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Pesticidal and Medicinal Value of Turmeric and Ginger in Tanzania and Their Antifungal Activity against Phytopathogens

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Abstract

Use of synthetic pesticides to manage crop pests has had a toll on human health, environmental safety and farmer's income creating a need for alternative crop protection strategies. Botanical pesticides have been reported to be effective in managing crop pests, and a number of them have been formulated and commercialized. This study was conducted in North-Eastern Tanzania to establish the pesticidal and medicinal value of turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*). Purposive sampling was adopted to select and interview 167 respondents drawn from farmers, traders, pharmaceutical shops, agro-shop operators and consumers of turmeric and ginger. Ginger and turmeric rhizomes were also collected for extraction, antifungal assay and biochemical analysis. Results showed that majority of the respondents were aware of the medicinal value of ginger and turmeric, with 59.5% having used the plants to treat respiratory related infections and healing skin surface and internal wounds. About 14% of farmers were aware of and had used aqueous botanical preparations from neem, moringa and *Tephrosia* to manage insect pests. Only 2.7% of farmers had used ginger powder as a protective insecticide on stored grains. Ginger and turmeric rhizome extracts showed high antifungal activity against *Pythium* (83% - 95%), *Fusarium oxysporum* f. sp. *lycopersici* (34% - 52%) and *Alternaria solani* (38% - 53%). A GC-MS analysis of ginger and turmeric extracts showed presence of *α*-zingiberene, *β*-sesquiphellandrene, *α*-farnesene, *ar*-curcumene, *α*-copaene, *ar*-tumerone and curlone. This study recommends that ginger and turmeric extracts be considered for development of a botanical pesticide and especially for management of damping off diseases.

Keywords

Botanical Pesticides, *Curcuma longa,* Medicinal Plants, Spices, *Zingiber officinale*

1. Introduction

Synthetic pesticides are effective in reducing damage caused by pests and diseases, but they also have adverse ripple effects on environmental and human health [1]. The active ingredients in the synthetic pesticides accumulate in the environment leading to pollution and killing of non-target organisms and pollinators [2]. These compounds also accumulate in food products, leading to toxicity and chronic illnesses in humans [3]. Due to the negative effects associated with the use of synthetic pesticides, there has been growing demand for safe and healthy food produced in a clean and safe environment and using safer crop protection products. Alternatives to synthetic pesticides include natural crop protection products derived from botanicals, microbial antagonists, predators and parasitoids [4] [5].

Turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) rhizomes are used mainly as spices and food preservatives but they also have medicinal value [6] [7]). Turmeric has been used extensively as a medicinal plant to manage human illnesses such as diabetes, wounds and skin infections [8]. Turmeric is also used to make beauty products for hair and skin [9]. Ginger has been used to manage human ailments including coughs, colds, indigestion, throat infections, flatulence and also lowers blood cholesterol and relieves pain [10]. The benefits of turmeric and ginger are attributed to presence of compounds with anti-inflammatory, anti-oxidant and anti-nausea properties. The antimicrobial compounds contained in turmeric and ginger that make them important sources of human medicine also make them suitable sources of plant protection products [11]. Turmeric and ginger are reported to be effective against an array of crop pests and pathogens [12] [13].

The antimicrobial activity and potential of bioactive compounds present in turmeric and ginger in management of plant fungal diseases has been demonstrated in various studies. Crude extracts of turmeric were reported effective in reducing the growth of *Podosphaera xanthii*, the causal agent of powdery mildew in cucumbers [7]. The n-hexane fraction of methanol extracts of turmeric rhizome effectively controlled wheat leaf rust in vivo [11]. Curcumin isolated from turmeric showed high antifungal activity against *Fusarium solani sensu lato*, a group of pathogens with quite a wide host-range [12]. Methanol extracts of ginger showed total reduction in growth of post-harvest fungi associated with maize *viz Aspergillus candidus*, *Penicillium versicolor*, *Fusarium oxysporum* and *Rhizoctonia solani* [13]. Rizwana [14] reported a 90% reduction in mycelia and complete inhibition of spore germination of *Alternaria alternata* by ethanol extracts of ginger. Ginger essential oil has showed significant inhibition in growth of several fungal pathogens causing root rot in ginseng [15]. Ethanol extract of ginger inhibited growth of fungal pathogens causing rot in soursop fruit [16]. Different varieties of turmeric and ginger contain varied amounts and concentrations of the bioactive compounds making them synergistically effective against a wide range of fungal pathogens. Unlimited studies have reported the potential of ginger and turmeric as sources of botanical pesticides.

This study was conducted to determine the utilization and awareness of pesticidal and medicinal value of turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) in Tanzania. The antifungal activity and biochemical composition of ethanolic extracts of turmeric and ginger was also assessed.

2. Materials and Methods

2.1. Description of the Study Site

A survey was carried out between September and October 2018 in the Northern and Eastern regions of Tanzania, covering six districts: Same, Korogwe, Tanga, Moshi, Lushoto and Muheza which are among the major producers of ginger and turmeric. Moshi District is located at 3S 37E; Same 4S, 38E and 4S, 37S; Lushoto 4S, 38E; Muheza 5S, 38E and Tanga 5S, 39E. Inhabitants of these districts had different socioeconomic activities. Same District, where most of the ginger is produced, receives rainfall of between 400 and 1000 mm per year, and has hilly mountains with plateau parts and an altitude of up to 2000 m above sea level [17].

2.2. Selection of Informants

The study sites within the study districts were purposively selected based on production, marketing or use of ginger and turmeric. A total of 167 respondents consisting of 38 farmers, 89 traders, and 42 users were sampled. The farmers were identified with the help of local agricultural officers and the consent to participate in the study was sought from each respondent. Both male and female respondents were selected based on their experiences in either production, sale or use of turmeric and/or ginger or their products. Targeted sampling was adopted for respondents operating agro-shops and pharmaceutical shops due to their low numbers [18].

