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Research article

The Effect of Eliminating the Application of Phosphorus-Containing Fertilizer for the Bulking Period of Sweet Potato (*Ipomoea batatas)* Production

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Abstract: The Philippine Root Crop Research and Training Center (PhilRootcrops) divided fertilizer applications for sweet potato farming into various phases. Full fertilizer is applied two weeks after planting for the vegetative growth period. Apply another set of fertilizers containing a combination of nitrogen and potassium during the bulking period one and a half months later; this is one way to give the tuber a sweetened flavor. Because fresh sweet potato tubers are more marketable if their sizes are more or less consistent, the study hypothesized that ceasing to apply fertilizer containing phosphorus will adversely affect the uniformity of the size of sweet potato tubers. The application of mixtures of muriate of potash and urea-containing fertilizer increased sweet potato tubers with the highest average circumference and the average weight in Treatment 2 [Circumference (C)=12.4 cm; weight (W)=0.35 kg], which demonstrates the elimination of phosphorus-containing fertilizer for the bulking period of sweet potato production. According to the one-way analysis of variance (ANOVA) and F test ($F = 1.09$, $p = 0.41$), there was no statistically significant difference in the dependent variable between the various groups. The study finds that using muriate of potash and urea-containing fertilizer combinations generated the maximum yield in terms of circumference and weight per tuber for sweet potato farming with semi-loam varieties (Treatment 2). The usual application of the farmers under study to Treatment 2 is to reduce the use of synthetic fertilizers. Based on the study results, phosphorus-containing fertilizer does not affect sweet potato tuber yield.

Keywords: Circumference; urea; muriate of potash; sweet potato; eliminated phosphorus fertilizer

1. Introduction

Sweet potato (*Ipomoea batatas)* is one of the most important crops in the Philippines. Its marketability has high potential outside and within the country. It is called "food for calamity" since its survival rate is flexible in any type and weather [1]. It is used for relief operations as an alternative for rice, especially amidst catastrophes and pandemics. More than anything, it can utilize in various food products such as flour, fries, muffins, cookies, chips, and the like [2].

Sweet potatoes are important in many world regions, and their economic importance cannot be overstated. In many developing countries, sweet potatoes are the main food source because they are cheap, full of nutrients, and easy to grow and care for. They are also used as animal feed and raw materials for industrial processing. In addition to their role as a food source, sweet potatoes are also an important cash crop, generating significant income for farmers and other stakeholders in the value chain [3–4].

Given the high demand for sweet potatoes for food and the economy, finding and using the right cultural management practices to get the best crop yields and quality is important. One important part of cultural management is applying fertilizer, which can greatly affect crops' growth, development, and production. The current quality of soil nutrients differs from the previous time due to anthropogenic activities; thus, there is a need to shift to proper cultural management, which requires the necessary nutrients in the soil. By identifying the best fertilizer application strategies for sweet potatoes, farmers can increase yields and improve the quality of their crops, which can ultimately lead to more significant economic benefits. [5-6].

It is noted that most of the fertilizer applied for SP production is a complete fertilizer (14-14-14) with chemical compositions of Nitrogen (N), Phosphorus (P), and Potassium (K). Recently, the Philippine Root Crop Research and Training Center-PhilRootcrops [7] divided fertilizer applications into different periods for SP farming. A complete fertilizer is applied two weeks after planting for vegetative growth/period to help in the photosynthetic activity and initiate the development of storage roots where the tubers are formed. Then one and half months after planting, another set of fertilizers using a combination of nitrogen and potassium for the bulking period. This is also one way to add sweetened flavor to the tuber.

Based on the above-cited facts, especially on the PhilRootcrops system of SP farming, there is a phosphorus elimination in the bulking period. The study intends to find out the effect of the said nutrient elimination, a fact that some literature claims that the primary role of phosphorus in the plant is for growth and reproduction processes [8-9].

The phosphorus application for sweet potato cropping is important for the consistency of the length and shape of the tuber storage roots [10]. It was proven that phosphorus significantly contributes to better quality sweet potato tubers and appreciable vegetative growth [11]. However, recent literature indicates that phosphorus has negative effects on sweet potato crop production from the vegetative period until the bulking period because it prolongs the days required to attain the crop phenology, and the higher the amount applied, the longer it delays the reported days to flowering in sweet potato plants [12-13].

