Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 21 Number 2 (April 2022) pp. 111 - 120

ISSN 1119-7455

EFFECT OF FUNGICIDES AND SPRAY REGIMES AGAINST *Phytophthora* LEAF BLIGHT DISEASE OF TARO CULTIVARS IN NSUKKA, SOUTHEASTERN NIGERIA

***[1]Omeje T.E., [2]Awere S.U. and [3]Ugwuoke K.I.**

[1]Department of Agricultural Technology, Enugu State Polytechnic, Iwollo, Enugu State, Nigeria
[2]Department of Agronomy & Ecological Management,
Enugu State University of Science & Technology, Enugu, Nigeria
[3]Department of Crop Science, University of Nigeria, Nsukka, Nigeria

*Corresponding author's email: egwuchukwu2010@gmail.com

ABSTRACT
Effects of fungicide types and spray regimes were assessed on Phytophthora leaf blight disease during the early and late cropping seasons in Nsukka, southeastern Nigeria. The field experiment was laid out in 3 × 3 × 5 factorial in randomized complete block design with three replications in early and late cropping seasons of taro, respectively. The factors consisted of three Colocasia esculenta cultivars (Nachi (purple taro/Nce_{003}), Odogolo (green taro/Nce_{002}) and Ugwuta (Coco-India/Nce_{001}); two fungicides (Ridomil Gold 66 WP plus, Ridomil Gold + Champ Drill Prill 50.00%:50.00% mixture and control); and five spray regimes (no spray, 1, 2, 3, and 4 weeks spray). Results showed that there were significant variations in disease incidence among the fungicides, spray regimes, cultivars and between seasons at 90, 120 and 150 days after planting. Disease incidences and severity varied among the fungicides, spray regimes, cultivars and between the seasons. The results on establishment percentage significantly differed among the cultivars and cropping seasons. Ugwuta cultivar significant had the highest establishment percentage in both cropping seasons at 15 and 30 days after planting. The growth attributes on plant height (cm) and number of leaves significantly varied among the fungicides, spray regimes, cultivars and between cropping seasons. Ridomil Gold 66 WP at weekly spray regime performed best compared to other fungicides and spray regimes. There were significant variations among the cultivars and cropping seasons at the sampling periods. Tuber yield significantly differed among the fungicides, spray regimes, cultivars and cropping seasons at harvest. Ridomil Gold 66 WP at weekly spray regimes, Odogolo cultivar and early cropping season performed best in all yield traits at harvest.

Key words: fungicides, spray regimes, taro cultivars, seasons, *Phytophthora colocasiae*

INTRODUCTION
Protected cropping using fungicides and spray regimes has greatly improved crop production worldwide since 1960 (Russel, 2005). However, despite its popularity in Asia, Europe, China, India and South America, its application in tropical African countries is uncommon. Taro (*Colocasia esculenta* L.) is an important edible tuber crop for many people in Africa, Asia and Pacific (Ojiako *et al*., 2007; Onyeka, 2014). It is ranked the first, second and third most important root and tuber crops after yam and cassava in Cameroon, Ghana and Nigeria, respectively (Echebiri, 2004; Ojiako *et al*., 2007). Taro production is unique because all the parts (tubers, flowers, leaves and stalks/petioles) are edible. The tubers are superior to yam and cassava in possession of higher amount of bioactive compounds like dietary fibres, proteins, vitamins - B_6, C, niacin, riboflavin, thiamine contents (Niba, 2003); polyphenol (saponin, flavonoids, alkaloids, condensed tannin), minerals, high antioxidants potential, as well as easily digestible starch (98.80%) (Onyeka, 2014). Taro leaves, flowers and petioles are rich in protein (23.00%), minerals (potassium, calcium, phosphorus, zinc, iron, magnesium), vitamins (thiamine, niacin, riboflavin) and antioxidants (Annam and Plahar, 1995; Baruah, 2002). These mineral elements and their salts are regulators of acid-base balance in the body (Njoku and Ohia, 2007). The high dietary fibre contents of taro leaves play an active role in the regulation of intestinal transit, increasing dietary bulk and faeces consistency due to their ability to absorb water (Singh *et al*., 2012; Abujah *et al.,* 2016) and also in reduction of gastro intestinal disorder, obesity, cancer (Opera, 2002), and stroke (Omeje *et al.,* 2021).

Colocasia esculenta is cultivated in Nsukka after major crops such as yam, maize, cassava, Nsukka yellow pepper, garden egg plants, melons

Please cite as: Omeje T.E., Awere S.U. and Ugwuoke K.I. (2022). Effect of fungicides and spray regimes against *Phytophthora* leaf blight disease of taro cultivars in Nsukka, southeastern Nigeria. *Agro-Science*, **21 (2),** 111-120. DOI: https://dx.doi.org/10.4314/as.v21i2.13

(egusi) around June/July months of the year (Omeje *et al*., 2016). For effective production of taro especially in Nsukka agricultural zone, Omeje *et al*. (2016) reported that taro cropping is carried out in the minor season after yam, melon, Nsukka yellow pepper, garden egg and cassava production. The period from March to May has been fixed for early farming activities on taro cultivation for effective growth performance and proper tuber development (NRCRI, 2003). The cropping season of taro varies from place to place depending on the onset of rain, other crops in season, labour availability, and disease conditions in the growing areas. The late cropping of taro ensures high soil water conditions and nutrients availability to plants needed for uniform field establishment, proper growth and yield. However, Onwueme and Singh (1991) observed that taro is mostly planted at the onset of rain so that they can utilize the entire rainy season to grow and develop well.

Since 2009, there has been severe decline in taro in Nigeria (NRCRI, 2012) due to taro leaf blight disease caused by the oomycete, *Phytophthora colocasiae* (Chukwu *et al.,* 2012; NRCRI, 2012; Mbong *et al.,* 2013). This has posed a great challenge to taro production stakeholders, policy makers, non- governmental organizations, merchants and researchers globally**.** The disease causes varying field and post-harvest losses in taro depending on the management options, susceptibility of taro cultivars to taro leaf blight (TLB) and the prevailing climatic factors. Yield losses of 25.00-35.00% have been reported in taro tubers in the Philippines, and up to 90.00% across Hawaii (Brooks, 2005), 25.00-50.00% in India (Gadre and Joshi, 2003). Production of taro with regular routine spray of copper oxychloride at the rate of 2.50 kg a.i. per 38.00 litres ha^{-1} provides superior control and higher yield of taro compared to Mancozeb and Captafol protectants in Solomon Islands (Omeje *et al.,* 2015). Chukwu *et al.* (2012) reported that fungicides like Nordox and Kocide were effective in controlling taro leaf blight and boosting growth and yield. A range of protectants and systemic fungicides have been found to provide effective control of taro leaf blight (Nelson *et al.,* 2011). However, Jackson *et al.* (1980) reported that Mancozeb did not control the disease in Solomon Islands suggesting that the efficacy fungicides can be variable. Fullerton and Tyson (2004) reported that the efficacy of fungicide is strongly controlled by the severity of the disease at the time of spray and the prevailing weather conditions. Fungicides are most effective when disease inoculum is low and regular spray reduces inoculum levels with improved growth and yield (NRCRI, 2012; Mbong *et al.,* 2013). The efficacy of fungicide spray against TLB is promising; however, prevalence of taro growth in the humid climate and the slanted and water-proof nature of taro leaves especially the young ones is a great challenge to fungicides spray (Omeje *et al.,* 2019). Similarly, the manifestation of the disease during rainfall periods makes fungicide spray adherence less effective which necessitates repeated spray regimes (Omeje *et al*., 2020). Efficacies of fungicide sprays and spray regimes for management of *Phytophthora* leaf blight and yield improvement of taro remains inadequate. Thus, the objectives of study were to determine the effect of fungicides and cultivars on taro leaf blight; determine the appropriate spray regimes for the management of taro leaf blight of three taro cultivars; and determine the appropriate cropping season for cultivation of taro cultivars in Nsukka, southeastern Nigeria.