2.3. Study Design and Data Collection

The survey was carried out in the six study districts using semi-structured questionnaires and face-to-face interviews specifically designed for each category of the respondents from farmers, major markets, agro-shops and pharmaceutical shops. Information obtained from each respondent included availability and utilization of ginger and turmeric, awareness on the medicinal and pesticidal value, home consumption, gender, age, level of education, occupation and marital status. Additional information sought included the length of time each respondent had used ginger and turmeric or their products, how they learnt about those uses and whether they would recommend the use of those plants or their products to other people. Since Kiswahili is the national language spoken and understood by all people in Tanzania, the questionnaires were translated with the help of the local agricultural officers.

Interviews with pharmaceutical shop attendants focused on whether they sold products that contained ginger or turmeric and the recommended use(s) of those products. Agro-shop operators were asked whether they were aware of botanical pesticides, whether they sold products containing botanical ingredients and the perspective of farmers about botanical products.

The survey was partly carried out to allow collection of samples from where ginger and turmeric were grown.

2.4. Sample Collection, Extraction and Antifungal Activity Assay

During the survey, rhizomes of turmeric and ginger were collected from the growers and separately packed in khaki bags for temporary preservation and transportation to the Life Sciences Laboratory at NM-AIST. The samples were cleaned off dirt using running tap water with slight brushing to remove the soil stuck between rhizome thumbs. The clean rhizomes were then chopped into 3 mm slices and thinly spread out on khaki sheets to dry under shade for seven days. The dry slices were ground into powder and soaked in 97% ethanol at the ratio of 1:3 for 72 h with constant shaking. The ethanol powder mixtures were separately filtered through double layer cheese cloth followed by a Whatman No. 1 filter paper and the filtrate was concentrated by evaporation under vacuum using a rotary evaporator at about 60˚C [14]. In order to maximize the quantity of extracts, the ethanol recovered from evaporation was used to resoak the filtrate and evaporation done every 72 h twice.

The extracts were tested for antifungal activity against *Fusarium oxysporum* f. sp *lycopersici*, *Alternaria solani* and *Pythium* sp. using poisoned food technique [19]. The three are the major fungal pathogens that cause wilt, early blight and damping off in tomato respectively. A stock solution was prepared at a concentration of 1 g/mL in ethanol for each of the extracts and added into molten potato dextrose agar media at a concentration of 30 μg per mL. The amended medium was plated in 9 cm Petri dishes and after setting, a 3 mm mycelial plug agar disc cut from actively growing cultures of *Fusarium oxysporum* f. sp *lycopersici, Alternaria solani* and *Pythium* sp. was placed central of each Petri plate. Positive control plates contained media amended with a fungicide, Ridomil Gold® (metalaxyl-M 40 g/kg and mancozeb 640 g/kg) while the negative control plates contained media with no amendment. The experiment was laid out in a completely randomized design, repeated once and each treatment was replicated three times. Antifungal activity was determined as the percentage fungal colony growth inhibition of the test pathogen by each extract as compared to the negative control using the following formula:

$$\%\ \text{Inhibition} = \frac{\text{Colony diameter}(\text{Control}) - \text{Colony diameter}(\text{Treatment})}{\text{Colony diameter}(\text{Control})} \times 100$$

2.5. GC-MS Analysis of Ginger and Turmeric Extracts

The ethanol extracts from ginger and turmeric were subjected to a GC-MS analysis to identify the constituent active compounds as described by Cheseto *et al.* [20]. One milligram of each of the extracts was dissolved in one mL of ethanol and vortexed for approximately 20 s. The solution was passed through a plug fitted with a filter paper and anhydrous Na_2SO_4 to dry the samples. The final volume was topped up to one millilitre and analysed with a GC-MS (Agilent Technologies Inc., Santa Clara, CA, USA) fitted with a low bleed capillary column, with helium as the carrier gas. The GC-MS oven temperature started at 35˚C and ended at 285˚C. The constituent active compounds were identified based on the compounds' mass spectra and retention time.

2.6. Data Analysis

The survey data was coded and subjected to descriptive analysis using IBM SPSS Statistical Package Version 22 to obtain frequencies and valid percentages. *In vitro* data was subjected to one way analysis of variance using GenStat® 15^{th} Edition, VSN International. The derived means were separated by Tukey's test at 5% probability level. GC-MS data was analysed using a Hewlett-Packard workstation equipped with ChemStation B.02.02 and the compounds' mass spectra and retention time compared with those registered in the NIST 05, 08, 11 library.

3. Results

3.1. Social Characteristics of Study Participants

Out of the interviewed participants, traders were the majority (68.9%) followed by farmers. About 58% of the respondents were male with most of the respondents aged between 20 and 39 years, thus representing over 70% of youth. There was a small representation (13.8%) of participants belonging to the ages between 40 - 49 years and above 60 years. About 70% of the participants had received primary education and about 6.6% of the participants had received tertiary education. There was a minimal representation of the civil servants and students (**Figure 1**).

3.2. Availability of Ginger and Turmeric in the Study Area

There were many farmers in Same District who produced ginger in large scale and had been in that business for more than five years (**Table 1**). Ginger was sold in all the sampled markets and it was the most common rhizome in the study districts with 100% availability in Lushoto, Moshi and Same. Turmeric was only available in some markets and in few districts at the time of the study. Less than 17% of the traders in Muheza, Tanga and Korogwe Districts sold a combination of ginger and turmeric. About 5.5% of traders in Muheza District exclusively sold turmeric (**Figure 2**).

