

Evaluation of Selected Botanical Spray on Field Management of Taro leaf blight and yield attributes of Taro (*Colocasia esculenta* L.) cultivars in Enugu State, Southeastern Nigeria

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ABSTRACT

The dwindling availability of synthetic fungicides together with increasing public concern on the environmental safety means that the use of plant materials to manage field pathogens are attracting increased attention. Therefore, the aim of this study was to determine the effect of botanicals on leaves growth, field management of *Phytophthora colocasiae* disease incidence, disease severity and yield attributes of taro cultivars. The study was carried out at Enugu State Polytechnic Iwollo Teaching and Research Farm. The experiment was laid out as a 3x 5 factorial in randomized complete block design (RCBD) with three replications. The experimental treatment materials consisted of three taro cultivars – Nachi, Odogolo and Ugwuta as main plot, while the sub-plots consisted of three botanicals- Neem (*Azadirachta indica*), siam weed (*Chomolanenae odorata*) and *Eucalypus* spp; a synthetic fungicide (Ridomil gold plus) as a standard positive treatment and control (No treatment) as a standard negative treatment. Data collected were analyzed by analysis of variance (ANOVA), while Fisher's least significant (F-LSD) was used to separate means where significant at 5% probability level. It was evident that variability existed across the taro cultivars and botanicals on number of leaves/stand, disease incidence, disease severity (%) and yield indices (kg/stand), (number of cormels/stand, cormel weight/stand, corm weight/stand, corm circumference/stand, total tuber weight/stand (kg/stand). Odogolo cultivar significantly ($P < 0.05$) had the highest number of leaves values (21.10, 21.50 and 14.90), while Ugwuta cultivar had the least number of leaves values (11.90, 19.80 and 14.70) at 90 to 150 days after planting, respectively. Ridomil gold significantly ($P < 0.05$) recorded the highest number of leaves (21.90, 28.70 and 21.60), and the least number of leaves (10.90, 15.20 and 9.60) was recorded by the control treatment at 90 to 150 days after planting. Disease incidence (%) significantly ($P < 0.05$) varied among the botanicals except at 120 and 150 days after planting with Ridomil gold scored the least disease incidence (%) (25.70, 9.10 and 3.30) and then the highest (100.00, 100.0 and 100.00) was scored by the control treatment throughout the sampling periods at 90 – 150 days after planting. Among the cultivars, Nachi cultivar scored the least disease incidence (%) (57.30, 62.40 and 41.90), and the highest disease incidence (%) (85.90, 66.20 and 43.20) was scored by the Ugwuta cultivar at 90 - 150 days after planting, respectively. Disease severity (%) also had significant ($P < 0.05$) variations among the botanicals throughout the study periods with Ridomil gold scoring the least (4.10, 0.70 and 0.30) disease severity, while the control treatment scored the highest disease severity (%) values (52.90, 63.80 and 49.90) throughout the study periods. Among the cultivars, Ugwuta cultivar consistently scored the highest significant ($P < 0.05$) disease severity (%) (29.30, 33.80 and 22.70), and the least disease severity score (19.50, 20.30 and 14.10) was consistently scored by the Nachi cultivar throughout the study periods. Cultivars and botanicals significantly ($P < 0.05$) differed in all yield indices (number of cormels/stand, cormel weight/stand, corm weight/stand, corm circumference/stand, total tuber weight/stand (kg/stand and tons/hectare). Odogolo cultivar significantly had the highest total tuber yield per hectare (t/ha) (27.20), while Nachi cultivar recorded the least total tuber (t/ha) (12.20) at harvest. The study revealed that botanicals affected the agronomic and the field management of taro leaf blight disease of taro cultivars.

Keywords: Taro cultivars, botanicals, ridomil, taro leaf blight, field management



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INTRODUCTION

Pre-agronomic practices are key determinant of the proper development of crops and if well adopted will effectively promote field disease management of *Colocasia esculenta* (L) cultivars. *Colocasia esculenta* (L.), also known as taro (Ugwuoke *et al.*, 2008;), is a significant edible herbaceous underground starch-rich tuber crop in a number of developing nations of Central and West Africa (CWA) and the Pacific. It belongs to the family of aroids known as the Araceae (Eze *et al.*, 2015). It is the third most major root and tuber crop in Nigeria after cassava and yam, and the first-most significant vegetable crop in Ghana (Echebiri, 2004) and the fourteenth-most significant vegetable crop worldwide (Brooks (2005)). The consumption system of taro edible parts are changing from poor resource income families, low-income women, large families, scarcity food to all year-round food, public ceremonial/social function foods among all poor and rich income resource families and groups due to its high delicacy, nutritional, therapeutic, industrial, and cultural benefits (Mwenye, 2009; Ogbonna and Nweze, 2012), as well as its increased versatility and use in various food and non- food formulations Omeje *et al.*, 2020. Taro consumption systems are exponentially growing around the world, both at home and at public social functions also due to its socio-economic factors for national growth and development.

Despite its many uses recently, particularly in Nigeria (5143kg/ha) compared to yields in Japan (13493kg/ha) and China (13333 kg/ha), many variables have contributed to its field production and post-harvest quality losses globally (Onwueme and Singh, 1991). Poor agronomic methods, such as ineffective pest and disease management techniques, unsuitable manuring and weeding regime choices, and the use of additional agrochemicals may have caused the extreme low yield. The taro leaf blight (TLB) disease, which is caused by the Oomycete *Phytophthora colocasiae* Mariam Raciborski on a global scale, is the cause of the most recent damaging taro field. When the infection is severe, *P.colocasiae* primarily damages the leaves and other components of the host plant (Nelson *et al.*, 2011). Within 3-7 days of the first symptom manifestations, which include the development of small to large brown spots/lesions surrounded by halos on the upper surface of leaves (Nelson *et al.*, 2011), the entire taro leaf area of the affected host plant is completely defoliated, with the surrounding blighted areas turning yellow. Depending on the local weather, cultivar genotypes, and methods for managing pests and diseases, the spots/lesions grow quickly and develop into large brown lesions (Hunter *et al.*, 1998), which drain vital plant nutrients from leaves through haustoria to produce white powdery rings of sporangia (Singh *et al.*, 2012). According to Nelson *et al.*, (2011), *P. colocasiae* can infect petioles and tubers under high humidity, nighty and daily time lows of 21-22°C, and highs of 25-28°C temperatures (Omeje *et al.*, 2015) and optimal pH of 6.5 (*Phytophthora*

colocasiae, 2013). These conditions result to poor tuber formation and total tubers yield loss (Misra *et al.*, 2008).

The field management of TLB still rely on the use of synthetic fungicides. This often leads to human and livestock poisoning, environmental pollution, emerging of resistance and resurgence of pests and diseases and the presence of pesticide residues in agricultural produces (Sande *et al.*, 2011). At present, TLB and post-harvest rot causing pathogens are the most serious challenges among the taro production stakeholders, processors and marketers globally. TLB field damage affect the qualities and quantities of tubers for consumption and planting materials (Eunice and Osuji, 2008) and other taro agro-based industrial uses. The resulting rapid decline in taro production and post-harvest storage are threatening the survival and existence of the crop and extinction is obvious (Ugbaja and Uzoegbunam, 2012), thereby making nations sustainable food production, nutritional, medicinal and socio-economic empowerment impracticable and less effective. In most instances, the management of pre and post-harvest quality losses should start before harvest in the field during production cycle. Many botanicals and their phytochemical compounds have been proven by many researchers to have promising fungicidal values of which Neem, *Azadirachta indica* (A Juss), (Akhtar and Manhood, 1997) Siam weed, *Chromolaena odorata* (Pharn *et al.*, 2001); Akinmoladum *et al.*, 2007) and *Eucalyptus* plant leaves extracts (Sameza *et al.*, 2014) are inclusive. However, documented report of the effect of *Azadirachta indica* (A. Juss), *Chromoleana odorata* and *Eucalyptus spp* leaves extracts on field management of *Phytophthora* leaf blight disease and their residual effect on improvement of post-harvest qualities of taro cultivars are at infant stage. Moreso, the efficacy of plant extracts activities against soil borne plant pathogens management have been conducted in greenhouse, in vitro with little or no trials in field conditions and has yet to meet the expectations for disease management efficacy under field conditions.

The immediate and effective management option against Oomycetes fungal pathogen especially *Phytophthora* leaf blight disease is by the spray of Ridomil gold plus (active ingredient (a.i): metalaxyl and copper oxide) at weekly or bi-weekly spray regimes depending on disease severity (Omeje, *et al.*, 2015) and weather conditions. This is an imported product that is costly, not easily available and procured by all levels of taro production stakeholders. Above all, the establishment of sustainable plant disease management in the tropics may be impacted by the prevalence, severity of plant disease, and nutritional contents of infected crops, as well as the post-harvest attributes of agricultural products. The use of plant-derived substances to manage field and post-harvest pathogens is gaining more attention as fungicide supply continues to decline and environmental awareness among the general population rises. Therefore, there is need to

compare the synthetic fungicide with botanicals on field management of taro leaf blight of taro cultivars. The study will provide a better management of *Phytophthora* leaf blight disease strategy and improvement on post-harvest qualities of taro cultivars that will provide the needs of all classes of taro stakeholders and all prospective farmers should adopt. Thus, the specific objective of the study was to determine the effect of botanicals on some agronomic attributes, field management of *Phytophthora* leaf blight disease and yield attributes of taro cultivars.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Department of Agricultural Technology Teaching and Research Farm, Enugu State Polytechnic, Iwollo, Enugu State, Nigeria. Iwollo is situated at latitude 6° 52' North and longitude 07° 24' East in the derived savannah Zone, at an altitude of 447.26 meters above sea level (m.a.s.l.). The average annual rainfall in the region is between 1500 and 2000 mm. The rainfall pattern is bimodal, with peaks in June/July and September and a brief period of low rainfall and relative humidity stress in August that is usually referred to as "August break". The rainfall pattern begins in March/April and ends in October/November. The dry season lasts from November - March. Temperatures are uniformly high in March and low in December/January and often between maximum of 28°C-30°C and minimum of 21°C - 22°C. There is practically no rain in January and February. However, temperatures are much reduced by cloudiness in the wet season and by haze in the dry season (Inyang, 2000). The relative humidity ranges from 69 - 80% (Uguru *et al.*, 2011). The soil is a well-drained sandy clay loam classified as an ultisol (USSD) classification belonging to Nkpologwu series (Nwadiakor, 1989).