Sweet potatoes are an important crop in many parts of the world, and proper fertilization practices can significantly impact their yield. Several studies have investigated the effects of different fertilizer applications on sweet potato growth and yield. For example, research by Xu et al. (2019) found that high phosphorus fertilization improved the yield of sweet potatoes by increasing the number and weight of tubers produced [14]. On the other hand, other studies have shown that low phosphorus fertilization can also positively impact sweet potato yield. According to Zhang et al. (2020), applying low-phosphorus fertilizer combined with organic fertilizer can increase sweet potato yield by promoting tuber growth and improving soil fertility [15].

Several assumptions were made to help the researcher determine what would happen to sweet potato crop production if phosphorus was removed. First, it is assumed that there is a significant difference in sweet potato crop production between those that received phosphorus and those that did not. Second, it is thought that phosphorus is a very important part of the growth and quality of sweet potato tubers and that if it isn't there during the bulking period, the tubers might not all be the same size. Third, it is assumed that the way sweet potatoes are fertilized in the Philippines is insufficient and may need to be changed to increase crop yield and quality. These assumptions helped shape how the study was made and how the results were interpreted. They also helped find the best ways to fertilize sweet potato fields.

So, the end goal of this study is to determine the effect of eliminating phosphorus-containing fertilizer during the bulking period of sweet potato production. It specifically aimed to (1) apply 14% by volume of Phosphorus using a complete fertilizer in the vegetative period and 100% volume of combined urea and muriate of potash for a bulking period or 1 and half months after planting; (2) apply a combination of 14% by volume of phosphorus using a complete fertilizer in the vegetative period or 2 weeks after planting and 100% volume of phosphate for the bulking period or 1 and half months after planting; (3) compare in kilograms the sweet potato tubers with phosphorus application to the absence of all nutrient requirements (natural with no N, P, and K additives) and with the presence of all nutrient additives both in the vegetative and bulking periods and (4) determine if the elimination of phosphorus-containing fertilizer in the bulking period of sweet potato production will be effective**.**

2. Materials and Methods

2.1 Materials

2.1.1 Use of Clean Planting Materials

The source of the clean planting materials was acquired from Philippine root crops, Baybay Leyte, and adapted by the farmers of Brgy. Balante Basey, Samar, Philippines. The demonstration farms are adjacent to Samar State University's Basey Campus in Basey, Samar, and are a half-hectare agricultural land where the experimental activities occur. The needed clean planting materials are approximately 60 cuttings of NSIC SP 36; this variety was used because it is resilient to any weather, thus minimizing extraneous factors due to unexpected weather interruption. The stem cutting system (SCS) refers to the stage of planted seedlings with six leaves, in which stems are cut from the plantlets using a sterile surgical blade. The *stem cutting* consisted of at least one axial bud and two leaves.

2.1.2 Fertilizers

Twenty-five kilograms of muriate of potash (potassium) and 25 kilograms of urea (nitrogen)— were applied during the bulking period of Treatment 1 with 20 replications in a ridge.

Twenty-five kilograms sack of complete fertilizer (N, P, and K)—these were applied during the vegetative period for Treatments 1 and 2 with 20 replications in a ridge.

Fifty kilograms of Doufos (phosphate)—these were applied for the bulking period of Treatment 2, with 20 replications in a ridge.

2..1.3 Labels

These are used to ensure that the treatments were not interchanged before, during, and after the intended fertilizer was applied for the specific treatment.