Ginger and turmeric were sold mainly as fresh rhizomes or in processed form,

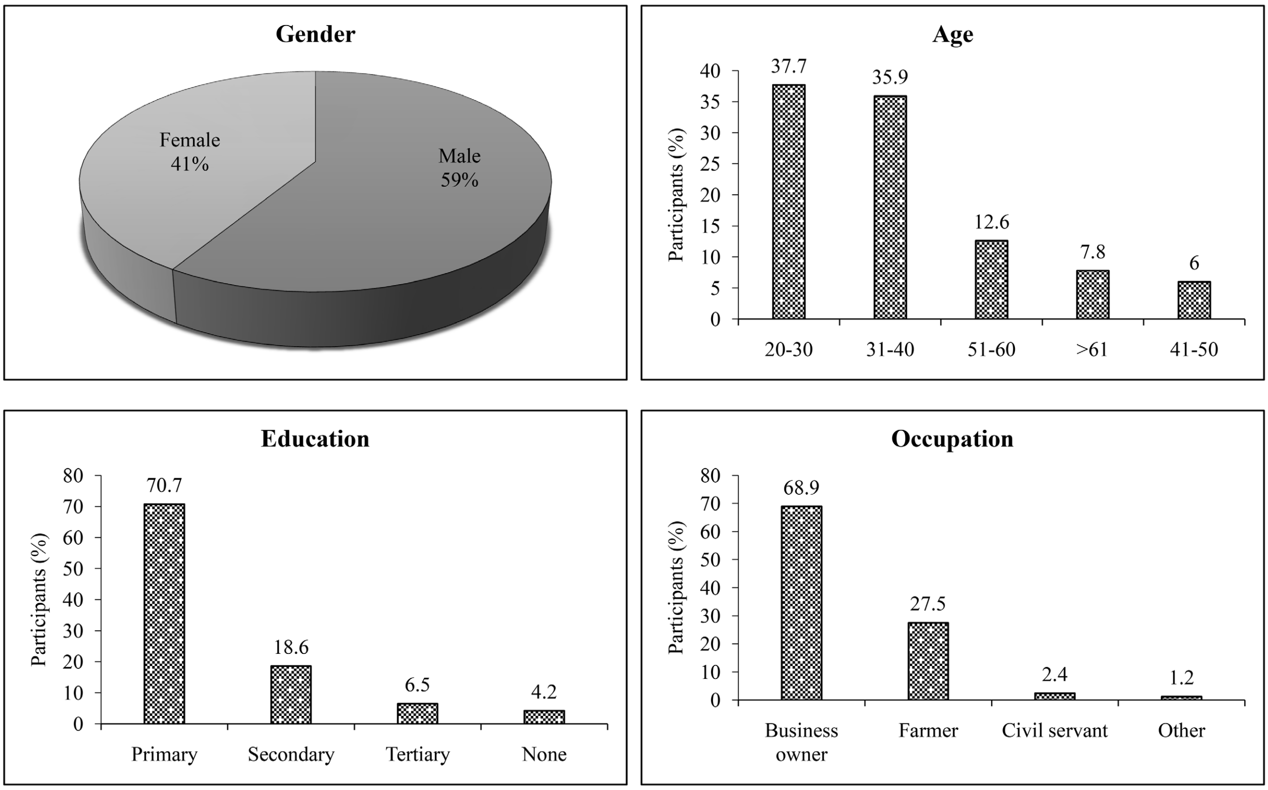

Figure 1. Gender, age, level of education and occupation of participants in selected districts in Northern Tanzania.

Table 1. Farmers' experiences in production of turmeric and ginger in Same District

Questions	Category	Percent participants	Observations
Plants grown	Turmeric	2.7	Only a single farmer had turmeric at the time, others were coming up
	Ginger	97.3	
Purpose of growing plants	Sale	75.7	Home uses include spicing tea and vegetables and marinating meat
	Home consumption	5.4	
	Both	18.9	
Acreage under ginger and turmeric production	<0.5	5.4	Ginger is intergrown with other crops like cassava, maize and arrow roots
	0.5 - 1	27.0	
	1 - 3	56.8	
	>5	10.8	
Number of years in ginger and turmeric farming	1 - 2	10.8	The number of years in ginger and turmeric production is relative to the age of the farmer
	2 - 5	21.6	
	>5	67.6	

with between 55 and 90% of the traders in Korogwe District selling fresh ginger rhizomes. Processed ginger and turmeric were sold as either dried chips or powder. The chipping and drying were done at the farm while grinding was done in a processing factory. The high sale of fresh rhizomes is related to their uses as spices and medicine (**Figure 3**).

