International Scholars Journals

International Journal of Manures and Fertilizers ISSN 2756-3863 Vol. 10 (2), pp. 001-008, February, 2022. Available online at https://internationalscholarsjournals.org/journal/ijmf/table-of-contents/2022 © International Scholars Journals



*Full Length Research Paper*

# Homemade Foliar Organic fertilizers based on local plant raw materials for strawberry farming in Rwanda

**James Okello[1,2*], Ali Mugume[2,3], Charles Muhwezi[4], Peter Nabasa[4], Zeddy Rusoke[2], Frederick Ssentongo[2]**

[1]Uganda Martyrs University (UMU) –Faculty of Agriculture - P.O. Box 5498 Kampala, Uganda.
[2]University of Technology and Arts of Byumba (UTAB) - Faculty of Agriculture, Environment Management and Renewable Energy - P.O. Box 25 Byumba, Rwanda.
[3]CAS Key Laboratory of Microbial Physiological and Metabolic Engineering, State Key Laboratory of Microbial Resources, Institute of Microbiology, Chinese Academy of Sciences, Beijing 100101, China
[4]University of Technology and Arts of Byumba (UTAB) – Faculty of Education - P.O. Box 25 Byumba, Rwanda.

Received 04 March, 2021; Accepted 08 May, 2021 and Published 22 January, 2022

## Abstract

**The present study was based on the findings from the baseline investigation carried out in four districts of Rwanda, namely, Muhanga, Kamonyi, Rulindo, and Gakenke. The baseline study revealed that strawberry farmers face the big challenge of lacking pesticides for pest control in their respective farms, among others. To mitigate the impact of the absence of pesticides on strawberry farming in Rwanda, the present study targeted the formulation of homemade organic foliar solutions, which in turn could be applied to strawberry crops for pest control. The foliar solution was produced in two consecutive phases and coded as UTAB-FOF1. The first phase consisted of conventional extraction using liquid leachate, which took around 15 days to complete, followed by the second phase of bioleaching performed at 30 degrees Celsius in order to concentrate the constituents of the mixture into a final product of the foliar fertilizer. The foliar solution was harvested through mechanical filtration and treated at 80 degrees Celsius for 20 minutes in order to increase its shelf life. Thereafter, the foliar solution was analyzed by a competent soil laboratory to assess its conformity. The values for essential nutrients in the foliar solution and secondary plant nutrients were found to be in the tolerable range, as they are all within the standard of thresholds. The on-farm trials performed in Gakenke district revealed that the foliar solution exhibits both fertilizer and pesticidal properties, and the field trial results showed that the strawberry treated with UTAB-FOF1 fertilizer showed a 1.6 fold relative growth rate of leaves and a 1.9 fold relative growth rate against controls. While the spray of the UTAB-FOF1 solution revealed repellent and insecticidal activities, the death rate of pests was not 100%. These findings provide validation evidence for UTAB-FOF1 as both a fertilizer and a pesticide.**

**Key words:** foliar fertilizer, indigenous knowledge, pesticidal activity, homemade and strawberry.

## INTRODUCTION

Foliar nurturing is the practice of feeding plants by spreading liquid fertilizer directly onto their leaves. Plants absorb nutrients through their stomata and epidermis. This method is appropriate for the application of small amounts of fertilizer, specifically micronutrients. Nowadays, foliar nourishing has been extensively used, especially in arid and semi-arid areas, and is recognized as an indispensable part of crop production, particularly

*Corresponding author: E-mail: jamesokellos@yahoo.fr

on horticultural crops (Patil and Chetan, 2018). Foliar application has demonstrated itself to be an outstanding technique for supplying plant necessities for secondary nutrients (calcium, magnesium, and sulfur) and micronutrients (zinc, manganese, iron, copper, boron, and molybdenum) while improving N-P-K needs for critical growth phase periods. Mainly, foliar feeding is anticipated to delay natural senescence processes just after the end of reproductive growth phases (McCall, 1980).