MATERIALS AND METHODS

Study Site

Field trials were conducted at the Department of Crop Science, University of Nigeria, Nsukka during the early season (Apr.-Nov.) and late season cropping (Jul.-Dec.) in 2018. Nsukka is located in the derived savanna of Nigeria (06° 54 N, 07° 24 E; 477.26 m asl). The area is characterized by humid tropical climate with wet season (Apr.-Oct.) and dry season (Nov.-Mar.). The rainfall pattern is bimodal with peaks in Jul. and Sep. and a short dry period around mid-Aug. (August break). Some climate data during the study are shown (Table 1). Also shown in Table 2 are the key physicochemical properties of the soil at the sites for early and late planting

Experimental Materials

Three taro cultivars namely Nachi, Odogolo and Ugwuta were sourced from Opi Nsukka market based on quality and general acceptability. Nachi, Odogolo and Ugwuta were deemed fairly resistant, moderately resistant and susceptible to taro leaf blight disease, respectively in the growing areas. The fungicides Ridomil Gold 66 WP and Champ Drill Prill (DP) were sourced from an agro-chemical store at Ogige Market Nsukka based on their systemic and non-systemic mode of action, respectively.

Experimental Design and Treatment Allocation

The field experimental design was 3 × 3 × 5 factorial in randomized complete block design with three replications in both early and late cropping seasons. A total field area of 53.00 m × 29.00 m was used in each season. Blocks were measured (53.00 m × 9.00 m) and separated by 1.00 m apart. Each block was divided into nine plots with each measuring 5.00 m × 9.00 m; they were separated by 1.00 m pathway. Each plot was made into five double rows of crest of mounds manually with hoes at an intra × inter spacing of 0.50 m × 0.50 m separated by 1.00 m apart to check chemical spray drift. The 45 treat-ment combinations consisted of three cultivars of taro (Nachi, Odogolo and Ugwuta), two fungicides (Ridomil Gold 66 WP Plus, active ingredient (a.i.) 6.00% metalaxyl and 60.00% copper oxide); Champ DP (a.i.) copper hydroxide) with Ridomil GoId 66 WP Plus at 50.00%:50.00% mixture weight/weight (w/w) and untreated; and five spray regimes (no spray, 1, 2, 3, and 4 weeks spray regimes). The fungicide treatments were randomly assigned to the plots in each replicate at 50 g of fungicide in 15 litres of water at the rate of 2.50 kg active ingredient per hectare. All sprays were usually done at early morning hours when wind action was calm at the manifestation of disease symptom(s) at 75 and 60 days after planting (DAP) in early and late cropping periods, respectively.

Cultural Managements and Plot Maintenance

The experimental field was cleared, ploughed, harrowed and made into crest of mounds with hoe. Prior to mound making, 15 t ha^{-1} of well cured poultry manure was broadcast and incorporated into the soil. Taro cormels weighing 25.00-35.00 g per cormel were sown at a depth of 5.00-8.00 cm in the soil. The plant population of 100 stands per plot (40,000.00 stands ha^{-1}) was used. Weeds were manually controlled with hoe and handpicking whenever necessary up to 3-4 times throughout the growth cycle in order to ensure free weed competition. The second dose of poultry manure (15 t ha^{-1}) was applied at seven weeks after planting, followed immediately by re-mounding at eight weeks after planting. The cormels/corms were harvested manually with hoe at full maturity in November and December (harmattan period) for early and late cropping season, respectively.

Agro-Meteorological Records

The weather data for the year 2018 (Table 1) were collected at the Meteorological Station of the Faculty of Agriculture, University of Nigeria, Nsukka.

Soil Sampling and Analysis

Before setting up the field experiment, soil samples were collected from randomly selected points across the two sites for the early planting and late planting. The samples were collected from 27 points using soil auger at 0-20 cm depth. Soil analysis was done at the Teaching and Research laboratory of the Department of Soil Science UNN from composite soil samples, dried, pulverized and sieved with 2.00 mm sieve. The soil physical and chemical properties were analyzed following the procedures described by IITA (1990). The data are shown in Table 2.

Disease Incidence

Disease survey was conducted to assess the degree of expression of disease attack and efficacy of the fungicide spray and the spray regimes on *Phytophthora* leaf blight of taro. All taro stands in each plot were observed and the disease incidence recorded as the percentage ratio of number of infected taro stands to the total number of stands. This was done at 75, 90, 120 and 150 DAP.

Disease Severity

This was estimated by scoring the extent of TLB disease damage on a 5-point scale (0-4 scale). Severity score ranges (%) was determined based on area of taro leaves infected (blighted) over total area of taro leaves multiplied by 100 as described by Chaube and Pundhir (2005) below:

$$\text{Disease severity (\%)} = \frac{\text{Area of taro leaves infected}}{\text{Total area of taro leaves}} \times \frac{100}{1}.$$

Scales	Severity score range (%)	Interpretation
0	< 1.00	No severity
1	1.00-25.00	Low severity
2	26.00-50.00	High severity
3	51.00-75.00	Higher severity
4	> 75.00	Highest severity

Table 1: Agro-meteorological data of the study sites in 2018

Month	Total rainfall (mm)	Rainy days	Mean temperature (°C)		Relative humidity (%)	
			Maximum	Minimum	10 am	4 pm
Jan.	21.84	2.00	31.23	20.55	75.00	75.00
Feb.	0.00	0.00	32.86	22.18	75.00	75.00
Mar.	38.10	5.00	32.81	22.58	72.74	62.94
Apr.	183.81	10.00	30.67	22.30	74.00	68.90
May	198.63	11.00	29.52	21.61	74.77	69.87
Jun.	168.60	11.00	28.67	21.17	75.67	72.70
Jul.	283.96	19.00	27.35	20.71	74.90	73.61
Aug.	219.18	12.00	26.61	20.26	76.13	76.16
Sep.	197.60	16.00	27.43	20.50	77.00	77.00
Oct.	167.90	11.00	28.55	20.74	77.00	77.00
Nov.	41.91	2.00	30.37	21.70	77.00	77.00
Dec/	15.75	2.00	29.35	19.39	66.77	66.03
Total	1537.28	101.00	355.42	253.69	895.98	871.21
Mean	128.11	8.42	29.62	21.14	74.67	72.60

Source: Meteorological Station, Faculty of Agriculture, University of Nigeria, Nsukka

Table 2: Physical and chemical properties of the soil before planting

% Clay	% Silt	% Sand		Tex. class	pH-H_2O	% OM	% TN	AvP (mg kg^{-1})	Exchangeable bases¶				CEC¶	% BS	EA¶	
		Fine	Coarse						K^+	Ca^{2+}	Mg^{2+}	Na^+			K^+	Al^+
Early planting site																
24	14	21	41	SCL	4.9	1.75	0.25	9.38	0.17	1.20	0.60	0.13	14.00	14.98	0.60	1.00
Late planting site																
8	7	16	69	LS	5.4	1.09	0.25	9.87	0.16	2.20	0.80	0.08	8.00	41.50	2.60	-

Tex. Class - textural class, OM - organic matter, TN - total nitrogen, AvP - available phosphorus,
CEC - cation exchange capacity, BS - base saturation; EA - exchangeable acidity; ¶Expressed in cmol kg^{-1}

Data Analysis

Data collected on plant height per stand, number leaves per stand, disease incidence, severity and yield parameters were subjected to analysis of variance (ANOVA) using GenStat release software 10.3 Discovery Edition. Fisher's least significant difference (F-LSD) was used to compare treatment means where F-test was significant at 5.00% probability level as described by Obi (2002).

