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# Comparative Study of Taro (*Colocasia esculenta*) Grown on Wetlands and Uplands for Yield and Other Agro-Morphological Traits

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## Abstract

Despite the numerous importance of taro, it still remains an underutilised crop in Ghana with little information on many aspects of the crop, especially agronomic practices. In order to obtain data that can be used to improve and sustain taro production, an experiment was conducted to study growth, yield, and other agro-morphological traits of three promising taro accessions (BL/SM/80, BL/SM/16, and KA/019) with the objective of comparing the growth and yield on wetland and upland and identify elite accessions for wetland or upland cultivation. The experimental field was laid out in a Randomised Complete Block Design (RCBD) replicated three times at each site. An experimental field measuring 15 m × 16 m was used for the study. Each replicate measured 4 m × 4 m with 1.5 m between plots in a block and 2 m between blocks or replicates. Plants in a plot were planted at 1 m × 1 m, with 25 plants per plot. Crop growth and development data were collected four weeks (30 days) after planting and at every four-week interval (30, 60, 90, 120, 150, 180, and 210) days after planting (DAP). Data on yield components were measured at harvest (7 months after planting). Five plants were randomly selected from each plot for data collection, and averages were estimated. Data collected was analysed using Statistics (9$^{th}$ edition). Analysis of variance (ANOVA) was used, and treatment means were separated by LSD at 5% probability (0.05) level where there are significant differences. Taro growth in both conditions (upland and wetland) during 30 - 120 days was characterised by an increase in above-ground plant growth. Plants planted in upland conditions recorded higher values for growth parameters. There was a significant difference ($p \le 0.05$ and $p \le 0.01$) in these growth parameters of taro at some of the periods at which data were collected. The study shows that upland cultivation of taro is possible, as yields obtained from wetland conditions did not differ from the yields of upland conditions. Cultivars BL/SM/80 and BL/SM/16 are recommended for upland cultivation. All three cultivars (BL/SM/80, KA/19, and BL/SM/16) are good for wetland cultivation.

## Subject Areas

Agronomy

## Keywords

Taro, Wetland, Upland, Cultivation, Sustainability, Food Security

## 1. Introduction

Taro, *Colocasia esculenta* (L) Schott, is a member of the monocotyledonous family Araceae and sub-family Aroideae [1] [2]. Taro is the most widely cultivated species in the genus *Colocasia* [3], and it is the fourth most consumed tuber crop in the world [4]. Taro (*Colocasia esculenta*) is a perennial herbaceous plant grown in the humid tropical areas. It is grown for its corms and provides food for many people. Taro is one of the main crops of socio-economic importance, such as providing income, ensuring food security, and enhancing food sustainability [5]. The corm of taro is an excellent source of carbohydrate [6] [7], and its digestibility is estimated to be 98% [8]. Due to its ease of assimilation, it is suitable for persons with digestive problems. Taro is useful to people allergic to cereals and can be consumed by children who are sensitive to milk, and as such, its flour has been used in infant food formulae [9]. The leaves of taro have higher levels of protein, potassium, calcium, phosphorus, iron, vitamin A, thiamine, niacin, riboflavin, and dietary fibre [10]-[12]. Taro provides a source of employment for people in most rural areas in Ghana, as it is mostly cultivated subsistently in the rural areas of Ghana [13]. Despite taro's contribution to food security, especially in Ghana, taro has received very limited research attention from agricultural, academic, and development institutions. Among the aspects that have not been worked on in detail with regard to Ghanaian taro include: plant population, fertilization, area of planting (wetland or upland), as well as breeding for elite varieties resistant to taro leaf blight disease [14]. The technical knowledge base of taro producers in Ghana is very low due to a neglect of the crop by extension services [13]. Most of the constraints mentioned above in the taro industry of Ghana can be tackled and, if possible, solved through research. The importance of taro is increasing as a subsistence crop in the rural areas of Ghana, and the rise in importance of the crop can be attributed to the price increase in cereals and other root crops such as yams. It is possible that the status of taro in Ghana can be improved to levels held by other root crops: cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), and potato (*Solanum tuberosum*). This will require increasing the area under cultivation and developing technology that will improve yields to levels that are at least nearer to the African and world averages of 5.9 and 6.6 t·ha$^{-1}$, respectively [15].

