Antifungal activity of *Erigeron floribundus* (Asteraceae) and Ripe Banana Peel-$NaHCO_3$ Extracts on Tomato in South-Kivu/DRC-Albertan Rift in the Great Lakes Region, Central-Africa

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## ABSTRACT

Tomato production faces significant challenges from fungal and bacterial diseases, often requiring chemical treatments. This study explores the potential of biopesticides derived from *Erigeron floribundus* and ripe banana peel-$NaHCO_3$ as sustainable alternatives to conventional fungicides. A completely randomized design was employed to test the efficacy of the biopesticides. Local methods were used to prepare the extracts. Tomato plants were treated with ripe banana peel-$NaHCO_3$, *Erigeron floribundus*, and a control (Dithane M45). Plant vigor, branch number, and disease incidence were monitored and recorded. Tomato plants treated with ripe banana peel-$NaHCO_3$ showed increased vigor and similar branch numbers compared to those treated with *Erigeron floribundus* and the control. There was no significant difference in disease incidence between the biopesticides and Dithane M45. Both biopesticides were effective in disease protection and promoting yield, demonstrating their potential as sustainable alternatives to chemical treatments. The study concludes that ripe banana peel-$NaHCO_3$ and *Erigeron floribundus* extracts are effective in protecting tomato plants from fungal and bacterial diseases while promoting growth and yield. Their non-toxic and environmentally friendly nature makes them suitable for sustainable tomato production.



*Keywords: Antifungal, ripe banana peel, Erigeron, market gardering*




## 1. INTRODUCTION

Agriculture is one of the main sectors contributing to socio-economic development worldwide, employing over 40% of the global workforce, with more than 52% in Africa and Asia [1]. Market gardening holds significant importance in human food supply [2], particularly in Africa where it constitutes a crucial component of urban and peri-urban agriculture, playing a pivotal role in the economic development of cities and ensuring food sovereignty [3]. Market gardening programs also play a vital role in nutrition and poverty alleviation efforts, contributing substantially to household income [4], with tomatoes (*Lycopersicon esculentum* Mill.) being a primary crop [5].

According to [2], tomatoes lead global vegetable production, followed by potatoes, with cultivation spanning over 170 countries. Global tomato production exceeded 141 million metric tons in 2009, with annual increases continuing [6]. In the Democratic Republic of Congo (DRC), tomato production decreased from 6,700 tons in 2002 to 5,720 tons in 2009, primarily due to pests causing a 30% reduction in cultivated areas from 340 hectares to 240 hectares between 2008 and 2010[7]. In Rwanda, tomato production in 2013 reached 123,300 tons, cultivated by 239,000 farming households across 6,281 hectares [8, 9]. Approximately 73% of the production is sold in rural markets, with 23% reaching urban markets, notably Kigali. In Burundi, 1.4 million small producers cultivate horticultural products for domestic and local markets, yielding an estimated 250,000 tons/year of fresh vegetables and 85,000 tons/year of fresh fruits as of 2005 [10]. Popular vegetables include tomatoes, onions, cabbage, carrots, peas, peppers, green beans, and various squash varieties.

Pests are the primary cause of damage and production loss, reducing tomato yields by 10-20% for farmers [11]. Additionally, various abiotic and biotic constraints during production and post-harvest operations further limit yields. In response, many farmers resort to intensive use of synthetic pesticides, neglecting associated health risks [12, 13]. Despite their immediate effectiveness, synthetic pesticides contribute to pest resistance; thereby diminishing crop yields a significant drawback [12, 13]. This issue is exacerbated by residues exceeding maximum allowable limits (MRLs) set by Codex Alimentarius or the European Union [14]. Farmers who frequently use these pesticides suffer from poisoning symptoms such as skin irritation, headaches, cough, dizziness, respiratory problems, fatigue, and diarrhea [12-16]. Moreover, environmental pollution results from pesticide overdose and inadequate packaging disposal practices [14].