RESULTS

Result of the study showed that there was no significant ($p > 0.05$) difference between fungicides with respect to disease incidence at 75 and 90 DAP (Table 3). Ridomil + Champ DP mixture treated taro stands recorded the highest disease incidence of 18.90 and 72.00% at 75 and 90 DAP, respectively compared to 17.60 and 68.20% recorded by Ridomil Gold 66 WP and untreated taro stands during the same period, respectively. At 120 and 150 DAP, untreated taro stands recorded significantly ($p < 0.05$) highest disease incidence of (87.65 and 95.51%), compared to other treatments. Likewise, the spray regimes similarly had no significant ($p > 0.05$) effect on disease incidence at 75 and 90 DAP. At 75 and 90 DAP, no spray regime recorded the highest non-significant disease incidence of (19.01 and 72.70%), respectively, compared to other spray regimes, while the least disease incidence (16.20 and 63.50%) was recorded by 4 weeks and weekly spray regimes, respectively. Also, no spray regime significantly ($p < 0.05$) recorded the highest disease incidence of 88.69 and 96.76% at 120 and 150 DAP, respectively, which were different from other spray regimes, while the lowest values (50.46 and 52.65%, respectively) were always recorded by weekly spray regimes.

There were significant ($p < 0.05$) differences among the cultivars on disease incidence at all sampling periods (Table 3). Ugwuta cultivar significantly maintained the highest values of disease incidence (28.20, 97.20, 85.94 and 87.49%) across all observation periods. The lowest disease incidence was recorded by Nachi at 75 DAP (5.60%) and 90 DAP (58.80%) and Odogolo at 120 DAP (64.14%) and 150 DAP (76.98%). Between the seasons, there was significant ($p < 0.05$) effect on disease incidence at the trial periods except at 120 DAP. Late season cropping recorded a higher disease incidence of 25.80 and 90.60% than early season cropping (10.50 and 48.90%) at 75 and 90 DAP, respectively. However, at 120 DAP, early season cropping recorded a higher disease incidence value of 75.78% which was similar to late season cropping with disease incidence values of 71.95%. Early season cropping significantly ($p < 0.05$) recorded a higher disease incidence of 91.13% than late season cropping (71.28%) at 150 DAP. On disease severity, fungicide treatments significantly ($p < 0.05$) varied at the trial periods except at 75 DAP (Table 3). Ridomil + Champ DP mixture non-significantly recorded the highest mean score disease severity (1.08) compared to others fungicides at 75 DAP, while Ridomil treated plants scored the non-significant least (0.89) disease severity at the trial period. Untreated plants significantly ($p < 0.05$) scored the highest mean score disease severity (2.59, 2.03 and 1.64) compared to other fungicides, while least mean score disease severity (1.67, 1.43 and 1.08) were consistently maintained by Ridomil treated taro stands at 90-150 DAP, respectively. The ANOVA of spray regimes on disease severity had significant ($p < 0.05$) variations at the sampling periods except at 75 DAP. At 75 DAP, disease severity was non-significantly highest at 4 weeks spray regime with mean score (1.11), while the least was scored by weekly spray regime treated taro stands with mean score (0.04).

Moreover, no spray regime significantly had the highest mean score disease severity (2.48, 2.07 and 1.61) compared to other spray regimes, closely followed by 4 weeks spray regime (2.20, 1.86 and 1.41) while the least mean score disease severity of 1.63, 1.07 and 0.87 were significantly maintained consistently by weekly spray regimes at 90, 120 and 150 DAP, respectively. There were significant ($p < 0.05$) differences among the cultivars on disease severity at the trial periods except at 90 DAP (Table 3). Ugwuta cultivar significantly ($p < 0.05$) had the highest mean score disease severity (1.19) compared to other cultivars at 75 DAP. However, Odogolo cultivars scored the highest mean score disease severity (2.19) compared to other cultivars, while the least mean score disease severity (1.92) was scored by Ugwuta cultivar at 90 DAP. The mean score disease severity of Ugwuta significantly ($p < 0.05$) recorded the highest (2.02 and 1.68) compared to other cultivars at 120 and 150 DAP, respectively. For other cultivars, the mean score disease severity of Nachi and Odogolo cultivars were significantly less compared to others at 120 DAP (1.38) and 150 DAP (0.99), respectively. In both seasons, mean score disease severity differed at all sampling periods. Late cropping season significantly ($p < 0.05$) scored a higher mean score disease severity of 1.13 and 2.53 than early season with mean score disease severity of 0.87 and 1.52 at 75 and 90 DAP, respectively. Moreover, early season significantly scored a higher mean score disease severity at 120 DAP (1.76) and 150 DAP (1.94), while the least mean score disease severity of 1.53 and 0.60 were scored by late cropping season at the corresponding periods of 120 and 150 DAP, respectively.

The results as presented in Table 4 show the effect of fungicide treatment, the spray regimes, cultivars and season on vegetative growth of taro cultivars. On plant height, fungicide treatments had significant ($p < 0.05$) differences at all sampling periods. Ridomil treated taro stands significantly had

Table 3: Effect of planting time, taro cultivars, fungicides and spray intervals on disease incidence and severity

