

Full Length Research Paper

Effect of substrate on cocoyam (*Xanthosoma sagittifolium* L. Schott) seedling production by PIF method and analysis of yield variables in comparison to conventional seeds

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Cocoyam production is hindered by the scarcity of seedlings in both quantity and quality for producers. This study seeks to evaluate the influence of *Tithonia diversifolia* on cocoyam seedling production using the PIF technique and the field performance of these seedlings compared to conventional seeds. Seedlings were established in propagators using white sawdust under four treatments: *T. diversifolia* fermented leaves extract and dried leaves, NPK, and control with no application. Thereafter, seedlings were transferred in the field alongside conventional seeds under three treatments: poultry manure, NPK and *T. diversifolia* fermented leaves extract, for yield performance analysis. The results indicate a significant effect of substrate on bud formation and seedling production. The highest number of buds and seedlings production was recorded with the control and *T. diversifolia* fermented leaves extract treatments. Field trials reveal that fertilization significantly increases the number of tubers per plant, with the highest number of tubers recorded in the treatments with NPK (11.28 ± 1.27) and poultry manure (11.3 ± 1.87) in seedlings from PIF. Furthermore, the application of NPK significantly increases the average weight of the tuber, with the highest average weight recorded in seedlings from PIF of about 325.29 ± 26.07 g, compared to 177.6 ± 7.8 g for conventional seed. The mass production of cocoyam seedlings through the PIF technique appeared as a promising, cost-effective, and an efficient alternative for enhancing cocoyam production.

Key words: Cocoyam, PIF, substrates, *Tithonia diversifolia*, growth, yield attributes.

INTRODUCTION

Cocoyam (*Xanthosoma sagittifolium* L. Schott) is one of the most important edible aroid species, serving as a staple food for approximately 500 million people worldwide (Lebot, 2020). Africa is the leading producer in the world,

with West and Central African countries, especially Nigeria, Ghana, and Cameroon, accounting for over 75% of the continent's total production (Okereke, 2020). In Cameroon, cocoyam is the second most cultivated crop in

the group of roots and tubers after cassava (Onyenweaku and Okoye, 2007). Nutritionally, cocoyam tubers and leaves are rich in essential minerals and vitamins, including iron, calcium, phosphorus, vitamin C, thiamine and riboflavin (Ramdeen and Alam, 2019). In addition, cocoyam flour has functional applications in baking and porridge production. It is also suitable for individuals with gastrointestinal disorders and diabetics due to its low-calorie content and high starch digestibility, attributed to the small size of its starch granules (Onyeka, 2014).

Despite its significance as a food source for millions of people in developing countries, cocoyam lacks an institutional framework for preserving and distributing its germplasm, especially in Cameroon. Consequently, farmers rely on corms from previous harvests, which are often limited in quality, quantity, and usually contaminated with diseases. This situation has led to a significant decline in cocoyam production over the years, resulting in its marginalization in agricultural policies and research interventions on root and tuber crops (Boakye et al., 2018). To tackle the challenge of providing pathogen-free planting materials, techniques such as micropropagation (Omokolo et al., 2003; Niemenak et al., 2013) and microtuberization (Tsafack et al., 2008; Djabou et al., 2018) have been explored. However, these methods are still costly and not affordable to smallholder farmers. An alternative method, called the 'plants issus de fragments de tige (PIF)' technique, which utilizes seedlings derived from stem fragments of the mother plant, has been developed by the African Centre for Research on Banana Plantain (CARBAP) and has shown promising results in enhancing seedling production in banana (Kwa, 2002). This technique has enabled the rapid regeneration of 20 to 100 seedlings, depending on the genotype, from a single sucker within a short period (2 to 3 months) and at a low cost (Kwa et al., 2009). Given that cocoyam also is a rhizomatous plant like banana, the PIF technique could also significantly increase the shoot production rate on a large scale, thereby making healthy planting material more accessible in terms of both quantity and quality (Pyabalo et al., 2020). Wood sawdust is widely used in plant propagation in propagators due to its low density and high capacity for water retention, high cation exchange capacity, good aeration, and drainage (Maharani et al., 2010; Souza et al., 2006). Additionally, it is readily available in the form of waste at a relatively low cost (Niederwieser, 2001; Agboola et al., 2018). Its main components, which consist of cellulose and hemicellulose, lignin, and all minor elements, are essential to plant growth (Boadu et al., 2023). Furthermore, several studies have demonstrated the potential of *Tithonia diversifolia* in plant production (Ewane et al., 2020; Meshuneke et al., 2020;

Tsategouck et al., 2020) and animal feeding (Purwani, 2011). Even if it has low palatability due to its content of phytic acid compounds, which tastes bitter for livestock, *T. diversifolia* has shown a positive effect as a vital stimulator for plant growth (Ewane et al., 2020; Meshuneke et al., 2020; Tsategouck et al., 2020) as well as fertilizer and fungicide in several cultures (Oyerinde et al., 2009; Kahoet al., 2011; Meshuneke et al., 2020). *T. diversifolia* is rich in nutrients such as N (about 3.5%), P (about 0.37%), and K (about 4.1%), which are rapidly decomposed when applied to the soil, thereby enriching the soil with N, P and K for the growth of crops (Kandungu et al., 2013; Tatsegouock et al., 2020). Its leaves, stem, and roots contain phytochemicals such as diterpenoids, alkaloids, flavonoids, chlorogenic acid derivatives, phenols, saponins, tannins, and terpenoids, which have increased the interest of researchers in the program of improving production (Umar et al., 2015; Oyeniyi et al., 2016; Kerebba et al., 2019).