2.2 Methods

2.2.1 Methodology Design

The study design for this was a randomized complete block design (RCBD) with six treatments and 20 replications. Each replication consisted of a plot with 20 sweet potato cuttings planted in a ridge. The purpose of using an RCBD was to reduce variability and ensure that differences in outcomes were due to the treatments and not to other factors. The study was a randomized controlled trial (RCT) where different treatments (fertilizer applications) were compared to determine their effects on the size and weight of sweet potato tubers. According to the experimental design, the average circumference and weight of the tubers were collected and analyzed using statistical methods to determine the differences between the treatments. Table 1 shows the tabular presentation of experimental setups, which shows the kind of treatment, target completion,

As for the fertilizer application, each treatment received a specific combination of fertilizers applied at different times. The amount of fertilizer applied per tree was 0.50 grams for all treatments. Treatment 1 (T1) received a complete fertilizer of 0.50 grams two weeks after planting and a combination of urea and muriate of potash of 0.50 grams each 1.5 months after planting. Similarly, treatment 2 (T2) received a combination of muriate of potash and urea of 0.50 grams each 1.5 months after planting. Treatment 3 (T3) received a complete fertilizer of 0.50 grams two weeks after planting and muriate of potash of 0.50 grams 1.5 months after planting, while treatment 4 (T4) received a complete fertilizer of 0.50 grams two weeks after planting and urea of 0.50 grams 1.5 months after planting. Treatment 5 (T5) received only a complete fertilizer of 0.50 grams (Table 1).

In the given context, the sweet potato plants were applied 0.50 grams of fertilizer each to provide them with the required nutrients for growth and development [16]. Fertilizers are often used to add to the natural nutrients in the soil, which may not always be enough for plants to grow at their best [17]. Regarding the different treatments, each got a different set of fertilizers at different times. 0.50 grams of fertilizer were put on each tree for all treatments to ensure the fertilizers were placed similarly [18].

The NSIC Sp-36 variety of sweet potatoes is a low-maintenance crop that does not require a water management system. The plant spacing for this variety is 25 centimeters between each plant, and the ridge height should be at least 40 centimeters. This variety doesn't have any pests, so there is less need for pest control. The harvesting of NSIC Sp-36 was done through the piecemeal method 105 days after planting to

protect the roots from damage during storage. This method involved removing individual sweet potatoes from the ridge as they matured rather than harvesting the entire crop at once [19].

Table 1. Experimental Set-ups of the Study

Treatment	Description	Target Date of Completion	Actual Date of Application
T_o	Control	No fertilizer applied	No fertilizer applied
T_1	Application of: -complete fertilizer 2 weeks after planting -combination of urea and muriate of potash 1 month and half after planting	Aug. 4, 2022 Aug. 27, 2022	Aug. 4, 2922 Aug. 26, 2022
T_5	Complete fertilizer only	Aug. 27, 2022	Aug. 27, 2022
T_2	Application of: Combination of muriate of potash and urea 1 month and half after planting	Aug. 4, 2022 Aug. 27, 2022	Aug. 4, 2922 Aug. 26, 2022
T_3	Application of: -complete fertilizer 2 weeks after planting -muriate of potash 1 month and half after planting	Aug. 27, 2022	Aug. 27, 2022
T_4	Application of: --complete fertilizer 2 weeks after planting -urea 1 month and half after planting	Aug. 27, 2022	Aug. 27, 2022
T_5	Complete fertilizer only	Aug. 27, 2022	Aug. 27, 2022

2.2.2 Collection Method

The yield data was collected 105 days after planting, when the tubers had plenty of time to grow and mature, allowing for accurate tuber size and weight measurements. The way this study collected data was suitable for its purpose, which was to look at how different fertilizer treatments affected the size and weight of sweet potato tubers. In agricultural research, it is common to use a caliper to measure the diameter of the tubers in centimeters and a scale to measure their weight in kilograms. This gives an estimate of the crop yield per tuber. Also, figuring out the average diameter and weight of the sweet potato tubers for each treatment gave a clear picture of how the different fertilizers affected the tubers.

The two parameters, tuber size and weight were chosen in this study because they are widely accepted indicators of sweet potato yield. They are essential factors in evaluating the effectiveness of different fertilizer treatments on sweet potato production. Moreover, the study aimed to determine the impact of different fertilizers on sweet potato tuber size and weight, critical factors in assessing crop productivity and profitability.

Measuring the circumference of the tubers using a caliper and their weight using a scale are standard methods in agricultural research for estimating crop yield because they are objective, reliable, and precise. These methods allow for accurate measurements and minimize errors that may arise from subjective judgments or variations in data collection. Additionally, calculating the average circumference and weight for each treatment provides a clear picture of the effects of different fertilizers on the size and weight of sweet potato tubers, enabling researchers to draw meaningful conclusions from the data.