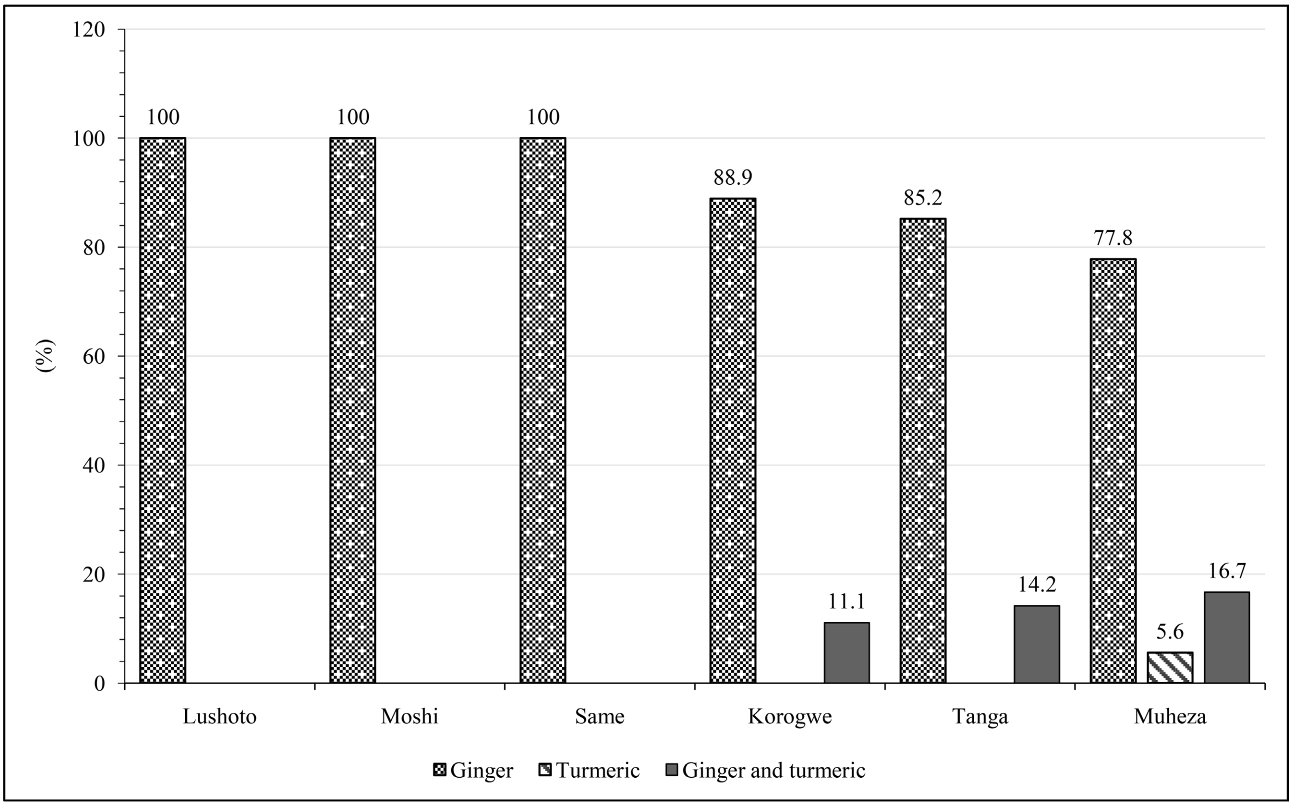

Figure 2. Percentage of traders selling turmeric and ginger in six districts in Northern Tanzania.

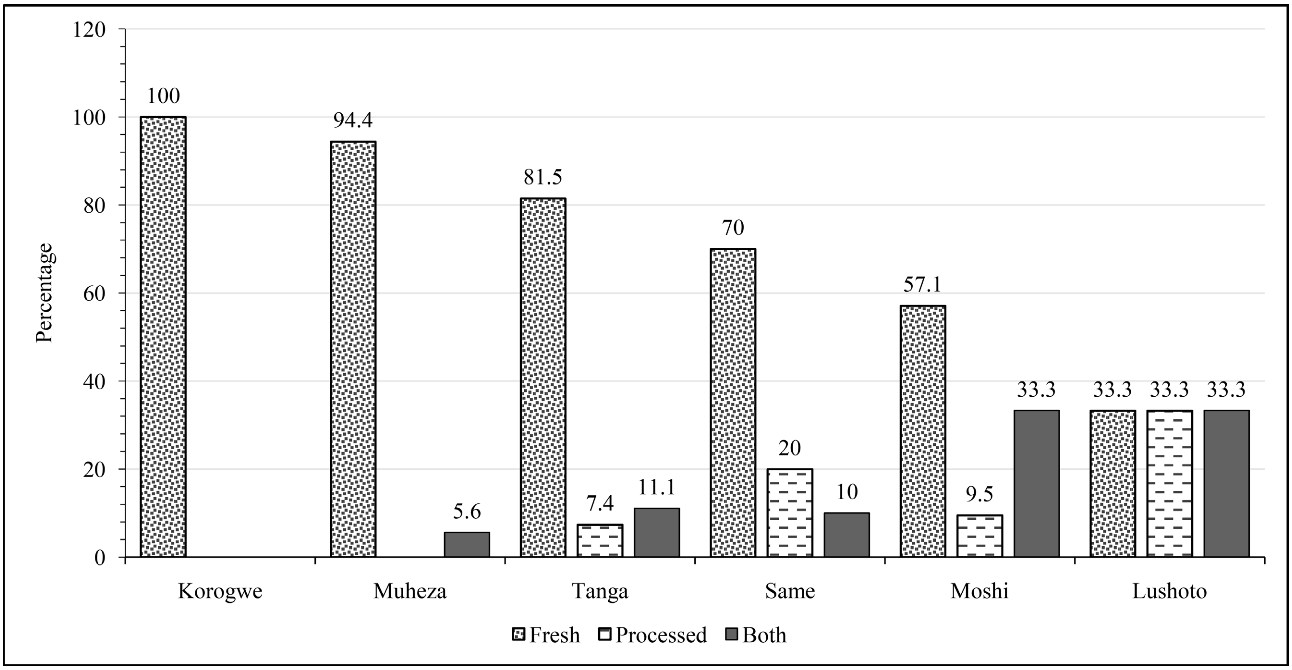

Figure 3. Percentage of traders selling fresh and processed turmeric and ginger in six districts in Northern Tanzania

3.3. Spice and Medicinal Use of Ginger and Turmeric

Turmeric and ginger were used as spices by 65% to 88% of the respondents. Muheza, Korogwe and Same Districts had the highest percentage of respondents who used turmeric and ginger as spices. The spices were used in tea, meats, vegetables and cereal meals. Turmeric and ginger were also used for medicinal purposes such as treating coughs and flu and healing skin wounds. About 3.7% of respondents used turmeric exclusively as a beauty product and this was common in areas where turmeric was grown. About 11% of the respondents in Muheza, Tanga and Korogwe Districts utilized the plants as spices, medicine and for beauty. Higher proportion of respondents in Lushoto District used turmeric and ginger as both spice and medicine. In Tanga District, the two plants were used for spicing, medicinal and beauty purposes (Table 2). All the respondents in the trader category used ginger and turmeric as spices.