Recent work on the positive effect of *T. diversifolia* on the production of good-quality of banana seedlings through the PIF method was demonstrated by Ewane et al. (2020) and Tatsegouock et al. (2020). The ability of *T. diversifolia* to produce over the year and be harvested approximately six times per year (Pazla et al., 2023) has increased the interest of researchers in the use of this plant in various areas of research. A recent study on cocoyam seedling production using the PIF technique reported a positive response in both red and white cocoyam cultivars, increasing the multiplication of seedlings with the use of arbuscular mycorrhizal fungi (Djeuani et al., 2023). However, to date, no work has been done to evaluate the behavior of cocoyam seedlings derived from PIF in field conditions. To effectively promote the use of cocoyam seedlings produced via PIF as planting material, it is essential to evaluate their field performance compared to conventional seeds used by farmers. This study assesses the impact of fermented leaves extract and dried leaves from *T. diversifolia* on cocoyam seedling production using the PIF method and analyzes the field performance of these seedlings in comparison to conventional seeds used by farmers.

MATERIALS AND METHODS

Overview of the experimental site

The experiment was conducted at the Research Farm of the Faculty of Agronomy and Agricultural Sciences, Annex of Bafia, University of Dschang, Cameroon, which is located at 4°45' North longitude and 11°14' East latitude. The area is characterized as a transition zone between the equatorial and savanna climates, with an average annual temperature of 24.9°C, an average yearly rainfall of

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Figure 1. Preparation of plant material and establishment of corm in the propagator. A=Cocoyam corm; B=Disinfection in a pepper solution; C=Drying; D=planting.

approximately 1455 mm, and sandy loam soil (Enyegue et al., 2014). The basic soil chemical and physical properties of the experimental site were analyzed at the Laboratory of Soil Analysis, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon.

Plant and preparation

The plant material consisted of corms and conventional tuber seeds from white cocoyam cultivar (Figure 1A), collected from producers in the district of Kon Yambetta, Mbam and Inoubou division, Bafia, Center Region, Cameroon. The corms were used to produce seedlings using the PIF technique, as described by Bodjona et al. (2020). The preparation of corms before establishment in the propagator consists of trimming and shelling. The trauma of the shoot apical meristem was induced following the method described by Bodjona et al. (2020) with modifications. Three cross incisions were made in the center of the explant to destroy the apical meristem and promote rapid development of all buds at the same time. The explants were disinfected with a biological solution of pepper (1/10 m/v) for 30 min (Figure 1B) and left to dry for 24 h (Figure 1C) under a shade before being established in a propagator containing sawdust purchased at a local sawmill located in Bafia. Conventional seed tubers were established in the field alongside with seedlings derived from PIF technique for growth and yield analysis.

Experimental design and substrates

The experiment was conducted in two phases: firstly, the germination of the corms in the propagators, and then, the establishment of seedlings in the field alongside with conventional tuber seeds. The germination of the explant was carried out using a fermented solution of *Tithonia diversifolia* and dried leaves. Fresh and mature leaves of *T. diversifolia* were collected around the farmlands surrounding the faculty. The first batch of leaves was thoroughly washed in running tap water, cut into small pieces, and then mixed with water in a 1:5 (w/v) ratio. This mixture was then fermented in a container at room temperature for 15 days, following the modified method of

Tatsegouock et al. (2020). At the end of the fermentation period, the liquid extract was directly used for explant treatment. The second batch of leaves was air-dried for 14 days, as described by Babajide et al. (2012). Seedlings were then established in a propagator under four treatments: control with no application, *T. diversifolia* dried leaves powder (15 g/plant), *T. diversifolia* fermented leaves extract (50 ml/plant), and NPK fertilizer (5 g/plant). Each treatment was repeated three times and arranged in a completely randomized block design.

The second phase of the experiment involved the field establishment of seedlings produced through the PIF technique, compared to those made from conventional seeds. Four substrates were tested: control (no fertilizer), poultry manure at 30 t/ha, fermented leaves of *T. diversifolia*, and NPK at 150 t/ha (Gwan et al., 2019). These substrates were arranged in a randomized complete block design with three replicates. The poultry manure was left to undergo decomposition for 7 days before the planting of the seeds. NPK fertilizer was applied three months after planting. The explants were placed on a layer of each treatment substrate approximately 10 cm thick and were then covered with an additional layer of sawdust measuring 3 to 5 cm (Figure 1D). A composite sample of soil was collected to a depth of 20 cm using an auger and analyzed before planting in the field.

Evaluation of vegetative growth in the propagator

The emergence of buds in each treatment was assessed seven days after the explants were established in the propagator. On the 30th day, the number of seedlings in each substrate was recorded. Following this evaluation, the seedlings from the greenhouse were transferred to plastic planter bags for a 14-day weaning period. After this acclimatization phase, the young plants were moved to field conditions once they had developed two or three new open leaves.

