INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY: APPLIED BUSINESS AND EDUCATION RESEARCH
2025, Vol. 6, No. 8, 3974 – 3986
http://dx.doi.org/10.11594/ijmaber.06.08.18

Research Article

Simulation and Characterization of Macro-Nutrient Deficiency Symptoms of Abaca (Musa textilis Née var. Inosa) Grown Using Nutrient Film Technique (NFT)

James Francienne J. Rosit[1]*, Romel B. Armecin[2], Marilyn M. Belarmino[3], Marilou M. Benitez[3], Lijueraj Cuadra[3]

[1]Philippine Fiber Industry Development Authority, Cebu City 6000, Philippines
[2]National Abaca Research Center, Visayas State University, Baybay City, Leyte 6521-A, Philippines
[3]Department of Horticulture, Visayas State University, Baybay City, Leyte 6521-A, Philippines

Article history:
Submission 04 June 2025
Revised 31 July 2025
Accepted 23 August 2025

**Corresponding author:*
E-mail:
jamesfranciennej.rosit@gmail.com

ABSTRACT

This study was conducted in order to determine the effects of macro-nutrient deficiency to the morpho-physiological and biochemical properties of abaca. Randomized Complete Block Design was used in the study with three nutrient omissions (N, P & K) replicated three times with 12 samples per treatment replicate. This was conducted at the National Abaca Research Center screenhouse, Visayas State University, Baybay City, Leyte. Abaca under N and K deficiency produces the shortest plant height, pseudostem length, pseudostem girth, leaf length and leaf width. N deficient plant produces the smallest total leaf area while P deficient plants reduce pseudostem length and leaf width of abaca. However, P deficient plants showed comparable effects to the plant height, pseudostem girth, leaf length and total leaf area of abaca plants with complete nutrients. Furthermore, chlorophyll a and chlorophyll b content of abaca was lowest under N deficiency while control, P and K deficient plants showed comparable results. Free radical scavenging activity was also lowest under N and K deficient plants. Stomatal aperture was lowest under N, P & K deficient plants while P deficiency decreases stomatal length. These results suggests that abaca is more sensitive to N and K deficiency as most of the morpho-physiological and biochemical properties of abaca was significantly reduced under these conditions.

Keywords: *Abaca, Macronutrient deficiency, Nutrient Film Technique (NFT)*

How to cite:
Rosit, J. F. J., Armecin, R. B., Belarmino, M. M., Benitez, M. M., & Cuadra, L. (2025). Simulation and Characterization of Macro-Nutrient Deficiency Symptoms of Abaca (Musa textilis Née var. Inosa) Grown Using Nutrient Film Technique (NFT). *International Journal of Multidisciplinary: Applied Business and Education Research*. *6*(8), 3974 – 3986. doi: 10.11594/ijmaber.06.08.18

Introduction

Abaca, scientifically known as *Musa textilis Née*, is a perennial crop closely related to the banana (Schlegel, 2010). Primarily originating from the Philippines, it has also spread to neighboring countries such as Indonesia and Malaysia. The plant features a cluster of leaves that form a tree-like structure known as a pseudostem, which contains a soft, non-fibrous core (Cook, 2001). This pseudostem comprises 12 to 25 leaves and has an average diameter of 30 to 40 cm (Shahri et al., 2014). It is renowned for its exceptional durability when submerged in water. Due to its strength and resilience, abaca fiber is extensively utilized in the maritime industry for applications such as ropes and fishing lines. The Philippines leads global production, contributing approximately 63.51% of the world's abaca raw fiber (Munar, 2024).

However, the Philippine Fiber Industry Development Authority (PhilFIDA, 2023) Regional Office 8 Annual Report indicates a concerning decline in abaca production over recent years, with a significant drop of about 64.4% in 2020 compared to previous years (Parac et al., 2021). Factors such as nutrient deficiency could affect fiber production, however, abaca bunchy top virus is the main problem in the industry. The abaca bunchy top disease, which presents symptoms similar to those of the banana bunchy top disease (BBTD), is prevalent and unique to the Philippines (Dizon et al., 2012; Sharman et al., 2008). Early indications of the disease include yellowing of the leaf margins and the lamina of young, unfurled leaves, along with a vague yellowish-white area visible in the furled leave. In severe cases, infected plants may produce no more than a meter-long pseudostem under field conditions. They can generate suckers with small leaves that are undersized, stiff, and narrow, often exhibiting chlorotic edges and arranged in a rosette formation (Raymundo & Bajet, 2000; Sta. Cruz et al., 2016). However, the symptoms of the abaca bunchy top virus (ABTV) resemble those associated with nutrient deficiencies of selected macronutrients. Thus, this study was conducted in order to determine and simulate the effects of nutrient deficiency to the growth and development of abaca and to distinguish the symptoms of nutrient deficient abaca plants from ABTV infected plants.

Materials and Methods

Preparation of Culture Solution

Three (3) nutrient omission treatments were used and these were compared to a complete nutrient solution. The different nutrient mixture includes a complete solution containing six (6) macronutrients (N, P, K, Mg, Ca, and S) and six (6) micronutrients (B, Cu, Fe, Mn, Mo, and Zn) and the others contained the complete solution minus one element (N, P, & K). The standard basic solution was prepared based on the nutrient omission trial protocol of Hoagland (Appendix Table 1) using distilled water as a diluent. To omit a nutrient, the study replaced some salts used in the Hoagland nutrient solution as shown in Appendix Table 2.