Foliar fertilizers are manufactured by simple formulation by mixing various amounts of secondary and micronutrients in water or by simple fermentation procedures using organic wastes as carbon resources. The later fertilizers contain indispensable plant nutrients and beneficial microorganisms that reprocess organic matter. Microorganisms have a significant role in the decomposition of substrates in the fermentation process. Towards the end of the fermentation process, phytohormones such as auxin and cytokinin, organic acids, plant growth promoters, and insecticidal agents are present in the foliar fertilizers (Phibun watthana wong and Riddech, 2019).

There are plentiful varieties of plants that can be used as substitute raw materials for the manufacture of foliar fertilizers. Some of the plants that can be used as alternative raw substances for fertilizer making include the Mexican sunflower (*T. diversifolia*) and fish bean (*T. vogelii*), chili pepper (*C. annuum*), marigold (*T. erecta*), papaya (*C. papaya*), and endod (*Phytolacca dodecandra) (M.* Yerizam et al., 2021). *T. diversifolia* has been used as a green manure for soil fertility improvement for its green leaf biomass and contains a considerable amount of nutrients, be around of 3.5% N, 0.37% P and 4.1% K on a dry matter basis (Jama et al., 2000); fish bean (*T. vogelii*) has the nitrogen content per 100 g dry matter is 3.7 g for 2-3 months old plants, falling to 1.2 g for 10 months old material, and the phosphorus content drops from 0.8 g to 0.2 g (Orwa, 2009); *C. annuum*which mainly contains capsaicin that has insecticidal activity against *Sitotroga cerealella, Alfalfa weevil, Myzuspersicae, Bemisiatabaci* (Li et al., 2019); while Papaya leaves contain alkaloid carpaine that exhibits insecticidal activity against *Spodopteralitura* (Rahayu et al., 2022).

The foliar solutions might serve as fertilizer as well as a pesticidal agent against a wide variety of pests. The present study targeted producing foliar solutions based on *T. diversifolia*, *T. vogelii, C. annuum, papaya* leaves (*C. papaya),* and *Phytolacca dodecandra*as the main substitute raw materials. Thus, it evaluates the applicability and effectiveness of the end product on strawberries. The foliar solution from the present study will stand as an alternative product to inorganic fertilizer and pesticides.

## MATERIALS AND METHODS

### Description of the study area

The District of Gakenke is one of five districts of the Northern Province of Rwanda. It borders with Rulindo District at its Eastern side, Burera and Musanze Districts at its North, Nyabihu District at its West, at the South by Kamonyi and Muhanga Districts. This District is divided into 19 administrative Sectors made of 97 Cells, 617 Villages. The District spreads over 704.06 Km2, with 345,487 inhabitants: 163,096 (47.2%) males and 182,391 females (52.8%). The density of the population in Gakenke District is 473 inhabitants/Km2. In relation to the population, 39.1% makes up the total percentage of youth in the district, which is also part of the working class. The climate in Gakenke district is generally a type of humid climate, with the average annual temperature varying between 160 °C and 290 °C. The humid wind comes from East to West. The rainfall is relatively abundant, with a scale between 1,100 and 1,500 mm per year. As it is the case in the Northern Province, Gakenke district has four different seasons: a small dry season from January to February, a high rain season from March to end May, a high dry season that extends from June to end August, and finally a small rain season from September to December (Intercontinental Consultants and Technocrats Pvt. Ltd. (India) and ALN Consultants Ltd (Rwanda), 2018). For Gakenke District, the mean size of land cultivated per household is 0.62 ha, which is above the national average (0.59 ha), rural average (0.6 ha) and urban average (0.46 ha). Gakenke District also has 80.5% of households cultivating under 0.9 ha of land. The proportion of cultivating households with under 0.3 ha of land by district shows that these households represent 43.1% in Gakenke District. Export crops are coffee and flowers. The percentage of households raising livestock is 84.5% of all households in Gakenke District, making it the first indicator countrywide. Gakenke district is characterized, in general, by high inclined hills separated by rivers and marshlands. The relief seems to comprise two distinctive regions: the high altitude region with mountains attaining at least 2 648 m (Mont Kabuye) and another region characterized by lowly inclined hills of 1,700 m of altitude, which in one way or another traduces soil erosion. Marshlands occupy an area of 361 hectares. These marshlands are generally exploited during the dry season (May–September). In relation to education, the net enrolment rate in primary school is 95.7% above the national average of 91.7%, and the secondary enrolment rate is 26.5%, which is above the national average of around 21%. These percentages rank the district in the first position in the Northern Province. The same survey revealed that the computer literacy rate for persons aged 15 and older stands at 3%, which is below the national average of 5.3% (Benineza et al., 2019).