Assessment of vegetative growth and yield variables in the field

A field trial was conducted to evaluate the performance of seedlings

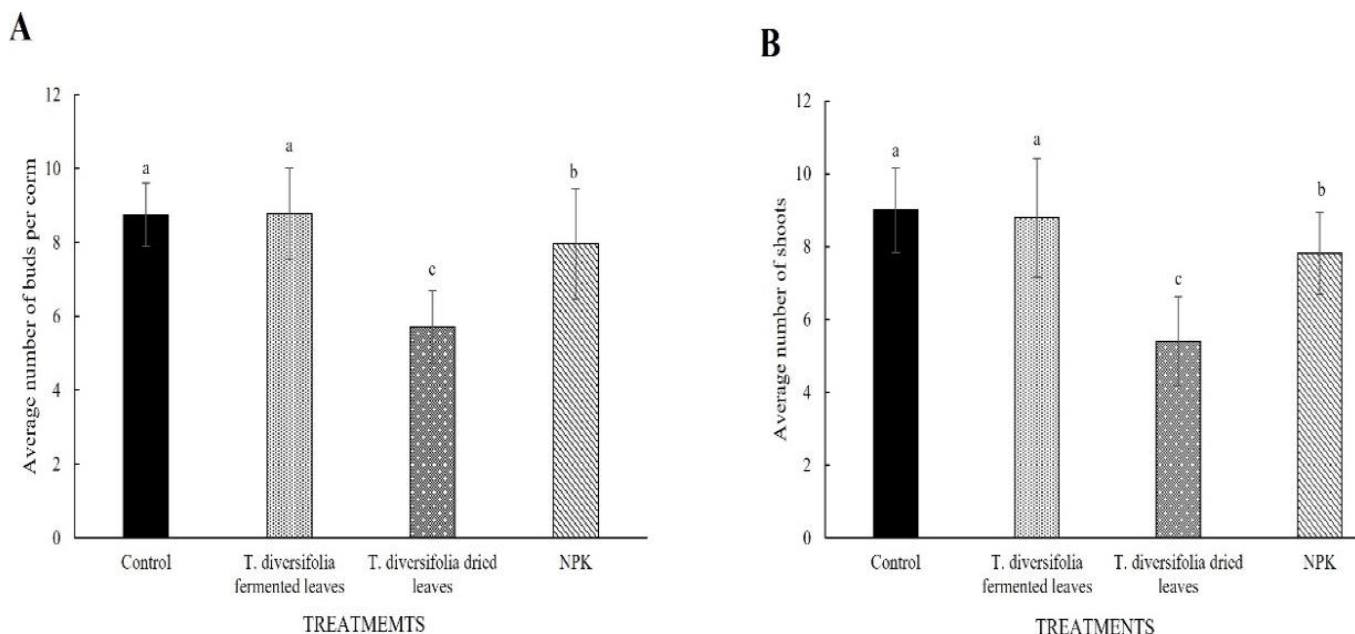


Figure 2. Effect of treatments on buds and shoots production in the propagator. A=Average number of buds per corm; B=Average number of shoots. Bands with different letters are significantly different according to the Student-Newman-Keuls at 5% threshold.

produced through the PIF technique compared to conventional seeds under the influence of poultry manure, *T. diversifolia* and NPK fertilizers. Growth variables were assessed at one, three, and five months after planting. These include the average number of leaves, average collar diameter and average plant height. Yield variables evaluated nine months after planting included the number of tubers per plant, tuber weight, the average tuber diameter, and the average tuber length. For both the mass propagation and the infield growing phases, the experiment was conducted using a randomized complete block design (RCBD) with three replications. In the mass propagation, the main factor was the substrate, which included control, *Tithoniadiversifolia* fermented fresh leaves, *T. diversifolia* dried leaves, and chemical fertilizer. For the infield assessment, the studied factors included substrate control, chemical fertilizer, poultry manure, *Tithoniadiversifolia*, and the type of seeds (conventional seeds and PIF seeds).

Statistical analysis

A one-way analysis of variance (ANOVA) was performed to assess the effects of various substrates on mass propagation. At the same time, a two-way ANOVA was conducted to determine the combined effects of substrates and seed types on growth and yield parameters. All statistical analyses were performed using R software version 4.3.3, with significance determined at $p < 0.05$ using the Student-Newman-Keuls test for data from the propagator and the Scott-Knott test for data from the field experiment.

RESULTS

Effect of substrates on seedling establishment by PIF in the propagator

The effect of the substrate on seedling establishment

using the PIF method was evaluated by measuring the average number of buds and shoots produced at one week and three weeks, respectively. No significant difference in the number of buds produced was observed between the control and the treatment with *T. diversifolia* fermented leaves, which exhibited the highest average number of buds, 8.5 ± 2.06 and 8.8 ± 2.12 , respectively ($p < 0.05$; Student-Newman-Keuls). The lowest number of buds 4.1 ± 2.12 was observed in the treatment with *T. diversifolia* dried leaves (Figure 2A). The effect of the substrate on shoots production followed the same trend as the number of buds produced (Figure 2B). Analysis of variance also indicated that the highest number of shoots produced was recorded in the control and the treatment with *T. diversifolia* fermented leaves 8.2 ± 1.06 and 8.08 ± 1.08 , respectively with no significant difference observed between these two treatments. These two treatments were followed by the treatment with NPK (7.82 ± 1.12). The lowest number of shoots produced was recorded in the treatment with *T. diversifolia* dried leaves (5.4 ± 1.23). At this stage, seedlings were weaned and placed in a plastic bag containing soil/sand (1/1) for acclimatization over two weeks before being transplanted in the field. The emergence of buds and the development of seedlings in the propagator and after weaning are illustrated in Figure 3.