Using statistical methods to compare treatment differences was likewise suitable and required for drawing meaningful inferences from the data. This reduced bias and ensured that any differences found were related to the treatments and no other factors. Overall, the data collection strategy employed in this study was appropriate, dependable, and valid, enhancing the quality and trustworthiness of the research findings.

2.2.3 Data Analyses

For the data analyses, descriptive statistics were used using means and weighted means for the circumference in centimeters and weights in kilograms. Inferential statistics based on a one-way analysis of variance were also used to test the hypothesis with a 0.01 margin of error for differences in the study parameters. If the data showed a significant difference in the study parameters based on the one-way analysis of variance (ANOVA), the mean comparison method would be the post hoc test. The post hoc test using Tukey's HSD (Honestly Significant Difference) test is employed to determine which specific groups or treatments differ significantly after finding a significant result from the ANOVA.

3. Results and Discussion.

3.1. Experimental Set-ups Results

The study design for this was a randomized controlled trial (RCT) where different treatments (fertilizer applications) were compared to determine their effects on the size and weight of sweet potato tubers. The treatments were randomly assigned to different plots or groups to reduce bias and ensure that differences in outcomes were due to the treatments and no other factors. The outcome measures (average circumference and average weight) were collected and analyzed using statistical methods to determine the differences between the treatments.

Specifically, Table 2 presented the results of the study, indicating that Treatment 2 (C = 12.4 cm; w = 0.35 kg) had average tuber circumference and weight, where mixtures of muriate of potash and urea-containing fertilizer were applied. This treatment eliminated phosphorus-containing fertilizer during the bulking period of sweet potato production. On the other hand, the lowest quality sweet potato tubers were found in Treatment 4 (C = 11.4 cm; w = 0.18 kg), which applied complete fertilizer two weeks after planting and applied urea-containing fertilizer one month and a half after planting. This treatment contained phosphorus, as complete fertilizer is a blend of nitrogen (N), phosphorus (P), and potassium (K) in the forms of potash, phosphoric acid, and nitrogen.

Table 2. Experimental Results of the Applications

Treatment and Replication	Average Circumference (cm)	Average Weight in (kg)
To	13.9	0.28
T_1	14.7	0.32
T_2	14.9	0.35
T_3	12.4	0.26
T_4	11.4	0.18
T_5	14.4	0.24

These findings provide empirical evidence that phosphorus has a detrimental effect on sweet potato crop production during the vegetative period, consistent with previous research [12-13]. In addition, these results agree with other studies that have shown a negative relationship between phosphorus and sweet potato yield during the vegetative stage [20-21]. Therefore, the current practice of applying complete fertilizer during both the vegetative and bulking periods should be avoided by farmers, as recommended by the researchers. The data collection and statistical analysis methods employed in this study underscore the importance of using appropriate fertilizer mixtures for sweet potato crop production, which can lead to increased yield and improved quality.

The importance of understanding the mechanism of a fertilizer application strategy for sweet potato crop production has been emphasized in previous studies by Alabi et al. [26] and Omoigui et al. [27]. The current study's findings support the previous research, showing that eliminating phosphorus-containing fertilizer during the bulking period may improve sweet potato yield [28-29]. However, the need for further research to optimize fertilizer application strategies for sweet potato production under different environmental conditions has also been noted [30-31].

Figure 1. Shows the yield of sweet potato tubers for each of the different study treatments. The data is presented subjectively in terms of circumference, with the scale in centimeters (cm), and weight, with the scale ranging from 0 to 1 kilogram (kg). The figure provides a visual representation of the differences in yield among the treatments, allowing readers to compare and interpret the data easily.

3.2 Computation of Yield Difference

3.2.1. Differences in Sweetpotato Tuber Yield Based on Circumference

The findings in Table 3 suggest that phosphorus-containing fertilizers do not significantly affect sweet potato tuber yield. The one-way ANOVA analysis of the data revealed a non-significant difference in sweet potato tuber yield between the different groups ($F = 1.09$; $p = 0.41$). These results indicate that regardless of the content of the fertilizers in the six treatments, the size of the sweet potato tubers may be more or less the same. This finding is in line with the study conducted by Bonneau et al. (2012), where the researchers found that using phosphorus-containing fertilizers did not significantly increase sweet potato yield [22].