### Raw Materials and Sampling

The materials used in this study were chili pepper (*C. annuum*), endod (*Phytolacca dodecandra*), *T. diversifolia*, *T. vogelii*, papaya leaves (*C. papaya*), wooden ash, cow urine, and water. The plant and animal materials used in this study were collected from the farmers' gardens in Gakenke District. The plant materials were randomly collec-

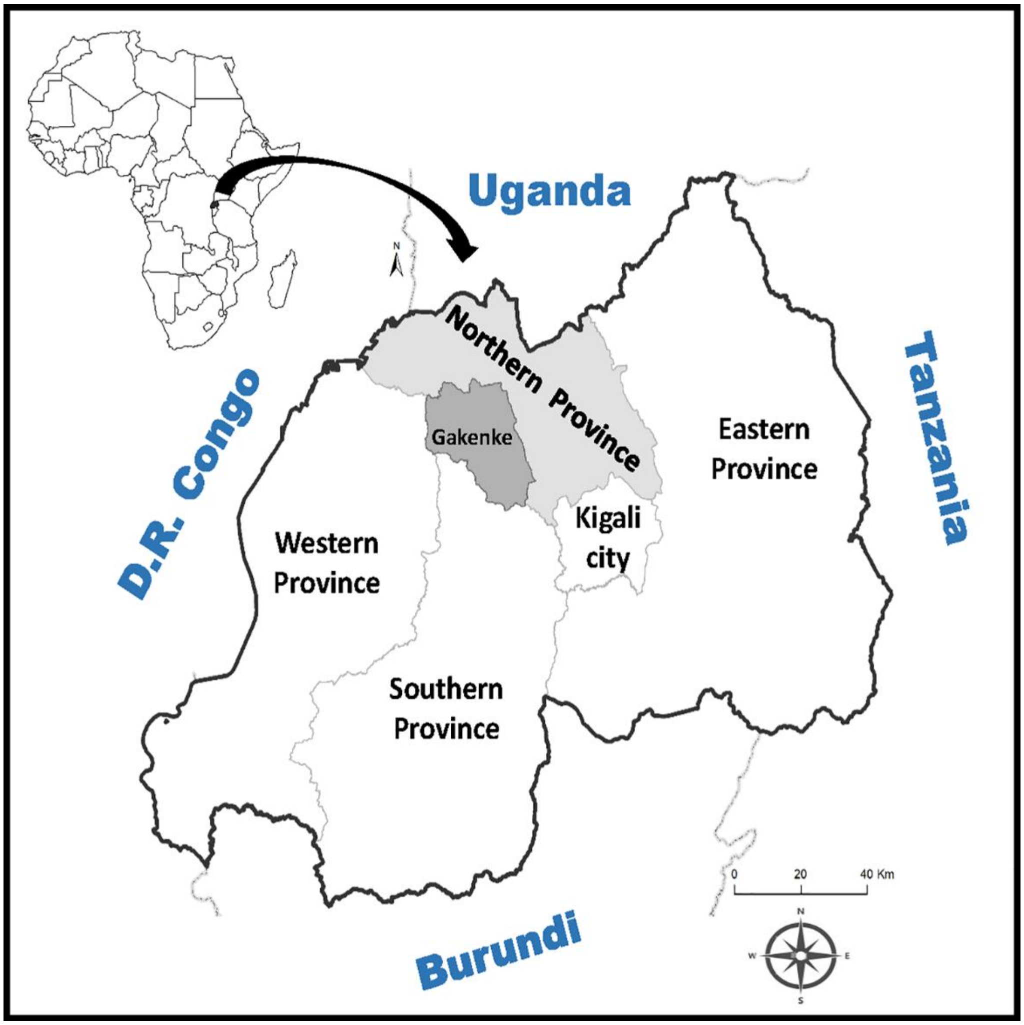


**Figure 1:** Administrative Map of Gakenke District.

ted from different farmers' gardens. The choice of plant raw materials depended on a literature scan that reported the presence of primary plant nutrients and insecticidal properties in the leaves of *T. diversifolia* (Jama et al., 2000) and *T. vogelii* (Rutunga et al., 1999), insecticidal activity in *C. annuum* (Li et al., 2019; Zhao et al., 2012), and larvicidal activity in *Phytolacca dodecandra* (Raja et al., 2015).