Bioactive compounds identified in *Erigeron floribundus* are flavonoids [17], terpenoids [17], phenolic acids [18], alkaloids [19] and saponins [19]. Flavonoids are known for their antioxidant and anti-inflammatory properties. In *Erigeron floribundus*, compounds such as quercetin and kaempferol derivatives have been identified. Terpenoids, such as sesquiterpenes, have been found in the essential oil of *Erigeron floribundus.* These compounds are often associated with antimicrobial and anti-inflammatory activities [17].Phenolic acids like caffeic acid and its derivatives are present in *Erigeron floribundus.* These compounds contribute to the plant's antioxidant and antimicrobial properties [18].Alkaloids are another group of bioactive compounds found in *Erigeron floribundus*, known for their potential therapeutic effects, including antimicrobial and anti-inflammatory activities[19]. Saponins have been reported in *Erigeron floribundus* and are recognized for their surfactant properties, which contribute to their antimicrobial activity [19].

Also, bioactive compounds identified in banana peels are phenolic compounds [20], flavonoids [21], tannins [22] and carotenoids [23]. Banana peels are rich in phenolic compounds such as catechol, gallic acid, and tannins, which have strong antioxidant and antimicrobial [20]. Flavonoids such as quercetin, kaempferol, and myricetin are present in banana peels and contribute to their antimicrobial and anti-inflammatory effects [21]. Tannins in banana peels have astringent properties that can inhibit the growth of various pathogens by precipitating microbial proteins [22]. Carotenoids are also found in banana peels, providing antioxidant benefits and contributing to the overall bioactivity of the peels [23].

Sodium bicarbonate (baking soda) itself does not contain complex bioactive compounds but has significant antimicrobial properties due to its alkalinity: Antifungal and antibacterial properties [24] and synergistic effects with other compounds [25]. Sodium bicarbonate creates an alkaline environment that inhibits the growth of fungi and bacteria by disrupting their cell walls and metabolic processes [24].When combined with natural antimicrobials like those found in banana peels, sodium bicarbonate enhances the efficacy of these compounds by altering pH levels and increasing permeability of microbial cells [25].

In the Albertan Rift of the Great Lakes region in Central Africa, the use of pesticidal plants is a traditional practice known for their biocidal properties (toxic, repellent, and anti-feedant) against a broad spectrum of pests. These plants are applied as aqueous extracts or intercropped for repellent purposes [26, 27]. Additionally, synthetic products with ecological and biological properties, such as sodium bicarbonate ($NaHCO_3$), are also utilized [28].

This paper evaluates the antifungal efficacy of *Erigeron floribundus* and ripe banana peel-$NaHCO_3$ extracts in protecting tomato plants against fungal and bacterial diseases, while also promoting growth and yield.

## 2. MATERIALS AND METHODS

### 2.1 Study area

This study was conducted in the western Albertan Rift area of the Great Lakes region of Central Africa, specifically in the Province of South Kivu, in the territory of Kabare. Kabare is situated southwest of Lake Kivu, between 28°45’ and 28°55’ longitude and 2°30’ and 2°50’ south latitude. The terrain in Kabare consists of alternating hills and valleys with volcanic soil rich in humus, although some areas have been degraded due to erosion and overexploitation. Generally, the soil texture is predominantly clayey with minimal sand content. Kabare experiences a humid tropical climate characterized by a 9-month rainy season from September to May and a short 3-month dry season from June to August. The average annual temperature is 19.5°C, and relative humidity ranges between 68% and 75%, providing favorable conditions for a diverse range of market gardening crops [29].