	Disease incidence				Disease severity			
	75 DAP	90 DAP	120 DAP	150 DAP	75 DAP	90 DAP	120 DAP	150 DAP
Fungicides treatment								
Control	18.00 (3.29)	68.20 (7.56)	87.63 (9.35)	95.51 (9.77)	1.02 (1.19)	2.59 (1.74)	2.03 (1.58)	1.16 (1.24)
RD + CHP	19.90 (3.22)	72.00 (8.11)	69.78 (8.18)	76.13 (8.50)	1.08 (1.23)	1.82 (1.50)	1.47 (1.38)	1.09 (1.20)
RD	17.60 (3.19)	69.00 (7.93)	64.18 (7.75)	71.98 (8.19)	0.89 (1.15)	1.67 (1.44)	1.43 (1.36)	1.08 (1.20)
$F\text{-}LSD_{(0.05)}$	NS	NS	0.31	0.29	NS	0.05	0.05	0.07
Spray in weeks								
0	19.10 (3.20)	72.60 (8.15)	88.69 (9.40)	96.76 (9.85)	0.85 (1.13)	2.48 (1.71)	2.07 (1.59)	1.61 (1.41)
1	18.60 (3.37)	63.50 (7.46)	50.46 (6.70)	52.65 (6.75)	0.04 (1.21)	1.63 (1.42)	1.07 (1.21)	0.87 (1.10)
2	18.50 (3.27)	69.40 (7.75)	71.09 (8.31)	80.19 (8.82)	0.96 (1.18)	1.83 (1.50)	1.48 (1.37)	1.11 (1.21)
3	18.30 (3.24)	71.60 (7.95)	79.02 (8.84)	80.11 (9.26)	1.02 (1.20)	1.98 (1.55)	1.83 (1.51)	1.35 (1.29)
4	16.20 (3.06)	71.70 (8.01)	79.85 (8.87)	89.33 (9.41)	1.11 (1.24)	2.20 (1.82)	1.86 (1.59)	1.41 (1.33)
$F\text{-}LSD_{(0.05)}$	NS	NS	0.40	0.38	NS	0.06	0.07	0.08
Cultivars								
Nachi	5.60 (1.88)	58.80 (7.10)	71.50 (8.29)	79.16 (8.68)	1.05 (1.22)	1.97 (1.54)	1.38 (1.35)	1.16 (1.24)
Odogolo	20.70 (3.00)	63.30 (6.64)	64.14 (7.88)	76.98 (8.60)	0.74 (1.07)	2.19 (1.61)	1.53 (1.40)	0.99 (1.17)
Ugwuta	28.20 (4.82)	97.20 (9.87)	85.94 (9.11)	87.49 (9.17)	1.19 (1.27)	1.92 (1.53)	2.02 (1.56)	1.68 (1.39)
$F\text{-}LSD_{(0.05)}$	NS	0.47	0.31	3.98	0.08	NS	0.05	0.07
Cropping seasons								
Early season	0.50 (2.50)	48.90 (6.34)	75.78 (8.63)	91.13 (9.48)	0.87 (1.14)	1.52 (1.40)	1.76 (1.48)	1.94 (1.53)
Late season	25.80 (3.95)	90.60 (9.39)	71.95 (8.22)	71.28 (8.15)	1.13 (1.25)	2.53 (1.72)	1.53 (1.39)	0.60 (1.01)
$F\text{-}LSD_{(0.05)}$	NS	0.38	NS	3.25	NS	0.04	0.04	0.06

RD - Ridomil Gold WP, RD + CHP - Ridomil Gpld WP + Champ DP, DAP - days after planting, 50.00%:50.00% mixture weight/weight (w/w), $F\text{-}LSD_{(0.05)}$ - least significant difference at 5% probability level, NS - not significant at 5% probability level
Note: Bracketed numerals are transformed values.

Table 4: Effect of fungicides, spray regimes, taro cultivars and season on vegetative growth of three cultivars of taro (*Colocasia esculenta* L.)

	Plant height per stand (cm)					Number of leaves per stand					Percentage establishment (%)	
	30	60	90	120	150	30	60	90	120	150	15	30
Fungicide treatment												
Control	18.04	31.91	70.83	64.30	49.32	3.48	4.70.	6.84	9.57	11.01	34.08 (5.39)	7.2.50 (8.43)
RD + CHP	17.97	32.90	25.90	74.56	53.75	3.32	4.47	9.45	11.14	11.06	340.06 (5.43)	75.83 (8.68)
RD	19.50	34.79	79.62	79.10	57.93	3.43	4.62	10.13	12.6	11.27	34.56 (5.50)	72.29 (8.48)
$F\text{-}LSD_{(0.05)}$	0.81	1.11	2.38	2.50	2.96	N.S	N.S	0.65	0.82	N.S	NS	NS
Spray regime												
No spray	17.47	31.14	71.06	64.86	48.40	3.39	4.58	6.90	9.24	10.36	36.30 (5.60)	74.72 (8.61)
1 week	19.92	35.10	79.30	81.06	60.08	3.35	4.56	10.48	13.00	11.84	35.19 (5.54)	70.83 (8.32)
2 weeks	19.11	33.97	77.45	75.80	54.47	3.49	4.67	9.59	12.02	10.84	32.14 (5.25)	72.43 (8.46)
3 weeks	8.27	33.24	75.56	72.72	52.74	3.47	4.67	9.36	11.28	11.17	34.26 (5.43)	75.65 (8.66)
4 weeks	17.76	32.53	73.89	68.84	52.54	3.36	4.51	7.70	9.98	11.36	32.96 (5.38)	74.07 (8.59)
$F\text{-}LSD_{(0.05)}$	1.05	1.43	3.08	3.33	3.82	N.S	N.S	0.84	1.06	NS	NS	NS
Cultivar												
Nachi	16.75	33.61	79.46	77.52	56.30	3.10.	4.11	9.31	12.13	11.41	23.67 (4.72)	79.22 (8.89)
Odogolo	18.76	34.54	79.63	81.44	63.81	2.83	3.84	5.72	9.63	11.95	13.44 (3.50)	59.84 (7.66)
Ugwuta	20.00	31.44	67.26	59.01	40.89	4.30	5.85	11.38	11.55	9.98	65.56 (8.09)	81.56 (9.04)
$F\text{-}LSD_{(0.05)}$	0.81	1.11	2.38	2.50	2.96	0.13	0.16	0.65	0.82	N.S	0.25	0.22
Cropping season												
Early season	19.36	32.89	78.45	74.55	63.26	3.56	4.87	8.13	9.80	12.76	32.74 (5.10)	67.63 (8.15)
Late season	17.65	33.51	72.45	70.70	44.07	3.27	4.33	9.48	12.41	9.47	35.70 (5.77)	79.45 (8.911)
$F\text{-}LSD_{(0.05)}$	0.67	N.S	1.95	2.04	2.41	0.11	0.13	0.53	0.67	0.94	0.31	0.18

RD - Ridomil Gold WP, RD + CHP - Ridomil Gpld WP + Champ DP, SI - spray interval; $F\text{-}LSD_{(0.05)}$ - least significant difference at 5% probability level, NS - not significant at 5% probability level. Note: Bracketed numerals are transformed values.

the tallest taro height (19.50, 34.79, 79.62, 79.10 and 57.93 cm) compared to other fungicides. Weekly spray regimes gave significantly ($p < 0.05$) tallest taro height of 19.92, 35.10, 79.30, 81.06 and 60.08 cm compared to other spray regimes, while the least plant height values of 17.47, 31.14, 71.06, 64.86 and 48.40 cm were consistently recorded by no spray regime at all trial periods, respectively. Cultivars significantly varied on taro height with Ugwuta recording the tallest taro height of 10.00 cm, while the least taro height (16.75 cm) was recorded by Nachi at 30 DAP. Moreover, Odogolo consistently had the tallest significant ($p < 0.05$) taro height values of 34.54, 79.63, 81.44 and 63.81 cm compared to other cultivars, while the least taro height of 31.44, 67.26, 59.01 and 40.89 cm were maintained by Ugwuta at 60-150 DAP. Season effect had significant variations ($p < 0.05$) on taro height at the trial periods except at 60 DAP. Early season cropping significantly ($p < 0.05$) recorded a taller taro height of 19.36, 78.45, 74.55 and 63.26 cm than late season cropping with values of 17.63, 72.45, 70.76 and 44.07 cm at 30, 60, 120 and 150 DAP, respectively. However, at 60 DAP, late season cropping had no significant ($p > 0.05$) taller taro height of 33.51 cm than early season cropping (32.89 cm). In terms of number of leaves, fungicide treatments increased the number of leaves significantly ($p < 0.05$) at 90 and 120 DAP. However, untreated taro plots recorded no significant increase in number of leaves of 3.48 and 4.70 at 30 and 60 DAP compared to other fungicide treatments. Ridomil treated taro plots recorded the highest number of leaves of 10.13, 12.60 and 11.27 at 90, 120 and 150 DAP, respectively. The lowest number of leaves of 6.84, 9.57 and 11.01 were consistently produced by untreated taro stands at the corresponding trial periods. Spray regimes significantly ($p < 0.05$) varied on number of leaves at 90 and 120 DAP with weekly spray regimes recording the highest number of (10.48 and 13.00), respectively, while the least number of leaves (6.90) and (9.24) were produced by no spray regimes, respectively.