## METHODS

### Foliar Fertilizers Production Process

Prior to foliar fertilizer making, the plant materials were subjected to sorting, washing with water, and then blending. The foliar organic fertilizer was made with fermentation starters made from cow urine. A mixture of 300 g of *Phytolacca dodecandra*, 300 g of papaya leaves, 160 g of *C. annuum*, 600 g of *T. diversifolia,* 300 g of *T. vogelii,* 200 g of wooden ash, and 2 l of cow urine were used to make 5 l of foliar organic fertilizer, coded UTAB-FOF1.

The foliar organic fertilizer was made in two sequential stages. The first stage involved foliar fertilizer extracted from the mixture by conventional extraction with liquid leachate (a water solution with bacteria from cow urine), which took roughly 15 days to accomplish. The second stage involved a bioleaching procedure where the mixture results of the first stage were heated at 30 °C in order to concentrate the constituents of the mixture into a final product of the foliar fertilizer.

### Foliar Organic Fertilizers Harvesting and Conservation

The concentration from the second phase was mechanically filtrated in order to separate the liquid concentrate from the by-products. By measuring the weight of an equal volume of water and the liquid foliar fertilizer, the mass concentration of the foliar fertilizer was calculated using the following equation:

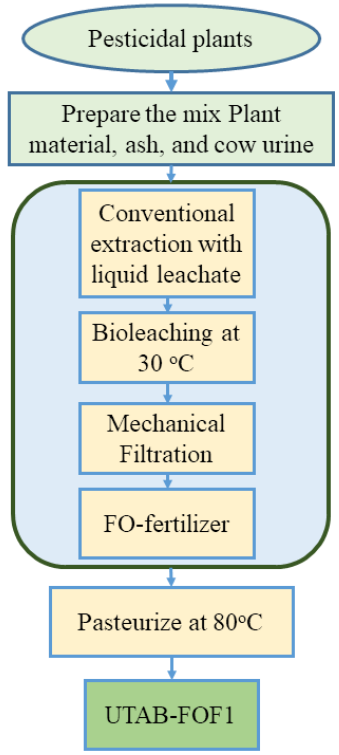


**Figure 2.** Flowchart for foliar liquid organic fertilizers.*FO – Foliar Organic, UTAB-FOF1 –Foliar organic fertilizer from UTAB*.

$$\text{Mass concentration} = \frac{(m_{\text{foliar solution}} - m_{\text{water}}) \times 1000\ \text{mL/L}}{V_{\text{sample (in mL)}}}$$

Where m is the mass and V is the volume.

A pretreatment was done prior to storing the foliar solution; the fertilizer was boiled at 80 °C for 20 minutes in order to kill spoiling microorganisms and extend the shelf life of the foliar solution.

### Laboratory analysis of foliar organic fertilizer

An aliquot was analyzed by an experienced laboratory of analysis, the soil laboratory of the National Agricultural Export Development Board (NAEB) of Rwanda, in order to evaluate the conformity of the foliar organic fertilizers produced from the present study. The analyzed parameters are as follows: pH, carbon: nitrogen ratio, total nitrogen, organic carbon, total primary nutrients (N-P2O5-K2O), soluble salts (conductivity), calcium, organic matters, Magnesium (%), Sulphur (%), Copper mg/kg, Iron mg/kg, Manganese mg/kg, Molybdenum mg/kg, Zinc mg/kg, Lead (Pb), Chromium (Cr), and Cadmium (Cd).

