ACTA
BOTANICA *PLANTAE*

Acta Botanica Plantae : 36–42 (2022)
http://www.actabotanica.org/

ORGINAL RESEARCH ARTICLE

Nitrate Fertilizer Improves the Physiology of Taro (*Colocasia esculenta* (L.) Schott var *esculenta*) Plants

Walter Faamatuainu and Falaniko Amosa
The University of the South Pacific, Alafua, Samoa, West Indies
Corresponding Author : Walter Faamatuainu (walterfaamatuainu@gmail.com)

Received 30 July 2022 | Revised 29 September 2022 | Accepted 19 October 2022 | Available Online October 28 2022

Citation: Ogori, A. Friday, Eke, M. Ojotu, Girgih, T. Abraha, and Abu, J. Oneh. 2022. Nitrate Fertilizer Improves the Physiology of Taro (Colocasia esculenta (L.) Schott var esculenta) Plants. Acta Botanica Plantae. V01i03, 36-42. DOI: http://dx.doi.org/10.5281/zenodo.7509322

ABSTRACT

This paper investigates the effects of nitrate fertilizers (NF) and ammonium fertilizers (AF) on the physiology of taro plants. A factorial experiment in a randomized complete block design with three replications was conducted. Four nitrogen treatments, three harvest dates and two taro cultivars were the experimental factors examined. Overall, the results showed that NF and AF produced optimum taro heights and chlorophyll indices (CI) respectively throughout the growing season. Further, NF produced the highest number of suckers for both taro cultivars during the six months period. The NF for the most part also produced optimum leaf blades yield (LY) and petioles yield (PY). Moreover, NF produced optimum corms yield (CY) for the 'White' taro cultivar. Therefore, the application of AF and NF influenced the physiology of taro plants.

Keywords: *Nitrate, ammonium, taro, physiology, taro plants*

INTRODUCTION

The global taro corms production is estimated at 11.8 million tons per annum and is ranked fifth behind other root crops such as potato, cassava, sweet potato and yam [1,24]. Taro is often called the "neglected root crop" because its production is very low in comparison to other root crops. Several factors have contributed to the decline in taro cultivation and the hesitation of the farmer to plant taro. Vulnerabilities to limited water supply and susceptibility to pest attacks are often the main issues that hindered taro cultivation [3,13,14]. However, taro can be cultivated in a range of ecological zones because of its wide environmental tolerance [13] . Globally, taro is found in Australia, Bangladesh, Brazil, Nigeria,Hawaii, Samoa and Trinidad and Tobago (TnT).

Nitrogen is one of the most influential nutrients in terms of crop growth, biological production and yield [31]. It is often the most limiting mineral nutrient for taro growth and development. Taro plants experiencing nitrogen deficiencies usually suffer from stunted roots, yellowing of the leaf blades, premature death of older leaves, and lower yield [18, 22] . On the contrary, optimum nitrogen supply, stimulates large leaf areas as well as accumulating substantial amounts of dry matter to the corms [15] . Understanding the physiology of taro plants under nitrogen fertilization will assist in identifying the time in which taro plant produce maximum yield. Usually, taro plants have three main physiological stages. These different periods include the vegetative, corm bulking and corms dormancy phases [27] . In addition, the accumulation and partitioning of dry matter are vital for determining crop productivity and providing valuable information for enhancing root crop yield [12]. Hence, the final yield of most crops is affected by physiological factors operating at different growth stages [27] .

Even though there are several studies that discuss the influence of applying varying nitrogen rates on taro [7, 8, 11, 16] there is a scarcity of information on the influence of different nitrogen sources (NF versus AF) on the physiology of taro plants. The application of AF and NF to a growing medium initiates several natural processes which convert one form of nitrogen into another. For example, bacteria can convert $(NH_2)_2CO$ to NH_4^+ or NH_4^+ to NO_3^-. During the conversion of ammonium to nitrate, hydrogen ions are released causing the medium to become acidified. Also, urea is usually transformed in the growing medium to ammonia in less than two days [17]. In most terrestrial ecosystems, nitrogen is available to crops through the mineralization process whereby organic nitrogen is transformed into inorganic nitrogen. Several inorganic forms of nitrogen exist, however, ammonium and nitrate are the preferred forms of nitrogen which are assimilated and absorbed by crops [5] .