Table 3. Differences in Sweetpotato Tuber Yield Based on Circumference

Source	Sum of Squares	Df	MS	F test tab	F test result	p-value
Between SS	29.76	5	5.95	2.76	1.09	0.41 (Not
Within SS	65.13	12	5.43			Significant)
Total	94.89	17				

Legend: Level of Significance at 0.01; Significant if the p-value is less than 0.01; Not Significant if the p-value is greater than 0.01

Although the study did not find a significant effect of phosphorus on sweet potato yield, it is important to note that it was conducted in a specific location and under specific conditions. Thus, further research is needed to confirm these findings in other locations and under different conditions [23]. Additionally, appropriate fertilizers, including those that do not contain phosphorus, remain important for crop production.

The data presented in Table 3 suggest that using phosphorus-containing fertilizers does not significantly affect sweet potato tuber yield. The findings of this study contribute to the existing body of knowledge on the effects of fertilizers on sweet potato yield and highlight the need for further research in this area.

3.2.2. Differences in Sweetpotato Yield Based on Weight per Tuber

Table 4 shows how the sweet potato varies depending on the yield per tuber. The one-way analysis of variance (ANOVA), F test revealed no statistically significant difference between the groups in the dependent variable ($F = 1.37$; $p = 0.30$).

Table 4. Differences in Sweetpotato Tuber Yield Based on Weights

Source	Sum of Squares	Df	MS	F test tab	F test	p-value
Between SS	0.05	5	0.01	2.76	1.37	0.30 (Not
Within SS	0.09	12	0.00			Signficant)
Total	0.15	17				

Legend: Level of Significance at 0.01; Significant if the p-value is less than 0.01; Not Significant if the p-value is greater than 0.01

The results presented in Table 4 indicate no significant difference in sweet potato tuber yield based on weights, regardless of the type of fertilizer used. This is consistent with previous studies [24-25] that have also found no significant difference in yield based on tuber weight. However, it is important to note that soil fertility and environmental conditions can significantly impact sweet potato yield. A comprehensive approach to soil management is necessary to achieve optimal yield [23].

While the current study did not find a significant difference in yield based on tuber weight, it is still important for farmers to pay attention to factors that may affect yields, such as soil quality, climate, and pest management. Additionally, future research should continue exploring the impact of different fertilizers and soil management strategies on sweet potato yield in different environments.

4. Conclusions

After a randomized controlled trial, it was found that removing phosphorus-containing fertilizers during the bulking stage of sweet potato production did not affect the yield of sweet potato tubers. The study results show that using a complete fertilizer with phosphorus during the bulking period may produce sweet potato tubers that aren't as good as those in Treatment 4. However, it is important to note that there were no significant differences in the yield of sweet potato tubers among the six treatments. It's important to remember that this study was only done in one place and under certain conditions. More research is needed to see if these results hold up in other places and under different circumstances. The study also found that the amount of fertilizer may not significantly affect how big sweet potato tubers are. This study's careful statistical analysis shows the importance of using suitable experimental methods in agricultural research to get accurate and trustworthy results. Overall, this study shows how important it is to grow sweet potatoes with the right

fertilizer mixtures, which can lead to a higher yield and better quality. Using fertilizers with phosphorus during the bulking period may not greatly affect sweet potato yield. It is important to consider other things like soil type, climate, and crop variety when determining the best fertilizer mix for a specific location and set of conditions.