However, taro production in Ghana is predominantly confined to wetland conditions, which are currently limited in extent and face significant challenges, including over-exploitation and degradation. As a result, the existing wetland resources are insufficient to support the expansion of taro production, highlighting the need for urgent efforts to ensure the long-term sustainability of this crop. The current production system cannot allow intensive taro production in Ghana. Developing an upland production system is an alternative for taro growing, as it will facilitate extensive taro production as well as reduce pressure on wetlands in Ghana. The objective of the study, therefore, was to compare the growth and yield of wetland and upland, and identify elite accessions for wetland or upland cultivation.

## 2. Materials and Methods

### 2.1. Experimental Site

The experiment was carried out at the Council for Scientific and Industrial Research (CSIR), Plant Genetic Resources Research Institute (PGRRI), at Bunso (longitude 6˚17'N, latitude 0˚27'W, and altitude 214 m above sea level) in the eastern region of Ghana, during the major rainy season in 2020, on taro (*Colocasia esculenta* (L) Schott.). The major soil type in the study area is mainly red, well-drained, and sandy loam. The soils are suitable for the cultivation of both food crops, such as taro, cassava, plantain, yam, cocoyam and maize; and cash crops such as cocoa, coffee, oil palm, citrus and cola, which are grown in the area. The area has an annual temperature of about 30˚C and 600 - 1200 mm of rain in a year, with an average humidity of 80%.

### 2.2. Planting Materials

Planting materials (BL/SM/80, BL/SM/16, and KA/019) used for the study were obtained from the CSIR-PGRRI. The accessions are tolerant of the taro leaf blight (TLB) disease and have very good taste.

### 2.3. Experimental Design

The experimental field was laid out in a Randomised Complete Block Design (RCBD), replicated three times. An experimental field measuring 15 m × 16 m was used for the study at each location. Each plot measured 4 m × 4 m with 1.5 m between plots in a block and 2 m between blocks. Plants in a plot were planted at 1 m × 1 m, giving 25 plants per plot. Taro stems (the apical 1 - 2 cm of the harvested corm with the basal 15 - 20 cm of the leaf petioles attached) were collected from the nursery and planted.

### 2.4. Data Collection and Analysis

Taro plant growth was evaluated at 30, 60, 90, 120, 150, 180, and 210 days after planting (DAP). At each evaluation, plant height (cm) was measured from the ground level to the shoot apex; the standing leaves on each individual plant were counted; the number of suckers around each plant was also counted. Additionally, data were collected on below-ground plant growth parameters, namely, corm length, corm diameter, and fresh corm weight or yield per plant. Corm length was the distance from the distal end of the corm to the proximal end, where the outer leaf petiole is attached to the corm. The diameter of the cross-section of the corm at the point where the outer leaf petiole is attached to the corm was taken as the corm diameter, and each fresh tuber was weighed. The dry matter of corms was estimated from five selected plants in each plot. The corms were washed, peeled, sliced into much smaller sizes, and bulked to obtain a composite sample. 100 g of the samples were weighed and oven-dried at 80˚C for 72 hours. Samples were again weighed after drying, and averages of three replicates were estimated. At final assessment, fresh corm weights of plants from 4 m × 4 m plots were obtained to estimate yield per hectare ($t \cdot ha^{-1}$) as follows:

$$\text{Corm yield}\left(t \cdot ha^{-1}\right) = \frac{\left(\text{yield of } 4 \times 4 \text{ plot}\right)\text{kg}}{\left(4 \times 4\right)} \times 10$$

Data collected was analyzed using Statistics (9th edition). Analysis of variance (ANOVA) was used, and treatment means were separated by LSD at 5% probability (0.05) level when there were significant differences.

## 3. Results and Discussion

### 3.1. Physiochemical Properties of Soil at the Experimental Sites

The results of the soil analysis for the two locations (wetland and upland) are shown in Table 1. The results indicated that the soils at both locations were texturally sandy loam. The acidity of the soils was not far apart; however, the wetland appeared to have more organic matter (3.44%) than the upland (1.93%). Generally, samples with organic matter content less than 1.5% are described as low and between 1.5 to 3.0% as moderate. The soil had its soil organic matter to be 1.926% for upland soils and 3.439% for the wetland soil. The soil organic matter levels in the upland were moderate, whilst those in the wetland were high. Total nitrogen contents of the soil samples follow the same trends as soil organic matter. Upland soil had its total nitrogen levels as moderate (0.125%). Total nitrogen values increased in the wetland by 0.191%, but were also moderate. Effective Cation Exchange Capacity (ECEC) indicates the soil's nutrient-holding capacity. ECEC values ranged from 8.249 to 7.447 $cmol_c\ kg^{-1}$ for upland and wetland, respectively. The basicity of the samples was low (less than 10.0 $cmolc \cdot kg^{-1}$).