### Field testing of foliar organic fertilizer

The foliar fertilizer that was made during the present study, UTAB-FOF1, was applied to strawberry crops for three weeks in order to determine the pesticidal and fertilizer potential of the foliar solution. A control was spread by water, namely $T_1$, on the other hand, a second control was monitored without any spray, namely $T_2$. The comparative assessment of vegetative growth patterns of strawberry spread with foliar fertilizer was made periodically for about 12 weeks. Strawberry crop development data were collected at an average interval of three weeks from the spread of fertilizer. The different observed parameters to determine vegetative crop growth patterns were the length of leaves and the length of roots. The data were recorded, tabulated, and compared to determine the effectiveness of foliar fertilizers compared to the controls. On the other hand, the foliar solution was spread on strawberry leaves attacked by pests. A control was sprayed with water and non-treated crops. The data was recorded as pictures before and after seven days of spraying.

## RESULTS AND DISCUSSIONS

### Foliar organic fertilizer harvesting and conservation

The procedure of making foliar solution was completed within around 15 days. Subsequently, the foliar solution was collected through mechanical filtration. A total of 4.1 liters of the concentrate for UTAB-FOF1 were collected, equivalent to 82% yield (v/v) from the total volume. The

**Table 1.** Results of laboratory analysis of foliar organic fertilizers.

| Parameter | Standard requirement (RS279:2021) | Value detected in UTAB-FOF1 | Test method |
|---|---|---|---|
| **Specific parameters: Requirement** | | | |
| pH | 6-9 | 7.38 | RS 71:2013 |
| Carbon: Nitrogen ratio, max. | 20:01 | 13 | Walkley-black titrimetry and conversion |
| Total Nitrogen, %, m/m, min. | 1 | 0.92 | Official Journal of the European Union (2003). Method 2.2.3 |
| Organic carbon, %, m/m, min. | 5 | 4.3 | Walkley-black titrimetry and conversion |
| Total primary nutrients – N-$P_2O_5$-$K_2O$ (solid and liquid organic fertilizer), %, m/m, min. | 2 | 1.47 | Atomic Absorption Spectrophotometry |
| Soluble salts (conductivity), $\mu Sm^{-1}$ max. | $2.10^4$ | $2.3*10^3$ | ISO11265:1994(E) |
| **Secondary plant nutrients: Limits** | | | |
| Calcium, as Ca, %, m/m | ≥1.0 | 31.5 | Atomic Absorption Spectrophotometry |
| Magnesium (%) | ≥0.5 | 650 | Atomic Absorption Spectrophotometry |
| Copper mg/kg | 8-300 | 6.3 | Atomic Absorption Spectrophotometry |
| Iron mg/kg | 1000-2500 | 861 | Atomic Absorption Spectrophotometry |
| Manganese mg/kg | 200-800 | 120.7 | Atomic Absorption Spectrophotometry |
| Molybdenum mg/kg | 0.5-1.0 | 4.3 | Atomic Absorption Spectrophotometry |
| Zinc mg/kg | 40-1000 | 26.9 | Atomic Absorption Spectrophotometry |
| **Metal contaminants: Acceptable maximum limit** | | | |
| Lead (Pb), (mg/kg) | 30 | 11.9 | Atomic Absorption Spectrophotometry |
| Chromium (Cr), (mg/kg) | 50 | 1.1 | Atomic Absorption Spectrophotometry |

mass concentration of foliar fertilizer calculated was 18.05 g/L.

**Laboratory analysis of foliar fertilizer**

The conformity test of the foliar fertilizer produced from the present study was done by analyzing the nutrient composition of UTAB-FOF1. The results of the analysis are recorded in the table below.

The above results showed that values for essential nutrients in organic fertilizer and secondary plant nutrients are in a tolerable range as they are all within the standard of thresholds. In addition, the foliar organic fertilizer made from this study has no metal contaminants, as the level of heavy metals is far lower than the maximum acceptable limits. Thus, the nutrient composition of foliar organic fertilizers from this study confirms the acceptability of UTAB-FOF1 fertilizer.