Sources of experimental materials

Collection of three taro cultivars

The most popularly growing cultivars in the study area: Nachi (Ede ofe/purple taro/Nce003), Ede ofe /green taro/Nce002) and Ugwuta (Coco- India/ Nce001) were sourced from Opi- Nsukka main market for the study. The rationale for the selection of the cultivars were on abundant, popularity, productivity, high prospect, and general acceptance as good cultivars in the study area.

Collection of botanical samples

Neem leaves: The Neem tree leaves were collected from the tree stands in Enugu Ngwo along Milkin hill - 9th Mile corner, Enugu State.

Siam Weeds: The leaves of Siam weed were collected along the roads and waste lands in Nsukka area.

Eucalyptus leaves: *Eucalyptus*: leaves were collected from tree stands at Enugu State Polytechnic, Iwollo, Ezeagu local government area, Enugu State, school environment.

Ridomil Gold plus: Ridomil Gold plus was sourced in Ogige Main Market, Nsukka at Agro chemicals store Enugu State.

Preparation of botanicals

Fresh leaves of botanicals were collected and washed thoroughly with tap water and then distilled water separately. They were air-dried for a week at a point they will be dry enough for milling. The dried samples were separately grinded in a laboratory Mill (Thomas Willey Model ED-5 made in USA) after which the ground samples were sieved to obtain processed powdered samples for the extraction. The processed powdered samples were kept in a sealed/hermetic air tight container to avoid contamination. By adoption of cold solvent extraction method (Junaid *et al.*, 2006; Doughari *et al.*, 2007), the 100 g of each processed powdered sample was mixed with 100 ml of solvent separately in larger rounded conical flask bottle to produce 100% extract concentration, respectively and were allowed to stand for 72 hours. The extracts were sieved through four layers of sterile cheese cloth filter and stored in sterile round conical flask which was used for field studies on growth, yield and management of *Phytophthora* leaf blight disease at weekly spray intervals for three months after planting. Therefore, the concentration was calculated by dividing the 50 grammes of plant samples separately by 500 ml of distilled water (aqueous extract) recommended by Ijalo *et al.*, (2010) modified method at the rate of 100 g of plant extract in one liter of distilled water on weekly extraction and spray schedules.

$$\frac{g}{100} \times \frac{500 \text{ ml}}{1}$$

Where g is the gramme of the plant sample and ml is the milliliter of solvent (distilled water).

Experimental field layout and treatment allocation

Field layout

The field design was a 3 × 5 factorial split-plot in randomized complete block design (RCBD) with three replications. The main plot was taro cultivars: Nachi (Ede ofe purple; Nce 003), Odogolo (Ede ofe green; Nce 002) and Ugwuta (Ede-India Nce 001, while the sub-plot was five pesticide treatments: Siam weed leaves extract, Neem leaves extract), *Eucalyptus* leaves extract), Ridomil gold plus (standard positive control), and Non-pesticide plots/standard negative control).

Establishment of field experimental site

Field was established when soil moisture and other soil factors including the plant materials were available for taro production in the study area. An experimental site measuring 75 m × 8.75 m (656.2 m²) was used for the study. The site was ploughed, harrowed for seed bed preparation. The cultivable site was divided into three blocks separated by 1 m apart. Each block was divided into 15 plots each measuring 3.75 m × 2.25 m (8.44 m²). Each plot was made into 15 rows of crest of mounds manually with hoe at an inter × intra row medium spacing of 0.75 m × 0.75 m separated by 1 m apart to check pesticide spray drift. There were 15 plots per a replicate and a total of 45 experimental plots.

Treatments and Treatment allocation

The main /whole plots was three taro cultivars: Nachi (Fde ofe purple; Nce 003), Odogolo (Ede ofe green ; Nce 002) and Ugwuta (Ede-India Nce 001) at average weight of 25-35 g per cormel and the sub - plots /treatments were three plant extract: Siam weed leaves extract, Neem leaves extract and *Eucalyptus* leaves extract all at 100% concentration, and an inorganic fungicide (Ridomil Gold 66 WP plus (active ingredient (a.i) 12% metalaxyl M and 60% copper hydroxide) (positive control) and no fungicide (Negative control assigned to each sub - plot as treatments). The treatments were randomly assigned to each plot in each block/replicate. The plant extracts at 100% concentration and Ridomil gold at 50 g per 16 litres of water were applied with knap sack sprayer (6.25 g) per 2 litres of water at the rate of 25 kg a.i per hectare (ha). An insecticide (Attacke 2.5 emulsifiable concentrate (EC) a.i lambdacyhalothrin was sprayed at the rate of 800 ml in 100 litres of water per hectare to check foliar taro insect pest infestations such as taro aphid, (*Myzus persicae*), Taro plant hopper (*Tarophagus proserpina*, Mealybugs (*Planococcus spp*). All sprays were usually done in the early morning hours in order to avoid much wind effect on spray drift and sunlight effect on botanicals at the manifestation of early symptoms of taro leaf blight disease in the field.

Cultural operations and plots maintenance

Experimental field was cleared, ploughed, harrowed followed by making of crest of mound with hoe after dividing of the entire field into blocks and plots. Prior to mound preparation, 15 tons/ha of well cured broiler manure was broadcast uniformly and incorporated into the soil before mounding for good taro establishment. The taro cultivars cormels at average weight of 25-35 g/cormel and mound were sown at depth of 5 - 6 cm in the soil. The plant population of 15 stands per plot (17,778 stands per ha) were used. The supplying was done three to four weeks after planting (WAP). Weeds were manually managed with hoe (hoe weeding) and hand picking where necessary at

3 - 4 times at two months interval. The second dose 15 tons/ha of broiler manure was applied at 7 - 8 weeks after planting followed immediately by earthing up (re mounding) for proper taro growth and development. The taro tubers were harvested manually with hoe at full maturity and senescence during dry period in October (early dry season period).

Soil samples collection

Field soil samples at (0-15 cm) depth were randomly collected with soil auger and taken to the Department of Soil Science, Laboratory unit for basic physicochemical routine analysis such as soil textural class, soil pH, organic matter (%), Total copper (Cu), Total lead (Pb), Total arsenic (As) (mg/ kg) and cation exchange capacity (CEC).

Agro- meteorological data collection

Agro-meteorological records for the year of study was collected at the Faculty of Agriculture, Meteorological center, University of Nigeria, Nsukka.

Soil temperature collection

Six soil thermometers were placed at 0-5 cm depth randomly in the field around 12 noon at each scheduled data collection for soil temperatures collection in all field experiments.

Field Rain water pH collection

Rain water P^H was collected from the beakers randomly placed in the taro field for rain water collection at the scheduled data collection (30 days intervals. Rain water P^H was determined at the Department of Soil Science Soil Science Laboratory of University of Nigeria, Nsukka in all field experiments.

Data collection

Data on leaves growth and disease parameters were collected from five randomly selected and tagged sampling stands from the central row. Data were collected on number of taro leaves/stand, disease incidence, disease severity on 5 point scale (0-4 scale) and yield attributes.

Disease incidence

The percentage ratio of the number of the leaf blighted stands over the total number of stands /plots at 30, 60, 90 120 and 150 days after planting were recorded

$$\text{Disease incidence (\%)} = \frac{\text{No of infected plants}}{\text{Total number of plants/plot}} \times \frac{100}{1}$$

Disease severity

This was estimated by scoring at intervals on a 5-point scale (0 - 4 scale) designed in the course of study where severity score ranges (%) (Table 1) was determined by area of taro leaves blighted over the total area of plant leaves multiplied by 100 (%) as described by Chaube and Pundihir, (2005); Omeje *et al.*, (2015).

Table 1: Disease severity score range (0 - 4) 5 points scale

Scale	Severity score range	Interpretation
0	<1	No severity
1	1-25	Low severity
2	26-50	Moderate severity
3	51-75	High severity
4	>75	Highest severity

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

Yield attributes: Yield data were collected after harvest on number of cormels/stand, cormels weight (kg)/stand, corm weight (kg)/stand, corm size (cm)/stand, total tuber yield (kg)/stand and total tuber yield/ha:

Data Analysis

Data collected were subjected to analysis of variance (ANOVA) by using Genstat Release 10.3DEsoftware (Genstat, 2011), and Fisher's least significant difference (F-LSD) was used to compared treatment means where significance was observed at 5% probability level as describe by Obi, (2002).