Table 2. Percentage of participants utilizing ginger and turmeric as spice, medicine and beauty in selected districts in Northern and Eastern Tanzania.

District	Spice	Spice and medicine	Spice, medicine, beauty	Total
Customers				
Muheza	88.9	0.0	11.1	100.0
Lushoto	66.7	33.3	0.0	100.0
Moshi	85.7	14.3	0.0	100.0
Tanga	70.4	18.5	11.1	100.0
Korogwe	77.8	11.1	11.1	100.0
Same	80.0	20.0	0.0	100.0
Trader participants				
Muheza	94.1	5.9	0.0	100.0
Lushoto	33.3	66.7	0.0	100.0
Moshi	89.5	10.5	0.0	100.0
Tanga	88.9	11.1	0.0	100.0
Korogwe	77.8	22.2	0.0	100.0
Same	70.0	30.0	0.0	100.0
User participants				
Moshi	88.8	5.6	5.6	100.0
Korogwe	100.0	0.0	0.0	100.0
Same	100.0	0.0	0.0	100.0
Tanga	66.7	22.2	11.1	100.0

3.4. Awareness on Medicinal and Pesticidal Value of Ginger and Turmeric

About 13.5% of the interviewed farmers were aware of botanical pesticides and have used aqueous botanical preparations from other plants such as neem, moringa, Mexican sunflower and *Tephrosia* to manage pests and diseases that affect vegetables. A negligible percent of the farmers had used ginger powder as an insecticide to manage postharvest insect pests of maize and beans with notable success (**Table 3**). There was a correlation of 0.429 between respondents who were aware of botanical pesticides and those who used ginger as a protective insecticide.

Table 3. Farmers' awareness on the medicinal and pesticidal value of ginger and turmeric and botanical pesticides in Same District.

Question	Category	Percent of participants	Observations
Awareness on medicinal value	Yes	59.5	Ginger used to manage flus, coughs and chest infections. Turmeric was used for skin related infections, wounds and ulcers.
	No	40.5	
Awareness on pesticidal value	Yes	2.7	Used as an insecticide to manage post-harvest pests of beans and maize
	No	97.3	
Awareness on botanical pesticides	Yes	13.5	Mostly farm preparations from plants such as neem, Mexican sunflower, moringa and *Tephrosia*
	No	86.5	

Over 60% of the respondents in the sampled districts were aware of medicinal value of ginger and turmeric with 59% of the interviewed farmers in Same District being aware on the medicinal value of the two plants. Respondents in Korogwe District had 100% awareness on medicinal value of the study plants (**Table 4**). Ginger was majorly used to manage respiratory infections such as flu and coughs and it was used in combination with other plants such as lemon and garlic. Turmeric was used for healing skin related infection, wounds, and ulcers.

Lushoto and Same Districts had the highest percentage of respondents with knowledge of the medicinal value of turmeric and ginger at 66.7% and 60%, respectively. Respondents from Muheza District had the lowest awareness on medicinal value of ginger and turmeric with over 60% indicating that they didn't know medicinal uses of the two plants. Between 30% and 50% of respondents from Lushoto and Tanga Districts indicated that they did not know any medicinal value of turmeric and ginger. Moshi and Korogwe Districts had the highest percentage of participants with knowledge of the medicinal value of ginger and turmeric (**Table 4**).

Pharmaceutical shops sold products containing ginger as tablets for soothing coughs, flu and other respiratory infections. They also sold slimming tea containing ginger and other plants such as lemongrass, lemon and fenugreek. Other natural products sold in the pharmaceutical shops included soaps containing neem, aloe vera and turmeric. The agro-shop operators were aware of botanical pesticides but sold none. They indicated that such products were not as common as the synthetic chemical pesticides and farmers were not aware of them. Some agro-shop operators however indicated that they were willing to sell botanical pesticides so long as the products were authentic, effective and farmers were aware of them and their efficacy.

Table 4. Percentage of traders and consumers aware of the medicinal value of turmeric and ginger in Northern and Eastern Tanzania.

District	Yes	No	I don't know	Total
Traders				
Muheza	23.5	11.8	64.7	100.0
Lushoto	66.7	0.0	33.3	100.0
Moshi	42.9	57.1	0.0	100.0
Tanga	31.8	18.2	50.0	100.0
Korogwe	42.9	57.1	0.0	100.0
Same	60.0	40.0	0.0	100.0
Users				
Moshi	61.1	38.9	0.0	100.0
Korogwe	100.0	0.0	0.0	100.0
Same	80.0	20.0	0.0	100.0
Tanga	88.9	11.1	0.0	100.0

3.5. Antifungal Activity of Ginger and Turmeric against Tomato Fungal Pathogens

Both ginger and turmeric extracts showed antifungal activity against *Pythium* sp., *Alternaria solani* and *Fusarium oxysporum* f. sp. *lycopersici*. The ethanol extracts of ginger inhibited the growth of *Pythium* sp. by 83%, *Fusarium oxysporum* f. sp. *lycopersici* by 34% and *A. solani* by 65%. The activity of ginger was lower than that of the commercial fungicide. Turmeric extracts inhibited the growth of *Pythium* sp. by 95%, *Fusarium oxysporum* f. sp. *lycopersici* by 62% and *A. solani* by 53%. The activity of turmeric extract against *Pythium* sp. was similar to that of the fungicide containing metalaxyl-M (40 g/kg) and mancozeb (640 g/kg). Turmeric extracts were more effective against *Fusarium oxysporum* f. sp. *lycopersici* than the commercial fungicide by about 40% (**Figure 4**).