**On-farm and field trials of foliar organic fertilizer**

The effectiveness of UTAB-FOF1 fertilizer on the vegetative growth pattern of strawberries was evaluated

**Table 2.** Efficacy of UTAB-FOF1 fertilizers on the growth of strawberry crops.

| **Parameter** | | **Non-treated crop (T2)** | **Spread with water (T1)** | **Spread with UTAB-FOF1** |
|---|---|---|---|---|
| Length of leaves (cm) | Before treatment | 3.5 | 3.5 | 3.5 |
| | First spray | 4 | 4 | 7.6 |
| | Second spray | 8 | 8 | 13.2 |
| | Third spray | 10.1 | 10.1 | 18.9 |
| Length of root (cm) | Before treatment | 5 | 5 | 5 |
| | First spray | 7 | 7 | 11.1 |
| | Second spray | 9 | 9 | 14.8 |
| | Third spray | 11 | 11 | 22.3 |
| Absolute growth (cm/week) | For leaves (12 weeks period) | 0.55 | 0.55 | 1.283 |
| | For roots (12 weeks period) | 0.5 | 0.5 | 1.442 |
| Relative growth (cm/week) | For leaves (12 weeks period) | 0.088 | 0.088 | 0.140 |
| | For roots (12 weeks period) | 0.066 | 0.066 | 0.124 |

Pests in strawberry garden: before spray of UTAB-FOF1 solution

Strawberry garden after treatment with UTAB-FOF1 solution

**Figure 3.**Field application of UTAB-FOF1 solution as insecticidal agent

by spraying the solution on the crop against control crops spread with water and non-treated crops (Table 2). The length of leaves and the length of roots were monitored over a period of 12 weeks. Furthermore, the pesticidal activity of the foliar fertilizer was evaluated by spraying the foliar solution on pineapple crops attacked by pests (Figure 3).

The results from the field application of foliar organic fertilizer in this study demonstrated that UTAB-FOF1 fertilizer is more effective for strawberry crops, as revealed by the relative growth rates of both leaves and roots. The results revealed that the strawberry treated with UTAB-FOF1 fertilizer showed a 1.6 fold relative growth rate of leaves and a 1.9 fold relative growth rate against the controls, non-treated or treated with distilled water. These findings provide additional validation evidence for UTAB-FOF1 fertilizer.

The findings from the field application of UTAB-FOF1 solution revealed repellent and insecticidal activities, as the death rate of pests was not 100% and the rest of the pests were not found on the farm. This activity might be due to different phytochemicals found in plant materials used for making UTAB-FOF1 fertilizer that exhibit pesticidal properties, such as capsaicin from *Capsicum annuum,* which has insecticidal activity against *Sitotroga cerealella, Alfalfa weevil, Myzus persicae, and Bemisiatabaci* (Li et al., 2019); and alkaloid carpaine from papaya leaves, which contains insecticidal activity against *Spodoptera litura* (Rahayu et al., 2022).

## CONCLUSION

The need for organic fertilizers is widely increasing worldwide in order to restore soil health and fertility, and they contain a reasonable amount of nutrients. During this study, foliar organic fertilizer was made (UTAB-FOF1). The mass concentration of both UTAB-FOF1 and UTAB-FOF1 fertilizer was calculated after fifteen days of conventional extraction with liquid leachate and bioleaching. UTAB-FOF1 fertilizer was found to have a mass concentration of 18.05 g/L. Afterwards, an aliquot of UTAB-FOF1 fertilizer was analyzed in the laboratory in order to gauge the conformity of this fertilizer. The results from the analysis showed that the composition of nutrients for essential requirements for organic fertilizers and secondary plant nutrients is in the acceptable range of standard threshold values, as most of the values approached the standard values with minor differences. Moreover, the laboratory analysis shows that foliar organic fertilizer is not contaminated with heavy metals, as the amounts of these metals are found to be far lower than the acceptable maximum values. The foliar organic fertilizer was tested on strawberry crops to evaluate its efficiency. The results from the field showed that the foliar fertilizer contained potential activities for the growth of the leaves and roots of strawberries within a period of 8 weeks. The relative growth rate for both leaves and roots of strawberries using UTAB-FOF1 was 1.6 folds and 1.9 folds, respectively. Furthermore, the foliar fertilizer revealed repellent properties for various pests found in strawberry gardens. The fertilizers produced in this study could provide a beneficial alternative to the use of inorganic fertilizers and pesticides and contribute to sustainable organic agriculture.