### 3.2. Vegetative Growth and Development

This is the period of rapid root and shoot development with initiation of corm development during two to four months after planting [16]. This stage is marked by an increase in growth parameters (plant height, petiole length, number of leaves, etc.) and slow corm growth [17]. Taro growth in both conditions (upland and wetland) during 30 - 120 days was characterised by an increase in above-ground plant growth, namely, plant height, number of leaves, leaf length, leaf width, and number of suckers (See **Figures 1-5**).

**Table 1.** Physical and chemical properties of the soil of the experimental plots.

| Physical Properties | Wetland | Upland |
|---|---|---|
| Sand (%) | 78.00 | 76.00 |
| Silt (%) | 22.00 | 24.00 |
| Clay (%) | 10.00 | 10.00 |
| Textural Class | Sandy Loam | Sandy Loam |
| **Chemical Properties** | | |
| PH | 5.48 | 6.12 |
| Organic Matter (%) | 3.44 | 1.93 |
| Total Nitrogen (%) | 1.19 | 1.12 |
| Total Organic Carbon (%) | 1.99 | 1.12 |
| Available P (ppm) | 22.08 | 12.22 |
| Exchangeable Na (me/100g) | 0.12 | 0.02 |
| Exchangeable K (me/100g) | 0.11 | 0.15 |
| Exchangeable Ca (me/100g) | 3.62 | 4.05 |
| Exchangeable Mg (me/100g) | 2.34 | 2.98 |
| ECEC (me/100g) | 7.45 | 8.25 |
| TEB (me/100g) | 6.19 | 7.19 |

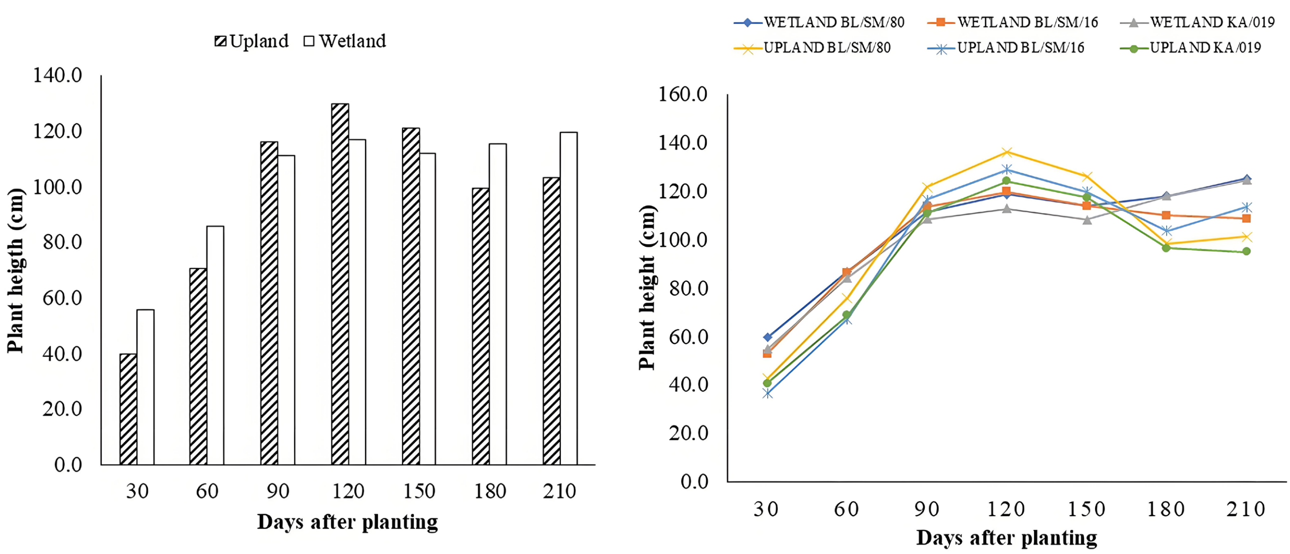
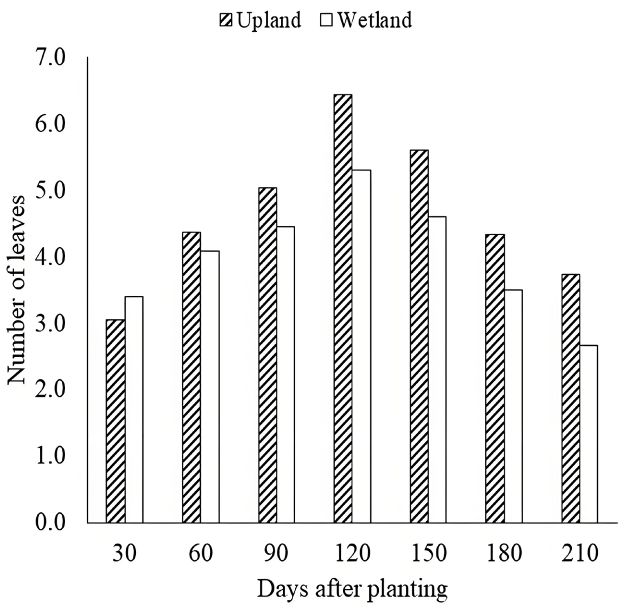