3.6. GC-MS Analysis of Ginger and Turmeric Ethanolic Extracts

GC-MS analysis of the ginger extract indicated presence of *α*-zingiberene, *β*-sesquiphellandrene, *α*-farnesene, *ar*-curcumene, *α*-copaene, *ar*-tumerone and hexanal among others (**Table 5**). Extracts of turmeric indicated presence of *ar*-turmerone, curlone, turmerone, *α*-zingiberene, E-*α*-atlantone, *β*-sesquiphellandrene and E-caryophyllene among others (**Table 6**).

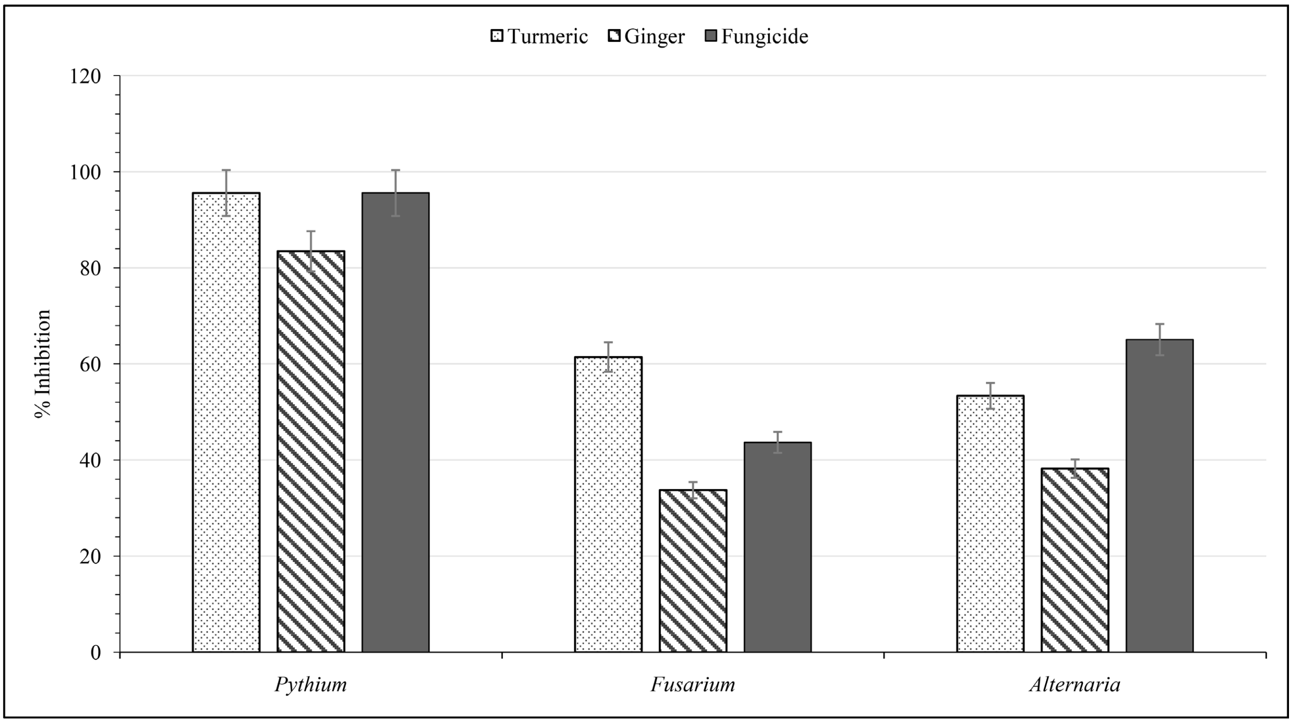

Figure 4. Percentage inhibition of colony radial growth of *Pythium, Fusarium and Alternaria* cultured on media amended with turmeric and ginger extracts at 7 days after incubation. Error bars show standard error.

Table 5. First twenty abundant bioactive compounds detected by GC-MS in ginger extract.

Peak no.	Retention time (min)	Compound identity	Abundance (%)
1	3.13	3,5,5-Trimethylhexyl S-2-(dimethylamino)ethyl propylphosphonothiolate	0.64
2	3.49	1-Pentene, 2-methyl-	2.40
3	3.83	Cyclopentane, methyl-	3.63
4	3.83	1-Pentene, 2-methyl-	3.54
5	17.76	E-Caryophyllene	0.62
6	18.11	E-*β*-Farnesene	0.63
7	18.51	*Ar*-Curcumene	7.54
8	18.68	*α* Zingiberene	24.43
9	18.76	*α*-Copaene	4.34
10	18.77	*α*-Farnesene	9.82
11	18.82	*β*-Bisabolene	3.45
12	19.02	*β*-Sesquiphellandrene	12.03
13	20.27	Cis-*α*-Bergamotene	0.80
14	20.60	a-Eudesmol	0.97
15	20.60	*β*-Eudesmol	1.31

Continued

16	20.67	*Ar*-tumerone	0.68
17	20.71	Tumerone	0.92
18	23.70	geranyl-p-cymene	0.68
19	23.99	Hexadecanoic acid, ethyl ester	0.98
20	25.56	Methyl linoleate	0.81

Table 6. First twenty abundant bioactive compounds detected by GC-MS in turmeric extract.

