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Climate change and sustainable management of taro (Colocasia esculenta (L.) Schott.) leaf blight in Western Highlands of Cameroon

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Abstract

Climate change is a change in the statistical distribution of weather over periods of time that range from decades to millions of years. An epidemic devastated taro (Colocasia esculenta) in West and Central Africa between 2005-2010 causing an estimated loss of over 70 billion FCFA to the Cameroonian economy followed by food insecurity, persistent price hikes and changes in feeding habits. The Ministry of Agriculture and Rural Development and the Ministry of Scientific Research and Innovation conducted surveys and wrote reports but no mitigation strategy was proposed. In this light, trials were conducted with a pre-packed fungicide (copper (II) oxide and metalaxyl) at 7, 14, 21 and 28 day spray frequencies. In another trial, taro was sown in December followed by constant irrigation and compared with rainy season planting in March. Data was typed in Excel and analysed with GENSTAT software while means were separated using the Least Significant Different at 5% probability. Results showed that a 28-day spray regime could be selected based on high yields of 60.44 t/ha, yield increase of 74.06, net benefit of 8.27 million FCFA/ha and a rate of return of 13.78. Results of irrigation gave yields of 61.81 t/ha and yield increase of 75.85 % with corresponding net benefits of 12 million FCFA/ha and a rate of return of 11.29. Consequently, early planting and monthly fungicide application can by proposed to farmers as these management methods are environmentally-friendly. In perspectives, further research in other agroecological zones and more active ingredients will be conducted.

Keywords*: taro leaf blight, Phytophthora colocasiae, spray frequency, planting date, sustainability, climate change*

Résumé

Le changement climatique est un changement de distribution statistique de la météorologie sur une période de temps qui varie d'une décennie à des millions d'années. Une épidémie du mildiou du taro (Colocasia esculenta) a ravagée cette culture en Afrique Occidentale et Australe de 2005 à 2010 causant une perte estimée à plus de 70 milliards de FCFA à l'économie camerounaise suivi par l'insécurité alimentaire, l'augmentation des prix et des changements des habitudes alimentaires. Le Ministère de l'Agriculture et du Développement Rural et le Ministère de la Recherche Scientifique et de l'Innovation ont conduit les enquêtes et ont écrit des rapports mais aucune méthode de mitigation n'a été proposée. Dans cette optique, les essais ont été conduits avec un fongicide mélangé au préalable (oxyde de cuivre (II) et métalaxyl) à une fréquence de pulvérisation de 7, 14, 21 et 28 jours. Dans un autre essai, le taro a été semé en décembre suivi d'une irrigation constante et comparé avec le semis en saison pluvieuse en mars. Les données ont été saisies sur Excel et le logiciel GENSTAT a été utilisé pour les analyses de variance alors que les moyennes ont été separés avec la methode de Plus Petite Difference Significative à la probabilité de 5%. Les résultats ont montré qu'une pulvérisation mensuelle peut être sélectionnée à cause d'un rendement élevé de 60,44 t/ha, une augmentation de rendement de 74.06%, un bénéfice net de 8,27 million FCFA/ha et une rentabilité de 13,78. Les résultats de l'irrigation ont donné un rendement de 61,81 t/ha et une augmentation de rendement de 75,85 % correspondant à un bénéfice net de 12 millions FCFA/ha et une rentabilité de 11,29. il ressort de ces travaux que les paysans peuvent utiliser les fongicides chaque mois ou semer le taro trois mois avant la période normale (mars) pour obtenir une bonne récolte. Ces deux méthodes ne nuisent pas à l'environnement. Dans un proche avenir, il serait souhaitable de conduire d'autres essais dans les zones agro écologiques hors des hautes terres de l'Ouest.