Even though, there are many factors that influenced the availability of nitrogen from different organic sources; temperature is one of the dominant factors which dictates the formation of inorganic nitrogen. Nitrogen form is essential for the cation-anion relationship in plants since ammonium and nitrate represent 70 to 80% of ions absorbed by plants [22] . In most cases, available nitrogen does not stay for long in the soil, because it is usually lost from the soil as a result of leaching, volatilization and runoff. Emitted ammonia and nitrous oxides are released into the atmosphere while nitrate and ammonium enters into the groundwater and surface water through leaching and runoff respectively [26]. Cations such as NH_4^+ are mostly absorbed into soil particle which delayed their conversion to NO_3^-.

Substrate nitrogen concentration, cation exchange capacity, soil pH, oxygen content and microbial activity also influenced nitrogen availability [9] .Generally, plants absorb both NO_3^- and NH_4^+. However, the preference between the two is not well understood. Thus, an experiment was implemented to determine the impacts of NO_3^- and NH_4^+ fertilizers on tomato (*Lycoperscion esculentum*) yield. The results show that elevated NH_4^+ rates lead to the high incidence of blossom-end-rot disease in tomato plants [9] . Furthermore, the influence of NO_3^- and NH_4^+ fertilizers on copper uptake by wheat and barley plants shows that the application of NO_3^- fertilizers increased copper uptake in contrast to NH_4^+ fertilizers.

Moreover, high levels of NH_4^+ cause toxicity which reduced the vegetative yield of wheat and barley plants [28]. Other studies revealed that ammonium uptake lowers the pH of the growing medium because plants will release hydrogen ions (H^+) to maintain a balanced pH inside the plants. However, the uptake of nitrates resulted in the release of OH^- ions by plants which will combine with H^+ ions in the medium to form water molecules to increase the pH of the medium [17].

Table 1. Temperature and rainfall at Mt Hope

Month	Temperature (°C)	Rainfall (mm)
November-2016	30.5	168.3
December	29.8	162.7
January-2017	30.8	50.6
February	31.0	15.3
March	31.3	43.1
April	32.7	0.4
May	32.0	104

Materials and Methods

Study site

A field experiment was conducted at the University of the West Indies field stations in Mt Hope (North 10°38'17.16, 61°25'40.8 West) which contain the River Estate soil series, fluventic eutropepts. The river estate (free drainage) soil was derived from micaceous and schist sand alluviums which usually have soil pH ranging from 5 to 6.2. Mixed vegetables are the preferred crops for the river estate soil [6]. The weather data and physiochemical properties of the soils at Mt Hope are given in Tables 1 and 2, respectively.

Treatments

The experiment was setup in a factorial design layout in a randomized complete block design (RCBD) with three replications. The factors include four nitrogen treatments (urea, calcium nitrate, polymer-coated urea and the control) with a constant 100 kg N/ha application rate, three harvests (two, four, and six MAP, chosen based on the literature pertaining to the physiology of taro (13, 19) and two taro cultivars ('Blue' and 'White'). The Blue taro cultivar was used because it is very popular in TnT as a result of its firm taste and is synonymous with the Blue Food festival held annually in Tobago. A festival is a culinary event that attracts tourists from all over the world to taste an

http://dx.doi.org/10.5281/zenodo.7509322

Table 2. Physiochemical properties at Mt Hope

Soils	Clay	Silt	Sand	pH	NH_4^+-N	NO_3^--N	P	K	Ca	Mg	Cu	Mn	Fe	Zn
	-------------%-------------				-------------mg/kg-------------									
Mt Hope	38.1	22.3	41.8	5.2	1.8	7	0.4	0.7	1.3	0.39	0.0004	0.002	0.09	0.0004

Table 3. Leaf blades yield of taro plants applied with AF and NF at three harvest periods