Experimental Design and Treatments

The study was conducted inside the screen house of the National Abaca Research Center (NARC), Visayas State University, Baybay City, Leyte from March to April 2025. Temperature and light were under normal outdoor conditions since the screen house allows the natural air circulation and the sample plants received equal light from 10 am to 2 pm. It was arranged in a Randomized Complete Block Design (RCBD) with four (4) treatments replicated three (3) times having twelve (12) samples per block per treatment. The treatments were designated as follows:

- T0 - complete with macro-and micro-nutrients
- T1 - complete with macro- and micro-nutrients except Nitrogen (N)
- T2 - complete with macro- and micro-nutrients except Phosphorus (P)
- T3 - complete with macro- and micro-nutrients except Potassium (K)

Experimental Set-up

A nutrient film technique (NFT) re-circulating hydroponic setup was constructed to accommodate four (4) treatments of the study. Each treatment has two (2) hydroponic solution containers as reservoirs in each replicate. Each container was provided with a submersible pump that provided the nutrient solution to

the feeding throughs (i.e. PVC 2½" x 4" x 4') that could accommodate six (6) samples in every setup.

Application of Culture Solution

Treatments were applied right after transplanting the samples to hydroponic containers. A submersible pump was used to pump the solution (treatments) from the bucket into the hydroponic container. The nutrient solution was circulated every 15 minutes during the daytime and every 1 hour during the night using a timer. This is to ensure that the samples will not die due to water stress.

Morphological Characteristics of Abaca

Data was collected at biweekly intervals until the termination of the study by measuring the following parameters; plant height, pseudostem length, pseudostem girth, leaf length, leaf width and total leaf area.

Stomatal Morphology

For stomatal characteristics, samples were gathered from the third fully expanded leaves from the top and imprinted using transparent nail polish. A compound microscope was used to magnify imprints at 4x and 10x (Zakariyya et al., 2017). The area of the field of view was determined using a calibrated micrometer slide. Stomatal aperture, stomatal length, and width were analyzed using ImageJ software (Mathias et al., 2024).

Chlorophyll Content and FRSA

The Hiscox and Israelstam, (1979) method were used to measure the amount of total chlorophyll. Samples were thinly sliced, bleached and were incubated using a water bath that contains 80% ethanol for 24 hours. Then, the absorbance of the solution was determined using a spectrophotometer (Epoch microplate spectrophotometer, Biotek™, Epoch™) set at 645 and 663 nm, and the rate was recorded and calculated using the equation of Aron (1949). Free radical scavenging of abaca was determined using the DPPH (1,1-diphenyl-1-1 picrylhydrazyl) assay following the procedure of Salas et al., (2015). The absorbance of the resulting solutions was read using a Shimadzu UV-Vis spectrophotometer at 517 nm using ethanol as the main reference.

Quantification of Macronutrients

Quantification of nutrients (N, P, & K) was done at the National Abaca Research Center (NARC) - Soil Analytical Laboratory using Kjeldahl digestion for N, while Phosphorous was quantified using the molybdenum blue Method by colorimetry and spectrophotometry at 470 nm (Wieczorek et al., 2022) and K was analyzed using the X-ray fluorescence (XRF) spectroscopy. Six (6) sample plants from each treatment in each block were composite for analysis with a total of 12 samples analyzed covering the four (4) treatments of the study.

Results and Discussion

Nutrient Deficiency Symptoms

During the course of this study, symptoms of nitrogen deficiency became distinctly evident. Symptoms emerged two weeks following the application of treatment (Fig. 1A). The older leaves began to exhibit a light green coloration accompanied by yellow spots primarily on the margins, extending toward the tips and subsequently the middle of the leaves. As the deficiency intensified, by four weeks post-treatment, chlorosis was notably pronounced in the older leaves (Fig. 1B). The leaves and the entire plant turned yellow (Fig. 1C). Additionally, necrosis was observed on some leaves, particularly at the tips (Fig. 1D). Four weeks after treatment, the shoots displayed reduced size and width, appearing very light green or yellow-green in color (Fig. 1E). It was also noted that the abaca samples exhibited stunted growth in comparison to other treatments.

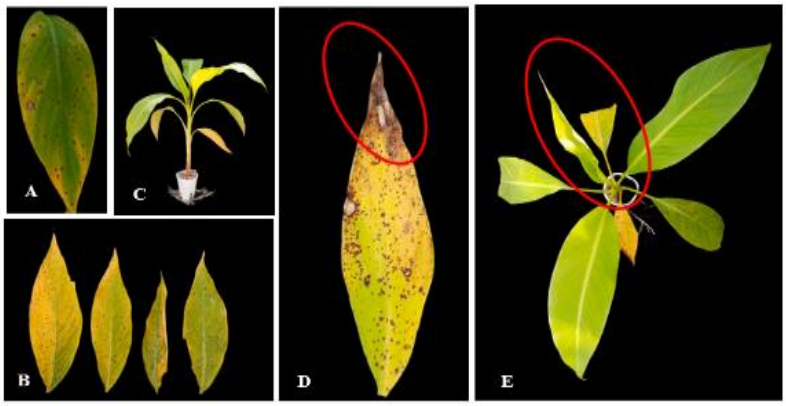


Figure 1. Visual symptoms shown by N deficient abaca plants (Musa textilis Née) 42 days after treatment exposure

The phenological development of plants is delayed under nitrogen deficiency during both the vegetative and reproductive growth stages (Fathi & Zeidali, 2021). Nitrogen is also a crucial component of chlorophyll structure (Mendoza-Tafolla et al., 2019). Consequently, when nitrogen is absent or deficient, chlorophyll synthesis is hindered, leading to a change in leaf color from green to yellow. Numerous plant species have shown a strong correlation between nitrogen levels and chlorophyll content, including cabbage (Westerveld et al., 2002), wheat (Kızılgeç et al., 2015; Shah et al., 2017), corn (Hurtado et al., 2010; Sawyer et al., 2011), and rice (Huang et al., 2016).