Soil physico-chemical analysis

The soil analysis of the experimental site, presented in Table 1, revealed that it is an acidic soil with a sandy clay

Table 1. Soil basic chemical and physical properties of the experimental.

Soilproperty	Value	Soilproperty	Value
pH (H ₂ O)	5.63	Potassium (meq/100g)	1.24
pH KCl	4.9	Sodium (meq/100g)	0.06
Clay (%)	29.66	Calcium (meq/100g)	1.84
Sand (%)	55.66	Magnesium (meq/100g)	0.61
Silt (%)	14.66	Organicmatter (%)	3.67
Organiccarbon(%)	2.13	Cationic exchange capacity (meq/100g)	12.15
Total nitrogen	0.06	Saturation (%)	29.86
Phosphorus (mg/kg)	27.12	-	-

**Figure 3.** Production of seedlings through PIF horticultural method. A= Shoots acclimatization; B= Shoots development after 30 days; C= Shoots from control treatment.

loam texture and a good water retention capacity, resulting in a stable structure and adequate aeration. The organic matter content is acceptable. However, it is deficient in nitrogen and phosphorus. The analysis of cation exchange and the sum of exchangeable bases revealed that this soil has low levels of nutrient cations. This limited capacity to retain nutrients may impact the growth of some crops.

Effect of fertilization and the type of seed on growth variables in the field

Data recorded for the average number of leaves, plant height, collar diameter, and leaf area indicated that seedlings from PIF performed better than those from conventional seeds. An increase in growth variables was observed in all the treatments over time. Fertilization has a positive effect on increasing growth variables for both ordinary seeds and seedlings from PIF compared to the control. The highest average plant height (83.6 ± 7.6 cm) and collar diameter (93.6 ± 17.9 mm) were recorded in the treatment with poultry manure at five weeks after planting with seedlings from PIF (Table 2). No significant difference was observed in the number of leaves among the different treatments. However, plants from conventional seed

exhibited lowest values compared to plant from seedling from PIF. Means followed by the same letter in a column within the parameter and the time are not significantly different according to the Scott-Knott test at 5% threshold.

Correlation analysis among growth variables under different fertilization

The analysis of the correlation of poultry manure fertilization with growth parameters is presented in Table 3. Plants from conventional seeds showed a positive correlation for the studied variables at one month after planting (MAP). In contrast, this correlation was observed only for leaves and height at 5 MAP. Regarding the plants from PIF, a strong positive correlation was observed between the variables at 5 MAP. This trend was also observed in the treatment with NPK, where a positive correlation between growth variables, such as leaf area, number of leaves, and height, was significant at 5 MAP for plants from PIF, but not at 1 MAP (Table 4). These data indicate that the active growth phase begins earlier for plants derived from conventional seeds compared to those derived from PIF seeds. However, by the time of storage, the active growth is more pronounced in plants from PIF

Table 2. Effect of fertilization and seed type on the growth parameter in the field.