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### 2.2 Experimentation

*Erigeron floribundus* plant organs and ripe banana peels were collected from a private plantation in Kabare during April 2023. Two kilograms of *Erigeron floribundus* leaves and two kilograms of ripe banana peels were harvested between April and May 2023. Plant identification was conducted by a botanist from the Department of Biology, Laboratory of Systematics and Plant Taxonomy at the Natural Sciences Research Center, CRSN/Lwiro. The total extracts were obtained using local methods proposed by Stoll [30]. Erigeron leaves were cleaned with water and pounded to obtain the filtrate along with residues (total extracts). These were macerated in 2.5 liters of tap water. The Erigeron extract was filtered through a cotton cloth for 24 hours and then mixed with 4 scoops of liquid soap, macerated for an additional 24 hours to complete 48 hours. Banana peels were cut into small pieces and macerated for 24 hours in 2.5 liters of tap water. The next day, the extract was filtered through a cotton cloth, mixed with 25 grams of baking soda per 5 liters, and left to macerate for 24 hours, also totaling 48 hours. The filtrate was mixed with water to reach a final volume of 2.5 liters. For preservation, these 5 liters of extracts were combined with 20 ml of palm oil and packaged in sterilized containers protected from light. Three treatment batches were prepared, each including three tomato plots with 50 plants per plot. The plants were observed throughout the growth cycle and treated weekly with these extracts. The first batch (PlotD-M45), serving as the control, was treated with dithane M45. The second batch (PlotE) received the Erigeron solution, and the third batch (PlotRbp-sb) received the ripe banana peel solution mixed with sodium bicarbonate. The Erigeron solution was diluted at a ratio of 1 liter of solution to 15 liters of water (1/15 dilution). The same ratio was maintained for the ripe banana peel solution mixed with $NaHCO_3$. Each treatment batch received a single spray of each preparation per week to ensure thorough coverage. Diseases were not inoculated in our field; fungal and bacterial diseases occurred naturally. Tomato seeds of the Marglobe variety were purchased from an agro-veterinary store in Kabare. The agronomic characteristics of Marglobe include its origin from the United States, early maturity (65 to 80 days), determinate growth, large smooth red fruits with dense flesh containing few seeds (weighing 160 to 300 grams), and resistance to diseases. Plowing and harrowing were conducted at the experimental site prior to transplanting. Plowing took place on March 15, 2023, followed by harrowing on March 22, 2023. Staking of the experimental fields occurred after the last operation. Tomato seeds were sown in the nursery on March 22, 2023, with germination starting three days later and complete germination achieved within a week. The study utilized a complete randomized design due to the homogeneity of the terrain and single-factor experimentation. Treatment allocations were randomly assigned, ensuring treatments did not repeat in adjacent plots. The land was divided into three blocks, each containing three plots repeated three times. Each plot measured 3 m x 3 m, with 0.50 m spacing between plots and blocks. The useful experimental field area was 10 m x 10 m (100 $m^2$), and the total field area was 12 m x 12 m (144 $m^2$).

Transplantation took place on April 22, 2023, with plants spaced 60 cm apart in all directions, accommodating two plants per hole. Organic matter, specifically dung, was added in pockets on the day of digging. Phytosanitary treatments were initiated one month after transplantation and continued at weekly intervals until final harvest. Two rounds of weeding, along with one hilling, were conducted during the experimental period. Fruit harvest occurred from August to September 15, 2023, encompassing all plots. Harvesting was staggered to collect ripe fruits weekly. Disease and insect pest incidence per plot were assessed by calculating the ratio of diseased plants (for both fungal and bacterial diseases) to the total number of plants per plot [31], using the following equation: $I\ (\%) = \frac{NI}{NT} x\ 100$

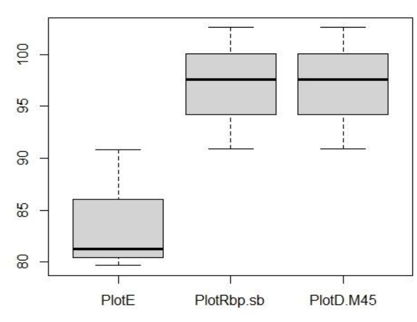
with I (%) = disease incidence, NI = number of plants infected by each type of disease and NT = total number of plants per plot.

### 2.3 Statistical Analysis

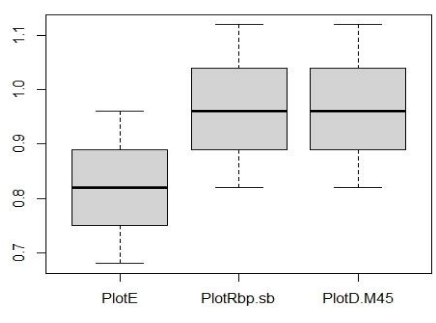
The data underwent one-way analysis of variance (ANOVA) using R 4.3.1 software [32]. Means were compared using the Least Significant Difference (LSD) method at a 5% confidence level.