The effects of phosphorus (P) deficiency in abaca are not as pronounced, as illustrated in Figure 2. However, a notable consequence of P deficiency is the narrowing of newly expanded leaves, which also leads to a reduction in their diameter and, consequently, a decrease in leaf lamina (see Figure 2B). At 42 days after the plants were exposed to a P-deficient nutrient solution, yellowing along the margins of older leaves became apparent (Figure 2C).

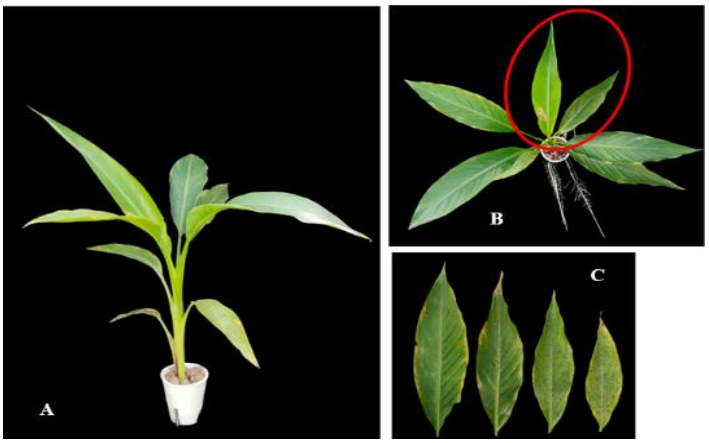


Figure 2. Symptoms shown by P deficient abaca plants (Musa textilis Née) at 42 days after deficiency exposure.

Phosphorus is a crucial nutrient vital for various physiological and metabolic processes, including energy metabolism, DNA synthesis, cell division, and the production of phospholipids, primarily as Pi esters or phosphate (Pi) (Isidra-Arellano et al., 2021). A deficiency in phosphorus disrupts the absorption of other essential nutrients, such as nitrogen (N), calcium (C), and potassium (K), negatively affecting the overall structure of the plants and leading to reduced growth.

At 28 days after exposure to K deficient medium, deficiency symptoms were also visible as presented in Figure 3. Chlorosis was observed on the leaf margins moving to the middle of the older leaves (Figure 3B). In prolonged exposure (i.e. 42 days), chlorosis covers almost the entire leaf of older leaves (Figure 3C). These results are in agreement with those reported by dos Santos Sarah et al., 2021, which showed potassium deficiency resulted in chlorosis starting from the older leaves of bean plants grown under a hydroponic system. Marathe et al., (2016), also reported the occurrence of brown spots especially on the older leaves of pomegranate plants. Reduced growth is the first visual symptom of potassium-deficient plants. Under prolonged nutrient deficiency, morphological symptoms appear. Yellowing and drying out of the leaf margins and necroses appear (Marathe et al., 2016). Stem diameter was also observed to reduce in tomatoes under K deficiency as reported by Kanai et al., (2010).

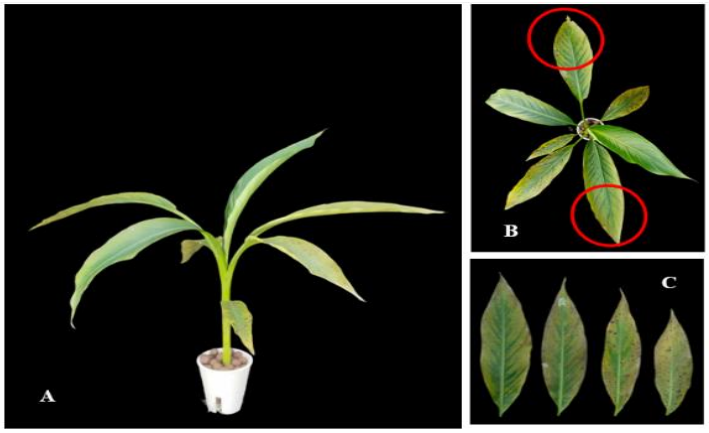


Figure 3. Visual symptoms shown by K deficient abaca plants (Musa textilis Née) 42 days after treatment exposure.

Morphological, physiological and Biochemical Responses of Abaca to Macronutrient Deficiency

At 28 and 42 days after exposure to different treatments, the control (positive control or All treatments) showed the tallest plant height which is comparable with those test plants exposed to the nutrient solution without Phosphorous (P) (Table 1). On the other hand, abaca plants that were grown in a nutrient solution in the absence of Nitrogen (N) showed the shortest plant height which also had the same effect as the plants that were subjected to a nutrient solution minus Potassium (K). This means that the plant height of abaca, P deficiency has little impact compared to K and N deficiency.

Furthermore, at 28 and 42 days of exposure of abaca plants to different treatments, the control (All nutrients)--treated plants had the longest pseudostem length compared to plants exposed to the nutrient solution without N, P, and K (Table 1). However, the pseudostem length of abaca plants exposed to the solution without N, P, and K were all comparable which means that the deficiency of either N, P, and K shortens the pseudostem of abaca. In addition, abaca plants under the control (i.e. with all nutrients) showed the widest pseudostem girth (Table 1) which also showed the same effect on abaca plants grown in the absence of P in the nutrient solution. On the other hand, abaca plants grown in the absence of N and K produce the smallest pseudostem girth. This would suggest that with the absence of N and K in the medium, the abaca plant could not expand its pseudostem girth properly. The decline in plant growth performance associated with nitrogen (N) deficiency is attributed to nitrogen being recognized as the most crucial mineral nutrient that significantly impacts plant growth, yield, and quality (Carranca et al., 2018). Nitrogen deficiency hinders cell division, ultimately affecting the overall development of vegetative leaves and stems in abaca (Carranca et al., 2018). Conversely, the reduced growth of

potassium (K)-deficient plants may be due to the sensitivity of photosynthetic product distribution and transport to K concentration. An ample supply of K enhances osmotic pressure in the phloem, facilitating the transfer of photosynthates from source to sink organs (Cakmak, 2005). However, in K-stressed plants, the loading of photosynthates in the phloem is impeded, leading to a significant reduction in the transport of these substances to the roots (Gerardeaux et al., 2010), which adversely affects the growth of K-deficient plants.