**Figure 1.** Relationship between plant height and days after planting in taro cultivars grown on upland and wetland.



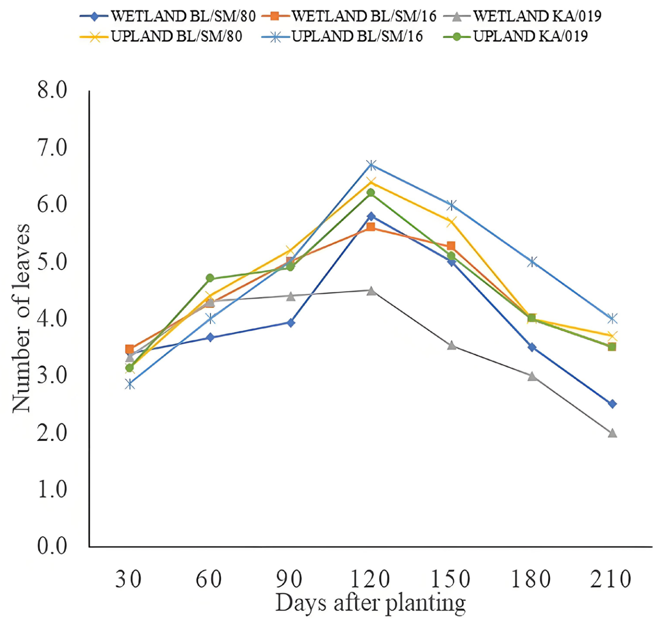




**Figure 2.** Relationship between the number of leaves and days after planting in taro cultivars grown on upland and wetland.

**Table 2.** ANOVA of environment and cultivar effect on the growth of taro at 30, 60, 90, and 120 DAP.

| Source of Variation | Plant Height (cm) | Number of Leaves | Number of Suckers | Leaf Length | Leaf Width |
|---|---|---|---|---|---|
| | | | **30 DAP** | | |
| Cultivar | 62.85 | 0.02 | 0.06 | 4.36 | 4.86 |
| Environment | 1120.22*** | 0.57** | 2.22 | 183.04*** | 96.33*** |
| Env. × Cult. | 3.04 | 0.07 | 2.22 | 2.46 | 0.83 |
| | | | **60 DAP** | | |
| Cultivar | 44.84 | 0.43 | 1.13 | 33.67 | 4.64 |
| Environment | 1030.58*** | 1.62** | 0.38 | 13.00 | 22.00 |
| Env. × Cult. | 27.62 | 1.22 | 0.25 | 7.85 | 4.9 |
| | | | **90 DAP** | | |
| Cultivar | 80.26 | 0.44 | 16.44*** | 162.42** | 38.32 |
| Environment | 120.13 | 16.43*** | 0.27 | 421.45** | 162.60** |
| Env. × Cult. | 30.86 | 0.48 | 0.33 | 14.02 | 3.33 |
| | | | **120 DAP** | | |
| Cultivar | 122.83 | 3.24** | 20.94*** | 224.59*** | 62.42** |
| Environment | 714.42* | 0.27 | 0.57 | 413.76*** | 184.32*** |
| Env. × Cult. | 28.25 | 0.95 | 0.97 | 6.62 | 3.26 |

*$p \le 0.05$, **$p \le 0.01$, and ***$p \le 0.001$.