Peak no.	Retention time (min)	Compound identity	Abundance (%)
1	17.78	E-Caryophyllene	1.46
2	18.50	*Ar*-Curcumene	2.61
3	18.65	α-Zingiberene	3.83
4	18.82	β-Bisabolene	1.29
5	19.01	β-Sesquiphellandrene	4.87
6	19.46	E-Nerolidol	0.51
7	19.82	Cis-Sesquisabinene hydrate	0.74
8	19.82	7-epi-cis-sesquisabinene hydrate	0.66
9	20.71	*Ar*-Turmerone	30.84
10	20.75	Tumerone	18.52
11	21.12	Curlone	18.78
12	21.24	Curcuphenol	0.55
13	21.60	6S, 7R-Bisabolone	1.97
14	21.81	Furazan	0.88
15	21.89	E-α-Atlantone	3.12
16	22.08	Tumerone	0.69
17	24.16	2,6-Nonadien-4-one, 9-(3-furanyl)-2,6-dimethyl-, (E)-	1.76
18	24.17	3-Methylbut-2-enoic acid, 3-methylphenyl ester	1.06
19	24.37	3-Methylbut-2-enoic acid, 3-methylphenyl ester	1.38
20	24.37	Hexane, 1,6-dibromo-	1.04

4. Discussion

4.1. Social Characteristics of the Survey Respondents

Majority of the respondents were aged between 20 and 40 years, most of them being men and having received at least primary school education. This is in concurrence with a study by Mmasa and Mhagama [21] that young people are involved in production and sale of agricultural produce. The involvement in agriculture gives the youth an alternative source of income in addition to formal employment. Moreover, that age group has the strength to provide the necessary workforce needed in the agricultural sector [22]. The observation that men were more involved in sale and growing of ginger and turmeric could be supported by the role of the male gender as the heads of households. Men own most of the property and they are the providers and protectors in the family [23]. Therefore, they mostly direct the activities carried out on the farms that they own [24]. The medicinal uses of ginger and turmeric were better elucidated by people above 40 years possibly because the number of years one has lived results in accumulation of information an individual has about their society. Similar observations were made by Silva *et al.* [25] who reckoned that the number of medicinal plants named by participants in their study was related to the age of the informant. However, Vandebroek and Balick [26] opined differently attributing such knowledge to migration habits which contribute to additional information. A higher level of education also exposes individuals to information and if well utilized, that information could lead to personal development. Nevertheless, Kalirajan and Shand [27] reported that there was no significant relationship between education of the farmers and attainment of higher yield. In this study, respondents who had received tertiary education were aware of botanical pesticides and understood their benefits compared to the synthetic chemicals. This finding is supported by Adebiyi and Okunlola [28] who accounted that the level of education of an individual influence their understanding and hence adoption of new technologies. Adoption and utilization of new technologies may lead to increased agricultural productivity as well as improved quality of the produce.

4.2. Availability of Ginger and Turmeric in the Study Area

It was gathered that ginger and turmeric were always available in the market any time of the year. The prices however change according to time of the year and seasons [29]. During harvesting, prices fall to about 0.3 US dollars and could go up to 2 US dollars per kilo of fresh rhizomes during the planting season. The prices at the harvesting season are usually determined by middlemen who buy the produce in large quantities and resell later at slightly higher prices. The farmers did not benefit fully and had no say in the prices of their produce [30]. Augustino [31] attributed the involvement of middlemen to failure of operations of the ginger factory in Same District. According to the interviewed ginger farmers, when the factory was operational, they sold their produce at better prices. The consideration of ginger and turmeric as sources of pesticides would hence create an alternative market for farmers and consequently a better income. There would be no conflict in the uses of these plants since they are always available in the markets. A recommendation by Maerere [32] to enhance marketing of spices in Tanzania would be met by this alternative market of botanical pesticides. It would not only widen the market for such plants but also increase the income for the farmer. Other plants with essential oils have been considered for non-food uses with notable success and effectiveness [33] [34].

4.3. Medicinal Uses of Ginger and Turmeric

The survey respondents reported that turmeric was used for beauty, spicing food and as medicine for healing internal and skin surface wounds. Ginger was used as a spice for tea and meat as well as a source of medicine for colds, coughs and other respiratory related infections. These uses have been reported elsewhere especially in Asia, where the plants originated from [6]. The effectiveness of ginger against respiratory infections may explain its popularity during the COVID-19 pandemic. Other reported benefits of ginger include improving digestion, blood circulation and lowering cholesterol [10] [35]. Some respondents claimed that ginger was used to improve libido as is substantiated by Yadav *et al*., [36] who reported that intake of about 15 grams of ginger daily could lead to increased testosterone levels. Turmeric is widely used as a beauty product [9] and in the study region it was culturally applied on brides on their wedding days.

4.4. Awareness on Pesticidal Value of Ginger and Turmeric

The study found that the respondents were totally unaware of the pesticidal value of turmeric. However, a negligible percent of the interviewed farmers was aware that ginger has insecticidal properties. They had used ginger powder to protect maize and beans against storage pests with notable success. A section of farmers in Same District were aware of botanical pesticides and had used aqueous preparations from *Azadirachta indica*, *Tithonia diversifolia*, *Tephrosia vogelii* and *Moringa oleifera* to manage crop pests. The pesticidal properties and the availability of commercial formulations of these plants have been well documented [37]-[42].

In addition to medicinal, beauty and spice uses, the compounds found in turmeric have been reported to have insecticidal, fungicidal, repellent and antifeedant properties on insect pests [43] [44]. Rajput and Chaudhari [45] reported a growth inhibition of about 54% on *Alternaria alternata*, the causal agent of leaf-spot disease of brinjals (*Solanum melongena*) by turmeric extracts. The efficacy of turmeric is enhanced when used in combination with extracts from other plants [46]. Ginger has been reported effective in managing both insect pests and pathogens. Hamada *et al.* [47] reported that ginger oils decrease the hatchability of cotton leafworm (*Spodoptera littoralis*) while Babu *et al.* [48] also reported toxicity and repellence of ginger oil and oleoresins against larvae of diamondback moth (*Plutella xylostella*) on cruciferous plants. Sinha *et al.* [13] reported the effectiveness of methanolic extracts of ginger as seed treatment in maize against seed borne pathogens such as *Rhizopus stolonifer, Rhizoctonia solani, Aspergillus niger, A. flavus* and *Penicillium versicolor*. Ginger has also been reported to inhibit production of mycotoxin in *Aspergillus flavus* by inhibiting biosynthesis of ergosterol [49].