Mots clés : *mildiou du taro, Phytophthora colocasiae, fréquence de pulvérisation, date de semis, durabilité, changement climatique*

Introduction

Climate change is a change in the statistical distribution of weather over periods of time that range from decades to millions of years. It can be a change in the average weather conditions recorded for over 30 years or a change in the distribution of weather events around an average (e.g. greater or fewer extreme weather events). Climate change may be limited to a specific region, or may occur across the whole world. In recent usage, especially in the context of environmental policy, climate change usually refers to changes in modern climate (global warming). Climate change may be a change in temperature, rainfall, solar radiation and water vapour, atmospheric trace gases (CO_2, O_3, CH_4, etc.), resulting from land use/ land cover changes, -culminating into biodiversity loss, increased disease causing agents (in both plants and animals) and food insecurity (Anon., 1994). Taro Leaf Blight (TLB) (caused by *Phytophthora colocasiae Raciborski*) epidemic is a glaring example of climate change consequences in crop diseases in sub-Saharan Africa.

Cocoyam (*Colocasia spp* and *Xanthosoma spp*) is an important staple food across many developing countries in Africa, Asia and the Pacific. It is particularly important in Sub-Saharan Africa where the two most commonly cultivated species (*Colocasia esculenta (L.) Schott* and *Xanthosoma sagittifolium (L.) Schott*) are grown extensively (Onyeka, 2014). The cultivation of cocoyam in most African countries is essentially by small-scale resource-poor farmers with minimal input. These crops play very important roles in the livelihood of rural farmers, who often resort to cocoyam as an alternative source of their daily calories during periods of food scarcity and economic stress.

Taro (*Colocasia esculenta*) tolerates shade more than most tropical crops and is therefore grown in many agroforestry systems such as coffee (*Coffea spp*), cocoa (*Theobroma cacao*) and oil palm (*Elaeis guineensis*) (Mbong et al., 2013; Onyeka, 2014) . It gets ready in September just by the time primary and secondary schools reopen. It therefore assists parents in providing school needs for their young ones. In this regard, the timeliness of the crop is highly appreciated compared to coffee that is harvested in december. It is essentially cultivated by women, empowering them as men sell coffee and cocoa (Cheteu, 2014, pers. Comm.). Culturally, most ceremonies depend on this crop such as marriages, funerals and delivery ceremonies. In these ceremonies, taro tubers are cooked and eaten directly or pounded before consumption. Pounded taro (commonly called “achu” in the North West Region) is the main dish of many tribes in the Region. Taro leaf is a vegetable that is highly appreciated by Cameroonians (Brunt et al., 2001; Mbong et al., 2013).

In Santchou Sub Division, the crop is called paracetamol or saviour due to the important place it occupies in the feeding habits of the population. Taro is naturally tasty and therefore, can be eaten with satisfaction even when there is no money to prepare stew or buy other ingredients. Despite the importance of taro in the Cameroon society, the crop is given less attention in research compared to other roots and tubers such as potatoes and banana. TLB epidemic was a catastrophic event to Cameroonians and the lack of research funds can justify the timidity to bring lasting solutions. Limited funds to carry out taro research when the Consultative Group for International Agricultural Research classified taro as a minor crop some decades ago (Onyeka, 2014).

TLB caused 100 % yield losses in many production fields and an average of 80% national production was lost to the disease epidemic in 2010 (Guarino, 2010; Njie, 2010; Fontem and Mbong, 2011). At least, 413,051 t of taro tubers was lost, estimated at 70 billion FCFA (MINADER/DESA, 2010). This led to price hikes from 133 to 500 FCFA/kg in the country for “Ibo coco” cultivars. Consumers who could not afford this amount were forced to purchase other taro cultivars that are less appreciated. When these cultivars were pounded, shorthand bananas were added to increase their palatability. Prices of some food crops also went up. Examples were yams (*Dioscorea spp*), macabo (*Xanthosoma sagittifolium*) sweet potatoes (*Ipomoea batatas*) and banana (*Musa spp*) whose prices were increased by 33, 100, 40 and 140 %, respectively. It should be noted that some villages attributed the disease to witchcraft while unconfirmed sources declared that consumers died after consuming the infected tubers. The impact of TLB on the livelihood of the cocoyam farmers was -worsened by the fact that some farmers literally abandon blighted fields due to the misconception that the disease could be transferred to humans (Onyeka, 2014). Following these stories, the population was afraid to consume the remaining taro and had to consume other food commodities. A school of thought holds that consumers died from an overdose of fungicides applied for blight management. According to these thinkers, the agricultural experts never gave the dose and frequency of fungicide application. In a Cameroonian scenario, one could also think that some farmers harvested the leaves that have been sprayed with pesticides unknowingly. This assumption is based on the fact that farmers never put up sign posts to indicate sprayed sites and neighbours are allowed to harvest taro leaves without permission.