Cultivars	Blue	White
2 MAP		
Control	0.57a	1.31a
Calcium nitrate	1.30b	3.32b
Polymer coated urea	0.68c	2.55c
Urea	0.90d	1.50d
4 MAP		
Control	0.63e	0.93e
Calcium nitrate	1.13f	2.79f
Polymer coated urea	1.02g	2.12g
Urea	0.85h	1.12h
6 MAP		
Control	0.62e	1.67i
Calcium nitrate	1.82i	3.27j
Polymer coated urea	1.33b	2.03k
Urea	0.71c	2.09l

Table 4. Petioles yield of taro plants applied with AF and NF at three harvest periods

Cultivars	Blue	White
2 MAP		
Control	1.71a	3.08a
Calcium nitrate	5.36b	11.54b
Polymer coated urea	2.00a	8.49c
Urea	3.23c	5.10d
4 MAP		
Control	1.52a	3.36a
Calcium nitrate	3.37c	14.89e
Polymer coated urea	3.44c	9.03c
Urea	4.42d	4.04f
6 MAP		
Control	3.21c	5.62d
Calcium nitrate	10.00e	14.17e
Polymer coated urea	6.92f	11.45b
Urea	3.60c	11.30b

array of delicacies such as taro blue cake, taro sponge cake and taro wine. While the White taro cultivar is one of the most common taro cultivars found at the local markets in Trinidad.

Planting materials

Taro suckers (uniform size of the two taro cultivars) from farmers were used as planting materials at 20 cm depth. Each plot contains eighty-five plants (55 × 55 cm spacing, plot dimensions is 9.5 × 2.8 m) whereby the inner fifteen plants were harvested for analysis.

Study implementation

The AF (polymer-coated urea and urea) and NF (calcium nitrate) (constant 100 kg/ha rate) were applied during the first month of planting, with the urea and calcium nitrate applied in split applications while the polymer-coated urea was applied in a single application. The calcium nitrate and urea fertilizers were applied at planting and at1 MAP while the polymer-coated urea was applied only at planting. Nitrogen from the polymer-coated urea is gradually released while nitrogen from calcium nitrate and urea is instantly available to plants. Phosphorus (50 kg P/ha) was applied using triple superphosphate while potassium (100 kg K/ha) was applied as muriate of potash to the plots at planting.

Data collected

The number of leaves, suckers, plants height and chlorophyll indices (CIs) were collected on a monthly basis to study the physiology of taro plants. Chlorophyll index measurements were taken using the Field Scout CM 1000 chlorophyll meter by Spectrum Technologies which uses a point and shoots action to instantly estimate the relative chlorophyll content of taro leaves. Fifteen taro plants were harvested per treatment at two, four, and six MAP. At each harvest, a spade was used to dig out the plants which were then washed with water to remove any soil on the plants. Taro plants were then air-dried and divided into leaf blades, petioles and corms. Fresh weights were recorded afterward.

Statistical analysis

Analysis of variance (ANOVA) was performed on the data collected using the IBM SPSS 20 statistical software. The comparisons between the treatment means were calculated using the least significant difference (LSD) at the 5% probability level (P values < 0.05).

RESULTS

Fig. 1A, B, C and D show the heights, CIs, leaves and suckers of taro plants from 1 to 6 MAP, under the influence of AF and NF. The ANOVA revealed that interactions between taro cultivars, fertilizers and MAP were statistically significant ($P < 0.05$). Overlapping between the error bars indicates no statistical significance. At 1 MAP, NF and AF produced the highest heights (Fig 1A) for Blue and White taro respectively. At 2 MAP, AF produced the highest heights for both taro cultivars. At 3 MAP, AF and NF produced the highest heights for Blue and White taro respectively. At 4, 5 and 6 MAP, NF produced the highest heights for both taro cultivars. Meanwhile; Fig. 1B shows that at 1 MAP, AF produced optimum CI for both taro cultivars. At 2 and 3 MAP, AF produced the highest CI for the two taro cultivars. At 4 MAP, NF and AF produced the highest CI for Blue and White taro respectively. At 5 MAP, NF produced the highest CI for Blue taro while AF produced the highest CI for White taro. Finally, at 6 MAP, AF and NF produced the highest CI for Blue and White taro respectively.