Type of seed	Time (months)	Control	NPK fertilizer	Poultry manure	<i>Tithonia diversifolia</i>
Height (cm)					
Conventional seed	1	11.6 ±3.59 ^j	16.47 ±4.86 ^j	18.93 ±6.03 ^j	17.03 ±3.9 ^j
	3	24.46 ±3.4 ^{2h}	22.9 ±5.83 ^h	26.67 ±6.53 ^g	22.6 ±3.8 ^h
	5	48 ± 7.29 ^e	45.39 ±11.3 ^e	53.88 ±9.1 ^d	52 ± 10.5 ^d
PIF	1	17.43 ±5.23 ⁱ	22 ± 2.52 ^h	21.13 ±3.8 ⁱ	20.53 ±3.2 ⁱ
	3	27.13 ±5.39 ^g	40.49 ±6.85 ^f	48.8 ±2.03 ^e	31.1 ±4.01 ^g
	5	52.86 ±8.94 ^d	70.07 ±8.6 ^b	83.6 ±7.6 ^a	61.8 ± 12.1 ^c
Number of leaves					
Conventional seed	1	2 ± 0.5 ^h	2.6 ±0.5 ^g	2.67 ±0.3 ^g	2.87 ±0.7 ^g
	3	4.2 ±0.6 ^f	4.27 ±0.8 ^f	5 ± 0.7 ^e	4.6 ±0.8 ^e
	5	5.9 ±0.3 ^d	7.6 ±0.36 ^b	7.47 ±0.9 ^b	7.73 ±0.5 ^b
PIF	1	3.73 ±0.29 ^f	5 ± 0.48 ^e	4.53 ±0.2 ^e	4.67 ±0.87 ^e
	3	5.3 ±0.39 ^e	6.93 ±0.27 ^c	6.73 ±0.8 ^c	6.4 ±0.48 ^d
	5	6.93 ±0.4 ^c	8.67 ±0.97 ^a	8.73 ± 0.35 ^a	8.6 ± 0.75 ^a
Diameter at the crown (mm)					
Conventional seed	1	20.55 ±4.9 ^e	27.32 ±7.9 ^e	24.38 ±5.5 ^e	24.03 ±4.6 ^e
	3	39.73 ±14.3 ^d	40.92 ±11.2 ^d	43.95 ±13.8 ^d	37.67 ±10.6 ^d
	5	53.27 ±13.2 ^c	58.67 ±11.4 ^c	62.65 ±21 ^c	58.53 ±10.8 ^c
PIF	1	27.93 ±7.6 ^e	42.43 ±5.9 ^d	30.81 ±6.4 ^e	33.8 ±5.14 ^d
	3	44.53 ±9.08 ^d	68.54 ±6.7 ^b	67.8 ±15.9 ^b	61.12 ±14.5 ^c
	5	60.33 ±8.6 ^c	84.67 ±8.36 ^a	93.6 ± 17.9 ^a	85.3 ± 27.3 ^a
Foliar area (cm²)					
Conventional seed	1	391. 7 ± 16.9 ^f	865 ± 176 ^f	725 ± 238.2 ^f	740 ± 196.6 ^f
	3	1353 ± 400.2 ^e	1378.3 ±428 ^e	1804 ± 589.5 ^e	1146.6 ±50.3 ^e
	5	1742 ± 334.5 ^d	1991 ± 597.5 ^d	2009 ± 386.7 ^d	1649.6 ±105 ^d
PIF	1	1191.6 ±320 ^e	1900 ± 155.9 ^d	1583.3 ±345 ^d	1361.6 ±303 ^e
	3	1850 ± 506. 8 ^e	4593.4 ±940 ^a	3776.2 ± 933 ^b	2918.6 ±593 ^c
	5	2272 ± 520.6 ^d	5237 ± 902.7 ^a	4750.3 ± 942 ^a	3829 ± 890 ^b

compared to those from conventional seeds, as confirmed by the better results in yield variables of PIF compared to conventional seeds. Compared to the treatment with NPK and poultry manure, the application of *T. diversifolia* has a positive effect on the correlation of growth variables for the plant from PIF and conventional seeds, both at the early stage of growth and at the late stage of preparation to storage (Table 5). Concerning the control with no fertilization, most of the correlation between growth variables was observed in both types of seeds at 1 MAP, while less correlation was observed at 5 MAP (Table 6).

Effect of fertilization and seed type on yield attributes

Yield attributes were evaluated at nine months after planting. These include the average number of tubers per plant, the average length of tubers, the average tuber diameter and the average weight of tubers (Figure 4). Fertilization significantly increased the number of tubers per plant with the highest number of tubers recorded in both treatments with NPK (11.28 ± 1.27) and poultry manure (11.3 ± 1.87) with seedlings from PIF (Figure 4A). The average number of tubers in the control from

Table 3. Correlation among growth parameters at early and late growth phases under poultry manure treatment in cocoyam plants regenerated from PIF and conventional seeds.

Type of seeds	Parameters	Poultry manure-1 month after planting			
		Number of leaves	Collardiameter	Leaf area	Height
Conventional	Number of leaves	1			
	Collardiameter	0.5365197*	1		
	Leaf area	0.4485087	0.4169806	1	
	Height	0.2579239	0.261954	0.5022253	1
PIF	Number of leaves	1			
	Collardiameter	-0.1330406	1		
	Leaf area	0.1541174	-0.04362221	1	
	Height	-0.1970655	-0.01027414	0.6502647*	1
		Poultry manure-5 months after planting			
		Number of leaves	Collardiameter	Leaf area	Height
Conventional	Number of leaves	1			
	Collardiameter	0.1914098	1		
	Leaf area	-0.08361129	-0.05951665	1	
	Height	0.4499605	0.2223251	-0.06441239	1
PIF	Number of leaves	1			
	Collardiameter	0.5498945*	1		
	Leaf area	0.6731307*	0.5577449*	1	
	Height	0.3142188	-0.2352709	0.2192035	1

*Means that the correlation is significant at 0.01 confidence level.

Table 4. Correlation among growth parameters at early and late growth phase under NPK treatment in cocoyam plants regenerated from PIF and conventional seeds.

Type of seeds	Parameters	NPK-1 month after planting			
		Number of leaves	Collardiameter	Leaf area	Height
Conventional	Number of leaves	1			
	Collardiameter	0.5157078*	1		
	Leaf area	0.6587877*	0.338634	1	
	Height	0.3289847	0.3293238	0.7907187*	1
PIF	Number of leaves	1			
	Collardiameter	0.2129633	1		
	Leaf area	0.4598005	0.3870152	1	
	Height	-0.2560738	0.2813358	0.3502849	1
		NPK-5 months after planting			
		Number of leaves	Collardiameter	Leaf area	Height
Conventional	Number of leaves	1			
	Collardiameter	0.3545396	1		
	Leaf area	0.03337837	0.4352503	1	
	Height	0.2512405	0.1400406	0.1518324	1
PIF	Number of leaves	1			
	Collardiameter	0.1592748	1		
	Leaf area	0.2549015	0.6490957*	1	
	Height	0.08064831	0.5399401*	0.4334713	1

(*) means that the correlation is significant at the 0.01 confidence level.