RESULTS

Basic Physicochemical properties of the experimental soil

The soil physicochemical properties of the experimental field (Table 2) showed a sandy clay loam textural class. Soil pH was slightly acid with pH of 4.80. The organic carbon and organic matter (%) were low (0.92 and 1.58), respectively. The cation exchange capacity was relatively high (20.80 meq/100 g soil), while the total arsenic, copper and lead were also low (0.17, 0.44 and 0.13 mg /kg), respectively.

Average rain water pH and Soil temperature (°C) conditions of the experimental field (30 - 150) days after planting.

Table 3 showed the average rain water pH and soil temperature of the experimental field. The average rainfall pH condition showed optimal range from pH 4.8 -5.9 of

slightly acidic to near neutral point throughout the trial periods, while the soil temperature also showed moderate to high temperature range from 28.28 - 39.50°C.

Agro-Meteorological data showing total monthly rainfall (mm), Rainy days, maximum and minimum temperature (°C), and Relative humidity (%) of the study year

The weather record in the experimental year, 2025 is shown in (Table 4). There were marked variations of climatic factors. Rainfall distribution revealed bimodal rainfall pattern with peak in July (283.96 mm). Every month recorded rainy days except January and February. A remarkable established rainfall was experienced from April - October with some periods of drought. The highest mean maximum and minimum monthly temperature was recorded in March (32.86°C and 22.58°C), while the least mean maximum and minimum monthly was also recorded in March and December (25.35°C and 19.39°C), respectively. The relative humidity for the year were recorded high in September and October (77%), while the least relative humidity was recorded in March and December (62.94% and 60.75%), respectively. However, the relative humidity in the year could not be followed closely with rainfall and relative humidity relationship which increased with increasing rainfall and decreased with the increasing temperature.

Effect of cultivars and botanicals on number of leaves per taro (*Colocasia esculenta* L.) plant stand recorded at 30 to 150 days after planting

Table 5 shows the main effect of cultivars and botanicals on number of plant leaves at 30-150 days after planting (DAP). There were significant ($P < 0.05$) differences among the cultivars of *Colocasia esculenta* L. on number of leaves/stand during the study periods except at 120 and 150 days after planting. Ugwuta cultivar recorded the highest number of leaves per plant stand (3.60 and 15.90), while Nachi cultivar had the least number of leaves per plant stand (3.30 and 5.50) at 30 – 60 days after planting, respectively. At 90 days after planting, Odogolo cultivar recorded the highest significant number of plant leaves (21.10), while Nachi cultivar had the least number of plant leaves per stand (11.90). However, the Odogolo cultivar maintained the highest non - significant ($P > 0.05$) differences on number of plant leaves per stand (21.50 and 14.90), While Ugwuta cultivar had the least number of plant leaves (19.80 and 14.70) at 120 and 150 days after planting, respectively. Among the botanicals, there were significant ($P < 0.05$) differences on number of plant leaves per t stand throughout the sampling periods. The Neem treated plots significantly had the highest number of leaves per plant stand (3.70) at 30 days after planting. Moreso, the Ridomil gold treated stands consistently recorded the highest significant ($P < 0.05$) differences on number of leaves per plant stand (12.00, 21.90, 28.70 and 21.60),

Table 2: Basic Physicochemical properties of the experimental soil.

Properties	Value
Particle size distribution (%)	
Clay	22.64
Silt	6.00
Fine sand	28.18
Coarse sand	43.18
Textural class	Sandy Clay Loam
Chemical Properties	
pH(H ₂ O)	4.80
pH(KCL)	4.10
Organic carbon (%)	0.92
Organic matter (%)	1.58
Exchangeable acidity (meq/100g soil)	20.80
As	0.17
Cu	0.44
Pb	0.31

Source: Soil Science laboratory unit, Department of Soil Science, University of Nigeria, Nsukka

Table 3: Average rain water pH and Soil temperature (°C) conditions in the experimental field (30 - 150) days after planting.

Sampling days after planning	Rain water PH	Soil temperature (°C)
30	5.9	37.16
60	6.3	35.00
90	6.6	28.20
120	5.0	37.00
150	4.8	39.50

Source: Department of Agricultural Technology, Research farm, Espoly, Iwollo

Table 4: Agro –Meteorological data showing total monthly rainfall (mm), Rainy days, maximum and minimum temperature (°C), and Relative humidity (%) of the study year.

Month	Total rainfall (mm)	Rainy days	Mean temperature (°C)		Relative Humidity (%)
			Maximum	Minimum	
January	0.00	0.00	31.23	20.55	75.00
February	0.00	0.00	32.81	22.18	75.00
March	38.10	5.00	32.86	22.58	72.74
April	183.81	10.00	30.67	22.30	74.00
May	198.63	11.00	29.52	21.61	74.77
June	168.60	11.00	27.67	21.17	75.67
July	283.96	19.00	28.35	20.31	74.90
August	219.18	12.00	28.53	20.36	76.13
September	197.60	16.00	29.63	20.50	77.00
October	167.90	11.00	29.65	20.74	77.00
November	41.91	2.00	30.37	21.70	77.00
December	15.75	2.00	25.35	19.39	66.77
Total	1537.28	101.00	354.42	253.69	895.98
Mean	128.11	8.42	29.54	21.14	74.67

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

while the Control treated stands had the least number of plant leaves per stand (9.80, 10.90, 15.20, and 9.60) at 60 -150 days after planting, respectively. Interaction effect of cultivars and botanicals on the number of taro leaves per stand showed significant ($P < 0.05$) differences throughout the sampling periods except at 90 days after planting (Table 5). Interaction effect of Nachi and Neem recorded the highest number of taro leaves per stand (3.90), Odogolo cultivar and control treated plots had the least number of taro leaves per stand (2.10) at 30 days after planting. At 60 days after planting, Ugwuta cultivar and Ridomil gold interaction had the highest significant ($P > 0.05$) different effect on number of taro leaves per stand

(18.60), while Odogolo cultivar by Neem and control treated plots recorded the least number of taro leaves per stand (4.70). However, at 90 DAP, Ugwuta cultivar and Ridomil gold non- significantly ($P > 0.05$) had the highest number of taro leaves/stand, while Odogolo cultivar and control interaction had the least number of taro leaves per stand (9.10).

At 120 and 150 days after planting, Nachi cultivar and Ridomil gold interaction maintained the highest significant number of taro leaves per stand (30.10, and 20.70), while Ugwuta cultivar and control treated plots also maintained the consistent highest number of taro leaves per stand (12.30 and 8.10), (Table 6).

Table 5: Effect of cultivars and botanicals on number of leaves per taro (*Colocasia esculenta* L.) plant stand recorded at 30 - 150 days after planting.

	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
Cultivar					
Nachi	3.30	5.50	11.90	20.30	14.80
Odogolo	2.80	10.90	21.10	21.50	14.90
Ugwuta	3.60	15.90	18.90	19.80	14.70
F-LSD _(0.05)	0.2	0.7	2.1	N.S	N.S
Botanical treatment					
Ridomil gold	3.00	12.00	21.90	28.70	21.60
<i>Eucalyptus</i>	3.20	10.90	18.10	19.30	14.00
Neem	3.70	10.50	17.80	19.90	14.80
Siam weed	3.30	10.90	17.90	19.50	13.90
Control	3.00	9.50	10.90	15.20	9.60
Grand mean	3.20	10.80	17.30	20.50	14.80
F-LSD _(0.05)	0.2	0.9	2.7	2.6	2.3
C.V. (%)	6.6	8.4	15.9	13.2	16.2

DAP= Days after planting, F-LSD_(0.05) = Fisher's least significant difference at 0.05 probability level, CV %= Percentage coefficient of variation, NS= Not significant at 0.05 probability level.

Table 6: Interaction effect of cultivars by botanicals on number of leaves per taro (*Colocasia esculenta* L.) plant stand recorded at 30 - 150 days after planting.

Cultivar	Botanical	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
Nachi	Ridomil gold	3.10	11.90	24.00	30.10	20.70
	<i>Eucalyptus</i>	3.20	11.50	22.00	23.60	17.70
	Neem	3.90	11.50	19.00	18.90	13.10
	Siam weed	3.20	11.30	18.70	19.30	12.70
	Control	3.20	8.10	11.00	15.60	9.60
Odogolo	Ridomil gold	2.30	5.60	15.50	26.10	20.30
	<i>Eucalyptus</i>	2.90	6.30	11.30	17.60	12.30
	Neem	3.60	4.70	11.70	18.90	14.30
	Siam weed	3.10	6.30	12.00	21.10	15.30
	Control	2.10	4.70	9.10	17.70	11.20
Ugwuta	Ridomil gold	3.60	18.60	26.20	30.00	23.80
	<i>Eucalyptus</i>	3.50	14.70	21.00	16.60	12.00
	Neem	3.60	15.20	22.70	21.80	16.90
	Siam weed	3.70	15.00	23.10	18.10	13.70
	Control	3.70	15.80	12.50	12.30	8.10
	Grand mean	3.20	10.80	17.30	20.50	14.80
	F-LSD _(0.05)	0.4	1.5	N.S	4.8	4.0
C.V. (%)	6.6	8.4	15.9	13.2	16.2	

DAP= Days after planting, F-LSD_(0.05) = Fisher's least significant difference at 0.05 probability level, CV %= Percentage coefficient of variation, NS= Not significant at 0.05 probability level.

Effect of cultivars and botanicals on disease incidence (%) of taro (*Colocasia esculenta* L.) recorded at 60 to 150 days after planting.