Table 1. Plant height (cm), pseudostem length (cm), and pseudostem girth (mm) of abaca (Musa textilis Née) 28th and 42nd days after treatment exposure

Source	Morphological Characteristics of Abaca					
	Plant Height (cm)		Pseudostem Length (cm)		Pseudostem Girth (mm)	
	28 days	42 Days	28 Days	42 Days	28 Days	42 Days
Control (+)	63.7^{a}	72.3^{a}	27.0^{a}	31.2^{a}	13.9	15.2^{a}
-N	54.1^{b}	56.5^{c}	21.4^{b}	23.2^{b}	12.2	12.7^{b}
-P	58.8^{ab}	64.7^{ab}	23.9^{b}	26.3^{b}	12.6	13.8^{ab}
-K	55.0^{b}	57.5^{bc}	22.2^{b}	23.9^{b}	11.7	12.0^{b}
Total	**231.6**	**251**	**94.5**	**104.6**	**50.4**	**53.7**
Mean	**57.9**	**62.7**	**23.6**	**26.1**	**12.6**	**13.4**
C.V (%)	**3.32**	**4.54**	**4.51**	**5.90**	**8.23**	**6.02**

Groups sharing a letter are not significantly different (Tukey HSD, p<0.05

The leaf morphology of the abaca was also affected by the absence of macronutrients (N, P, and K) in the solution (Table 2). At 28 and 42 days after treatment application, abaca plants exposed to the complete nutrient solution had the longest leaves compared to abaca plants exposed to the solution in the absence of N and K. However, this particular treatment is comparable to abaca plants without P in the solution. This means that under prolonged exposure to the K and N deficient media, the reduction in the extension of abaca leaves is more pronounced. Conversely, at 42 days post-treatment, abaca plants in the control group (with all nutrients) exhibited the widest leaves when compared to those grown in nutrient solutions lacking nitrogen (N), phosphorus (P), and potassium (K). The abaca plants that were grown in the absence of N had narrower leaves, similar to those cultivated without P and K. This observation suggests that the lack of any of these essential nutrient's results in smaller and narrower leaves. Additionally, at 42 days after treatment, the total leaf area of abaca plants in the control group was greater than that of plants lacking N. However, their leaf area was comparable to that of plants grown without P and K. This means that abaca leaf morphology is greatly affected and is more sensitive to the absence of N.

Table 2. Leaf length (cm), leaf width (cm), and total leaf area of abaca (Musa textilis Née) 28th and 42nd days after treatment exposure

Source	Morphological Characteristics of Abaca					
	Leaf Length (cm)		Leaf Width (cm)		Total Leaf Area (in^2)	
	28 days	42 Days	28 Days	42 Days	28 Days	42 Days
Control (+)	26.9^{a}	30.0^{a}	8.1	9.4^{a}	324.1	503.7^{a}
-N	23.8^{b}	24.4^{c}	7.3	6.9^{b}	197.5	263.9^{b}
-P	25.8^{ab}	27.3^{b}	7.6	7.8^{b}	249.1	370.6^{ab}
-K	24.4^{b}	25.1^{bc}	8.1	7.7^{b}	228.6	311.2^{ab}
Total	**100.9**	**106.8**	**31.1**	**31.8**	**999.3**	**1449**
Mean	**25.2**	**26.7**	**7.7**	**7.9**	**249.8**	**362.3**
C.V (%)	**3.01**	**3.22**	**6.75**	**5.88**	**20.2**	**21.5**

Groups sharing a letter are not significantly different (Tukey HSD, p<0.05

The reduction in the leaf morphology of nutrient-deficient abaca plants especially in the absence of N in the nutrient solution, would cause stress to abaca plants because N has a significant role in biomass synthesis. After all, it is involved in plant photosynthetic activities, as in upregulating photoassimilates and plant size (Prado, 2021). On the other hand, the reduction in the leaf morphology of K-deficient plants was possible because K is important in cell turgidity as well as maintenance of pH to have normal stress-free metabolic processes in the cytoplasm (Wang et al., 2013). It is also very needed for cell growth and development, which is one of the most important processes for the proper function and development of plants (Hepler et al., 2001).

As shown in Table 3, the concentrations of nutrients N, P, and K in abaca leaf tissues decreased in response to the various treatments. Abaca plants lacking nitrogen in the solution exhibited the lowest nitrogen content in comparison to the other treatments. A similar trend was observed in abaca plants that were exposed to solutions devoid of phosphorus which ultimately resulted in having the lowest P content compared to other treatments. Furthermore, abaca plants grown in the solution without K showed the lowest K content on their leaf tissues.

As presented in Table 4, the biochemical properties of abaca were influenced by the various treatments applied. These findings corroborate the previous results, indicating that the symptoms observed in abaca plants were attributed to the absence of nitrogen (N), phosphorus (P), and potassium (K) in the nutrient solution. Abaca plants lacking potassium exhibited the highest chlorophyll content among the treatments, whereas those without nitrogen displayed the lowest chlorophyll levels.