Table 5. Correlation among growth parameters at early and late growth phase under *T. diversifolia* treatment in cocoyam plants regenerated from PIF and conventional seeds

Type of seeds	Parameters	<i>Tithonia diversifolia</i> -1 month after planting.			
		Number of leaves	Collardiameter	Leaf area	Height
Conventional	Number of leaves	1			
	Collardiameter	0.1628022	1		
	Leaf area	0.1190176	0.3711856	1	
	Height	0.481712	0.6034512*	-0.06849259	1
PIF		Number of leaves	Collardiameter	Leaf area	Height
	Number of leaves	1			
	Collardiameter	0.5064465	1		
	Leaf area	0.8918579*	0.5303004*	1	
	Height	0.02272662	0.53003	-0.07225894	1
<i>Tithonia diversifolia</i> -5 months after planting					
Conventional		Number of leaves	Collardiameter	Leaf area	Height
	Number of leaves	1			
	Collardiameter	0.2942723	1		
	Leaf area	0.4727981	0.386125	1	
PIF	Height	0.1795077	0.508712	-0.05313622	1
		Number of leaves	Collardiameter	Leaf area	Height
	Number of leaves	1			
	Collardiameter	0.6062062*	1		
	Leaf area	0.6095443*	0.8151721*	1	
	Height	0.5427272*	0.4628643	0.5736977*	1

(*) means that the correlation is significant at the 0.01 confidence level.

Table 6. Correlation among growth parameters at early and late growth phase under no fertilization treatment in cocoyam plants regenerated from PIF and conventional seeds.

Type of seeds	Parameters	Control-1 monthafterplanting			
		Number of leaves	Collardiameter	Leaf area	Height
Conventional	Number of leaves	1			
	Collardiameter	0.4258948	1		
	Leaf area	0.6917918*	0.4565256	1	
	Height	0.1388812	0.7646556*	0.3772545	1
PIF	Number of leaves	1			
	Collardiameter	0.6805097*	1		
	Leaf area	0.5374096*	0.7998562*	1	
	Height	0.5975509*	0.5541618*	0.7783844*	1
Control-5 monthsafterplanting					
Conventional		Number of leaves	Collardiameter	Leaf area	Height
	Number of leaves	1			
	Collardiameter	0.1573037	1		
	Leaf area	0.05440092	0.8467557*	1	
	Height	0.1253872	0.07800254	-0.1059221	1

Table 6. Contd.

	Number of leaves	1			
PIF	Collardiameter	0.003828524	1		
	Leaf area	0.06920115	0.6133635*	1	
	Height	-0.001561403	0.4762208	0.4197452	1

(*) means that the correlation is significant at 0.01 confidence level.

conventional seeds was 6.8 ± 0.48 . In contrast, 8.14 ± 0.05 tubers were observed in the control from the PIF seedlings. No significant difference was observed in the number of tubers for conventional seeds under fertilization. The application of NPK significantly increased the average weight of tubers, with the highest average weight recorded for seedlings from PIF (325 ± 1.86 g) (Figure 4B). The highest average length of tubers was recorded in seedlings from PIF fertilized with NPK (19.59 ± 1.86 cm), followed by those fertilized with poultry manure (16.86 ± 1.79 cm) (Figure 4C). However, fertilizer did not affect the length of tubers from conventional seeds. No significant difference was observed in the average diameter of tubers for seedlings from PIF in all the treatments (Figure 4D). The same trend was observed for tubers from conventional seeds.

Principal component analysis among some growth and yield variables

The growth parameters such as leaf area and the number of leaves as well as yield parameters such as the number of tubers per plant and the weight of tubers were analyzed using the principal component analysis (PCA) due to their relevance in the determination of the global yield at harvest (Figure 5). The score plot (PC1 vs. PC2) clearly shows that conventional and PIF plants are separated from one another by PC1 (79.9%) while the four fertilization conditions are separated from each source of plants by PC2 (15.7%). In plants regenerated from PIF, a positive correlation was observed between the weight of tubers and leaf area in NPK fertilization. In contrast, a negative and strong correlation was observed between leaf area and the number of tubers from plants under *T. diversifolia* fertilization. Meanwhile, a strong and positive correlation was observed between the number of tubers and the number of leaves in poultry manure fertilization. This PCA revealed that plants produced from PIF seeds exhibit a better response to all the investigated parameters. However, although plants with a higher number of leaves and leaf area produced more tubers, they had less tuber weight.