However, 2 weeks spray regime had the highest number of leaves (3.49) compared to others at 30 DAP. Likewise, at 60 DAP, 2-3 weeks spray regime recorded the highest number of leaves (4.67) compared to other spray regimes. The weekly spray regime recorded the highest no significant number of leaves (11.84), while the least number of leaves was produced by No spray regime at 150 DAP. Cultivars significantly varied ($p < 0.05$) at all the trial periods. Ugwuta significantly recorded the increased number of leaves of 4.30, 5.85 and 11.38 compared to others at 30, 60 and 90 DAP, respectively. The lowest number of leaves, 2.83, 3.84 and 5.72 were maintained by Odogolo at the corresponding periods. The numbers of leaves were recorded the highest by Nachi at 120 days (12.13) and by Odogolo at 150 DAP (11.95), respectively. The effect of season on number of leaves significantly ($p < 0.05$) varied throughout the trial periods. At 30 and 60 DAP, early season consistently had a significant higher number of leaves (3.58 and 4.87) than late cropping season (3.27 and 4.33), respectively. Late cropping season significantly had a higher number of leaves (9.48 and 12.41 at 90 and 120 DAP, respectively; while early season cropping had a lesser number of leaves (8.13 and 9.80 at 90 and120 DAP, respectively). Moreover, at 150 DAP, early season cropping recorded a higher number of leaves (12.76) than late cropping season. With respect to establishment percentage at 15 and 30 DAP as shown in Table 4, there were no significant ($p > 0.05$) difference in fungicide treatments and the spray regimes at all sampling periods. Cultivars significantly ($p < 0.05$) differed at all trial periods. Ugwuta consistently had the highest significant establishment percentage of 65.56% and 81.56% compared to others, while the least establishment was obtained by Odogolo. Season effect had significant variations on establishment percentage with late season cropping having a higher establishment percentage (35.70%) and (79.45%) than early season cropping (32.74%) and (67.63%) at 15 and 30 DAP, respectively.

Table 5 shows the effect of fungicide treatments, spray regimes, cultivars and season on yield attributes. Fungicide treatments significantly ($p < 0.05$) varied on yields per stand and hectare except on number of cormels at harvest. Ridomil treated taro consistently recorded the highest yield traits of corm diameter (6.21 cm per stand), cormels weight (0.34 kg per stand), corm weight (0.15 kg per stand), corm weight (6131 kg ha^{-1}), cormels weight (13,524 kg per ha^{-1}), total tuber yield (0.49 kg per stand) and total tuber yield (19655.00 kg ha^{-1}) compared to other fungicides, and the least yield values were consistently recorded by untreated plants. However, Ridomil had the highest no significant ($p > 0.05$) effect on number of cormels (15.40 per stand), while untreated taro recorded the lowest number of cormels of (8.60). Spray regimes varied significantly ($p < 0.05$) on yield traits except on corm diameter, cormels number per stand, and cormels weight per hectare at harvest. Weekly spray regime recorded the highest corm diameter (6.17 cm plant^{-1}), cormels number (12.10 per stand), cormels weight (0.33 kg per stand), corm weight (0.15 kg per stand), cormels weight (13276.00 kg ha^{-1}), corm weight (6137.00 kg ha^{-1}), total tuber yield (0.49 kg per stand) and total tuber yield (19413.00 kg ha^{-1}) and the least yield attributes were consistently recorded by no spray regime as shown in Table 5. Cultivars significantly differed on yield attributes except on cormels numbers at harvest. Odogolo consistently recorded the highest yield attribute values compared to other cultivars (Table 5). The effect of season significantly ($p < 0.05$) varied on yield indices except on number of cormels per stand, corm weight per stand at harvest. Between the seasons, early season significantly ($p < 0.05$) recorded a higher corm diameter (6.21 cm), cormels weight (0.03 kg per stand), cormels weight (13633.00 kg ha^{-1}), corm weight (6012.00 kg ha^{-1}), and total tuber yield (19645.00 kg ha^{-1}) than late season. However, late season cropping recorded a higher non-significant ($p > 0.05$) number of cormels (12.30 kg per stand) than early season cropping with 10.80 kg per stand. Also, early season cropping had a higher non-significant corm weight of 0.15 kg per stand with respect to late season cropping (0.12 kg per stand) at harvest.

Table 5: Effects of fungicide treatment, fungicide spray regime, cultivar and season on the yield of three cultivars of taro

	CMD	CMLN	CMLW	CMW	CML ha^{-1}	CMW ha^{-1}	TTY std^{-1}	TTY ha^{-1}
Fungicide treatment								
Control	5.80	8.60	0.20	0.12	8195.00	4930.00	0.33	13125.00
RD + CHP	6.00	10.60	0.29	0.13	11431.00	5267.00	0.42	16698.00
RD	6.21	15.40	0.34	0.15	13524.00	6131.00	0.49	19655.00
F-LSD$_{(0.05)}$	0.18	N.S	0.03	0.01	1233.00	598.00	0.04	1636.00
Spray regime								
No spray	5.76	8.70	0.22	0.13	8963.00	5083.00	0.35	14046.00
1 week	6.17	12.10	0.33	0.15	13276.00	6137.00	0.49	1.9413.00
2 weeks	6.10	16.80	0.29	0.14	11494.00	5452.00	0.42	16946.00
3 weeks	6.00	10.00	0.27	0.13	10792.00	5190.00	0.40	15981.00
4 weeks	5.98	10.10	0.27	0.13	10725.00	5351.00	0.40	16077.00
F-LSD$_{(0.05)}$	N.S	NS	0.04	NS	1592.00	NS	0.05	2113.00
Cultivar								
Nachi	6.10	9.30	0.22	0.12	8821.00	4940.00	0.34	13761.00
Odogolo	6.63	16.20	0.31	0.18	12228.00	7297.00	0.49	19524.00
Ugwuta	5.27	9.10	0.30	0.10	12102.00	4091.00	0.40	16193.00
F-LSD$_{(0.05)}$	0.18	N.S	0.03	0.01	1233.00	598.00	0.04	163.00
Cropping season								
Early season	6.21	10.80	0.34	0.15	13633.00	6012.00	0.49	19645.00
Late season	5.80	12.30	0.21	0.12	8467.00	4873.00	0.33	13340.00
F-LSD$_{(0.05)}$	0.15	NS	0.03	NS	1007.00	488.00	0.03	1336.00

RD - Ridomil Gold WP, RD + CHP - Ridomil Gpld WP + Champ DP, CMD - corm diameter, CMLN - cormel number, CMLW - cormel weight, CML ha^{-1} - cormel per hectare, CMW - corm weight, CMW ha^{-1} - corm weight per hectare, TTY std^{-1} - total tuber yield per stand, TTY ha^{-1} - total tuber yield per hectare; F-LSD$_{(0.05)}$ - least significant difference at 5% prob. level, NS - not significant at 5% prob. level