The effect of cultivars and botanicals on disease incidence were shown in (Table 7). There were no significant ($P > 0.05$) different effect on disease incidence (%) across the taro cultivars at the trial periods except at 90 days after planting. However, at 90 days after planting, Ugwuta cultivar recorded the highest significant disease incidence (%) (85.90(9.2)) followed by Odogolo (72.40(8.2)), while the least disease incidence (25.70(7.1)) was recorded by Nachi cultivar during the trial period. Among the botanicals, there were significant ($P < 0.05$) different effect on disease incidence (%) throughout the trial periods except at 60 days after planting. However, Ridomil Gold treated stands

consistently recorded the least disease incidence (25.70(4.9); 9.10(2.5) and 3.30(1.4)), while the highest disease incidence (100(10.00)) were consistently recorded by the control treated stands throughout the sampling periods at 90-150 days after planting, respectively.

Interaction effect of cultivars by botanicals on disease incidence (%) of Taro (*Colocasia esculenta* L.) recorded at 60 to 150 days after planting.

The interaction effect of taro cultivars by botanicals on disease incidence (%) as presented in Table 8 showed no significant ($P > 0.05$) different effect throughout the sampling periods at 60 – 150 days after planting. Odogolo cultivar by Neem had the least disease incidence (0.0(0.7)), while Ugwuta by Control recorded the highest

Table 7: Effect of cultivars and botanicals on disease incidence (%) of taro (*Colocasia esculenta* L.) recorded at 60 - 150 days after planting.

	60 DAP	90 DAP	120 DAP	150 DAP
Cultivar				
Nachi	1.90 (1.1)	57.30 (7.1)	62.40 (7.4)	41.90 (5.8)
Odogolo	3.80 (1.5)	72.40 (8.2)	64.20 (6.5)	42.10 (5.9)
Ugwuta	3.90 (1.5)	85.90 (9.2)	66.20 (7.7)	43.20 (5.8)
F-LSD _(0.05)	N. S	1.2	N. S	N. S
Botanical treatment				
Ridomil gold	2.30 (1.3)	25.70 (4.9)	9.10 (2.5)	3.30 (1.4)
<i>Eucalyptus</i>	1.90 (1.1)	84.30 (9.1)	76.20 (7.8)	39.00 (6.3)
Neem	2.20 (1.1)	79.50 (8.8)	70.70 (7.5)	40.60 (6.4)
Siam weed	2.90 (1.4)	69.90 (8.0)	66.00 (8.1)	29.20 (5.4)
Control	6.70 (2.1)	100.00 (10.0)	100.00 (10.0)	100.00 (10.0)
Grand mean	3.20 (1.4)	71.90 (8.2)	64.40 (7.2)	42.40 (5.9)
F-LSD _(0.05)	N.S	1.6	1.9	0.8
C.V. (%)	92.5	19.8	27.1	14.8

DAP= Days after planting, F-LSD_(0.05) =Fisher's least significant difference at 0.05 probability level, CV %= Percentage coefficient of variation, NS= Not significant at 0.05 probability level. Note: Mean separation was applied to the square root transformed values enclosed in parentheses

Table 8: Interaction effect of cultivars by botanicals on disease incidence (%) of taro (*Colocasia esculenta* L.) recorded at 60 - 150 days after planting.

Cultivar	Botanical	60 DAP	90 DAP	120 DAP	150 DAP
Nachi	Ridomil gold	2.60 (1.4)	21.00 (4.9)	7.00 (2.4)	0.00 (0.7)
	<i>Eucalyptus</i>	0.00 (0.7)	89.50 (9.5)	73.40 (8.6)	41.70 (6.5)
	Neem	6.70 (1.9)	86.40 (9.3)	73.30 (8.6)	28.70 (5.4)
	Siam weed	0.00 (0.7)	65.10 (7.7)	77.30 (8.8)	45.80 (6.8)
	Control	0.00 (0.7)	100.00 (10.0)	100.00 (10.0)	100.00 (10.0)
Odogolo	Ridomil gold	7.10 (2.0)	14.00 (3.7)	11.30 (2.9)	4.90 (1.8)
	<i>Eucalyptus</i>	5.60 (1.8)	63.30 (7.8)	78.40 (6.2)	42.20 (6.5)
	Neem	0.00 (0.7)	62.10 (7.6)	53.90 (7.4)	24.10 (4.9)
	Siam weed	4.40 (1.7)	47.20 (6.6)	79.30 (6.2)	38.30 (6.2)
	Control	2.20 (1.4)	100.00 (10.0)	100.00 (10.0)	100.00 (10.0)
Ugwuta	Ridomil gold	4.80 (1.8)	42.20 (6.4)	9.10 (2.2)	4.90 (1.8)
	<i>Eucalyptus</i>	0.00 (0.7)	86.60 (9.3)	60.30 (7.8)	33.00 (5.8)
	Neem	0.00 (0.7)	90.00 (9.5)	70.90 (8.5)	34.90 (5.9)
	Siam weed	4.20 (1.7)	97.20 (9.9)	71.80 (8.5)	37.70 (6.2)
	Control	10.40 (2.9)	100.00 (10.0)	100.00 (10.0)	100.00 (10.0)
	Grand mean	3.20 (1.4)	71.90 (8.2)	64.40 (7.2)	42.40 (5.9)
	F-LSD _(0.05)	N.S	N.S	N.S	N.S
C.V. (%)	102.5	19.8	27.1	14.8	

DAP= Days after planting, F-LSD_(0.05) =Fisher's least significant difference at 0.05 probability level, CV %= Percentage coefficient of variation, NS= Not significant at 0.05 probability level. Note: Mean separation was applied to the square root transformed values enclosed in parentheses

disease incidence (10.40(2.9) interaction effects at 60 days after planting. The interaction of Nachi cultivar by Ridomil recorded the least no significant ($P > 0.05$) different effect on disease incidence (21.00(4.9), 7.00(2.4) and 0.90(0.7), while the least disease incidence (100% (10.00) were recorded by Nachi by control, Odogolo by control and Ugwuta by control interaction during the trial periods at 90 – 150 days after planting, respectively.

Effect of cultivars and botanicals on severity (%) of *Phytophthora* blight disease of taro (*Colocasia esculenta* L.) recorded at 60 to 150 days after planting

The effect of cultivars and pesticides showed significant

($P < 0.05$) different on disease severity (%) throughout the sampling periods except at 60 days after planting (Table 9). However, Nachi cultivar consistently had the least significant ($P < 0.5$) different on disease severity (%) (19.50(4.1), 20.30(3.9) and 14.10(3, 3), while the highest disease severity (29.30(5.1), 33.80(5.3) and 22.70(4.3) were also consistently recorded by Ugwuta cultivar at 90 – 150 days after planting, respectively. On botanical pesticides, there were significant ($P < 0.05$) different effect on disease severity among the pesticides used during the trial periods except at 60 days after planting. However, the Ridomil Gold treated stands consistently scored the least mean significant ($P < 0.05$) disease severity (4.10(1.9), 0.70(1.0) and 0.30(0.8), while the control stands scored

Table 9: Effect of cultivars and botanicals on severity (%) of *Phytophthora* blight disease of taro (*Colocasia esculenta* L.) recorded at 60 -150 days after planting.

	60 DAP	90 DAP	120 DAP	150 DAP
Cultivar				
Nachi	0.80 (0.9)	19.50 (4.1)	20.30 (3.9)	14.10 (3.3)
Odogolo	0.90 (1.0)	27.40 (4.7)	21.70 (4.2)	16.10 (3.5)
Ugwuta	3.30 (1.4)	29.30 (5.1)	33.80 (5.3)	22.70 (4.3)
F-LSD _(0.05)	N.S	0.8	0.4	0.4
Botanical treatment				
Ridomil gold	1.60 (1.2)	4.10 (1.9)	0.70 (1.0)	0.30 (0.8)
<i>Eucalyptus</i>	1.40 (1.0)	27.50 (5.2)	18.00 (4.2)	16.20 (3.9)
Neem	0.50 (0.9)	29.80 (5.5)	25.90 (5.0)	11.20 (3.3)
Siam weed	0.70 (0.9)	12.70 (3.4)	17.70 (4.2)	10.70 (3.3)
Control	4.00 (1.7)	52.90 (7.2)	63.80 (7.7)	49.90 (7.1)
Grand mean	1.70 (1.1)	25.40 (4.6)	25.20 (4.5)	17.70 (3.7)
F-LSD _(0.05)	N.S	1.0	0.5	0.5
C.V. (%)	89.5	23.0	11.1	14.4

DAP= Days after planting, F-LSD_(0.05) = Fisher's least significant difference at 0.05 probability level, CV % = Percentage coefficient of variation, NS= Not significant at 0.05 probability level. Note: Mean separation was applied to the square root transformed values enclosed in parentheses.

Table 10: Interaction effect of cultivars by botanicals on disease severity (%) taro (*Colocasia esculenta* L.) recorded at 60 - 150 days after planting.