DISCUSSION

This work aimed to assess the impact of *T. diversifolia*

leaves fermented extract and dried leaves on cocoyam seedling production through PIF and analyze the field performance of the seedlings produced in comparison to conventional seeds. Our results revealed no significant difference in the number of buds and seedlings produced across the control, the treatment with NPK, and *T. diversifolia* fermented leaves. However, *T. diversifolia* dried leaves did not give good results for bud and seedling production compared to the control and the treatment with *T. diversifolia* fermented leaves. The fermentation process increases the bioavailability of nutrients while reducing the phytic acid content, making phosphorus available for utilization and other nutrients (Pazla et al., 2023; Pazla et al., 2024). Almost all the buds established were converted into seedlings as the number of buds produced was the same as the number of shoots established in all the treatments. In fact, under natural conditions, the growth of the apical buds in cocoyam plants inhibits the growth of axillary buds present in the axils of the leaf sheaths (Djeauni et al., 2021). The destruction of the apical meristem led to increased production of buds and seedlings. Our results showed that it is possible to obtain more than eight plants after 30 days compared to the 3 to 4 obtained by Djeuani et al. (2023). The difference in the number of buds observed in this study may be due to the different types of fertilization techniques used. The positive influence of fertilization with *T. diversifolia* fermented leaves on growth has been widely elucidated in banana seedlings production through PIF (Sadomi et al., 2010; Ewane et al., 2020; Tatsegouock et al., 2020). These authors observed a significant increase in the number of banana seedlings under substrate fertilization and *T. diversifolia* powder (Ewane et al., 2020).

The evaluation of growth and yield variables for seedlings from PIF versus conventional seeds in the field revealed, for all evaluated variables, a high performance of plants from PIF compared to those from conventional seeds. These differences may be attributed to the enhanced capacity of PIF-derived plants to uptake water and nutrients from the soil immediately after planting, unlike conventional seeds that require three to ten weeks for corm development and shoot establishment (Lebot, 2020). The treatments with NPK and poultry manure showed better performance for almost all evaluated growth and yield parameters. The positive effects of NPK and poultry manure on the growth and yield of cocoyam

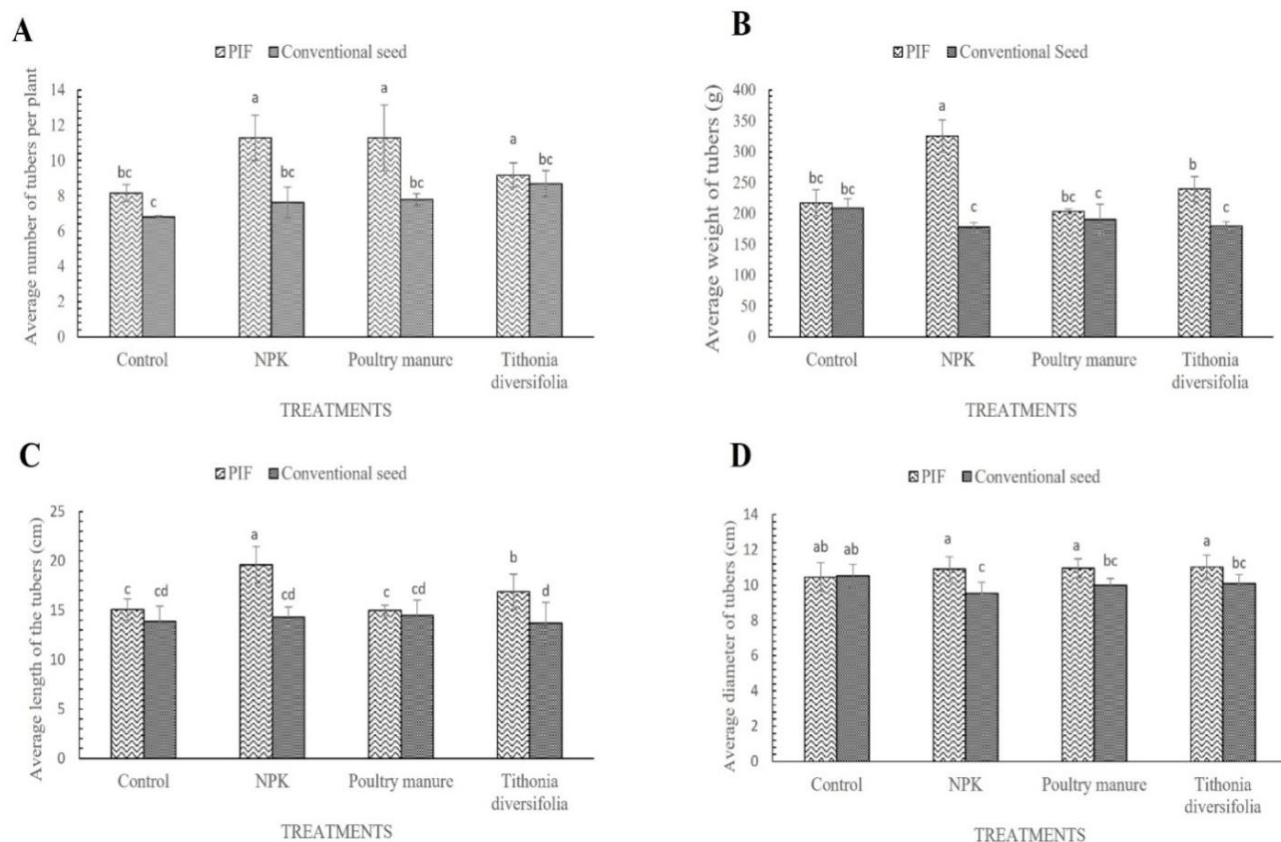


Figure 4. Effect of fertilization and seed type on yield variables at 10 months after planting. A= average number of tubers per plant; B= average weight of tubers; C= average length of tubers; D=Average diameter of tubers. For each parameter, bands with different letters are significantly different according to the Scott-Knott test at 5% threshold.