## ACKNOWLEDGEMENTS

The authors would like to thank all sponsors for their financial support of the present study. Our special thanks go to the Rwanda Organic Agriculture Movement ("ROAM"), Bio Vision Africa Trust ("BvAT"), and the Swiss Department for Development and Cooperation ("SDC") for the research grant under the Ecological Organic Agriculture Initiative (EOA-I) project.

## REFERENCES

Benineza, G. G., Rwabudandi, I., & Nyiransabimana, M. J. (2019). Landslides hazards assessment using geographic information system and remote sensing: Gakenke District. IOP Conference Series: Earth and Environmental Science, 389(1), 012015. https://doi.org/10.1088/1755-1315/389/1/012015

Intercontinental-Consultants-and-Technocrats-Pvt.-Ltd.-(INDIA), & ALN-Consultants-Ltd-(RWANDA). (2018). Resettlement Action Plan for Indicative feeder roads in the District of GAKENKE, Rwanda. Ministry Of Agriculture And Animal Resources, Rwanda Feeder Roads Development Project.

Jama, B., Palm, C. A., Buresh, R. J., Niang, A., Gachengo, C., Nziguheba, G., & Amadalo, B. (2000). Tithonia diversifolia as a green manure for soil fertility improvement in western Kenya: A review. Agroforestry Systems, 49(2), 201-221. https://doi.org/10.1023/A:1006339025728

Li, B., Yang, M., Shi, R., & Ye, M. (2019). Insecticidal Activity of Natural Capsaicinoids Against Several Agricultural Insects. Natural Product Communications, 14(7), 1934578X1986269. https://doi.org/10.1177/1934578x19862695

M.Yerizam, Norfhairna, N., Margaretty, E., Hajar, I., Meilianti, M., Supraptiah, E., Silviyati, I., & Salsabila, J. (2021). Liquid Organic Fertilizer Production From Kersen Leaves (Muntingia Calabura L.) And Eggshells With Addition Of Spoiled Rice Local Microorganism (Mol) Bioactivator. Atlantis Highlights in Engineering, 9.

Orwa. (2009). Tephrosia vogelii. Agroforestry Database 4.0, 1-5.

Patil, B., & Chetan, H. (2018). Foliar Fertilization of Nutrients. MARUMEGH Kisaan E-Patrika, 3, 49-53.

Phibunwatthanawong, T., & Riddech, N. (2019). Liquid organic fertilizer production for growing vegetables under hydroponic condition. International Journal of Recycling of Organic Waste in Agriculture, 8(4), 369-380. https://doi.org/10.1007/s40093-019-0257-7

Rahayu, S. E., Leksono, A. S., Gama, Z. P., & Tarno, H. (2022). The Bio-Insecticidal Activity of Papaya (Carica papaya L.) Leaves Extract against Spodoptera litura

Fabr. (Lepidoptera: Noctuidae) Larval Growth. Indian Journal Of Agricultural Research(Of). https://doi.org/10.18805/IJARe.AF-747

Raja, N., Masresha, G., & Jemberie, W. (2015). Insecticidal Activity of Phytolacca dodecandra L. Herit (Phytolaccaceae) Plant Extracts Against Cabbage Flea Beetle Phyllotreta cruciferae Goeze (Coleoptera: Chrysomilidae). American-Eurasian Journal of Scientific Research, 10(5), 325-331. https://doi.org/10.5829/idosi.aejsr.2015.10.5.9550

Rutunga, V., Karanja, N., Gachene, C., & Palm, C. (1999). Biomass production and nutrient accumulation by Tephrosia vogelii (Hemsley) A. Gray and Tothonia diversifolia Hook F. fallows during the six-month growth period at Maseno, Western Kenya. Biotechnologie, Agronomie, Société et Environnement, 3.

McCall WW (1980). Foliar Application Of Fertilizers. Hawaii Cooperative Extension Service: College of Tropical Agriculture and Human Resources, University of Hawaii, General Home Garden Series No. 24.

Zhao, J. W., Zheng, Y., He, Y. X., & Weng, Q. Y. (2012). [Biological activity of capsaicin and its effects on development and fecundity in Bemisia tabaci (Gennadius) (Hemiptera: Aleyrodidae)]. Ying Yong Sheng Tai Xue Bao, 23(2), 531-535.