TLB epidemic in Cameroon can only be compared to earlier records in Western Samoa where 99% of the taro exports were lost and only 0.5 % of their export figures remained within 2 years (Paulson and Rogers, 1997). These figures demonstrated the fact that TLB has devastating impact on the livelihoods and food security of small farmers and rural communities dependent on the crop (Singh et al., 2012). The socio-economic impact of TLB in causing a threat to global food security cannot be overemphasized. According to Fisher et al. (2012) more than 600 million people could be fed each year by halting the spread of fungal diseases in the world's five most important crops alone. The overwhelming impact of plant diseases on human societies and food security is well illustrated by the effect of late blight disease of potato in Ireland during the 1840s, at a time when potatoes were important staple foods for the majority of the population. The disease was one of the factors that led to mass starvation, death and migration to the United States (Woodham-Smith, 1962; Bourke, 1964; Zadoks, 2008; Martins et al., 2013). There have been numerous other plant disease epidemics throughout agricultural history that have resulted in a major socio-economic impact; for example, the epidemics caused by coffee rust in Sri Lanka (1890s), brown spot of rice in India (1940s), wheat stem rust in north America (1960s), rubber leaf blight in Latin America (1910s), and downy mildew of grape in Europe in the 1800s (Brunt et al, 2001).

Due to the long dry season of april 2010 followed by much wind, conditions were favourable for disease epidemics and the inocula were transported over long distances. This is therefore, one of the highest disease outbreaks that West and Central African countries have faced in the last decades caused by climate change. However, no sustainable solutions have been proposed to the farmers. This study aimed at looking for sustainable management strategies for TLB. The specific objectives of this study were to assess the effect of fungicide applications on TLB severity and compare the effect of planting dates on TLB severity.

2. Material and methods

2.1 Fungicide application

Field experiments were conducted during 2012 cropping season in Dschang (5° 26' N, 10 ° 04'E, and 1400 m altitude), Cameroon. Preceding crops in the site were taro, beans (*Phaseolus vulgaris*) and maize (*Zea mays*). Weed species in and around the site were Ageratum *houstonianum*, *Bidens pilosa*, *Setaria spp*, *Brachiaria spp.* A randomized Split-plot design was used with two factors (fungicide and cultivar) replicated three times. Fungicide regime was assigned to main plots while cultivars occupied sub-plots. Main plot measuring 4*2.5 m, were separated by a taro-free zone 1 m wide to limit inter plot interference.

Two morphologically distinct taro cultivars: "Ibo coco" (Dark green petioles cultivar) and "Ehkoueh'lah" (light green petioles small leaves cultivar) which were grown in the Western highlands of Cameroon and used for study (Purseglove, 1972). The soil was ploughed to a depth of 30 cm and taro seeds were planted on the March 20, at the spacing of 1*0.5 m (20000 plants/ha). Poultry manure was applied a day before planting, at the rate of 10 t/ha while the second poultry manure application (6 t/ha) was conducted three months after planting. The manure was spread round the plant but 5 cm away from the stem. Mineral fertilizer (NPK 12-11-18 + 2.7 MgO+8 S) was applied at the rate of 800 kg/ha three months after planting. The field was weeded both manually and chemically. Shielded sprays of paraquat (2.5 l/ha) coupled with hand weeding was used to control weeds before canopy formation. Subsequent weeding was manual and carried out when necessary. Moulding was implemented after mineral fertilizer application. Corms were harvested on the November 4 and december 4, 2012 (7.5 and 8.5 months after planting) for "Ibo coco" and "Ehkoueh'lah", respectively, when most of the leaves had senesced. The corms were separated from the petioles, counted and marketable tubers weighed for each sub-plot. Marketable tuber yields were expressed as tonnes fresh weight per hectare. Yield increases attributed to fungicide protection were calculated (Tarla et al., 2011) as follows:

$$\text{Yield increase (\%)} = \frac{(\text{Yield sprayed} - \text{Yield unsprayed}) * 100}{\text{Yield sprayed}}$$ **Eq. 1**

