.33b	105.00	11.93a	1.50	13.43a	0.45
T_3	3.67	2.90	320.00b	96.67	12.80a	1.24	14.04a	0.40
T_4	2.80	1.53	295.00b	63.33	9.73b	0.93	10.66b	0.42
T_5	3.73	2.53	316.67b	66.67	10.42a	0.98	11.40b	0.40
Mean	3.28	2.11	329.33	80.33	13.01	1.20	14.22	0.42
CV %	23.37	31.41	28.84	30.14	25.36	30.17	23.05	10.71

In a column, means followed by the same letters and without letters are not significantly different at 5% level, HSD

Legend: T_1-1.0 m x 0 .50 m at 2 cuttings hill^{-1} (20,000 hills at 40,000cuttings), T_2-1.0 m x 0.25 m at 1 cutting hill^{-1} (40,000 hills at 40,000 cuttings), T_3-1.0 m x 0.25 m at 2 cuttings hill^{-1} (40,000 hills at 80,000 cuttings), T_4-1.0 m x 0.30 m at 1 cutting hill^{-1} (33,333 hills at 33,333 cuttings),T_5-1.0 m x 0.30 m at 2 cuttings hill^{-1} (33,333 hills at 66,666 cuttings)

Sweetpotato planted at wider spacing produced significantly bigger tubers per hill due to adequate space, thereby lesser competition. Getachew et al (2012) reported that the highest weight of marketable yield per hill was obtained at wider spacing because of the lesser competition for growth factors. The absorption of adequate amount of nutrients and interception of more light for photosynthesis leads to the increased weight of marketable yield per hill. The high marketable yield (t ha^{-1}) was due to the wider spacing resulting in low competition. The lowest marketable root yield (tha^{-1}) was obtained from plants spaced at 1.0 m x 0.30 m (T_4) when planted at 1 cutting per hill. The results indicated that planting sweetpotato at wider spacing could be done, provided that two cuttings per hill would be planted to compensate for the wider spacing. One cutting per hill can still be adopted for sweetpotato production as it provided an acceptable yield when planted at a closer spacing (Sarcol & Cagasan 2016). Moreover, Ehisianya et al (2011) found that increasing the number of cuttings per hill from 2 to 3 did not significantly affect the total root yield when planted at closer spacing. Likewise, the highest total root yield (tha^{-1}) was observed in T_2 (13.43 tha^{-1}) and T_3 (14.04 tha^{-1}) when plants were spaced at 1.0 m x 0.25 m at 1 and 2 cuttings hill^{-1}, respectively. These results can be attributed to the recommended planting distance of 1.0 m x 0.25 m for sweetpotato at 40,000 hills per hectare (Abogadie and Bacusmo 2018 personal communication). Moreover, this study proved that there was no significant difference in the total root yield (t ha^{-1}) of sweetpotato when planted either one or two cuttings per hill.

Profitability Analysis

The profitability analysis of sweetpotato (NSIC Sp36) affected by plant density is presented in Table 5. Sweetpotato grown at a spacing of 1.0 m x 0.25 m at one cutting per hill obtained the highest gross margin of PhP160,240.00 ha^{-1} due to higher root yield and less cost in planting materials at one cutting per hill. This was followed by sweetpotato planted at a distance of 1.0 m x 0.25 m at two cuttings per hill with PhP159,702.00 ha^{-1}. The lowest gross margin (PhP119,745.00) was attained from plants at 1.0 m x 0.30 m spacing with one cutting per hill. This result can be attributed to a few numbers of hills per hectare of 33,333 only. Planting sweetpotato at a wider spacing had a few number of hills per hectare which could affect its total productivity.

Table 5. Cost and return analysis of sweetpotato production as affected by planting density

Treatment	Weight of Marketable Roots (t ha^{-1})	Gross Income (PhP)	Total Variable Cost (PhP)	Gross Margin (PhP)
T_1-1.0m x 0.50m at 2 cuttings hill^{-1}	11.45b	171,750.00	44,534.32	127,216.00
T_2-1.0m x 0.25m at 1 cutting hill^{-1}	13.43a	201,450.00	41,210.32	160,240.00
T_3-1.0m x 0.25m at 2 cuttings hill^{-1}	14.04a	210,600.00	50,898.32	159,702.00
T_4-1.0m x 0.30m at 1 cutting hill^{-1}	10.66b	159,900.00	40,155.57	119,745.00
T_5-1.0m x 0.30m at 2 cuttings hill^{-1}	11.40b	171,000.00	48,176.82	122,824.00

Gross income was based on the prevailing market price of Php 15.00 kg^{-1} of sweetpotato during the time of harvest.

CONCLUSION

Planting density significantly affects the number of primary lateral vines, leaf area index, fresh herbage weight (t ha^{-1}), the marketable weight of roots hill^{-1}, and total root yield (t ha^{-1}) of NSIC Sp36 sweetpotato variety. It is concluded that the number of hills per hectare is a critical consideration in attaining high productivity regardless of the number of cuttings hill^{-1}. High productivity in sweetpotato production can be achieved using an optimum number of hills per hectare of 40,000 hills at one cutting per hill. In this study, sweetpotato grown at 1.0 m x 0.25 m spacing with one cutting per hill obtained the highest gross margin of PhP160,240.00 ha^{-1} due to higher root yield and less cost of planting materials. This was followed by sweetpotato planted at 1.0 m x 0.25 m with two cuttings per hill (PhP159,702.00 ha^{-1}).

Recommendation

For higher productivity and profitability per hectare in sweetpotato production, it is recommended to plant 40,000 cuttings per hectare at one cutting per hill with 1.0 m x 0.25 m planting distance.

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