Cultivar	Botanical	60 DAP	90 DAP	120 DAP	150 DAP
Nachi	Ridomil gold	1.50 (1.1)	2.90 (1.6)	0.20 (0.8)	0.00 (0.7)
	<i>Eucalyptus</i>	0.00 (0.7)	26.80 (5.1)	16.30 (4.1)	12.90 (3.6)
	Neem	1.50 (1.2)	31.60 (5.6)	14.60 (3.8)	8.30 (2.9)
	Siam weed	0.00 (0.7)	13.00 (3.3)	11.20 (3.4)	6.80 (2.7)
	Control	0.00 (0.7)	62.00 (7.9)	59.00 (7.7)	42.80 (6.6)
Odogolo	Ridomil gold	2.70 (1.4)	3.50 (1.6)	1.40 (1.2)	0.40 (0.9)
	<i>Eucalyptus</i>	4.30 (1.7)	26.30 (5.1)	23.40 (4.8)	14.80 (3.9)
	Neem	0.00 (0.7)	23.00 (4.8)	11.50 (3.4)	7.20 (2.7)
	Siam weed	1.70 (1.3)	8.40 (2.9)	12.90 (3.6)	8.40 (2.9)
	Control	3.30 (1.6)	36.80 (6.0)	59.10 (7.7)	49.80 (7.1)
Ugwuta	Ridomil gold	2.50 (1.6)	5.90 (2.5)	0.60 (1.0)	0.40 (0.9)
	<i>Eucalyptus</i>	0.00 (0.7)	29.40 (5.4)	26.60 (5.1)	21.00 (4.4)
	Neem	0.00 (0.7)	34.80 (5.9)	27.20 (5.2)	17.90 (4.2)
	Siam weed	0.40 (0.9)	17.70 (4.2)	16.80 (4.1)	16.90 (4.2)
	Control	6.90 (2.0)	59.70 (7.7)	73.10 (8.6)	57.30 (7.6)
	Grand mean	1.70 (1.1)	25.40 (4.6)	25.20 (4.5)	17.70 (3.7)
	F-LSD _(0.05)	N.S	N.S	0.8	N.S
C.V. (%)	89.5	23.0	11.1	14.4	

DAP= Days after planting, F-LSD_(0.05) = Fisher's least significant difference at 0.05 probability level, CV%= Percentage coefficient of variation, NS= Not significant at 0.05 probability level. Note: Mean separation was applied to the square root transformed values enclosed in parentheses.

the highest mean disease severity (52.90(7.2), 63.80(7.7) and 49.90(7.1), at 90 – 150 days after planting, respectively.

Interaction effect of cultivars by botanicals on disease severity (%) taro (*Colocasia esculenta* L.) recorded at 60 to 150 days after planting

The interaction effect of cultivars by botanicals as shown in (Table 10) scored non- significant ($P > 0.05$) different effect on mean disease severity (%) throughout the sampling periods except at 120 days after planting. Nachi cultivar and Ridomil gold combined effect non -significantly scored the least mean disease severity (2.90(1.6) and 0.00(0.7), while Ugwuta cultivar by control maintained the

highest mean disease severity score (59.70(7.7), 57.30(7.6) at 90 and 150 days after planting, respectively. However, Nachi cultivar by Ridomil gold scored the least significant ($P < 0.05$) mean disease severity (0.20(0.8), while the highest mean disease severity (73.10(8.6) interaction was scored by Ugwuta cultivar and control treated stands at 120 days after planting (Figure 1a & 1b).

Effect of cultivars and botanicals on yield components (kg/stand) of taro (*Colocasia esculenta* L.) recorded per plant and hectare basis (t/ha).

The result in (Table 11) shows the main effect of taro cultivars and botanical pesticides on cormels number, cormel weight, corm circumference (cm), corm weight and

Table 11: Interaction effect of cultivars by botanicals on yield components (kg/stand) of taro (*Colocasia esculenta* L.) recorded on plant stand and hectare basis (t/ha).

	Yield components per stand				Hectare equivalent			
	No of cormels	Cormel weight (kg)	Corm circumference (cm)	Corm weight (kg)	Total tuber yield (kg)	Cormel weight (t/ha)	Corm weight (t/ha)	Total tuber yield (t/ha)
Cultivar								
Nachi	15.00	0.44	22.80	0.25	0.69	7.90	4.30	12.20
Odogolo	24.50	1.08	25.10	0.45	1.53	19.20	8.00	27.20
Ugwuta	15.60	0.79	24.10	0.41	1.20	14.10	7.30	21.40
F-LSD _(0.05)	2.1	0.11	1.1	0.06	0.14	2.0	1.0	2.5
Botanical treatment								
Ridomil gold	22.90	0.86	25.90	0.41	1.27	18.70	7.90	26.70
<i>Eucalyptus</i>	16.90	0.76	24.40	0.41	1.17	13.60	7.20	20.80
Neem	18.40	0.76	23.40	0.37	1.14	13.60	6.70	20.20
Siam weed	18.90	1.05	25.20	0.45	1.50	15.20	7.30	22.50
Control	14.70	0.42	21.10	0.21	0.63	7.50	3.70	11.20
Grand mean	18.40	0.77	23.90	0.37	1.14	13.70	6.60	20.30
F-LSD _(0.05)	2.7	0.14	1.4	0.07	0.18	2.5	1.3	3.3
C.V. (%)	15.1	19.0	6.0	20.8	16.8	19.0	20.8	16.8

No = Number, Kg = Killogram, Cm = Centimeter, T/ha = Ton per hectare, F-LSD_(0.05) = Fisher's least significant difference at 0.05 probability level, CV % = Percentage coefficient of variation.

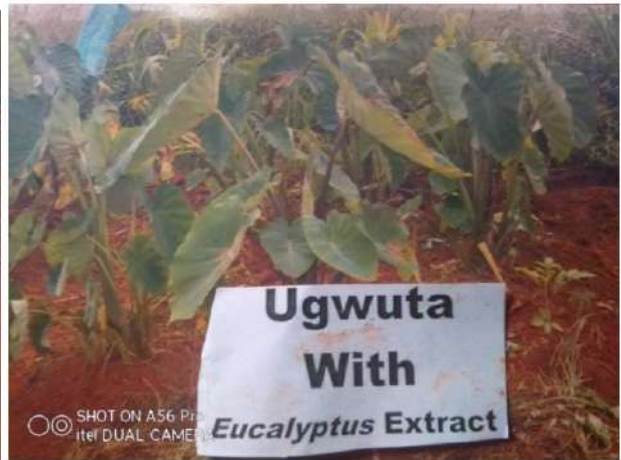
Table 12: Interaction effect of cultivars by botanicals on yield components (kg/stand) of taro (*Colocasia esculenta* L.) recorded on plant stand and hectare basis (t/ha).

Cultivar	Botanical	Yield components per stand				Hectare equivalent			
		No of cormels	Cormel weight (kg)	Corm circumference (cm)	Corm weight (kg)	Total tuber yield (kg)	Cormel weight (t/ha)	Corm weight (t/ha)	Total tuber yield (t/ha)
Nachi	Ridomil	17.60	0.57	24.71	0.29	0.86	10.60	5.10	15.70
	<i>Eucalyptus</i>	16.40	0.57	25.57	0.25	0.81	9.90	4.50	15.40
	Neem	16.30	0.46	25.19	0.28	0.87	8.20	5.00	13.30
	Siam weed	15.50	0.59	23.73	0.27	0.75	10.20	4.30	14.50
	Control	11.30	0.39	21.35	0.25	0.64	7.00	2.70	9.70
Odogolo	Ridomil	29.60	1.69	26.95	0.59	2.28	30.10	10.40	40.50
	<i>Eucalyptus</i>	22.20	0.87	24.92	0.47	1.34	15.50	8.30	23.80
	Neem	22.00	0.86	25.08	0.53	1.39	17.90	9.40	27.30
	Siam weed	24.90	0.77	24.75	0.48	1.25	13.80	8.40	22.20
	Control	23.50	0.45	23.53	0.19	0.64	8.00	3.40	11.40
Ugwuta	Ridomil	21.40	1.15	25.97	0.39	1.54	15.40	6.90	25.30
	<i>Eucalyptus</i>	12.10	0.85	22.61	0.46	1.31	15.10	8.20	23.30
	Neem	17.00	1.01	25.21	0.53	1.54	20.40	9.50	30.90
	Siam weed	16.20	1.12	21.69	0.41	1.53	19.90	7.20	27.10
	Control	9.30	0.22	18.43	0.15	0.37	3.90	4.90	8.80
	Grand mean	18.40	0.77	23.98	0.37	1.14	13.70	6.60	20.30
	F-LSD _(0.05)	N.S	0.25	2.42	N.S	0.32	4.4	N.S	5.7
	C.V. (%)	15.1	19.0	6.0	20.8	16.8	19.0	20.8	16.8

No= Number, Kg= Killogram, Cm = Centimeter, T/ha= Ton per hectare, F- LSD_(0.05) = Fisher's least significant difference at 0.05 probability level, CV %= Percentage coefficient of variation, NS= Not significant at 0.05 probability level.