Fungicide applications were initiated the very day the first symptoms of taro blight were observed. This was on July 8, 2012, 110 days after planting (DAP). Plantomil 72 WP was applied at the rate of 3.33kg/ha (50 g in 15 L for 150 m^2) using a Jacto knapsack sprayer that delivers 1000 L/ha at a maximum pressure of 4 kg/cm^2.

The nozzle was the hollow cone type. In order to make the fungicide stick to the leaves, an adhesive, Polyfix (aqueous solution of polyvinyl alcohol) was added to the spray mixture at the rate of 1.33 L/ha. Plots were sprayed on a 7, 14, 21 and 28 day schedule, while control plots were left unsprayed (Fontem and Aighewi, 1993; Fontem et al., 2003). A protective screen was placed between sprayed and unsprayed plots to control fungicide drift.

The crop was exposed to naturally-occurring inocula in the field. Disease severity (percent leaf area diseased) was scored weekly on three central row plants of each sub-plot with the aid of a 1-9 rating scale, developed by the Potato International Centre (CIP). Seventeen and 21 weekly ratings, initiated from the first foliar taro blight symptoms were scored for “Ibo coco” and “Ehkoueh’lah”, respectively per sub-plot. Values for standardised area under diseased-progress curves (SAUDPC) were calculated from the severity data according to the formula suggested by Campbell and Madden (1990).

$$SAUDPC = \sum_{i=1}^{n=1} \frac{(y_i + y_{i+1})(t_{i+1} - t_1)}{2(t_n - t_1)}$$ **Eq. 2**

Where : y_i = disease severity, t_i = time in days and t_n-t_1 = duration of the epidemic in days.

Economic analyses were conducted for costs and returns to each fungicide spray frequency on each cultivar. The market price for a bucket (15 kg) of “Ibo coco” was 200 and 400 FCFA/kgfor “Ehkoueh’lah”, obtained from interviewing at random 50 taro producers and 50 local vendors. This price was used to estimate the total returns. Increase in taro yield over control plots was assumed to be solely due to fungicide applications. The cost of protecting one hectare of taro with fungicide (CP) was calculated (Tarla et al., 2011) as follows:

CP = ((RF X CF) + CL) n **Eq. 3**

Where CF = cost of a kg of fungicide (16,000 FCFA), CL = Cost of Labour used in protecting a hectare of taro, cost of adhesive and depreciation of the sprayer (66,000 FCFA), RF = Rate of Fungicide applied (3.33 kg/ha) and n = number of fungicide applications.

Total returns were the values of the marketable yields obtained in each treatment. A net return for each spray frequency was calculated by deducting the cost of fungicide protection from the total return of that spray frequency. The net increase in revenue due to fungicides treatment was assessed by deducting the net return from the non-treated plot from that obtained in each fungicide spray frequency. The rate of return (net benefit/cost of fungicide protection ratio) was calculated, to determine the most economically efficient fungicide spray frequency.

2.2 Planting date

Seven morphological agronomic characteristics separate the 4 cultivars: blade length, petiole colour, colour of stain of petiolar junction, form of rhizome lateral tubers, duration of cycle, number of tubers per plant mean yields per hectare. Trails were conducted in Dschang (5.5° North, 10.05° East 1400 m above sea level). Tubers weighing 100-150 g were collected in the Western Highlands of Cameroon in 2011. The site selected for the experiments were never cultivated with an Araceae during the past 5 years the main vegetation consisted of *Tithonia diversifolia, Bidens pilosa, Ageratum conyzoides, Mimosa invisa, Pennisetum purpureum, Ageratum houstonianum, Amaranthus spinosus.*

The climate is a sudano-Guinean type with a long rainy season (mid-march to mid-november) a short dry season from mid-november to mid-march). Average precipitation ranges from 1800-2000 mm temperatures ranges between 21-24°C with air humidity above 70%. The study was conducted on a ferralitic soil (Yerima and Van Ranst, 2005).