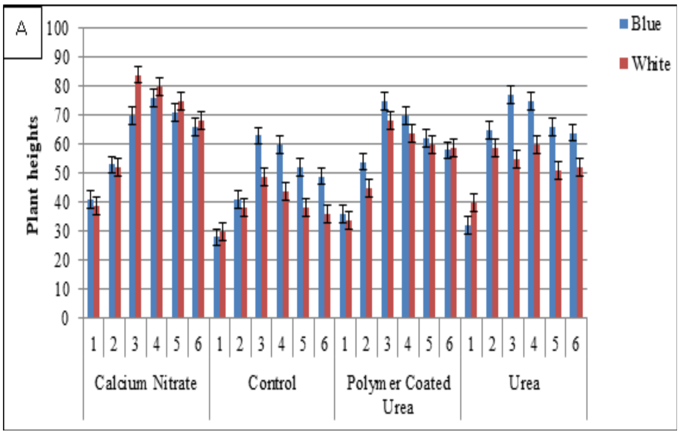
Figure 1C shows that the Blue taro had more leaves than the White taro at 2, 3, 4, 5 and 6 MAP. The highest leaves production for both cultivars was reported at 3 MAP. Meanwhile, Figure 1D shows that at 1 MAP, all nitrogen treatments produced two suckers for White taro and three suckers for Blue taro. At 2, 3, 4, 5 and 6 MAP, NF produced the highest suckers for both taro cultivars.

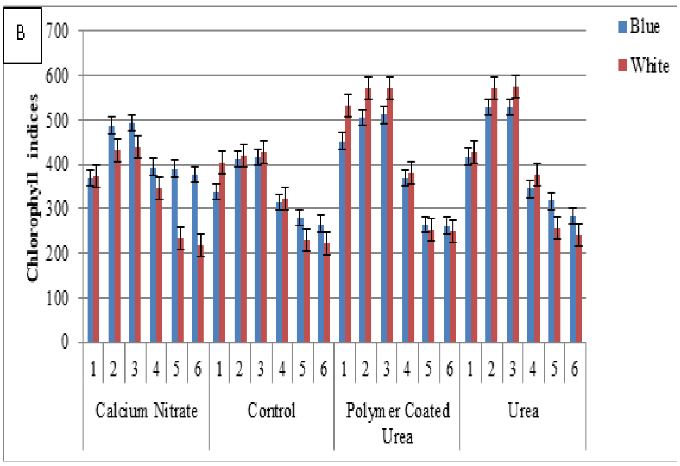
Tables 3, 4 and 5 show the leaf blades, petioles and corms yield (ton/ha) of two taro cultivars at three harvest intervals applied with AF and NF. The ANOVA revealed that interactions between taro cultivars, fertilizers and MAP were statistically significant ($P < 0.05$). Table 3 shows that at 2, 4 and 6 MAP, NF produced the highest LY for the two taro cultivars. Table 4 shows that NF produced the highest PY for the two taro cultivars at 2 MAP. At 4 MAP, AF and NF produced the highest PY for Blue and White taro respectively. At 6 MAP, NF produced the highest PY for both taro cultivars. Regarding CY (Table 5), at 2 MAP, AF and NF produced the highest CY for Blue and White taro respectively. At 4 MAP, NF produced

Table 5. Corms yield of taro plants applied with AF and NF at three harvest periods

Cultivars	Blue	White
2 MAP		
Control	1.43a	1.32a
Calcium nitrate	1.80b	2.20b
Polymer coated urea	2.42c	2.05c
Urea	2.34d	2.00c
4 MAP		
Control	2.59e	2.50d
Calcium nitrate	5.58f	8.74e
Polymer coated urea	4.83g	6.50f
Urea	4.41h	3.58g
6 MAP		
Control	5.98i	6.72h
Calcium nitrate	8.36j	15.39i
Polymer coated urea	10.51k	9.22j
Urea	6.16l	7.75k