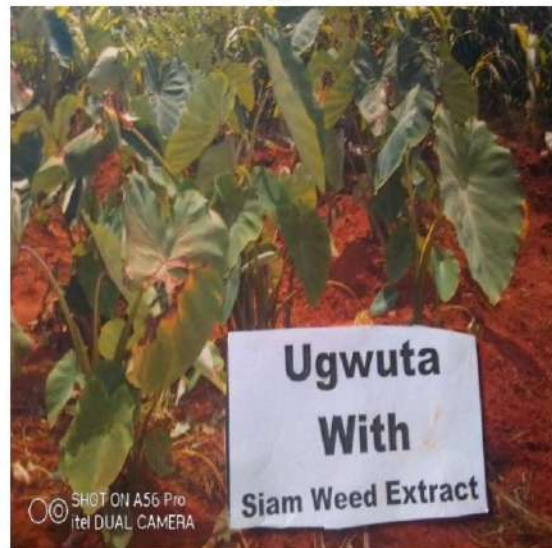
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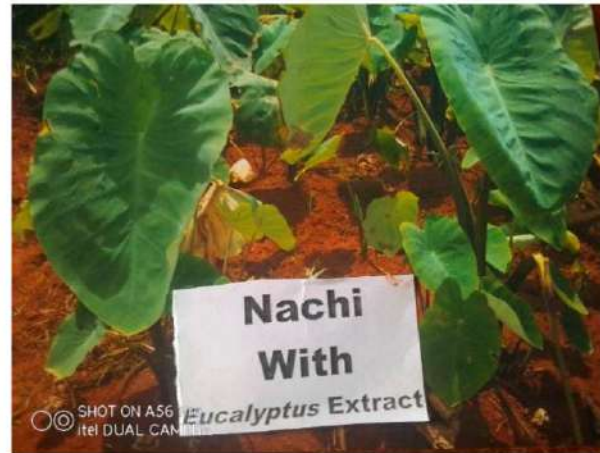
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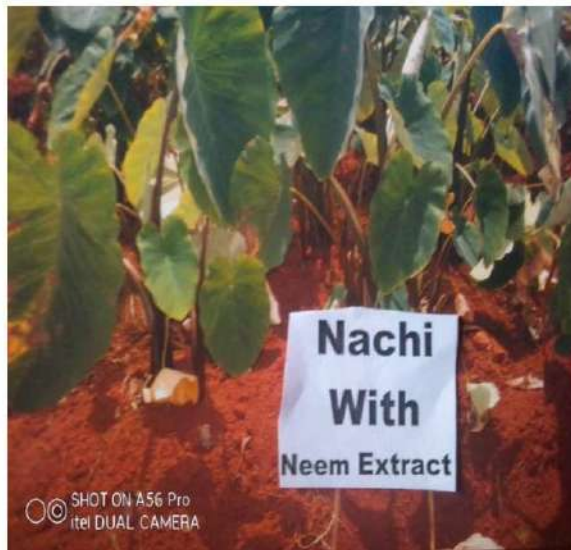
Figure 1a: Effectiveness of the selected botanicals on taro cultivars leaves against Phytophthora leaf blight disease at 120 days after planting. Official Publication of Direct Research Journal of Agriculture and Food Science: Vol. 13; 2025; ISSN: 2354-4147



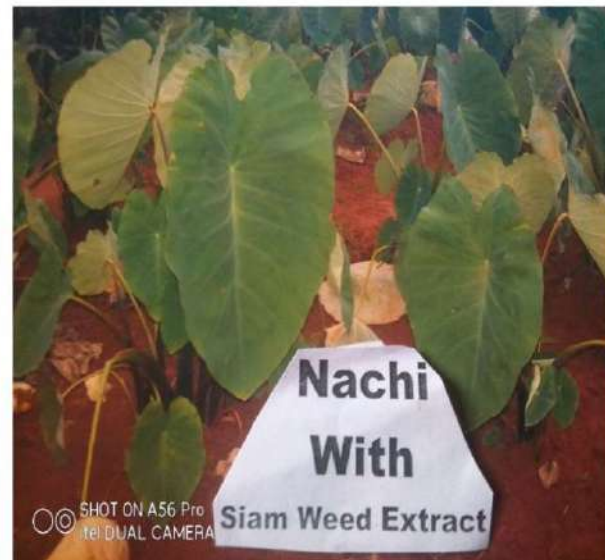
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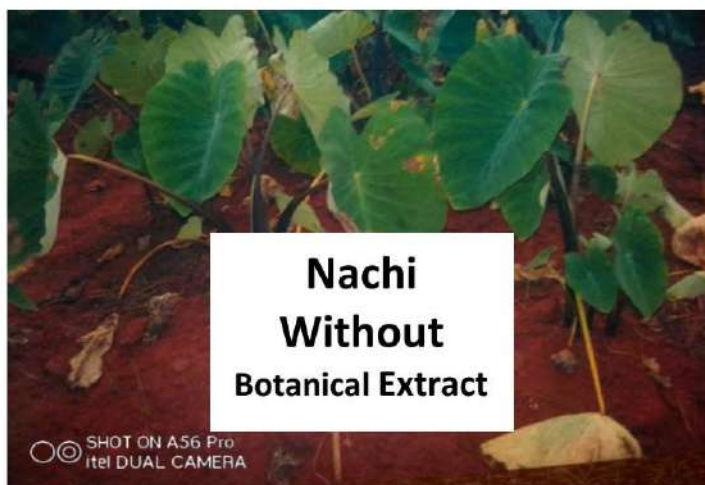
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Figure 1b: Effectiveness of the selected botanicals on taro cultivars leaves against Phytophthora leaf blight disease at 120 days after planting. Official Publication of Direct Research Journal of Agriculture and Food Science: Vol. 13; 2025; ISSN: 2354-4147

total tuber yield (kg/stand) at harvest. The main effect of cultivars on yield parameters significantly ($P < 0.05$) varied among the taro cultivars. Odogolo cultivar consistently produced the highest significant ($P < 0.05$) number of cormels (24.5), cormel weight (1.08 kg/stand), corm circumference (25.10 cm), corm weight (0.45 kg/stand), and total tuber yield (1.53 kg/stand), while the least cormel number (15.00), cormel weight (0.44 kg/stand), corm circumference (22.8 cm), corm weight (0.24 kg/stand), and total tuber yield (0.69 kg/stand) were consistently maintained by Nachi cultivar at harvest. Among the botanicals, there were significant ($P < 0.05$) differences on yield parameters at harvest (Table 11). Ridomil gold treated plots consistently produced the highest significant ($P < 0.05$) cormel number (22.90), cormel weight (0.86 kg/stand), corm circumference (25.90 cm), corm weight (0.4 kg/stand) and total tuber yield (1.27 kg/stand), while the least cormels number (14.7), cormel weight (0.42), corm circumference (21.10 cm), corm weight (0.21 kg/stand) and total tuber yield (0.63 kg/stand) were also maintained by control treated plots at harvest.

On hectare equivalent (t/ha) as presented on Table 10, Odogolo cultivar consistently produced the highest significant ($P < 0.05$) differences on cormel weight (19.20 t/ha), corm weight (8.00 t/ha) and total tuber yield (27.20 t/ha). In contrast, the least yield indices on cormel weight (7.90 t/ha), corm weight (4.30 t/ha) and total tuber yield (12.20 t/ha) were produced by Nachi cultivar at harvest. Moreover, Ridomil gold consistently produced the highest significant ($P < 0.05$) yield indices on cormel weight (18.70 t/ha), corm weight (7.90 t/ha) and total tuber yield (26.70 t/ha), and the least yield indices, cormel weight (7.30 t/ha), corm weight (3.70 t/ha) and total tuber yield (11.20 t/ha) were maintained by the control treated taro stands.

Interaction effect of cultivars by botanicals on yield components (kg/stand) of taro (*Colocasia esculenta* L.) recorded on plant stand and hectare basis (t/ha).

The interaction effect of taro cultivars and botanical pesticides significantly ($P < 0.05$) varied on yield indices (kg/stand) except on number of cormels and corm weight as shown in (Table 12) at harvest. However, Odogolo cultivar and Ridomil gold consistently produced the highest significant ($P < 0.05$) yield indices on cormel weight (1.69 kg/stand), corm circumference (26.95 cm/stand) and total tuber yield (2.28 kg/stand), while the least cormel weight (0.22 kg/stand), corm circumference (18.43 cm) and total tuber yield (0.37 kg/stand) were produced from Ugwuta cultivar by control treated stands at harvest". On hectare equivalent (t/ha) as shown in (Table 11), there were significant ($P < 0.05$) differences on yield indices except on corm weight (t/ha) at harvest. The interaction effect of Odogolo cultivar by Ridomil gold consistently had the highest cormel weight (30.10 t/ha), corm weight (10.40 t/ha) and total tuber yield (40.50 kg/ha), while the least cormel weight (3.90 t/ha), corm weight (4.90 t/ha) and total tuber yield (8.80 t/ha) were produced from Ugwuta cultivar by

control interaction effect at harvest.

DISCUSSION

Globally, the production and consumption systems of taro are increasing exponentially both at home and public social functions among the low and rich resource classes due to its high nutritional, delicacy, medicinal, industrial and socio-economic benefits. *Phytophthora colocasiae* and post-harvest rot pathogens are the most serious challenges among taro producers, marketers and processors, thereby affecting the quantitative, qualitative and functional properties of *Colocasia esculenta* (L.) cultivars globally.

Basic physicochemical properties of the experimental soil

The low values on organic carbon, organic matter, medium cation exchange capacity and slightly acidic nature of the experimental site on soil physicochemical properties may be attributed to anthropogenic activities and leaching loss due to the ultisol and slight acidic properties of the study area. Enwezor, (2013) reported that available exchangeable bases are rated medium in the humid climatic region of southeastern zone of Nigeria. This result also agrees with their reports that soils of southern parts of Nigeria belong to the soil group characterized by low soil pH, organic matter, organic carbon and exchangeable cations.