**Table 3.** ANOVA of environment and cultivar effect on the growth of taro at 150, 180, and 210 DAP.

| Source of Variation | Plant Height (cm) | Number of Leaves | Number of Suckers | Leaf Length | Leaf Width |
|---|---|---|---|---|---|
| | | | **150 DAP** | | |
| Cultivar | 79.76 | 3.78** | 16.08** | 113.24* | 20.46 |
| Environment | 360.01 | 8.96** | 9.39* | 46.24 | 27.11 |
| Env. × Cult. | 13.26 | 0 | 4.2 | 3.21 | 2.47 |
| | | | **180 DAP** | | |
| Cultivar | 3.24 | 4.02*** | 8.82** | 88.61* | 11.81 |
| Environment | 1123.70* | 4.70*** | 3.25 | 131.87* | 43.56* |
| Env. × Cult. | 106.95 | 0.47 | 2.18 | 3.48 | 8.79 |
| | | | **210 DAP** | | |
| Cultivar | 18.69 | 0.58 | 15.37** | 122.78** | 13.15 |
| Environment | 1193.98** | 0 | 7.22 | 0.11 | 16.94 |
| Env. × Cult. | 509.79 | 0.42 | 0.96 | 26.52 | 18.15 |

*p ≤ 0.05, **p ≤ 0.01, and ***p ≤ 0.001.

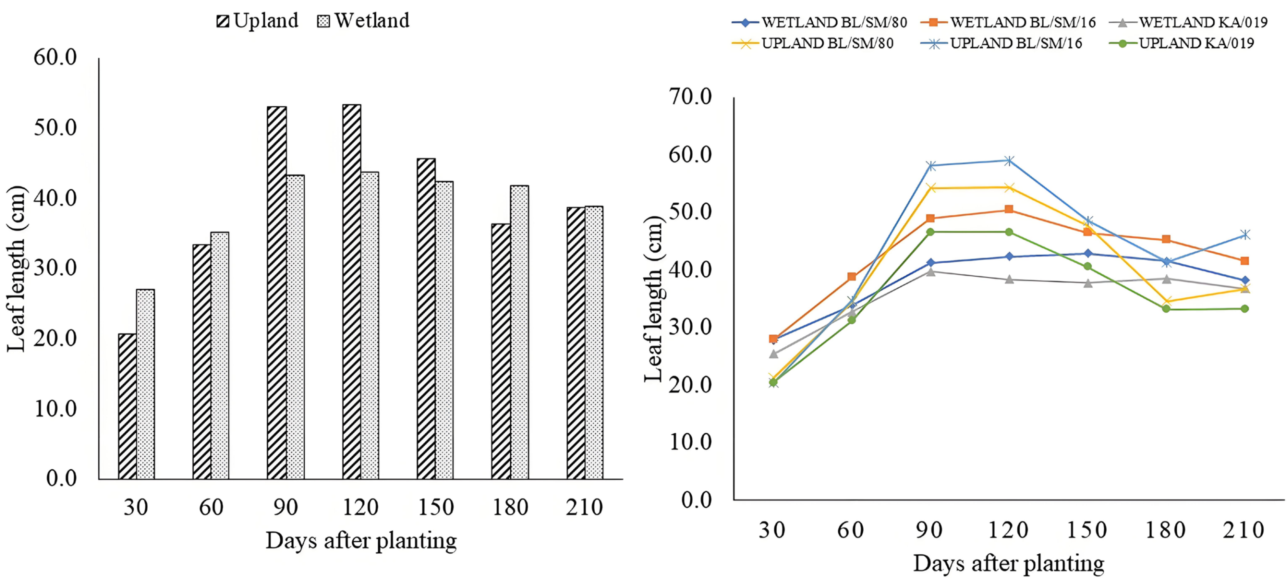



**Figure 3.** Relationship between leaf length and days after planting in taro cultivars grown on upland and wetland.

This was followed by a decrease in the growth of taro from 120 - 210 days after planting (DAP). growth. There was a significant difference (p ≤ 0.05 and p ≤ 0.01) in these growth parameters of taro at some of the periods data were collected among the environment and cultivars (See **Table 2**). The rate of increase estimated from the magnitude of the slope of the regression equation did not differ by environment or cultivar. The rate of decline in the growth of taro 120 DAP was similar in magnitude to the rate of increase before 120 DAP. In this study, maximum growth was obtained at 120 DAP and then declined. This was confirmed by [18], who found that the growth of taro reaches a maximum at 120 DAP. The study also conforms to