## 3. RESULTS

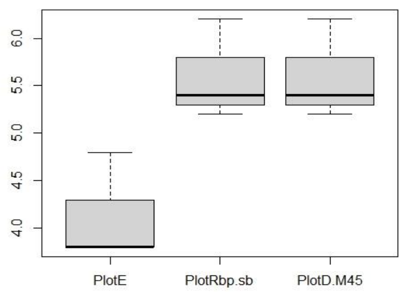
Figure 1 illustrates the variations in several key parameters across different treatments:The average height of plants treated with ripe banana peel-$NaHCO_3$ was 97.03 cm, 83.92 cm for *Erigeron*, and 94.93 cm for Dithane M45. Plants treated with *Erigeron* had an average collar diameter of 0.82 cm, while those treated with ripe banana peel-$NaHCO_3$ and Dithane M45 had average collar diameters of 0.9667 cm and 0.9567 cm, respectively. *Erigeron*-treated plants averaged 4 branches, Dithane M45-treated plants had 5 branches, and ripe banana peel-$NaHCO_3$-treated plants had 6 branches. The average yield was 83.27 tons/ha for ripe banana peel-$NaHCO_3$, 45.21 tons/ha for erigeron, and 84.85 tons/ha for dithane M45.



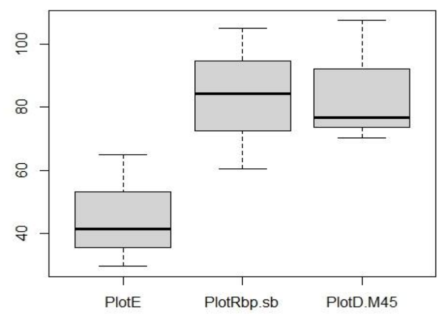

**(a) Plant height (cm)**




**(b) Collar diameter (cm)**




**(c)Number of branches**




(**d) Yield (tons /ha)**

**Fig. 1. Boxplot of plant height,collar diameter, number of branches and yield**

Let us statically analyze the data in Figure 1. The summary of the analysis of variance (Anova) is shown in Table 1.

**Table 1. Anova of plant height,collar diameter, number of branches and yield**

| | Source of variations | F value | Pr (>F) |
|---|---|---|---|
| (a) | Plant height (cm) | 7.04 | 0.00949*** |
| (b) | Collar diameter (cm) | 4.967 | 0.0268** |
| (c) | Number of branches | 2.333 | 0.178 |
| (d) | Yield (tons /ha) | 3.729 | 0.0886 |

Codes de signification : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 1 shows a significant difference in plant height and collar diameter: the height and collar diameter of the tomato plants differ when using *Erigeron*, ripe banana peel-$NaHCO_3$, and Dithane M45. Let's compare the means using the Least Significant Difference (LSD) method. The treatments subjected to ripe banana peel-$NaHCO_3$ have more slender and vigorous tomato plants compared to those of the control (Dithane M45) and *Erigeron*. Similarly, those subjected to the Dithane M45 treatment were more slender and vigorous than those treated with *Erigeron*. There is no significant difference in the number of branches and yield of the tomato plants; i.e., the number of branches and yield of the tomato plants are the same when using *Erigeron*, ripe banana peel-$NaHCO_3$, and Dithane M45.

Table 2 presents the average incidence of fungal and bacterial infections.

**Table 2. Incidences of cryptogamic (fungal) and bacterial**

| Diseases | Traitments | Effective | Incidence (%) | Chi-square | dl | Pr (>F) |
|---|---|---|---|---|---|---|
| Cryptogamic (Fungal) | Erigeron | 3 5 3 | 7.3 | 1.5048 | 2 | 0.4712 |
| | Ripe banana peel-sodium bicarbonate ($NaHCO_3$) | 3 2 4 | 6 | | | |
| | Dithane M45 | 3 1 1 | 3.3 | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bacterial | Erigeron | 11 | 8 | 4 | 15.3 | 0.85153 | 2 | 0.6533 |
| | Ripe banana peel-sodium bicarbonate ($NaHCO_3$) | 7 | 3 | 6 | 10.6 | | | |
| | Dithane M45 | 10 | 4 | 6 | 13.3 | | | |

Significance at 5 %(.05)

The statistical analysis revealed no significant difference (P≥0.05) between the effects induced by the treatments of *Erigeron*, ripe banana peel-$NaHCO_3$, and Dithane M45 on the incidence of fungal and bacterial diseases. This indicates that there is no variability in the incidence of these diseases when applying these different bio-pesticides compared to Dithane M45.