For each season, it was cleared each experimental unit measured 5*2 m was planted with a single cultivar: Makoumba; Ehkwan’frè; Ehkoueh’deh, Ehkoueh’lah. Tubers were sown on 13th december 2011 and 8th march 2012 for the first season and second season, respectively. Tubers were sown single per hole 50*100 cm apart to give a planting density of 20,000 plants/ha. Spot application of poultry manure was conducted 5 days before planting at a rate of 6.8 t/ha. Half a tonne per hectare of mineral fertilizer (19-12-19+5B+1,2S), containing nitrogen, phosphorus, potassium, boron and sulphur was applied in a 10 radius around the main petiole during hilling 101, 72 days after planting for the first second season, respectively.

Manual weeding was conducted from the 30 DAP at 30 days intervals. Two insecticide treatments (fenobucarb 500 g/ha) were applied against

Tarophagus propersine (Cicadellidae) on the 45 and 75 DAP for both seasons. During the first season, a motopump which delivers 10 L/s of water was used to irrigate the field twice a week from 13th december 2011 to 8th march 2012. A bamboo fence was used to control domestic animals. During the trial, a complete block design was used with 4 repetitions. Each block consisted of 4 morphologically distinct cultivars.

Crops were exposed to naturally-occurring inocula (Tarla et al., 2011). Field observation of disease symptoms was followed by microscopic observations to confirm the causal agent. Disease severity was collected weekly from 4 central row plants using International Potato Centre scale of 1-9. Stardardised area under disease-progress curve (SAUDPC) was calculated (Campbell and Madden, 1990). Marketable tubers were registered during harvest during both seasons (223, 244, 244, 272 DAP for Makoumba, Ehkoueh'deh, Ehkoueh'lah, Ehkwan'frè cultivars, respectively). Yield loss due to change in planting period was calculated for each cultivar as follows (Tarla et al., 2011):

$$\%Y = \frac{YS1*100}{YS2} \qquad \textbf{Eq. 4}$$

%Y= Yield Loss ; YS 1 = Yield in season 1 ; YS2 = Yield in season 2.

2.3 Data analysis

Monthly depreciation rate of motor pump accessories was estimated at 24,500 FCFA/season considering that a machine is supposed to last for 48 months. A total of 27.36 litres of fuel was used during the trial a unit cost of 525 FCFA a litre giving a total of 402 190 FCFA. Labour (CL) in man-days (MD) was estimated at 672 000 FCFA when a MD was taken to be 1500 FCFA with 16 workers for 28 days. The total cost of irrigation was therefore taken to be 1,097,690 FCFA/ha. Total revenue was estimated for irrigated: (a) non irrigated (b) experimental units. The net revenue (c) was considered to be the difference between the irrigated the non-irrigated total revenue c=a-b. The net benefit (d) was the difference between the net revenue (c) the cost of irrigation (e). Rate of return (f) is the number of times each unit invested in irrigation brought gain (f = d/e). A kilogramme of taro was considered to be 267, 400, 400, 200 FCFA for "Makoumba", "Ehkoueh'deh", "Ehkoueh'lah", "Ehkwan'frè" cultivars respectively during the season 1.

During the season 2, the prices were 200, 333, 333, 133 FCFA for "Makoumba", "Ehkoueh'deh", "Ehkoueh'lah", "Ehkwan'frè", cultivars, respectively (Horton, 1982; Tarla et al, 2011). For taro yields and TLB severity, analyses of variance were conducted using GENSTAT while means were separated using the Least Significant Difference at 5% probability.