*Analyses of variance (ANOVA) table reports significance of treatments and their interactions. Different letters in each column indicate least significant differences at P < 0.05; P < 0.01; ** significant at P < 0.01*





http://dx.doi.org/10.5281/zenodo.7509322

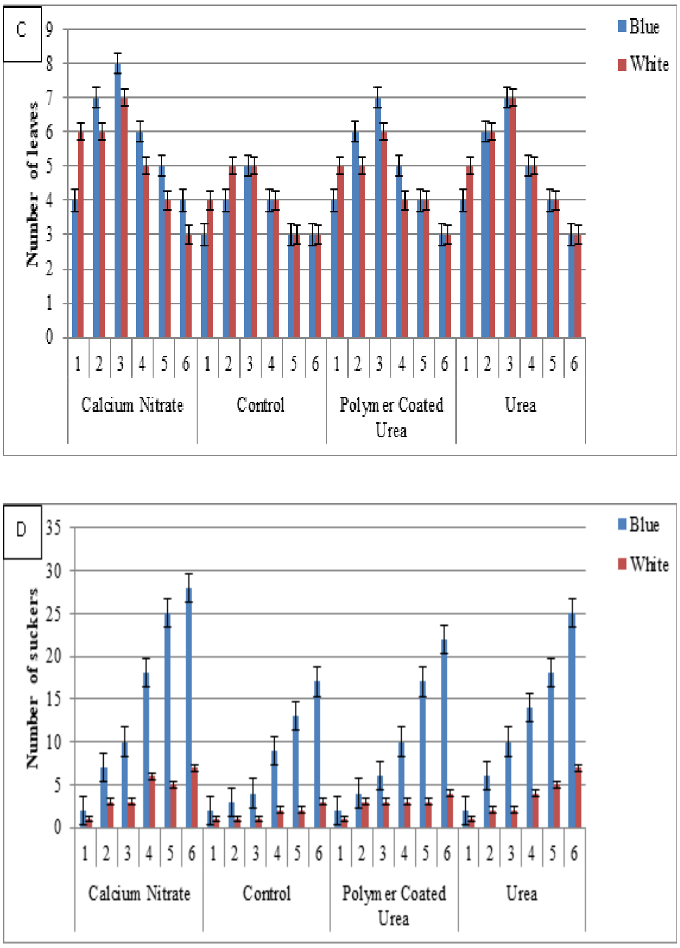


Fig. 1. Heights (A), chlorophyll indices (B) and number of leaves (C) and suckers (D) of taro plants applied with AF and NF

the highest CY for both taro cultivars. At 6 MAP, AF produced the highest CY for the Blue taro while NF produced the highest CY for the White taro.

DISCUSSIONS

During the latter growth stages, the results show that NF produced taller taro plants than AF. The literature review suggested that ammonium fertilizers acidified the growth medium which leads to stunted growth in plants. Generally, ammonium uptake lowers the pH of the growing medium because plants released hydrogen ions (H^+) in order to maintain a balanced pH inside the plants. However, the uptake of nitrates resulted in the release of OH^- ions by plants which combines with H^+ ions in the medium to form water molecules [17] . The trend in taro heights from our experiment is similar to results reported from taro cultivars in Hawaii, Bangladesh and Uganda whereby taro heights increased during the early growth stages before gradually declining as the taro plants approached maturity [2, 4, 20, 25, 29] . The results above also indicate that the patterns followed by chlorophyll indices measurements for the two cultivars are similar to the height measurements. Therefore, a correlation test was used to determine the association between the two variables.