## 4. DISCUSSION

The treatments subjected to ripe banana peel-$NaHCO_3$ produced more slender, vigorous, and branching tomato plants compared to those treated with erigeron and the control (Dithane M45). Göksel and Kılınç [33] demonstrated that the application of ripe banana peel-$NaHCO_3$ had a positive impact on plant growth, with treated plants showing an increase in height, biomass, and root development compared to control plants. Our results align with those of Zhang et al. [34], who also found that the application of sodium bicarbonate to tomato plants positively affected growth, with treated plants showing increased height, number of leaves, and root development compared to untreated plants. Additionally, Khalil and Hassan [35] investigated the combined use of banana peel extracts and sodium bicarbonate in controlling tomato leaf mold caused by *Cladosporium fulvun*. This combination provides a synergistic effect, enhancing disease control while being environmentally friendly. Banana peel extract can inhibit the growth of pathogen, suggesting the potential as a natural fungicide [36] and it has antibacterial properties that can effectively reduce the incidence of bacterial wilt in tomatoes caused by *Ralstonia solanacearum* [37].Thus, sodium bicarbonate treatments reduced early blight severity and supported plant health[38].

However, tomato plants subjected to ripe banana peel-$NaHCO_3$ and Dithane M45 treatments were more slender, vigorous, and branching than those treated with erigeron and Dithane M45. Our findings for *Erigeron* treatment contrast with those of Almeida et al. [39] and Ghosh et al. [40]. Almeida et al. [39] found that using *Erigeron floribundus* extracts on tomatoes significantly increased plant growth, particularly in height and root development, and led to higher fruit yield. Likewise, Ghosh et al. [40] reported that *Erigeron floribundus* extracts stimulated tomato plant growth, promoting larger plant size and better nutrient absorption. These results suggest that erigeron can promote tomato plant growth.

No variability in the incidence of fungal and bacterial diseases was noted when applying these different bio-pesticides compared to Dithane M45. Our results show that the two extracts are as effective as Dithane M45. Kacem et al. [41] indicated that *Erigeron floribundus* extract has variable effectiveness on the incidence of cryptogamic diseases and tomato insect pests. Similarly, studies by Elad et al. [42] showed that sodium bicarbonate is effective against tomato late blight but has little effect on other fungal and bacterial diseases. Additionally, Bonnet-Bruno [43] reported that while the polyphenol content of 400 Degree Day (dd) bananas remained unchanged, 600 and 900 dd bananas showed a significant increase in polyphenol contents during ripening. These polyphenol compounds in bananas have effects on diseases and insect pests. Several authors Saeed and Saleem [44], Ritchie et al. [45], Horowitz and Dufault [46], Ming and Zhang [47], Jones and Jones [48], and Thakore [49] reported the use and the effectiveness of sodium bicarbonate to manage fungal pathogens in tomato plants. Again, it is effective at controlling the spread of fungus and can be used as an affordable alternative to chemical fungicides [50].

## 5. CONCLUSION

At the end of this study, the results showed that ripe banana peel-$NaHCO_3$ produced more slender, vigorous tomato plants with an identical number of branches compared to those treated with erigeron and the control (Dithane M45). No variability in the incidence of fungal and bacterial diseases was noted when applying these different bio-pesticides compared to Dithane M45. The bio-pesticide extracts (*Erigeron floribundus* and ripe banana peel-$NaHCO_3$) provide good protection against diseases and support good tomato production, comparable to Dithane M45. This work recommends that the population use ripe banana peel-$NaHCO_3$ and *Erigeron floribundus* for the production and protection of tomato crops in the area. They are non-toxic and environmentally friendly.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

All author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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