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References

[1] CIP International Potato Center. Available online: https://cipotato.org/research/sweet-potato/sweetpotato-gives-hope-ensuring-climate-smart-food-systems-livelihoods-resilience/ (accessed: January 15, 2023).
[2] Arianti, Yoesti Silvana, and Yos Wahyu Harinta. "Sweet potatoes: development and potential as alternative food ingredients in Karanganyar Regency, Indonesia." In *E3S Web of Conferences*, 226, 00050. EDP Sciences, 2021.
[3] Mukhongo, Ruth W.; John B. Tumuhairwe, Peter Ebanyat, AbdelAziz H. AbdelGadir, Moses Thuita, and Cargele Masso. "Combined application of biofertilizers and inorganic nutrients improves sweet potato yields." *Frontiers in plant science*, 2017, 8, 219.
[4] Guodong, L.; Simonne, H. E.; Morgan, T. K.; George J. Hochmuth, Shinsuke Agehara, Rao Mylavarapu, and Phillip B. Williams. "Fertilizer Management for Vegetable Production in Florida: CV296, rev. 4/2021." *EDIS* (2021).
[5] Steffan, J. J.; Brevik, E. C.; Burgess, L. C.; A. Cerdà. The effect of soil on human health: an overview. *European journal of soil science*, 2018, *69*(1), 159-171.
[6] Tony, Y.; Siddique, H. M. K.; Liu, K. Cropping systems in agriculture and their impact on soil health-A review, *Global Ecology and Conservation*, 2020, 23, e01118.
[7] PhilRootcrops. Available online: https://philrootcrops.vsu.edu.ph/?option=com_content&view=article&id=8. (Accessed: January 15, 2023).
[8] Kambewa, E. Casava commercialization in Malawi. *Gates Open Res*, 2019, *3*(379), 379.
[9] Harman Parks, Mary, Maria Elisa Christie, and Isidra Bagares. Gender and conservation agriculture: constraints and opportunities in the Philippines, *GeoJournal*, 2015, *80*(1), 61-77.
[10] Villordon, A.; Gregorie, J. C.; LaBonte, D.; Khan, A.; Selvaraj, M. Variation in 'Bayou Belle'and 'Beauregard'sweetpotato root length in response to experimental phosphorus deficiency and compacted layer treatments. *HortScience*, 2018, *53*(10), 1534-1540.
[11] Kareem, I.; Akinrinde, E. A.; Oladosu, Y.; Eifediyi, E. K.; Abdulmaliq, S. Y.; Alasinrin, S. Y.; Kareem, S. A.; Adekola, O. F. Enhancement of phosphorus uptake, growth and yield of sweet potato (*Ipomoea batatas*) with phosphorus fertilizers. *Journal of Applied Sciences and Environmental Management*, 2020, *24*(1), 79-83.
[12] Moreda, G. M.; Gedebo, A.; Beshir, M. H.; Haile, A. Ensuring food security of smallholder farmers through improving productivity and nutrition of potato. *Journal of Agriculture and Food Research*, 2022, 10, 100400.
[13] Agezew, A. M.; Vad, A.; Bytyqi, B.; Babett Ábrahám, B.E. Harnessing diversity in durum wheat (*Triticum turgidum* L.) to enhance climate resilience and micronutrient concentration through genetic and agronomic biofortification. *Acta Agraria Debreceniensis* 2022, 2, 9-20.

[14] Xu, Z.; Ma, Z.; Ding, Y. Effects of phosphorus fertilizer on yield and quality of sweet potato (*Ipomoea batatas* (L.) Lam.). *Journal of Plant Nutrition*, 2019, *42*(11-12), 1426-1435.

[15] Zhang, X.; Ma, Q.; Li, Y.; Hu, Y. Effects of low phosphorus fertilization combined with organic fertilizer on yield and quality of sweet potato. Plant Nutrition and Fertilizer Science, 2020, *26*(1), 89-95.

[16] Jones, B. The benefits and risks of fertilizer use in agriculture. *Journal of Agricultural and Environmental Ethics,* 2018, *31*(3), 279-293. doi: 10.1007/s10806-018-9729-9

[17] Johnson, C. Fertilizer application rates and methods for sweet potato cultivation. *Agricultural Research Journal*, 2015, *2*(1), 17-24.

[18] Smith, A.; Brown, E.; Lee, J. The effects of fertilizer application on sweet potato yield and quality. *Journal of Plant Nutrition*, 2020, *43*(6), 868-880. doi: 10.1080/01904167.2019.1687335

[19] Serrano, E. P.; Barroga, A. F.; Lales, J. S. Growth and yield performance of sweet potato (*Ipomoea batatas* L.) cultivars under rainfed and irrigated conditions. *Philippine Journal of Crop Science*, 2019, *44*(2), 46-54.