Consequently, the Pearson correlation was found to be 0.803 and the relationship was statistically significant at the 5% probability level. To our knowledge, no literature discussed the relationship between the physiology of taro plants and chlorophyll index measurements. It was noted from the literature review that the chlorophyll index meter was used to measure the influence of salinity (environmental stress) on other plants such as sunflower. It was concluded that higher salinity rates lead to lower chlorophyll index meter reading [30]. Moreover, the chlorophyll index meter accurately predicts crude protein and in vitro ruminal organic matter of a grass (*Bracharia decumbens*) used in livestock feed [10]. Regarding the number of leaves, other researchers concluded that taro plants had fewer leaves at 1 and 2 MAP, and rapid leaves development at 3, 4 and 5 MAP [2, 4, 8, 11, 20, 21, 23, 29]. The results also show that nitrate fertilizers produced more taro suckers than ammonium fertilizers. In terms of yields, nitrate based fertilizers produced more LY than ammonium based fertilizers. Also, the results overwhelmingly show that nitrate fertilizers produced more PY than ammonium fertilizers. Moreover, NF produced optimum CY for White taro.

CONCLUSION

Overall, NF performed better than AF. This is in-line with the literature which suggests that the uptake of ammonium fertilizers lowers the pH of the growing medium since hydrogen ions (H^+) are released to maintain a balanced pH inside the plants. However, the uptake of nitrates causes the plants to release OH^- ions which combine with H^+ ions in the medium to form water molecules [17].

Acknowledgments

European Commission for funding through the CARPIMS scholarship and the support by the Department of Food Productions. Professor Vincent Lebot is also acknowledged for his invaluable guidance and advice in writing the manuscript.

REFERENCES

[1.] Akwee, P., Netondo, G., Kataka, J., and Palapala, V. (2015). A critical review of the role of taro Colocasia esculenta L.(Schott) to food security: A comparative analysis of Kenya and Pacific Island taro germplasm. *Scientia* 9, 101-108.

[2.] Amosa, F. (1993). Early-season interspecific competition in dryland taro (Colocasia esculenta L. Schott) systems., University of Hawaii, Hawaii.

[3.] Bourke, R. M. (2012). The decline of taro and taro irrigation in Papua New Guinea. *Senri Ethnological Studies*.

[4.] Cable, W. J., and Asghar, M. (1983). Comparative performances of some taro cultivars at Laloanea, W. Samoa. *Alafua Agricultural Bulletin*8, 30-35.

[5.] Crohn, D. (2004). Nitrogen mineralization and its importance in organic waste recycling. *In* "Proceedings, National Alfalfa Symposium", pp. 13-5.

[6.] Ekwue, E., and Bartholomew, J. (2011). Electrical conductivity of some soils in Trinidad as affected by density, water and peat content. *Biosystems engineering*108, 95-103.

[7.] Fa'amatuainu, W. (2016). Dry matter accumulation and partitioning of two improved taro (Colocasia esculenta (L.) Schott) cultivars under varying nitrogen fertilization rates in Samoa, The University of the South Pacific, Samoa.

[8.] Faamatuainu, W., and Amosa, F. (2016). Effect of Nitrogen Fertilization on the Physiological Aspects of Two Improved Taro Cultivars (Colocasia esculenta (L.) Schott in Samoa. *American-Eurasian Journal of Agricultural & Environmental Sciences***16**, 1462-1466.

[9.] Heeb, A., Lundegårdh, B., Ericsson, T., and Savage, G. P. (2005). Effects of nitrate-, ammonium-, and organic- nitrogen- based fertilizers on growth and yield of tomatoes. *Journal of Plant Nutrition and Soil Science*168, 123-129.

[10.] Hughes, M. P., Wuddivira, M. N., Mlambo, V., Jennings, P. G., and Lallo, C. H. (2014). Non-destructive foliar chlorophyll measurement has the potential to predict crude protein concentration and in vitro ruminal organic matter digestibility in Bracharia decumbens herbage. *Animal Feed Science and Technology*195, 14-27.

[11.] Jacobs, B. C., and Clarke, J. (1993). Accumulation and partitioning of dry matter and nitrogen in traditional and improved cultivars of taro (Colocasia esculenta (L.) Schott) under varying nitrogen supply. *Field Crops Research*31, 317-328.