Table 3. Nutrient content of abaca (Musa textilis Née) 42 days after treatment exposure

Source	Tissue Analysis (N, P, and K)		
	Nitrogen (%)	Phosphorus (ppm)	Potassium (%)
Control (+)	4.1[a]	204.5[a]	13.3[a]
-N	2.2[b]	185.9[a]	12.8[a]
-P	3.9[ab]	65.0[b]	13.4[a]
-K	4.2[a]	241.4[a]	7.4[b]
Total	**14.4**	**696.8**	**46.9**
Mean	**3.6**	**174.2**	**11.7**
C.V (%)	**18.0**	**14.9**	**2.78**

Groups sharing a letter are not significantly different (Tukey HSD, p<0.05

Table 4. Chlorophyll a, chlorophyll b, and %FRSA of abaca (Musa textilis Née) 42 days after treatment exposure

Source	Biochemical Properties of Abaca		
	Chlorophyll a (mg/g)	Chlorophyll b mg/g)	FRSA (%)
Control (+)	20.6[b]	8.5[b]	25.8[c]
-N	6.6[d]	2.7[d]	30.7[b]
-P	14.9[c]	6.0[c]	33.2[a]
-K	26.2[a]	12.7[a]	26.7[c]
Total	**68.3**	**29.9**	**116.4**
Mean	**17.0**	**7.4**	**29.1**
C.V (%)	**0.14**	**0.23**	**1.28**

Groups sharing a letter are not significantly different (Tukey HSD, p<0.05

Additionally, chlorophyll b levels were also highest in abaca plants deprived of potassium, with the lowest values recorded for both parameters in the absence of nitrogen This

indicates that the absence of nitrogen significantly impacted and reduced the levels of chlorophyll a and chlorophyll b in abaca. Furthermore, the free radical scavenging activity (FRSA) of the abaca plants was similarly affected by the lack of N, P, and K. Abaca plants without phosphorus demonstrated the highest FRSA, while those in the control group (with all nutrients) and those without potassium exhibited the lowest FRSA. This suggests that abaca plants lacking phosphorus produce more antioxidants than those subjected to the other treatments.

The reduction in chlorophyll a (Chl a) and chlorophyll b (Chl b) due to nitrogen (N) deficiency can be attributed to the findings of Chen et al., (2024). They noted that a decrease in nitrogen supply adversely affects the plant's normal growth by lowering the levels of chlorophyll a, chlorophyll b, as well as the Chl a to Chl b ratio. Chlorophyll is a vital pigment that plays a crucial role in photosynthesis, as it converts light energy into chemical energy during the day, thereby providing essential resources for plant growth and development, and represents the fundamental basis of these processes. Negi et al., (2016) highlighted that nitrogen deficiency can lead to stress that damages the intracellular structure of chloroplasts, thereby reducing chlorophyll content and increasing vulnerability to light injury. Given that chlorophyll is a nitrogen-containing compound synthesized in chloroplasts, a deficiency in nitrogen directly impacts its biosynthesis. Under conditions of nitrogen deficiency, nitrogen is redirected to various tissues and storage organs, leading to the degradation of chlorophyll and the manifestation of leaf senescence. As leaves are the primary sites for photosynthesis in plants, nitrogen deficiency triggers leaf senescence, which subsequently reduces the plant's photosynthetic capacity (Bolivar, 2006).

Conversely, the free radical scavenging activity of abaca plants increases under nutrient deficiency. This occurs because, in nutrient-deficient conditions, oxidative stress arises when the equilibrium between antioxidant defense and the production of Reactive Oxygen Species (ROS) is disrupted (Shin et al., 2005). Both deficiencies and excesses of macronutrients can lead to this imbalance, resulting in an overproduction of ROS in plants, which swiftly triggers oxidative defense reactions (Parvin et al., 2020). When plant stress reaches a critical threshold, the balance between antioxidants and ROS is compromised. At elevated concentrations, ROS become toxic to plant cells, necessitating the scavenging of excess oxidants to mitigate harmful effects (del Río, 2015). Previous studies indicate that the activity of ROS-scavenging enzymes increases under low phosphorus stress, protecting chloroplasts from damage due to photooxidative stress and maintaining redox homeostasis (Li et al., 2018).

Additionally, the stomatal length and aperture of abaca plants were significantly influenced by the absence of nitrogen (N), phosphorus (P), and potassium (K) in the solutions, as tabulated in Table 5. The shortest stomatal length and aperture were observed in abaca plants lacking phosphorus, although it was comparable in plants deprived of other nutrients. The longest stomatal length recorded was observed in abaca plants deprived of nitrogen (N) and in the control group while all nutrient deficiency reduced stomatal aperture. This indicates that exposure to the absence of phosphorus (P) and potassium (K) resulted in a decrease in stomatal length and aperture in abaca plants consequently impacting photosynthesis and various physiological functions. The smallest stomatal aperture was observed on K-deficient abaca plants because potassium is a crucial cation that plays a vital role in plant growth and development. It contributes to charge balance, osmotic pressure regulation, and enzyme catalysis (Hawkesford et al., 2012).

Table 5. Stomatal morphology of abaca (Musa textilis Née) 42 days after treatment exposure

Source	Biochemical Properties of Abaca		
	Stomatal Length (µm)	Stomatal Width (µm)	Stomatal Aperture (µm)
Control (+)	0.028[a]	0.030	0.0083[a]
-N	0.028[a]	0.030	0.0033[b]
-P	0.025[b]	0.028	0.0026[b]
-K	0.026[b]	0.027	0.0020[b]
Total	**0.107**	**0.115**	**0.0162**
Mean	**0.026**	**0.028**	**0.0040**
C.V (%)	**2.75**	**5.19**	**21.9**

Groups sharing a letter are not significantly different (Tukey HSD, p<0.05

Stored in vacuoles, potassium (K) plays a crucial role in generating osmotic pressure, which is essential for turgor and growth expansion. The transport of water through aquaporins across plant tissues is largely dependent on the cationic osmotic potential, primarily influenced by potassium (Maurel et al., 2015). Potassium actively contributes to maintaining cellular turgidity across various plant parts, ensuring that the stomatal guard cells remain open (Sardans & Peñuelas, 2021). In conditions of low potassium availability, plants become more susceptible to wilting in dry soils, and even moderate K deficiency can hinder photosynthesis by diminishing overall stomatal conductance and adversely affecting photosynthetic and biochemical processes in plants (Cakmak, 2005).