[19], who reported that the rapid decline in shoot growth of taro was shown at about four to six months after planting. This was characterised by a reduction in growth (plant height, petiole length, number of leaves, etc), and a decrease in leaf area per plant. The higher values for growth on upland conditions are in agreement with [20] who also reported higher growth in upland-grown taro than in wetland. Number of suckers, on the other hand, recorded maximum values at 210 DAP, and this was significant ($p \le 0.05$) at 150 DAP for the environment with plants on wetland conditions recording higher values. Significant differences ($p \le 0.05$ and $p \le 0.01$) were seen among the cultivars for growth (**Figure 5**, **Table 2**, and **Table 3**). The difference in growth among the cultivars may be due to genetic differences [21], which suggests that there was a differential growth response of plant genotype. The interaction effect between the environment and the cultivars did not show any significance.

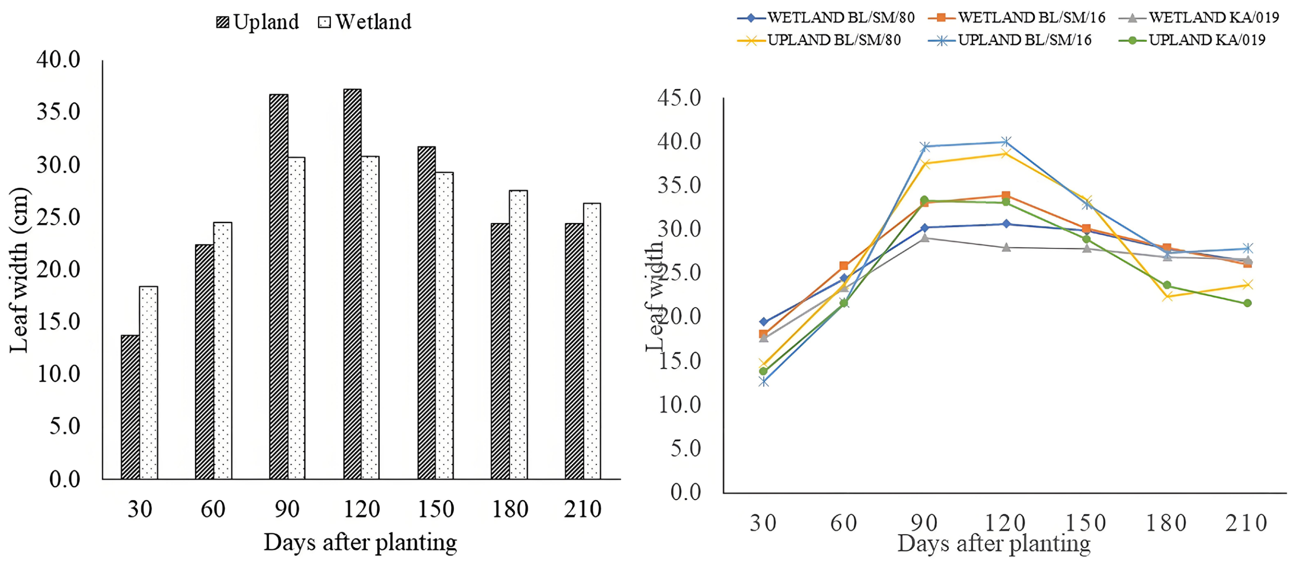



**Figure 4.** Relationship between leaf width and days after planting in taro cultivars grown on upland and wetland.

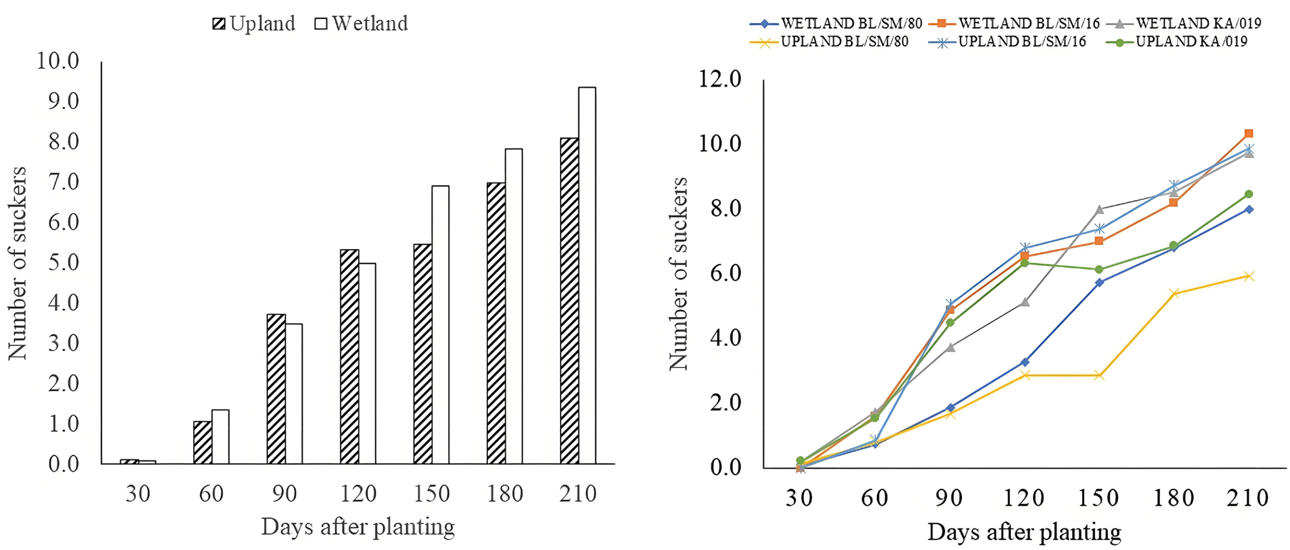



**Figure 5.** Relationship between the number of suckers and days after planting in taro cultivars grown on upland and wetland.

### 3.3. Corm Yield and Yield Components

Although corm diameter was not significantly affected by both cultivar and environment, it was consistently lower in accession KA/019 (12.6 cm and 14.0 cm) for upland and wetland, respectively, than in accessions BL/SM/80 and BL/SM/16. Corm length, on the other hand, was significantly ($p < 0.001$) affected by both cultivar and environment, with the cultivars on wetland recording higher values than those on upland, and accession BL/SM/80 recording high values (18.4 cm and 23.1 cm) for upland and wetland, respectively (**Table 