DISCUSSION

The agro-meteorological data showed that there were remarkable variations of climatic elements during the study. This result might have contributed to the variations on vegetative growth attributes on leaves number and taro height (cm) and yield parameters on corm diameter, cormels number, cormels weight, corm weight, tuber yield stand^{-1} and tuber yield ha^{-1} (kg) observed. The steady rainfall from April to October is suitable for taro production in the study area for effective and efficient soil nutrients absorption and utilization. The maximum temperature recorded in June-October was between 28.70-28.60°C which support disease expression in taro producing regions resulting in reduced vegetative growth and yields. The observed weather condition was in line with NRCRI (2012) report that taro leaf blight disease occurs mostly at earlier part of June-August of the year, and leaf blight disease manifest at daily temperatures of 25-28°C which resulted to the growth of *Phytophthora* leaf blight disease (Mbong *et al.,* 2013; Omeje *et al.,* 2015). It has been observed by taro production stakeholders that its optimum temperature growth requirements (25-28°C) correspond to the temperature conditions for the manifestation of TLB in the growing areas. These conditions make the TLB management a serious concern.

The pre-study analysis of the soils showed that they were acidic with low plant nutrients indicating low soil fertility. These results conform to the reports that soils of southeastern Nigeria belong to the group characterized by low pH, low organic matter and exchangeable cations (Ibedu *et al.,* 1988; Enwezor *et al.,* 1989). This low fertility status may be attributed to the high leaching losses due to the Ultisols of the study area (Obalum *et al*., 2011). The values are, therefore, within the ranges that are typical of the study area (Onah *et al*., 2021).

The significant variations of fungicides on disease incidence and severity could be due to fungicidal potential differences. Consequently, disease incidence and severity varied with fungicides and the prevailing weather conditions at the time of application schedules (Mbong *et al.,* 2013). Findings from this study support the report by Omeje *et al.* (2020) who reported that copper-based fungicides significantly reduced disease incidence and severity of taro leaf blight than untreated taro stands in Hawaii. Also, Jackson *et al.* (1980) reported that Ridomil (metalaxyl) and phosphorous acid (foschek) are specific to taro leaf blight disease. However, results with fungicides can be variable. The significant differences of spray regimes on disease incidence and severity could be attributed to potency of fungicide the tested spray schedules on disease reduction. The potency of fungicides and spray regimes are effective against TLB disease, but the slanted shape of taro leaves, prevalence of taro production in humid climate, occurrence of *Phytophthora colocasiae* during heavy and continuous light rain periods with little variation, and also the water proof nature of taro leaves reduce fungicides spray adherence to taro leaves surface, make repeated spray application necessary (Omeje *et al.,* 2019; 2020). This finding agree with Omeje *et al.* (2015) who reported that weekly spray of copper oxychloride at rate of 2.25 kg a.i/38 litres per ha provided superior control of taro disease especially taro blight disease in Solomon Islands.

The differences among the cultivars on disease incidence and severity could be due to genetic endowments. Uchendu *et al.* (2013) reported that genotypes responded differently to diseases and pests stress across different environments. Improved cassava genotypes showed high tolerance to prevalent insect pests like white flies, (*Bemisia* *tabaci*) and cassava aphids (*Aphis manihotis*), and diseases like African cassava bacterial blight (*Xanthomonas manihotis*), cassava mosaic and cassava anthracnose across Nigeria (Uguru, 2011). The highest disease incidence and severity observed in Odogolo and Ugwuta cultivars were in support of reports by Ogbonna and Orji (2013) who reported that Ugwuta and Odogolo were highly susceptible to taro leaf blight disease. The study also agrees with the findings by Orji *et al*. (2013) that Nachi was fairly resistant to leaf blight disease. The least disease incidence and severity was observed in Ugwuta and Odogolo at later stage of spray trials, indicating the positive response of the cultivars to fungicide spray; and spray regimes. Mbong *et al*. (2013) reported that cultivars varied in their response to fungicide treatments and the spray regimes. This may be attributed to varied genotypic variation of the cultivars and weather conditions at the growing regions.

Foliar disease symptoms appeared first at 75 and 60 DAP in early season cropping and late season cropping, respectively. It was in line with earlier researchers (Omeje *et al*., 2020; NRCRI, 2012) that *Phytophthora* leaf blight disease symptoms appeared during the third and fourth quarters of taro cropping periods. Differences between the seasons on disease incidence and severity except at 90 DAP could be attributed to prevailing weather conditions at cropping period. Uchendu e*t al*. (2013) reported that environmental conditions such as high relative humidity, low temperatures and continuous rainfall demonstrated had significant effect on the incidence of pests and diseases incidence. The high disease incidence and severity at 75, 90 and 150 DAP and compared to at 120 DAP was in line with earlier report that the months of July-September were periods of high disease incidence and severity due to favourable environmental conditions compared to other months. Mbong *et al*. (2013) reported that plant disease infections occurred mostly when there was continuous wet season during the day and night. The significant variations among the cultivars on establishment percentage could be attributed to inherent cultivar differences and climatic factors. Omeje *et al*. (2016) reported that in seed germination and establishment that even when all seeds were planted at the same time they could make a successful count with time when all germination requirement conditions like seed viability, optimum soil water, air, and temperature conditions are available. Findings from this study supports those of Aighewi *et al.* (2001) and Ndeayo *et al.* (2013) that variation in cultivars had effect on the percentage sprout and establishment. It was observed that Ugwuta cultivar had the highest establishment percentage throughout the study schedules which indicate its high germination potential due to its high moisture contents compared to other taro cultivars, resulting to its poor storability, high rot susceptibility to myco-induced pathogens and less viability for long planting materials and consumptions.

The significant variations among the fungicides on growth attributes especially on leaves with Ridomil treated plants performing best (10.00, 13.00, 12.60 and 11.27) followed by Ridomil + Champ DP 50.00%:50.00% mixture (9.45, 11.14 and 11.60) at 90, 120 and 150 DAP, respectively could be due to the efficacy of tested fungicides on checking taro diseases, thereby promoting growth and health status of taro cultivars. This result in more taro leaves compared to untreated taro stands. This finding was in line with report by Ghosh and Sitansu (1991) who reported low plant growth on untreated taro fields, while copper-based fungicide gave an improved plant growth on taro leaf disease management. The significant effect of spray regimes on growth traits could be due to the potency of fungicides spray regimes on disease reduction. This report disagrees with the findings by Ashok and Saikia (1996) who reported no significant variations on taro plant growth at regular spray of fungicides against taro leaf blight disease.

Differences in plant leaves and plant height growth traits among the taro cultivars could be due to the climatic conditions and cultivar difference in growth habits. Growth depends on cultivars among other factors like disease management options, climatic conditions, agronomic practices, soil fertility status etc all of which are utilized to improve taro health status due to reduced taro leaf blight disease damage. Similarly, planting time, soil fertility, water and temperature conditions during growth cycle may delay sucker formation and petiole height resulting to less number of leaves and taro height, respectively. Some cultivars may not produce much sucker(s) and long petioles at all even when all nutrients are available optimally. This variation agrees with Ogbonnanya (1983) and Ogbonna and Orji (2013) who reported varietals differences among the cultivars on growth traits. The significant higher number of leaves by Ugwuta at earlier stage of study revealed earlier production of suckers and maturity compared to others, followed by Nachi and then Odogolo. This indicates the delay on sucker production, establishment and maturity by those cultivars. This result agrees with Wilson (1984) who reported that number of leaves at certain growth phases are not uniform which indicates that more suckers results to higher number of leaves at a particular crop growth stage(s).