3. Results

3.1 Fungicide application

Pesticide application for TLB management has been prescribed and applied by many farmers. Fungicide application remains the fastest and most effective means of TLB management. The most important factors that determine fungicide efficacies include application frequency, dose and active ingredient. The first disease symptoms were recorded on the 110th day after planting. Disease severity increased faster on the control plots compared to the treated. The disease severity of all sprayed plots were significantly (P= 0.003) lower than the control plots (table 1). All spray regime gave higher yields than the control. Though the 28-day frequency gave the lowest yields, this fungicide application regime gave the highest net benefit and rate of return. In terms of sustainability (economic viability and environmental friendliness), monthly application was therefore the best application interval using a pre-packed fungicide of copper (60% and metalaxyl (12%) at 3.33 kg active ingredient/ha (table 2).

3.2 Planting date

Taro planted three months before the rainy season was studied. The crop was planted in December and irrigated to field capacity using a motor pump. Watering was conducted twice a week. The first disease symptoms appear on day 104 during the rainy season while dry season crops were attacked on day 195, when the crop was attaining its maturity. The

Table 1 : Effect of Plantomil 72 WP spray frequency on the standardized area under diseases progress curve (SAUDPC) of taro blight

Variety	Spray schedule	SAUDPC
"Ibo coco"	7-day	0.11b
	14-day	0.12b
	21-day	0.16b
	28-day	0.19b
	Unsprayed	**0.75a**
"Ehkoueh'lah"	7-day	0.16b
	14-day	0.18b
	21-day	0.19b
	28-day	0.19b
	Unsprayed	**0.63a**

Table 2: Effect of fungicide on the yield, mean tuber weight, net benefit and rate of return of "Ibo coco" and "Ehkoueh'lah" cultivars of taro

Cultivar	Spray schedule	Yield (t/ha)	Mean tuber weight (g)	Net benefit (Millions FCFA.ha^{-1})	Rate of return
"Ibo coco"	Unsprayed	16.11a^{z}	114.96a	7.16	3.51
	7-day	62.11b	166.90b	7.94	7.36
	14-day	61.22b	162.32b	8.21	11.41
	21-day	60.78b	166.38b	8.27	13.78
	28-day	60.44b	161.02b		
"Ehkoueh'lah"	Unsprayed	33.11a	81.90 a	3.86	1.63
	7-day	49.06b	112.59b	4.81	3.65
	14-day	48.44b	109.83b	4.63	5.51
	21-day	46.78b	109.43b	4.77	6.63
	28-day	46.83b	112.06b		

^{z}Means of each variety in the same column with the same letter are not significantly different ($p<0.05$) according to Fisher`s LSD

standardized area under disease progress curve was significantly lower on the dry season crop compared to the rainy season crop (table 3).

When the number of commercial tubers were counted, dry season crops gave three times the number of tubers compared to the rainy season. Total fresh tuber yields were evaluated at 61.81 t/ha during the dry season and 14.94 t/ha for rainy season cultivation of "Ibo coco".For one hectare, it was estimated that a farmer could invest 1.098.000 FCFA to irrigate his crop but obtained net revenue of 13.5 million FCFA and a net benefit of 12.4 million FCFA when compared to rainy season cultivation of Ibo coco cultivar. The rate of return was evaluated at 11.29 (table 4).

Table 3: Evolution of late blight SAUDPC (%) with planting periods

Variety	Season 1	Season 2
Ehkwan'frè	27.66b^{z}	65.12 b
Ehkoueh'lah	17.30c	59.14 c
Ehkoueh' deh	16.30c	56.86 c
Makoumba	34.84a	74.50a

4. Discussion

Pesticide application for disease management has been prescribed and applied by many researchers. Fungicide application remains the fastest and most effective means of TLB control. The most important factors that determine fungicide efficacies include application frequency, dose and active ingredient (Fontem, 1995; Tarla et al., 2011). Testing the efficacies of other active ingredients will also be important (Tarla et al., 2014a). Apart from yams, cocoyam gives more income to growers more than any other root and tuber crop. It should be noted that the yields obtained in these trials were higher than obtainable yields reported in other countries like Egypt, Nigeria, Ghana and china (Onyeka, 2014). These yield yields were attributed to the cultural practices which farmers do not always take the time to practice on their fields.