4**). Similarly, corm yield plant$^{-1}$ and dry matter were significantly affected by cultivar ($p < 0.05$) and environment ($p < 0.001$). The higher corm yield plant$^{-1}$ and dry matter values were obtained by plants in the wetland. Among the accessions, BL/SM/80 attained the highest corm yield plant$^{-1}$ and dry matter at both environments (See **Table 4**). Total yield (t·ha$^{-1}$) for cultivars and environment is represented in **Figure 6**. Although cultivars on wetland produced higher corm yield (t·ha$^{-1}$) than those on upland, these values did not show any significance. Among the accessions, cultivar BL/SM/80 produced significantly ($p < 0.01$) higher corm yield (12.5 t·ha$^{-1}$ and 14.1 t·ha$^{-1}$) for upland and wetland, respectively (See **Figure 6**). According to [17], corm bulking occurred after the attainment of maximum leaf area index, and the partitioning of dry matter to the corms remained constant, especially after 150 DAP, which is the period of growth during which corm diameter and length increase rapidly. This study agrees with the reports by [17], as corm initiation and bulking occurred from 120 to 180 DAP, which was characterized by a reduction in vegetative growth. There are many reports that the yield of root and tuber crops, which is a positive function of corm characteristics (corm diameter, corm length, and weight), is affected by water availability and temperature [22]. In this study, higher corm characteristics (corm length, corm diameter, corm yield per plant, corm yield per hectare, and dry matter) were highest under wetland conditions, which were characterised by high water holding capacity and low temperature. The observations support the earlier findings that the highest yields are obtained when taro is planted on wetlands. This finding is attributed to water availability and low temperature [20] [22]. Among the cultivars, the highest corm characteristics were