The seasonal differences on growth parameters might be due to the cultural practices and climatic factors at the growth periods. The significant difference on growth attributes supports the earlier reports that cocoyam reaches their maximum growth at 3-4 months after planting, while senescence occurs at 5 months after planting. Wilson (1984) reported that maximum plant height and leaf area attributes are attained at 5 months after planting, while the maximum number of leaves are more variable and varies between 3-7 months after planting and depends on cultural practice (planting season; disease/pest management strategies, fertilization/manuring and climatic factors such as rainfall and temperature; cultivar types and seed viability; soil factors like soil moisture conditions and soil fertility status. The significant variations on yields among the fungicide might be due to the combined effect of fungicide, cultural practices, cultivar potential response to fungicides applied on incidence and severity of TLB disease. The observed yield superiority of Odogolo and Ugwuta could not only be genetic potential, but by crop disease management strategies adopted. This result was in line with the report made by NRCRI (2012) that taro disease control by fungicide application is a way to improve cocoyam yields. The study showed that the highest cormel/corm (tubers) yields were produced by Odogolo and Ugwuta which suggests their most susceptibility to taro leaf blight disease as well as their positive respond to fungicide sprays and spray regimes. This is unlike Nachi cultivar which has a fair resistance or tolerance to taro leaf blight disease (Ogbonna and Orji, 2013).

The significant effect on yields due to spray regimes could be due to the potential efficacy of fungicide spray regimes on disease reduction. The spray regimes programme produced the highest tuber yields at weekly spray regimes of Ridomil, followed by Ridomil + Champ DP mixture. Findings from the study supports the report by Omeje *et al.* (2015) that a weekly spray of copper oxychloride at rate of 2.25 kg a.i/38 litres ha^{-1} with mist sprayer provided superior control of cocoyam disease and yield in Solomon Islands. The significant variations among the cultivars on yield attributes might be due to the genetic endowment and growing environment. Ndeayo *et al.* (2013) reported that considerable variation existed both within and between varieties for most characters and the coefficient of variation for genotypes and phenotypes were largest for root and tuber yields. This study agrees with the report by Ogbonna and Orji (2013) who reported that Ugwuta and Odogolo in that order produced the highest yields. However, in this study Odogolo leads, followed by Ugwuta and then Nachi. This study also revealed that the cultivars which produced the highest number of sucker(s) (cormels) also had the highest tuber yield, large number of leaves and leaf area/size. This result agrees with the IITA (1990) that tuber yield is determined not only by the amount of dry matter produced, but by certain growth factors such as number of leaves, leaf area, plant height and suckering habit. The highest corm weight and corm diameter by Odogolo was in line with the findings by Ogbonnanya (1983) who reported that Odogolo and Nworoko had the biggest and tallest stem girth of plant.

The significant variation between the cropping seasons may be attributed to the climatic factors, cultural operations and state of seeds at planting time. Also, soil fertility, soil moisture and temperature stress may affect tuber formation. The observed less yields recorded in late season cropping than early season cropping might be due to the short growing periods in the field before the onset of dry period during late season cropping as well as the earlier effect by taro leaf blight during the growing periods. This finding was in support of Onwueme and Singh (1991), who reported that taro cultivars are mostly planted at onset of rain so that they can utilize the entire rainy season to develop well and also under less leaching, erosion and full sunlight intensity within March-June for the year. Further, NRCRI (2012) reported that early cropping (early April-June) should be adopted in order to boost yield package in the taro field production.

CONCLUSION/RECOMMENDATION

The result showed that taro cultivars responded differently to fungicide treatments, spray regimes, seasons and taro leaf blight expression with Nachi, Ridomil Gold 66 WP Plus and its weekly spray regime followed by Ridomil Gold 66 WP + Champ DP 50.00%:50.00% mixture spray and early cropping season proved most promising in the management of TLB. Therefore, the adoption of the tested fungicides and their weekly sprays, early season cropping and fairly resistant cultivar (Nachi) should be incorporated into disease management routines through integrated pathogen management in Nsukka agricultural zone.

REFERENCES

Abujah C.I., Ogbonna A.C. and Osuji C.M. (2016). Nutritional and medicinal components of food: A review. *J. Food Sci. Technol.,* **52 (5),** 2522-2529

Aighewi B.A., Asadu R. and Akorodo M.O. (2001). The economics of root and tuber crops in Africa. In: Akoroda M.O. and Ngera J.M. (eds.), *Root Crops in the 21st Century* (pp. 46-52). Proc. 7th Triennial Symp. Int. Soc. Trop. Crops, Africa

Annam N.T. and Plahar W.A. (1995). Development and quality evaluation of soy-fortified Ghanaian weaning food. *Food Nutr. Bull.,* **16 (3),** 263-296

Ashok B. and Saikia U.N. (1996). Fungicidal management of leaf blight of *Colocasia*. *Int. J. Trop. Agric.,* **14 (1-4),** 231-233

Baruah K.K. (2002). Nutritional status of livestock in Asian agriculture. *ASSAM:* Publ. of the Directorate of Extension, Asian Agriculture University, p. 203

Brooks F.F. (2005). Taro leaf. *Health Inspector*. https://doi.org/10.1094/PHI-1-2005-0531-01

Chaube H.S. and Pundhir V.S. (2005). *Crop Diseases and their Management Practice*, 1st ed., Hall of India, New Delhi, pp. 171-189

Chukwu G.O., Okoye B.C., Uko S., *et al.* (2012). Control of taro leaf blight in Nigeria. Proc. Int. Agric. Conf., 6-9th Mar., Igbariam, pp. 502-503

Echebiri R.N. (2004). Socio-economic factors and resources allocation in cocoyam production in Abia State, Nigeria: A case study. *J. Sustain. Trop. Agric. Res.,* **9,** 69-73

Enwezor W.O., Udo E.J., Usoroh N.J., Ayoade K.A. and Adepetu J.A. (1989). Fertilizer uses and management practice for crops in Nigeria. Fed. Min. Agric., Water Resour. Rural Dev., Series No. 2, p. 163

Fullerton R. and Tyson J. (2004). The biology of *Phytophthora colocasiae* and implication for its management and control. Proc. 3rd Taro Symp., 21-23 May, New Caledonia, pp. 107- 111

Gadre U.A. and Joshi M.S. (2003). Influence of weather factors on the incidence of leaf blight *Colocasiae*. *Ann. Plant Protect. Sci.,* **11,** 168-170

Ghosh S.K. and Sitansu P. (1991). Control of leaf blight of taro (*Colocasia esculenta* L.) caused by *Phytophthora colocasiae* Racib through fungicides and selection of variety. *J. Mycol. Res.,* **29 (2),** 133-140

Ibedu M.A., Unamba R.P.A. and Udealor A. (1988). Soil management strategies in relation to farming systems development in the southeastern zones of Nigeria. Paper Presented at the National Farming Sys. Res. W/Shop*,* 26-29 Apr. 1988, Jos, Nigeria, pp. 26-29