The low arsenic, copper and lead concentrations in the experimental soil site may be attributed to anthropogenic activities like fertilization, livestock manure and pesticide applications and geogenic nature/soil properties of the experimental site. Heavy metals are considered as a part of the soil, but they can cause severe damage to soils and plants when they are highly concentrated. Heavy metals vary in nature and the way they accumulate in soil or plant. Copper is an essential micro-element in soil and necessary for plants growth as co-factor enzymes. Its availability in agricultural soil is affected by soil pH in which it is more in acidic soil than in alkaline soil (Keiblinger *et al.*, 2018).

Its high accumulation in agricultural soil is mainly due to use of copper-based fungicides and other agro-based activities like inorganic/organic copper containing fertilizer applications. Copper toxicity in soil could significantly inhibit soil microbial activities especially soil microbial groups like Rhizobiales, destruct cell membrane and cause protein denaturation in microbes such as bacteria, actinomycetes, and fungi (Wange *et al.*, 2019) including reduction in biosynthesis of chlorophyll and crop yield. The copper levels in the experimental soil site is below the safe maximum permissible limit (MPL) of 5 - 36 mg/kg (FAO/WHO, 2011). Lead source in soil is through its geogenic contribution which reduces soil microbial activities. Its effects in soil include reducing soil

nutrients, microbial diversity and soil fertility (Osmani *et al.*, 2015), including earthworm mortality. Meanwhile, its accumulation in plant can cause DNA damage, reduction of chlorophyll contents due to destruction of roots and shoot systems, inhibition of seed germination (Gichner *et al.*, 2008). Lead toxicity in soil can be reduced through phytoremediation and phytostabilization strategies. Its natural mobility and availability are controlled by soil pH, organic matter contents, ionic exchange capacity and soil texture. Lead concentrations in the experimental soil site is very far below the safe maximum permissible limit of 85 mg/kg (FAO, 2009).

Arsenic concentrations in agricultural soil has become a global challenge (Kayode *et al.*, 2020). Its sources in agricultural soil can be both anthropogenic and natural (Smedley and Kinniburgh, 2002; Pigna *et al.*, 2015). Arsenic concentration in soil varies with geographical location and the nature of anthropogenic activities. The high concentration of arsenic is toxic and thus non-essential to plants. Arsenic toxicity to plants ranged from the inhibition of the root extensions to slowing the growth rate of plant (Mirza *et al.*, 2014), disruption of crop cells biochemical functions, loss of fertility in plants and yield reduction. It also impedes the general metabolisms of the crop (Finnegan and Chen, 2012). Arsenic levels in the experimental soil of 0.17 mg/kg is lesser below the safe maximum permissible limit of 4.5 mg/kg (FAO/WHO, 2011). This could be attributed to less use of arsenic containing pesticides, fertilizers, cattle dipping vats, chicken litters as a part of organic manure in the farmland, as well as no coal mining and non-ferrous smelting activities in the study area. It has been reported that arsenic occur in soil through non-ferrous smelting, gold mining, arsenic rich coal mining and application of arsenic containing insecticide/fertilizers (Masindi *et al.*, 2018).

Rainfall pH and soil temperatures of the experimental field

The rainfall pH and soil temperature conditions of the experimental field also showed marked variation on rainfall pH and soil temperatures like the weather records. The average rainfall pH of 6.6 and soil temperature of 28.20°C of the study field are at the range that promote taro leaf blight disease manifestation. Generally, soil temperature is one of the major factors in soil borne disease manifestation than air temperature. The soil temperature is greatly controlled by air temperature. *Phytophthora*, (2013) reported that the ideal environmental conditions for *Phytophthora* leaf blight epidemic growth and development depends on weather conditions of daily temperature (20 - 28°C), continuous intermittent heavy rainfall with optimal pH of 6.5. In this study, it was observed that the soil temperature from 29°C and above does not favor *Phytophthora colocasiae* manifestation in the growing area. The warmer weather at 120 - 150 days after planting with low humidity and zero – little rainfall are

relatively free of taro leaf blight epidemic during the study periods. This support the report that taro cultivars have to be planted in an open area and humid warmer areas for effective and efficient *Phytophthora colocasiae* disease management (Omeje *et al.*, 2020). Tarla *et al.*, (2014) also recommended dry season planting of taro cultivars for *Phytophthora colocasiae* disease escape when both soil and air temperatures will be at maximum conditions.

Weather condition report

The significant variations on agro-meteorological data conditions during the study might have contributed to the marked variations recorded on agronomic traits on growth, their disease conditions and yield attributes of taro cultivars,. The heavy rainfall from May to October was suitable for taro cultivation in the region. The temperature conditions recorded in July and August (28.35 and 28.53°C) support *Phytophthora* leaf blight disease expression on taro cultivars. This is in line with NRCRI, (2012) report that taro leaf blight disease occurs mostly at earlier part of June/July – August of each year depending on weather conditions and most especially high in the month of July due to continuous and steady light rains in the month . The annual rainfall of more than 1500 mm distribution relatively evenly throughout in the year has been observed by Rural Industries Research and Development Corporation (RIRDC, 2003) as a “common taro leaf blight enhancing condition”. The daily and night temperatures of 25-28°C and 20-21°C results in manifestation of *Phytophthora colocasiae* epidemic (Mbong *et al.*, 2013; Omane *et al.*, 2012). *Phytophthora colocasiae* outbreak and severity is weather dependent especially temperature, rainfall and humidity. However, the prolonged drought during the study periods at 120 - 150 days after planting (3rd - 4th quarters of the year reduced the disease incidence and severity and growth which may affect the tuber formation and subsequently to post-harvest attributes.

Effect of botanicals on growth attributes, disease parameters and yield indices of taro cultivars (*Colocasia esculenta* L.)

Botanicals greatly enhanced significant improvement on taro leaves growth, *Phytophthora* leaf blight field management and yields. The significant differences on growth attributes may be attributed to genotypic factors, cultural practices (disease management options), climatic factors (rainfall and temperature) and soil conditions in the study area. Growth attributes depend on the genotypic cultivar variations and field management options. Cultivar differences were highly significant in all the growth parameters measured most especially on plant leaves per stands. This is a very good indication of the existence of remarked genetic variation among the cultivars used in this study. Some taro cultivars may not produce much suckers

and long petioles at all even when all growth resource requirements are adequate. The significant differences on growth indices among the cultivars is in line with Singh, (1994) and Ogbonna and Orji, (2013) who observed cultivar differences among the taro cultivars on growth characters. The significant high number of leaves by Ugwuta cultivar at earlier stage growth cycle of the study showed its earliest field establishment, production of suckers and maturity compared to other taro cultivars, followed orderly by Odogolo and Nachi cultivars. The result was in consonance with a report by Omeje *et al.*, (2016) who observed earliest establishment of Ugwuta cultivar compared to other cultivars in the field. The late field establishment by Nachi and Odogolo indicates their delay on sucker formation and maturity.

The significant differences among the botanicals on growth attributes especially on leaves with Ridomil gold treated taro performing the best, followed by Neem, *Eucalyptus* and siam weed might be due to efficacy of tested pesticides on managing taro leaf blight disease, thereby promoting growth and health status of taro cultivars. This gives rise to more taro leaves compared to non - pesticide taro stands. NRCRI, (2012) has earlier reported that one of the effects of disease management on taro was to enhance growth and health status of the crop. These findings are in consonance with report by NRCRI, (2012) who reported less plant growth on untreated taro field, while Copper-based fungicides gave an improved growth on treated taro stands (NRCRI, 2012). Further, this study observed slow increase and fairly fixed number of taro leaves among the cultivars throughout the study. This is in line with Wilson, (1984) who reported that some taro cultivars produce high number of leaves at a certain growth stage. However, botanicals proved effective and promising pesticides for improved taro growth. This might be attribute to their phytochemical compounds such as tannin, flavonoids phenols, alkaloids, saponins etc. The presence of phytochemical compounds modifies the biochemical functions (Lawal *et al.*, 2015). La Ode Santiaji *et al.*, (2018) and Maria *et al.*, (2019) reported that natural compounds derived from plant extracts contain potent promising bioactive compounds which have a great potential in reducing infection conditions by *Phytophthora spp*, thereby leading to proper growth and health status of crops. Further, the bioactive compounds especially saponins, phenols, alkaloids, tannin, flavonoids are generally produced by plants mainly to counteract pathogens, herbivores, and hostile environmental conditions (Moses *et al.*, 2014).

The non-significant differences on interaction effects of cultivars by botanicals on growth parameters could be attributed to interaction of various factors of closely related or similar factors in the study area. Growth is a net result of various interaction of growth factors such as soil properties, climatic variables and agronomic practices (disease management, weeding regimes, tillage and earthing up practices, etc). It also includes the differences

on leaves and leaf stalks growth pattern for height behavior and various biochemical and metabolic activities at growth stage (Channappagouder *et al.*, 2008). Similarly, planting season, soil moisture and temperature conditions during the growth phase may delay sucker formation and petiole height resulting in less number of leaves and plant height (Omeje *et al.*, 2015). Taro growth is delayed during dry periods together with no disease progress in the field which indicates that taro growth and disease conditions are highly related to temperature conditions which is not preferable for taro and taro leaf blight growth at maximum temperature conditions.