**Table 4.** Effects of different environments on the yield of three cultivars of taro 7 months after planting.

| | ENVIRONMENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | UPLAND | | | WETLAND | | | | |
| CULTIVAR PARAMETER | BL/SM/80 | BL/SM/16 | KA/019 | BL/SM/80 | BL/SM/16 | KA/019 | ANOVA Cultivar | ANOVA Environment |
| Corm Diameter (cm) | 16.2 | 14.8 | 12.6 | 15.3 | 14.9 | 14.0 | ns | ns |
| Corm Length (cm) | 18.4 | 15.2 | 13.4 | 23.1 | 20.8 | 18.8 | *** | *** |
| Corm Yield/Plant (kg) | 0.8 | 0.5 | 0.4 | 0.9 | 0.6 | 0.5 | * | *** |
| Dry Matter (%) | 34.8 | 32.8 | 33.3 | 40 | 35.3 | 41.5 | * | *** |

*significant (0.05), ***significant (0.001), ns = not significant.

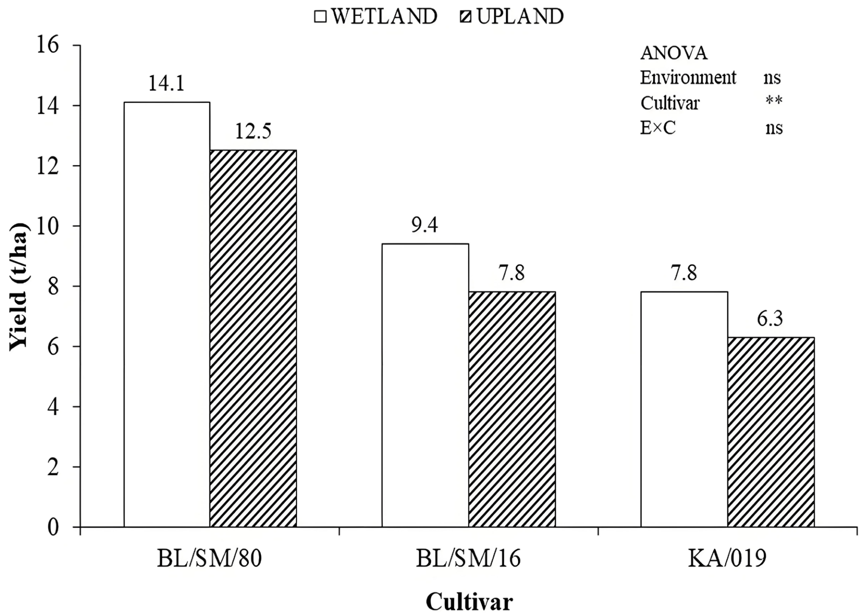



**Figure 6.** Effects of different environments on the yield of taro cultivars.

seen in BL/SM/80 and this might be due to genotypic differences. Thus, one cultivar could better utilise resources (water and nutrients) than the other. [23] established that there were varietal differences in nutrient uptake and dry matter accumulation in various components of taro plants.

## 4. Conclusion and Recommendation

The study indicates that the growth of taro in wetlands did not differ significantly from that in uplands. The study shows that upland cultivation of taro is possible, as yields obtained from wetland conditions did not differ from the yields of upland conditions. It is noteworthy that the yield obtained in this study was without additional production inputs (water, fertilizer, etc.). Therefore, with intensive management in association with commercial production, higher yields of taro can be obtained in Ghana, whether planted on upland or wetland. Accessions BL/SM/80 and BL/SM/16 performed better in both environments than accession KA/019. Although the study indicated that upland cultivation of taro is possible, to obtain yields as high as those obtained in wetlands and convince farmers to adopt it, it is recommended that more cultivars that can perform well in upland conditions be developed, as further studies are conducted to evaluate additional production inputs necessary to improve the yield in upland conditions. For example, irrigation, soil nutrients through fertilization, and intercropping.

## Additional Information

Data are available on request.

## Human and Animal Rights

The authors did not use animal or human bodies as objects or materials for this study.

## Author Contributions

LL, RB, and RAA conceived and designed the research at a meeting; LL and RB monitored data collection; LL, RB, and RAA analyzed and interpreted the data and discussed findings; RB, LL, and RAA reviewed the manuscript, carefully edited it, and made valuable inputs.

## Conflicts of Interest

The authors declare no conflicts of interest.

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