Taro gave more yields during the dry season compared to the rainy season. These findings agree with previous studies which show that dry season cultivation produced four times the quantity of tubers that rainy season crop produced (Tarla et al., 2014b). Yield loss attributable to TLB in this study was 75.83%. This

Table 4: Yields, yield loss, net benefit and rate of return of four taro cultivars for two seasons

Cultivar	Yield season 1	Yield season 2	Yield loss (%)	Net benefit (millions FCFA.ha^{-1})	Rate of return
Makoumba	61.81 a^{z}	14.94d	75.85	12.40	11.29
Ehkwan'frè	44.50 c	17.57c	60.50	5.5	4.97
Ehkoueh'lah	43.38 c	21.19b	54.62	9.2	8.37
Ehkoueh' deh	51.50 b	33.83a	34.28	8.2	7.49

^{z}Means of each variety in the same column with the same letter are not significantly different ($p<0.05$) according to Fisher`s LSD

value was lower than the national average attributed to the low temperatures in the Western Highlands which does not favour rapid disease development. Tsopmbeng et al., (2014) showed that sporangia from the lower altitudes were generally smaller and more aggressive compared to the sporangia from the higher larger and less aggressive.

Fungicide application presented some challenges in the Cameroonian setting due to small farm sizes (Matthews et al., 2003). In most cases, the farmer did not own a sprayer and the cost of renting one to apply on the small plot was not economically viable. In cases where farmers own, most of them where faulty and dirty while the fungicides were of doubtful quality. Some of the fungicides had expired while others were never registered in the country.

Though this method is economically viable, it may not work in all situations. Some parts of the world do not have water while vegetables may be more expensive during the dry season compared to taro cultivation. Cassava (Manihot esculenta) (Euphorbiaceae) and sweet potatoes have replaced taro in many parts of Cameroon today. The Government of Samoa encouraged agricultural diversification when TLB stroke the country (Jackson, 1996; Semisi, 1996). With the current taro deficit, it will take a lot of effort from farmers and the government of Cameroon to produce enough taro which can compete with other crops as it was the case before the disease outbreak.

The introduction of TLB to the Caribbean in 2004 led to the annihilation of the taro crop in the Dominican Republic, Cuba and Puerto Rico (Rao et al., 2010). The overwhelming impact of plant diseases on human societies and food security is well illustrated by the effect of late blight disease of potato, caused by the pathogen P. infestans (Mont.) de Bary in Ireland during the 1840s, at a time when potato was an important staple food for the majority of the population. The disease was one of the factors that led to mass starvation, death and migration. There have been numerous other plant disease epidemics throughout agricultural history that have resulted in a major socio-economic impact; for example, the epidemics caused by coffee rust (*Hemileia vastatrix*) in Sri Lanka (1890s), brown spot of rice (*Cochliobolus miyabeanus*) in India (1940s), wheat stem rust (*Puccinia graminis*) in north America (1960s), rubber leaf blight (*Microcyclus ulei*) in Latin America (1910s), and downy mildew of grape (*Plasmopara viticola*) in Europe (1880s) (Brunt et al., 2001).

Raciborski (1900) was the first to study the biology of P. colocasiae as an incitant of TLB. It was close to a century later that TLB epidemics were reported in South East Asian countries and it appeared in West and Central African, just during the last decade. Farmers and Scientist both accept that a dry spell came followed by dusty winds before the TLB appeared. The inoculum was either transported over long distances during this period or the pathogenicity became high only after those events (Raciborski, 1900; Bandyopadhyay et al., 2011; Omane et al., 2012).