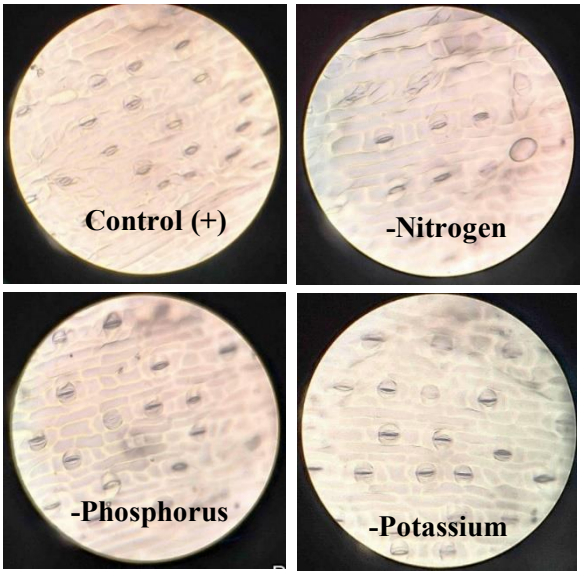
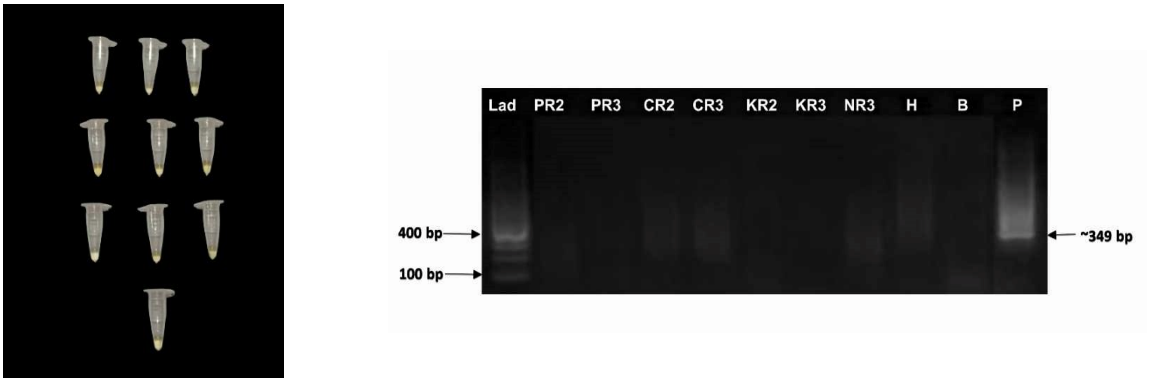


Figure 4. Stomatal morphology of macronutrient-deficient abaca plants viewed using a compound microscope @40x zoom

Detection of Abaca Bunchy Top Virus (ABTV)

Prior to conducting the study, samples were tested for the presence of the abaca bunchy top virus using the Loop-mediated Isothermal Amplification Test Kit developed by the Philippine Fiber Industry Development Authority (PhilFIDA). Ten sample plants were examined, and the results indicated that they were free from ABTV and the associated disease, as illustrated in Figure 10A. The orange color depicted in the vials serves as an indication of a negative result for ABTV.



(A) **(B)**

Figure 5. Abaca bunchy top virus (ABTV) detection using Loop-mediated isothermal amplification (LAMPARA) (A) and polymerase chain reaction (PCR) (B).

Following the completion of the study, the plants underwent ABTV detection via Polymerase Chain Reaction (PCR) at the Plant Disease Diagnostic Laboratory (PDDL) at Visayas State University in Baybay City, Leyte. The results indicated that the nutrient-deficient plants tested negative for ABTV (see Figure 10B). Therefore, it can be concluded that the samples were disease-free and that the symptoms observed in the nutrient-deficient abaca plants were attributed to a lack of essential macronutrients such as nitrogen (N), phosphorus (P), and potassium (K).

Conclusion

The study affirmed that macronutrient deficiencies, specifically nitrogen and potassium, significantly reduced abaca growth and impaired its physiology. Nitrogen deficiency led to stunted growth, reduced chlorophyll content, and visible necrosis, while potassium deficiency affected stomatal conductance and leaf expansion. Phosphorus deficiency had comparatively milder effects than nitrogen and potassium. These findings underscore the necessity of balanced fertilization to achieve optimal abaca productivity.

References

Aron, D. (1949). Copper enzymes isolated chloroplasts, polyphenoloxidase in Beta vulgaris. Plant Physiology. 24: 1-15.