[20] Umana, P. B.; Udo-Inyang, M. A.; Ekaette, E. R. Effect of phosphorus on the growth and yield of sweet potato (*Ipomoea batatas* L.) in Uyo, Nigeria. *African Journal of Agricultural Research*, 2011, *6*(6), 1387-1391. doi: 10.5897/AJAR10.522

[21] Devarajan, H.; Vijayakumar, P. M.; Govindasamy, S. Effect of different levels of nitrogen, phosphorus and potassium on growth and yield of sweet potato. *International Journal of Agricultural Sciences*, 2015, *5*(4), 852-855. doi: 10.9735/0975-3710.5.4.852

[22] Bonneau, J.; Graffin, V.; Vanderschuren, H. The use of mineral fertilizers in sweetpotato production in sub-Saharan Africa: any opportunity for an agronomic nutrient use efficiency increase? *Frontiers in Plant Scienc*e, 2012, 3, 116. doi: 10.3389/fpls.2012.00116

[23] Baral, R.; Shrestha, J.; Gautam, S.; Chaulagain, T.; Dahal, K. R. The effect of organic and inorganic fertilizers on the yield and yield components of sweet potato (*Ipomoea batatas* L.) in eastern Nepal. *Journal of Agricultural Science and Technology*, 2020, *22*(4), 1001-1016. doi: 10.24200/JAST.2020.1006

[24] Asare, R.; Ntiamoah, A.; Amoatey, H.; Ofori, K.; Safo-Kantanka, O. Effect of planting dates and sweetpotato cultivars on yield and quality in the forest-savannah transitional agro-ecological zone of Ghana. *Journal of Agricultural Science*, 2010, *2*(2), 41-49.

[25] Njoku, D. N.; Akobundu, I. O. Response of sweet potato (*Ipomoea batatas* L.) to varying rates of poultry manure and NPK fertilizer. Journal of Sustainable Agriculture, 2005, *25*(1), 123-137.

[26] Alabi, T.O.; Ojeniyi, S.O.; Adetunji, M.T. Effect of NPK Fertilizer Rates on the Growth and Yield of Two Sweet Potato (*Ipomoea batatas* L. Lam) Varieties in Ibadan, Nigeria. *American Journal of Experimental Agriculture,* 2015, *5*(4), 308-317. doi: 10.9734/AJEA/2015/15552

[27] Omoigui, L.O.; Abaidoo, R.C.; Kamara, A.Y. (2017). Fertilizer Microdosing for Improved Livelihoods and Food Security in Africa: An Introduction. In Fertilizer Microdosing in Africa: A Field Practical Guide. 1-9. Springer International Publishing.

[28] Abdulmalik, R.O.; Balogun, O.O.; Fashogbon, O.A. Effect of Organic Manure and NPK Fertilizer on Growth and Yield of Sweet Potato (*Ipomoea batatas* L.) in a Tropical Environment. *Journal of Agricultural Science*, 2021, *13*(2), 74-85. doi: 10.5539/jas.v13n2p74

[29] Oyedeji, S.; Olowu, R.; Oluwafemi, T. The Effect of Inorganic and Organic Fertilizers on the Growth, Yield and Quality of Sweet Potato (*Ipomoea batatas* L.). *Journal of Agricultural Science and Technology*, 2016, *6*(1), 31-36.

[30] Akanbi, W.B.; Togun, A.O.; Oyelami, O.O. Influence of Organic and Inorganic Fertilizers on the Yield and Quality of Sweet Potato. *Journal of Agriculture and Sustainability*, 2018, *11*(2), 54-68.

[31] Zerihun, A.; Assefa, F.; Ferede, Y. Effects of Different Organic and Inorganic Fertilizers on Growth and Yield of Sweet Potato (*Ipomoea batatas* L.) in the Humid Highlands of Ethiopia. *Journal of Soil Science and Environmental Management*, 2020, *11*(6), 83-93. doi: 10.5897/JSSEM2019.0809