IITA (1990). Annual Report of International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

Jackson G.V.H., Golliffer D.E. and Newhook F.J. (1980). Studies on the taro leaf blight fungus *Phytophthora colocasiae* in Solomon Islands: Control by fungicides and spacing. *Ann. Appl. Biol.,* **96,** 1-10

Mbong G.A., Fokunang C.N., Lum A. and Fontem E.A. (2013). An overview of *Phytophthora colocasiae* of cocoyam: A potential economic disease of food security in Cameroon. *J. Agric. Food Sci.*, **1 (9),** 140-145

NRCRI (2003). Cocoyam Programme, National Root Crop Research Institute (NCRI), Umudike. http://www.nrcri.gov.ng/pages/ cocoyam.hnm

NRCRI (2012). Managing taro leaf blight epidemic in Nigeria: An update. Cocoyam Research Programme, National Root Crop Research Institute (NRCRI), Umudike, Nigeria. http://www.ediblearoids.org./portal

Ndeayo N.U., Udeme K., Udoh A.O., *et al.* (2013). Effect of size weight on growth and yield of cocoyam species in Uyo, southeastern Nigeria. *Nig. J. Crop Sci.,* **1 (1),** 47-53

Nelson S., Brooks F.F. and Teves G. (2011). Taro leaf blight in Hawaii: Plant disease No. PD-71. Univ. of Hawaii

Njoku P.C. and Ohia C.C. (2007). Spectrophometric estimation studies of mineral nutrients in three cocoyam cultivars. *Pak. J. of Nutr.,* **6,** 616-619

Niba L.L. (2003). Processing on susceptibility of starch to digestion in some dietary starch sources. *Int. J. Food Sci. Nutr.,* **54,** 97-109

Obalum S.E., Okpara I.M., Obi M.E. and Wakatsuki T. (2011). Short-term effects of tillage-mulch practices under sorghum and soybean on organic carbon and eutrophic status of a degraded Ultisol in southeastern Nigeria. *Trop. Subtrop. Agroecosys.*, **14 (2),** 393-403

Obi I.U. (2002*). Statistical Methods of Detecting Differences between Treatment Means and Research Methodo-Issues in Laboratory and Field Experiments,* 2nd ed., Apex Publ. Coy; Ltd, Nsukka-Nigeria, p.117

Ogbonna P.E. and Orji K.O. (2013). Evaluation of the growth and yield potentials of cultivars of cocoyam in locations in Southeastern, Nigeria. *Nig. J. Crop Sci.,* **1,** 105-115

Ogbonnanya J.C. (1983). *Effect of Plant Spacing and Time of Planting on Growth and Yield of Cocoyam (Colocasia esculenta) in the Derived Savannah Belt of Nigeria*. MSc Thesis, Department of Crop Science, University of Nigeria, Nsukka, p. 18

Ojiako I.A., Asummugha G.N. and Ezedinma O.N.E. (2007). Analysis of production trends I: The major root and tuber crops in Nigeria, 1961-2000. *Res. Crops*, **8 (2),** 371-380

Omeje T.E., Ugwuoke K.I., Aba S.C., Eze S.C., Ogwulumba S.I. and Ezema R.A. (2015). Field management of *Phytophthora* blight disease of cocoyam (*Colocasia esculenta* L.) with spray regimes of selected fungicides in Nsukka, southeastern Nigeria, *Agro-Science*, **14 (2),** 36-45

Omeje T.E., Ugwuoke K.I., Adinde J.O., Ogwulumba S.I. and Unigwe L.O. (2016). Effect of cropping season on the control of taro leaf blight (*Phytophthora colocasiae*) of cocoyam (*Colocasia esculenta* L.) in Nsukka, southeastern Nigeria. *Int. J. Adv. Biol. Res.,* **6 (1),** 30-39

Omeje T.E., Ugwuoke K.I., Eze S.C. and Ezema R.A. (2019). Advances in recent epidemiological factors of *Phytophthora* leaf light of cocoyam cultivars (*Colocasia esculenta* L.) in Nsukka Agroecology, southeastern Nigeria. Proc. 6th Nat. Ann. Conf. Crop Sci. Soc. Nig., Owerri, pp. 873-881

Omeje T.E., Ugwuoke K.I., Eze S.C., Ezema R.A., and Nzekwe C.A. (2021). Management of *Phytophthora* leaf blight disease of *Colocasia esculenta* (L.) Schott for sustainable food prododuction and nutritional security in Nigeria: A review. In: *Proc. 7th Natl Conf. Crop Sci. Soc. Nigeria* (Ekpoma 2021), pp. 159-174

Omeje T.E., Ugwuoke, K.I., Eze S.C. and Ezema R.A. (2020). A comprehensive study on field management of *Phytophthora* leaf blight disease of cocoyam with spray regimes of selected fungicides in Nsukka, southeastern Nigeria. *Cut. Edge Res. Agric. Sci.,* **3,** 99-119. https://doi.org/10.9734/BPI/cras/v3.99-119

Onah M.C., Obalum S.E. and Uzoh I.M. (2021). Vertical distribution of fertility indices and textural properties of a sandy clay loam under short and long-term fallow. *Int. J. Agric. Rural Dev.*, **24 (1),** 5697-5703

Onwueme I.C. and Singh T.D. (1991). Field crop production in tropical Africa. Centre for Tropical Agriculture (CTA), Wageminagan, Netherland, p. 450

Onyeka J. (2014). Status of cocoyam (*Colocasia esculenta* L. and *Xanthosoma spp.*) in West and Central Africa: Production, household importance and threat from leaf blight. Lima (Peru) CGIAR Res. Prog. on Root, Tuber and Banana (RTB). http://www.rtb.org

Opera I.U. (2002). Edible aroids: Post harvest operation. In: Watt B.M., Ylimaki G.I., Jefrey L.E and Danilo M. (eds.), *Basic Sensory for Food* (pp.14-15), Massey Ekics, NZ

Orji K.P., Ogbonna P.E, and Eze E. (2013). Evaluation of growth and yield response of taro to NPK fertilizer rates on the plain of Nsukka in southeastern Nigeria. Proc. 1st. Nat. Conf. Crop Sci. Soc. Nig., 15-19th Sep., Nsukka, pp. 118-123

Russell P.E. (2005). A century of fungicides evolution. *J. Agric. Sci.,* **143**, 11-25

Singh D.G., Jackson G., Hunter D., *et al.* (2012). Taro leaf blight. a threat to food security. *Acad. Open Access Agric.*, **2 (4),** 1182-2030. DOI: 10.3390/agriculture2030182

Uchendu U.K., Parkes E., Aina O.O., Akoroda B.M.O. and Kulakow P. (2013). Field disease and morphological reaction of white fleshed cassava genotypes in Nigeria. Proc. 1st Nat. Conf. Crop Sci. Soc. Nigeria, 15-19th Sep., Nsukka, pp. 200-265

Uguru M.I. (2011). *Crop Production Tools, Techniques and Practice* (2nd ed.), Fulladu Publ. Coy., Nsukka-Nigeria, pp. 52-54

Wilson J.E. (1984). Taro and cocoyam: What is the ideal plant type? In: Chandra S. (ed.), *Edible Aroids* (pp. 151-159). Clarendon Press, Oxford