The foliar disease symptoms appeared first around 60 days after planting. These were seen as lesions, wild fire blight, small brown water-soaked lesions and with orange host exudation, as well as yellowing around the blighted leaf regions. These were in line with the report of Onyeka *et al.*, (2011) and Mbong *et al.*, (2013). The non-significant of taro cultivars on disease incidence throughout the study except at 90 days after planting could be due to uncondusive weather conditions for taro leaf blight disease manifestation and cultivar variations. Improved cassava genotypes showed high tolerance to prevalent disease across Nigeria. Uchendu *et al.*, (2013) reported that genotypes respond differently to disease and pests across different environments. Ugwuta cultivar scored the highest disease incidence, while the Nachi cultivar was the least, followed by Odogolo cultivar. Mbong *et al.*, (2013) observed that taro cultivars are genetically varied and respond differently to pesticides spray. These results are in line with the reports of Ogbonna and Orji (2013) and Orji *et al.*, (2013) who found that Ugwuta and Odogolo in that order were the most susceptible cultivars to taro leaf blight disease, while Nachi cultivar was fairly resistant or tolerant to taro leaf blight disease. This suggests the possibility of improving taro cultivar traits by genotypic selection (Nwofia and Ojmelukwe, 2012). The significant disease incidence at 90 days after planting suggests that taro leaf blight is at its highest severity and peak period at 4 weeks after the disease symptoms manifestation in taro (Eze *et al.*, 2017). This could be the period when taro blight can cause its maximum damage to taro stands. The non-significant genotypic effect on disease incidence among the cultivars and less disease incidence at the 3rd - 4th quarters of the year may be due to long drought conditions during the periods. It is worthy to note that warmer and open environment with low relative humidity and zero - little rainfall are relatively free of taro leaf blight epidemic. Mbong *et al.*, (2013) observed that symptoms suggestive of taro leaf blight appeared on taro cultivars across many Southern regions of Nigeria, followed by disappearance of the symptoms with onset of dry period/drought in the field. This is an indication that taro leaf blight incidence and severity are weather dependent.

Botanicals significantly influenced the severity of taro leaf blight (TLB) throughout the sampling periods except at the initial spray schedule (60 days after planting).

Ridomil gold consistently scored the least disease severity, followed by siam weed, Neem, and *Eucalyptus* leaves extracts at 90, 120 and 150 days after planting. The significant variations could be due to pesticides potentials, cultivars response to pesticides, and the prevailing climatic variations (rainfall, temperature, wind action, etc. during the spray schedules. Jackson *et al.*, (1980) observed that the range of protectants and systemic fungicides have been found to provide effective management of taro leaf blight. This study supported the report of Ooka (1983) who found that copper-based fungicides effectively reduced disease incidence and severity of taro leaf blight than the control stands in Hawaii. It has been reported that Ridomil gold and Phosphoric acid (Foschek) are specific to Oomycete fungi - *Phytophthora colocasiae* leaf blight. However, botanicals, siam weed, Neem and *Eucalyptus* proved effective in taro leaf blight disease incidence and severity reduction. This could be attributed to the presence of bioactive compounds like tannin, saponin, flavonoids, alkaloids and phenols in the spray formulation. The presence of tannins, phenols, flavonoids, etc. in plant extracts has been reported to provide an alternative means of managing crop pathogens. The presence of tannin in plant extracts has been reported to possess fungicidal properties, thus serving as a defense mechanism in plants against herbivores, pathogens and hostile environment, as well as promoting the healing of wounds and inflamed mucous membrane (Okwu and Okwu, 2004). These results are in accordance with many researchers, although on different organisms, Neem leaf extracts against early blight and wilt disease of tomatoes caused by *Alternaria solani* and *Fusarium oxysporium*, respectively (Patil *et al.*, 2001; Hassanein *et al.*, 2008); Foliar spray of neem leaf extracts against mycelial growth of *Alternaria solani*, early blight of potato caused by *Alternaria alternata* (Babu *et al.*, 2000); Cashew nut shell (CNSL) extracts against *Phytophthora palmivora* caused by black pod rot on cocoa (La Ode Santiaji *et al.*, 2018). Gamguly, (1994) reported that aqueous neem leaf extracts inhibited the mycelial growth and spore germination of *Helminthosporium oryzae* and *Pyricularia oryzae* the causal agents of blast and brown spot of rice, respectively. The phytochemical active materials in siam weed (*Chromolaena odorata* L) leaf extracts contained alkaloids, phenols, flavonoids, saponins, anthraquinones, cardenoids and tannins which have biological properties as antifungal, antibacterial and nematicidal (Agaba *et al.*, 2015; Okpashi *et al.*, 2014; Lawal *et al.*, 2015). Also, botanical pesticides from *Eucalyptus* leaves produce *Eucalyptus* essential oils which have active ingredients of 1,8- cineole (26.4%), β -pinene (14.1) and p-cymene (10.20%) as the major natural compounds that contribute to its antioxidants, antifungal, antibacterial and larvicides (Sameza *et al.*, 2014)

The interaction effects of cultivars and botanicals on disease incidence and severity were not significantly varied throughout the study. This could be due to taro

genetic variations, climatic, pathogenic factors and pesticides potentials. The superiority of Nachi cultivar by Ridomil gold interaction on reduction of disease incidence and severity indicates the reduction of disease incidence and severity with resistant cultivar and pesticide spray interaction. These results are in support of report by NRCRI, (2012) that disease resistant cultivar with pesticides spray is one of the measures to reduce disease incidence and severity for effective taro field production. Mbong *et al.*, (2013) reported that taro cultivars varied in their response to pesticides treatments. It has been also reported that the use of botanicals in field disease management is highly limited due to their rapid degradation in the presence of high sunlight, rainfall and wind action (Eze and Ogbonna, 2011; Omeje *et al.*, 2020), high variability from one source or batch to another, and high selectivity to target organisms (Omeje *et al.*, 2020). The highly non-significant cultivars by botanicals interaction observed on disease severity clearly indicates that cultivars by pesticides interaction across the trial periods plays non-significant role in this crop. It also suggests that the efficacy on the various botanicals was similar across the taro genotypes Jackson *et al.*, (1980) has reported that Mancozeb was non-significant in taro disease management in Solomon Islands.

Genotypes play significant differences on crops yield improvement. The significant differences on yield parameters among the cultivars could be attributed to cultivar's genotypic endowments, variation on infection status and response to management options. Cultivar differences were highly significant for all the yield indices measured. This indicates the existence of remarked genetic variation among the cultivars used in this study. Nachi cultivar consistently had the least values in terms of yield and other associated yield traits measured due to its lowest number of cormels and corn circumference. Among the yield parameters measured, Odogolo cultivars had the highest corm weight, corm circumference followed by Ugwuta cultivar. Genotype also affected the number of cormels/stands. This result corroborates with the work of Ogbonna and Orji, (2013); Omeje *et al.*, (2015) who reported that Odogolo cultivar had the highest corm weight and the general variation among taro cultivars on yield traits. This could be attributed to its exhibition of relatively large stem base girth and number of cormels or secondary shoot number per stand which are basic indices of high yield. It has been reported that the most important goal in all taro production program is yield (Ivancic and Lebot, 2000). Plant stem base, number of secondary shoot/cormel number and height are important factors in taro cultivars yield. In this study, the cultivars that produced the highest number cormels/suckers also had the highest tuber yield, number of leaves and petioles/plant height. These results agree with IITA, (1990) that yield is determined not only by the amount of dry matter produced, but by certain growth factors such as number of leaves, leaf area/ size, plant height and secondary shoots habits.

These findings were in accordance with the work of Ali *et al.*, (2009) and Eruola *et al.*, (2012). The highest corm weight reported in this work by Odogolo cultivar is in accordance with Ogonnaya, (1983) and Singh, (1994) who observed that Odogolo cultivar had the widest stem girth and tallest taro plant height. High significant ($P < 0.05$) effect was observed in all yield parameters across the botanicals with Ridomil gold showing superiority among the pesticides. This could be due to their high efficacy on the management of *Phytophthora colocasiae* outbreak, and cultivars potential response to pesticides. The superiority of Odogolo and Ugwuta cultivars could not only be genetic potential, but by disease management options tested. The increase in growth and health status of taro through pesticides spray might have contributed positively to high yield recorded.

The least yield and the associated yield attributes by Ugwuta under zero pesticides spray is a good indication of its high susceptibility to taro leaf blight (TLB), thereby leading to the least yields compared to other taro cultivars. Yield is drastically reduced by taro leaf blight epidemic. The high yield in this study is* an expression of the potency of pesticides in improving yields. These are in support of NRCRI, (2012) that taro disease management is a way to improve taro yield indices. The present study showed that the highest yield traits produced by Odogolo and Ugwuta suggest that these cultivars were the most susceptible to taro leaf blight and also responded positively to pesticides spray. Botanicals which are cheap, environmentally safe, high biodegradable, locally available exhibited remarkable management of taro disease development and may be considered promising alternative for protection of taro plants against *Phytophthora colocasiae* Racib with effective improvement on taro cultivars yields.

Conclusion

The study showed that the selected botanical extracts which are cheap, environmentally safe, highly biodegradable, locally available and non-food poisoning exhibited a remarkable management of *Phytophthora* leaf blight disease development. Botanicals found to be promising on the management of *Phytophthora* leaf blight and in order of their effectiveness and potentiality were as: Siam weeds, *Chromolaena odorata* Eucalyptus spp Neem, *Azadirachtaindica*. The botanicals are highly recommended to taro producers as an alternative natural and potential promising fungicides against *Phytophthora* leaf blight disease for effective improvement on taro growth, yields and to the common health danger of synthetic commercial fungicides. Also, the taro cultivars with any of the selected botanicals utilized are highly recommended for improved agronomic and *Phytophthora* leaf blight management.

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