[12.] Lahai, M., and Ekanayake, I. J. (2009). Accumulation and distribution of dry matter in relation to root yield of cassava under a fluctuating water table in inland valley ecology. *African Journal of Biotechnology*8.

[13.] Lebot, V. (2009). "Tropical root and tuber crops: cassava, sweet potato, yams and aroids," Cabi.

[14.] Lee, W. (1999). Taro (Colocasia esculenta). *Ethnobotanical Leaflets*1999, 4.

[15.] Manrique, L. A. (1994). Nitrogen requirements of taro. *Journal of plant nutrition*17, 1429-1441.

[16.] Mare, R., Modi, A., Tenywa, J., Joubert, G., Marais, D., Rubaihayo, P., and Nampala, M. (2009). Influence of planting date and organic fertilisation on growth and yield of Taro landraces. *In* "9th African Crop Science, Conference Proceedings, Cape Town, South Africa, 28 September-2 October 2009", pp. 179-189. African Crop Science Society.

[17.] Mattson, N., Leatherwood, R., and Peters, C. (2009). "Nitrogen: All forms are not equal." Cornell University, Cornell University.

[18.] Miyasaka, S. C., Hamasaki, R. T., and De la Pena, R. S. (2002). Nutrient Deficiences and Excesses in Taro.

[19.] Miyasaka, S. C., Ogoshi, R. M., Tsuji, G. Y., and Kodani, L. S. (2003). Site and Planting Date Effects on Taro Growth. *Agronomy Journal*95, 545-557.

[20.] Noor, S., Talukder, M., Bhuiyan, M., Islam, M., Haque, M., and Akhter, S. (2015). Development of Fertilizer Recommendation for Aquatic Taro (Colocasia esculenta) in Grey Terrace Soil. *Pertanika Journal of Tropical Agricultural Science*38.

[21.] Orji, K., and Ogbonna, P. (2015). Effects of Cultivars and NPK Fertilizer on Foliage and Sucker Production of Taro [Colocasii esculenta (L.)] on Plains of Nsukka, Southeastern Nigeria.

[22.] Osorio, N., Shuai, X., Miyasaka, S., Wang, B., Shirey, R., and Wigmore, W. (2003). Nitrogen level and form affect taro growth and nutrition. *HortScience*38, 36-40.

[23.] Prasad, K. (1999). Response of taro to applied nitrogen and boron on Rewa soil series., USP, USP.

[24.] Quero-García, J., Ivancic, A., Letourmy, P., Feldmann, P., Molisale, T., and Lebot, V. (2006). Heritability of the main agronomic traits of taro. *Crop Science*46, 2368-2375.

 http://dx.doi.org/10.5281/zenodo.7509322

[25.] Rogers, S., Rosecrance, R., Chand, K., and Iosefa, T. (1992). Effects of shade and mulch on the growth and dry matter accumulation of taro (Colocasia esculenta L. Schott). *Journal of South Pacific agriculture 1 (3)*, 1-4.

[26.] Ruark, M. (2012). "Advantages and disadvantages of controlled-release fertilizers." University of Wisconsin-Madison.

[27.] Sivan, P. (1976). Drymatter accumulation and distribution in three cultivars of taro, USP, USP.

[28.] Tills, A. R., and Alloway, B. (1981). The effect of ammonium and nitrate nitrogen sources on copper uptake and amino acid status of cereals. *Plant and soil* **62**, 279-290.

[29.] Tumuhimbise, R., Talwana, H., Osiru, D., Serem, A., Ndabikunze, B., Nandi, J., and Palapala, V. (2009). Growth and development of wetland-grown taro under different plant populations and seedbed types in Uganda. *African Crop Science Journal*17.

[30.] Turhan, H., Genc, L., Smith, S., Bostanci, Y., and Turkmen, O. (2008). Assessment of the effect of salinity on the early growth stage of the common sunflower (Sanay cultivar) using spectral discrimination techniques. *African Journal of Biotechnology*7.

[31.] Vitousek, P. M., and Farrington, H. (1997). Nutrient limitation and soil development: experimental test of a biogeochemical theory. *Biogeochemistry*37, 63-75