“Makoumba” gave the highest yields in season 1 the lowest yields in season 2. Despite the fact that taro irrigation is not practiced in Africa, the crop gives better yields under irrigated conditions than rainfed agriculture (CIRAD, 1991). Susceptible varieties are generally high-yielding in the absence of the disease (Vanderplank 1982; 1984). This may explain why farmers in Cameroon plant. “Makoumba”cultivar more than any other variety. This result also confirms the fact that high-yielding cultivars are generally susceptible to disease.These high yields were attributed to the intrinsic characteristic of each cultivar to give good yields, thefertility of the soil. In the world, mean yields are estimated at 5-6 t/ha (Katanka, 2004) while 5 to 10 t/ha (CMA-AOC, 2010) are obtained in Africa. In experimental fields, yields are generally higher than in yields obtained in farmers’ fields.Marketable yield losses attributed to late blight varied from 34.28 to 75.85. These values were low compared to national average of 80%. These low values can be attributed to the fact that planting in November does not eradicate the disease. Secondly, worst case scenarios are obtained in farmers’ fields due to the repeated cultivation of the same crop for many generations using the same planting material. Three years after the appearance of this disease, taro has become rare expensive leading to a change of feeding habits from the consumption of taro products to other roots tubers or other foodstuff. Late blight (*Phytophthora infestans* (Mont.) de Bary) is responsible for high yield losses in vegetable fields in Cameroon. On huckleberry (*Solanum scabrum*) (Solanaceae), yield losses of up to 100% have been reported inthe nurseries (Fontem and Schippers, 2004) 5-46 % field damage (Fontem et al., 2003).

In Cameroon, tomatoes fruit losses of about 100% in the untreated fields have been reported (Fontem et al., 1996). Potato yield losses due to the disease can attain 71 % (Fontem and Aighewi, 1993; Fontem et al., 2001). Plant diseases caused by Phytophthora species were and remain without thought a threat to global food security (GILB, 2001). Rates of return were high varying from 11.29 to 4.97 with the former obtained from “Makoumba” cultivation. Economic losses of US$ 8467 (4.2 million FCFA) (Fontem et al., 2003) €3494 (2.3 million FCFA), (Tarla et al., 2011) have been attributed to huckleberry late blight in Cameroon. These rates of return also collaborates with data reported on huckleberry (Tarla et al., 2011) proving the economic validity of the technology used.

Apart from planting dates, other cultural practices such as planting density and irrigation frequency helps to reduce disease severity (Jackson et al., 1980; Akubuilo, 1985). Crop sanitation reduces the disease from the crop (Agrios, 1978; Fontem, 1995). Relying on the removal of leaves with lesions as a methodof control would quickly lead to a complete defoliation of thecrop with consequent effects on yield (Adams, 1999). Desirable cultural characteristics and quality are often lostduring breeding to produce resistant cultivars; meanwhile the choice of taro cultivars by farmers is driven by their personal tastes and market considerations (Brooks, 2005; Nelson et al, 2011). Yields reported in this study are higher than the world average (6 t/ha). Katanka (2004) reported only 12 t/ha on fertile soils.

5. Conclusion

TLB is the highest disease epidemic that has damaged a crop in the last decades. It can be managed effectively using fungicide application and early planting period. Fungicide application on taro can limit TLB leading to yield increases of 74.06%. Economically, the monthly fungicide spray schedule gave high returns of 13.78 and 6.63 million FCFA/ha for "Ibo coco" and "Ehkoueh'lah" cultivars respectively, suggesting the profitability of applying this fungicide against taro blight. Based on the high rate of return recorded by "Ibo coco", this cultivar is recommended to growers with month application of Plantomil Plus. For planting date, disease severity was higher in season 2 compared to season 1. "Makoumba" gave the highest yields with 61.81 t/ha in season 1 followed by "Ehkoueh'lah" (51.50t/ha),"Ehkwan'frè" (44.50t/ha), "Ehkoueh'deh" (43.38t/ha). Yield losses attributed to TLB varied from 34.28 to 75.85% according to the cultivar. "Makoumba" registered the highest disease severity net benefit of 12 399 000 FCFA. Based on these results, growers could sow taro in December and irrigate in order to escape the high disease pressure of the season 2.

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