Bolivar, D.W. (2006). Recent advances in chlorophyll biosynthesis. Photosynth Res 89, 1–22 (2006). https://doi.org/10.1007/s11120-006-9076-6

Cakmak, I. (2005). The role of potassium in alleviating detrimental effects of abiotic stresses in plants. J. Plant Nutr. Soil Sci. 2005, 168, 521–530. [Google Scholar] [CrossRef]

Carranca, C., Brunetto, G., & Tagliavini, M. (2018). Nitrogen nutrition of fruit trees to reconcile productivity and environmental concerns. Plants. 2018;7:4. doi: 10.3390/plants7010004. [DOI] [PMC free article] [PubMed] [Google Scholar]

Chen, L.H., Xu, M., Cheng, Z., & Yang, L.T. (2024). Effects of Nitrogen Deficiency on the Photosynthesis, Chlorophyll a Fluorescence, Antioxidant System, and Sulfur Compounds in Oryza sativa. International Journal of Molecular Sciences, 25(19), 10409. https://doi.org/10.3390/ijms251910409

Cook, J.G.A. (2001). Natural Fibres of Vegetable Origin. In Handbook of Textile Fibres; COOK, J. G., Ed.; Woodhead Publishing, 2001; pp 3–78. https://doi.org/10.1533/9781845693152.3.

del Río, L.A. (2015). ROS and RNS in plant physiology: An overview. Journal of Experimental Botany, 66, 2827–2837.

Dizon, T.O., Damasco, O.P., Lobina, I.T., Pinili, M.S., Lalusin, A.G., & Natsuaki, K.T. (2012).

Induction of putative resistant lines of abaca (Musa textilis Nee) to Banana bunchy top virus and Banana bract mosaic virus through in vitro mutagenesis. Journal International Society for Southeast Asian Agricultural Sciences (ISSAAS), 18(1):87-99.

dos Santos Sarah, M.M., de Mello Prado, R., de Souza Júnior, J.P., Teixeira, G.C. M., dos Santos Duarte, J.C., & de Medeiros, R.L.S. (2021). Silicon Supplied via Root or Leaf Relieves Potassium Deficiency Effects in Common Bean. Sci Rep. 2021;11:19690. doi: 10.1038/s41598-021-99194-z. [DOI] [PMC free article] [PubMed] [Google Scholar]

Fathi, A., & Zeidali, E. (2021). Conservation tillage and nitrogen fertilizer: a review of corn growth, yield and weed management. Cent Asian J Plant Sci. Innov., 1(3), 121–142. https://www.cajpsi.com/article_137559_7f1740644996104fe39b1b433015cfb.pdf

Gerardeaux, E., Jordan-Meille, L., Constantin, J., Pellerin, S., & Dingkuhn, M. (2010). Changes in plant morphology and dry matter partitioning caused by potassium deficiency in Gossypium hirsutum (L.). Environ. Exp. Bot. 67, 451–459. doi: 10.1016/j.envexpbot.2009.09.008 CrossRef Full Text | Google Scholar

Hawkesford, M., Horst, W., Kichey, T., Lambers, H., Schjoerring, J., Skrumsager M., & White P. (2012). Functions of macronutrients. In Marschner's Mineral Nutrition of Higher Plants, 3rd ed.; Marschner, P., Ed.; Elsevier Ltd.: Amsterdam, The Netherlands, 2012; pp. 135–189. [Google Scholar] [CrossRef]

Hepler, P.K., Vidali, L., & Cheung, A.Y. (2001). Polarized cell growth in higher plants. Annu.Rev. Cell. Dev. Biol. 17, 159–187. doi: 10.1146/annurev.cellbio.17.1.159 PubMed Abstract | CrossRef Full Text | Google Scholar

Hiscox, J.D., & Israelstam GF. (1979). A Method for the Extraction of Chlorophyll from Leaf Tissue without Maceration. Canadian Journal of Botany, 57, 1332-1334. https://doi.org/10.1139/b79-163

Huang, L., Yang, J., Cui, X., Yang, H., Wang., S., & Zhuang, H. (2016). Synergy and Transition of Recovery Efficiency of Nitrogen Fertilizer in Various Rice Genotypes under Organic Farming. Sustainability, 8(9), 854. https://doi.org/10.3390/su8090854

Hurtado, S.M.C., Silva, C.A., Resende, Á.V., de Corazza, E., Shozo, L., & Satoshi F. (2010). Sensibilidade do clorofilômetro para diagnóstico nutricional de nitrogênio no milho. Ciência e Agrotecnologia, 34(3), 688–697. https://doi.org/10.1590/S1413-70542010000300023

Isidra-Arellano, M.C., Delaux, P.M., & Valds-Lopez, O. (2021). The Phosphate Starvation Response System: Its Role in the Regulation of Plant-Microbe Interactions. Plant Cell Physiol. 2021; 62:392–400. doi: 10.1093/pcp/pcab016. [DOI] [PubMed] [Google Scholar]

Kızılgeç, İ.F., Yıldırım, M., Akıncı, C., Albayrak, Ö., & Basdemir, F. (2015). The availability of advanced durum wheat population in yield and quality basis selection. Ziraat Fakültesi Dergisi-Süleyman Demirel Üniversitesi, 10(2), 62–68.

Li, P., Weng, J., Zhang, Q., Yu, L., Yao, Q., Chang, L., & Niu, Q. (2018). Physiological and Biochemical Responses of Cucumis melo L. Chloroplasts to Low-Phosphate Stress. Front. Plant Sci. 2018;9:1525. doi: 10.3389/fpls.2018.01525. [DOI] [PMC free article] [PubMed] [Google Scholar]

Marathe, R.A., Murkute, A.A. & Dhinesh, B.K. (2016). Mineral Nutrient Deficiencies and Nutrient Interactions in Pomegranate. Natl. Acad. Sci. Lett. 2016;39:407–410. doi: 10.1007/s40009-016-0487-4. [DOI] [Google Scholar]

Maurel, C., Boursiac, Y., Luu, D.T., Santoni, V., Shahzad, Z., & Verdoucq, L. (2015). Aquaporins in Plants. Physiol Rev. 2015 Oct;95(4):1321-58. doi: 10.1152/physrev.00008.2015. PMID: 26336033.