4.5. Antifungal Activity of Turmeric and Ginger against Tomato Fungal Pathogens

The antifungal activity exhibited by ginger extracts against *Pythium* sp. in the current study has been supported by findings reported by Suleiman and Emua [50] where *Pythium* cells were completely lysed by ginger extracts. Zagade *et al.* [51] however reported an antifungal of about 60% of ginger extracts against *Pythium ultimum* responsible for damping off in chili. The activity of ginger extracts against *Fusarium* has been challenged by Prasad *et al.* [52] who reported a higher activity of about 71% against *F. solani* responsible for wilt and rot in pearl millet. Azman *et al.* [53] however reported a much lower activity of aqueous ginger extracts against *Fusarium oxysporum*. According to Naik *et al.* [54] ginger extracts reduced the growth of *Alternaria solani* by about 54% an activity slightly higher than observed in the current study. Bhalerao *et al.* [55] however reported a higher antifungal activity of ginger extracts of about 79% against *A. solani*.

The activity of turmeric observed in this study against *Pythium* sp. is significant especially since it was equal to that of the commercial fungicide (metalaxyl-M 40 g/kg and mancozeb 640 g/kg). Though Zagade *et al.* [51] reported an activity of about 82%, the study did not have a positive control. Gholve *et al.* [56] however reported a lower antifungal activity of turmeric against *Pythium* by about 24%. The effect of turmeric extract against *Fusarium* was higher than even the positive control in the current study. However, it could also be that metalaxyl and mancozeb, contained in the positive control, have limited effect on the cells of *Fusarium*.

The activity of plant extracts is dependent on type of solvent, composition and abundance of bioactive compounds and susceptibility of the pathogens [57] [58]. The cell walls of *Fusarium*, *Alternaria* and *Pythium* are all made up of different components and therefore the susceptibility level to the extracts must vary [59] [60] [61]. The extracts also contain different compounds and their mode of action against the fungal cells is varied. Presence and concentration of bioactive compounds in plants is subject to geographic location and variety or cultivar [62]. The similarity in the compounds detected in ginger and turmeric is because the two plants belong to the same plant family, Zingiberaceae.

4.6. GC-MS Analysis of Ginger and Turmeric Ethanolic Extracts

The major compound detected in the ginger extract was a sesquiterpene, *α*-zingiberene, followed by *β*-Sesquiphellandrene by abundance. The antimicrobial activity of zingiberene has been associated with changes in morphological and cellular changes of *Fusarium* spp [63]. Another study conducted by Sharma *et al.* [64] reported high antibacterial and antifungal activity of ginger essential oils containing zingiberene and other monoterpenes. In the current study, turmeric extracts showed high amounts of *ar*-turmerone, turmerone and curlone by abundance. The *ar*-turmerone has has caused changes in the structure of mycelia, oagulation of the cytoplasm and inhibition of conidiophore growth in *Podospahera xanthii* causing powdery mildew in cucumber [65]. The bioactive sesquiterpene has also supressed growth of *Phytophthora infestans* and *Erysiphe graminis* at 500 ppm [66]. Curcumin is a major compound usually found in abundance in turmeric and was largely missing in the current analysis despite being associated with major antifungal activities against an array of fungal pathogens [67]-[69]. Turmeric extract also showed presence of *ar*-curcumene, a compound associated with high anti-inflammatory activities [70] explaining its medicinal application by participants in the study.

5. Conclusions

The study found a high level of awareness among farmers and traders on medicinal value of ginger and turmeric. The respondents had negligible awareness on pesticidal value of turmeric and ginger. Only ginger powder was reported to protect grains from storage pests with notable success. This indicates a big gap that could be bridged through training and awareness creation through various extension services. Ginger and turmeric are available in the Tanzanian market all year round, in varying quantities depending on the season. However, production of turmeric was low even in Same District, which is a major producing region of ginger. The cessation of turmeric production was due to a reduced market for the crop. Therefore, processing the turmeric and ginger rhizomes to produce pest control products coupled with awareness creation would create additional markets and increase demand for the produce, thereby motivating the farmers to increase production. This would also improve household incomes, create employment opportunities and contribute to sustainable farming of other essential crops, especially vegetables.

Ginger and turmeric extracts exhibited high antifungal activity especially against *Pythium,* the causal agent for damping off. The antifungal activity was possibly due to presence of bioactive compounds present in ginger and turmeric. The two study plants should therefore be considered for development of a botanical pesticide for management of damping off. The adoption of turmeric and ginger as sources of botanical pesticides would contribute to the conservation of ecological biodiversity and protect the environment from the adverse effects of using synthetic pesticides in agricultural production.

6. Recommendations

Following the findings in this study, it is recommendable that ginger and turmeric be considered as sources of a botanical pesticide. Since there are enough studies supporting their effectiveness, the compounds that make them effective should be formulated and availed for registration as plant protection products. More trials should be conducted on other fungal pathogens in order to focus on developing a broad-spectrum botanical fungicide. Experiments should be conducted using extracts from ginger and turmeric on plants infected with the studied fungal pathogens especially under open field conditions. A cost-benefit analysis needs to be done in order to understand the economic significance of botanical pesticides being preferred to synthetic chemicals.

7. Limitations of the Study

The primary limitation of this study was its focus on specific geographical areas in Tanzania. While the regions are a representative of ginger producing areas, the results may not fully apply to all regions producing the studied and other spices in the country. Tanzania is also known to produce other spices with major medicinal properties which could have been included in the current study, other than focusing on ginger and turmeric. Despite this, the study provides valuable insights into the medicinal and pesticidal value as presented by the growers and traders in Tanzania. Additionally, the GC-MS analysis data helps to show how much of the most active biochemical compounds are present in the varieties grown in Tanzania.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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