red and white cultivars were previously reported by Gwan et al. (2019). The increase in these parameters under NPK and poultry manure fertilization may be linked to the enhanced availability of nitrogen (N), phosphorus (P), and potassium (K) in the soil treated with these compounds (Kumar and Kanjana, 2009; Baishya et al., 2015; Zaman et al., 2011). The results mentioned above demonstrate the crucial role of N, P, and K in various physiological processes within the plant, which in turn influence plant growth. Nitrogen is an essential macro-element in organic molecules found in plants, including proteins, nucleic acids, purines, pyrimidines, coenzymes, and the production of chlorophyll. Phosphorus is a component of sugar phosphates, nucleic acids, nucleotides, coenzymes, and phospholipids. Potassium is essential for the activation of enzymes and coenzymes, protein synthesis, photosynthesis, sugar transport, the uptake of other nutrients and the movement of these nutrients within the plant.

The application of *T. diversifolia* fermented leaves had a positive effect on increasing growth parameters compared to the control for both conventional seeds and seedlings

from PIF. Indeed, organic amendment as *Tithoniadiversifolia* has been shown to contribute directly to seedlings' growth and yield through nutrient supplementation and indirectly by modifying soil physical properties such as stability of aggregates and porosity that can improve the roots' growth, rhizosphere and stimulate plant growth (Chagas-Paula et al., 2012; Oroka and Ureigbo, 2019). Further analysis of the physico-chemical characteristics of seedling-derived PIF will provide more information for its use in non-gluten derivative products

Conclusion

This study aimed to evaluate the response of cocoyam to mass propagation using PIF and to compare the field performance of seedlings produced from PIF with those from conventional seeds. Our results have highlighted the positive effect of *T. diversifolia* on bud and shoot production in the propagator. However, in field conditions, this effect was less pronounced than that of NPK and poultry manure application for growth and several yield

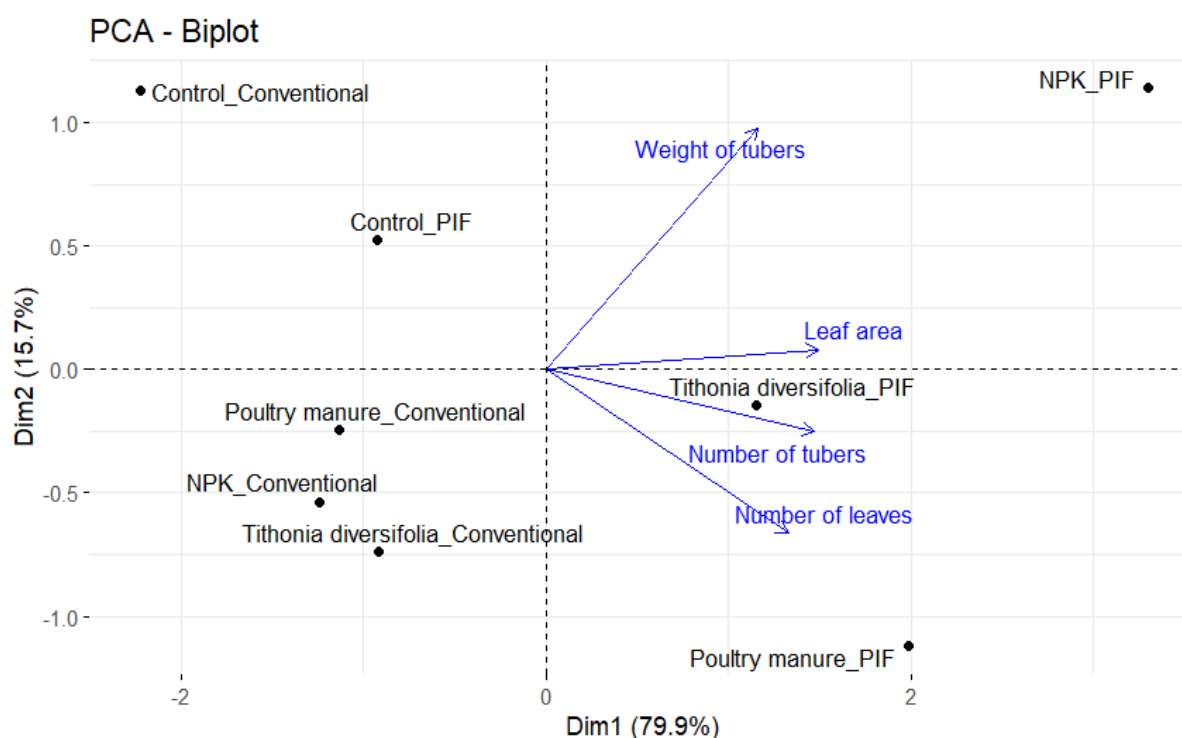


Figure 5. Principal component analysis among growth and yield parameters according to the type of seeds.

parameters, except for the average weight and average length of tubers. Then *T. diversifolia* could help to reduce the use of chemical input in cocoyam seed production and be recommended to smallholder farmers for ecologically responsible agriculture. Indeed, this is the first report for the evaluation of the growth and yield performance of cocoyam seedlings from PIF.

CONFLICTS OF INTEREST

The authors declared no conflict of interest.

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