Mendoza-Tafolla, R.O., Juarez-Lopez, P., Ontiveros-Capurata, R.E., Sandoval-Villa, M., Iran, A.T., & Alejo-Santiago, G. (2019).

Estimating Nitrogen and Chlorophyll Status of Romaine Lettuce Using SPAD and at LEAF Readings. Not. Bot. Horti Agrobot. Cluj-Napoca, 47(3), 751–756. https://doi.org/10.15835/nbha47311525

Matias, K.M.L., Sotto, R.C., Bautista, N.S., Protacio, C.M., & Magdalita, P.M. (2024). Influence of Drought Stress and Foliar Application of Salicylic Acid on Early Vegetative Stage of Cacao. Philippine Journal of Science, 153(2).

Munar, J. (2024). Revitalizing the abaca industry. Manila Chronicle, May 28, 2024

Negi, S., Barry, A.N., Friedland, N., Sudasinghe, N., Subramanian, S., Pieris, S., Holguin, F.O., Dungan, B., Schaub, T., & Sayre, R. (2016). Impact of nitrogen limitation on biomass, photosynthesis, and lipid accumulation in Chlorella sorokiniana. Journal of Applied Phycology, 28, 803–812

Parac, E.P., Cruz, F.C.S., & Lalusin., A.G. (2021). Resistance reaction of Abaca (Musa textilis Nee) hybrids to bunchy top and establishment of disease severity rating scale for screenhouse screening. Governance, 3(2), 18-26.

Parvin, K., Nahar, K., Hasanuzzaman, M., Bhuyan, M., Mohsin, S.M., & Fujita M. (2020). Exogenous vanillic acid enhances salt tolerance of tomato: Insight into plant antioxidant defense and glyoxalase systems. Plant Physiol. Biochem. 2020;150:109–120. doi: 10.1016/j.plaphy.2020.02.030. [DOI] [PubMed] [Google Scholar]

Philippine Fiber Industry Development Authority (PhilFIDA). (2023). Fiber statistics 2023. https://philfida.da.gov.ph/index.php/2016-11-10-03-32-59/2016-11-11-07-56-39

Prado, R.M. (2021). Mineral nutrition of tropical plants. Mineral Nutrition of Tropical Plants. Austria, Springer Cham. 339p.

Raymundo, A.D. (2000). Saving abaca from the onslaught of the bunchy-top disease. Philippine Agricultural Scientist 83:379-385.

Salas, F., Salas, R., Pole, V.N., & Quevedo, M. (2015). Shelf-Life and Free Radical Scavenging Activity of Tomato (Lycopersicon Esculentum Mill.) Fruits Coated with Safe Phytochemicals. J. Food Nutr. Sci.. 3. 94-99. 10.11648/j.jfns.s.2015030102.28.

Sardans, J. & Peñuelas, J. (2021). Potassium Control of Plant Functions: Ecological and Agricultural Implications. Plants, 10(2), 419. https://doi.org/10.3390/plants10020419

Sawyer, J.E., Lundvall, J., Hawkins, J.S., & Barker, D.W. (2011). Sensing nitrogen stress in corn. Iowa State University. https://store.extension.iastate.edu/Product/Sensing-Nitrogen-Stress-in-Corn-pdf

Shah, S., Houborg, R., & McCabe, M. (2017). Response of Chlorophyll, Carotenoid and SPAD-502 Measurement to Salinity and Nutrient Stress in Wheat (Triticum aestivum L.). Agronomy, 7(3), 61. https://doi.org/10.3390/agronomy7030061

Shahri, W., Tahir, I., & Ahad, B. (2014). Abaca Fiber: A Renewable Bio-Resource for Industrial Uses and Other Applications. In Biomass and Bioenergy: Processing and Properties; Springer, 2014

Sharman, M., Thomas, J.E., Skabo, S., & Holton, T.E. (2008). Abaca bunchy top virus, a new member of the genus Babuvirus (family Nanoviridae). Archives of Virology.153:135-147.

Shin, R., Berg, R.H., & Schachtman, D.P. (2005). Reactive oxygen species and root hairs in Arabidopsis root response to nitrogen, phosphorus and potassium deficiency. Plant & Cell Physiology, 46, 1350–1357

Sta. Cruz, F.C., Belen, G.B., & Alviar, A.N. (2016). Serological and Molecular Detection of Mixed Bunchy Top and Mosaic Virus Infections in Abaca (Musa textilis Nee). Philippine Agricultural Science99(1):68-78.

Wang, M., Zheng, Q., Shen, Q., & Guo, S. (2013). The critical role of potassium in plant stress response. Int. J. Mol. Sci. 2013;14:7370–7390. doi: 10.3390/ijms14047370. [DOI] [PMC free article] [PubMed] [Google Scholar]

Westerveld, S.M., McKeown, A.W., McDonald, M.R., & Scott-Dupree, CD. (2002). Chlorophyll and nitrate meters as nitrogen monitoring tools for selected vegetables

in southern Ontario. In XXVI International Horticultural Congress: Toward Ecologically Sound Fertilization Strategies for Field Vegetable Production. 627, (pp 259–266). https://doi.org/10.17660/ActaHortic.2003.627.33

Wieczorek, D., Żyszka-Haberecht, B., Kafka, A., & Lipok, J. (2022). Determination of phosphorus compounds in plant tissues: from colourimetry to advanced instrumental analytical chemistry. Plant Methods. 18. 22. 10.1186/s13007-022-00854-6.

Zakariyya, F., Setyawan, B., & Wahyo, S. (2017). Stomatal, Proline and Leaf Water Status Characters of Some Cocoa Clones (Theobroma cacao L.) on Prolonged Dry Season. Pelita Perkebunan: a Coffee and Cocoa Research Journal 33(1): 109-117. https://doi.org/10.3390/foods12183519