Cultivation and postharvest handling practices affecting yield and quality of major spices crops in Ethiopia: A review

Tsegaye Shimelis Hordofa and Tasisa Temesgen Tolossa

Abstract: Developing agricultural production and productivity is the most important strategy in fostering critical capital shortage and enhancing economic growth and poverty reduction in Ethiopia. Spices, being a cash crop, have an immense potential for countries economic development through improving smallholder farmers, creation and expansion of employment opportunities and distribution of income and foreign exchange earnings. The diverse agro ecology, abundant cultivable land and cheap labor, proximity to the potential export market and favorable policy environment supports growing a wide variety of spice crops in Ethiopia. Pepper, ginger, turmeric, black cumin and korarima are the leading spices crops cultivated in Ethiopia. Even though, there is potential to produce and export spice crops, Ethiopia could not boost production and quality and hence, could not be competitor in the world spices market. Cultivation practices and techniques being practiced by smallholder farmers is not improved and more of traditional. Postharvest handling practices are also one of the concerns of spices growers in Ethiopia as most of the fresh harvested spices crops contained high amount of moisture, highly perishable and susceptible to microbial attack. Injudicious harvest and inappropriate

ABOUT THE AUTHOR

Tsegaye Shimelis Hordofa (MSc in Horticulture) is Lecturer, Researcher, and Reviewer at School of Plant Sciences, Haramaya University. His Key research interest is on Developing Improved Production Technologies and Postharvest Management of Horticultural Crops.

Tasisa Temesgen is Lecturer, Researcher, Reviewer and Coordinator for Natural Resources Management program, Haramaya University. He is specialized in Irrigation Agronomy from Haramaya University. His research interest is on Irrigation water management and soil conservation.

PUBLIC INTEREST STATEMENT

Spices, being a cash crop, have an immense potential in developing Ethiopian economy through improving smallholder farmers, creation of employment opportunities, distribution of income and foreign exchange earnings. The country has diverse agro climatic condition, abundant cultivable and irrigable land and favorable policy environment for growing and exporting a wide variety of spices. Among the spices, Pepper, ginger, turmeric, black cumin and korarima are the leading spices crops cultivated in Ethiopia. Due to traditionally and unimproved cultivation and postharvest handling practices the country could not boost production and quality and hence could not be competitor with major spices producer and exporter. Therefore, it was felt necessary to review the cultivation and postharvest handling practices in Ethiopia, to develop improved cultivation practices and postharvest handling technologies that sustain production, productivity and quality to contend with major spices producing countries in the world.
postharvest handling practices may be potential threat for low quality. It is so important to know the existing cultivation and postharvest handling practices and constraints of major spices to increase production and productivity and quality thereby increasing profitability for growers. Therefore, by using and adhering to the improved cultivation and postharvest handling practices it is possible to boost production and reduce postharvest losses within a limited period.

Subjects: Agriculture & Environmental Sciences; Agronomy; Food Additives & Ingredients

Keywords: spices crops; postharvest; yield quality; cultivation practices; spices production

1. Introduction

Agriculture remains the backbone of Ethiopian economy with traditional practices that have been handed down through generations still practiced in many parts of the country. It forms one of the largest components of the Ethiopian economy, contributing 34% of the country’s gross domestic product (GDP), over 75% of total export earnings and 71% of employment (ATA (Ethiopian Agricultural Transformation Agency), 2017-18). Spices, being a cash crop, have an immense potential for developing countries economy through enhancing the purchasing power of the smallholder farmers, creation and expansion of employment opportunities and distribution of income and foreign exchange earnings and thus helping in poverty reduction and ensuring food security in Ethiopia (Tiru et al., 2017).

The favorable and diverse agro-climatic condition, abundant cultivable land and cheap labor, proximity to potential export market (European and Middle East) and a favorable policy environment (Herms, 2015) supported growing many spices crops in Ethiopia. Thus, the country hosts several indigenous and exotic spice crops, which are being produced and used widely since time immemorial (Tiru et al., 2017). Ethiopia is a homeland of many spices, such as korarima, long red pepper, black cumin, coriander, cardamom, turmeric, and ginger, sweet paprika pepper (ACP (Agricultural Commodities Programme), 2010).

Though, Ethiopia has suitable agro-climatic conditions for spices production and is geographically better located towards the EU countries, it could not be much benefited from this sub-sector economy according to EMI (Ethiopian Ministry of Industry) (2015). This could be due to poor cultivation practices and constraints such as absence of planting materials and improved varieties and shortage of high yielding, lack of irrigation facilities, disease-resistant, shortage of suitable crop management recommendations such as seed rate/population density, fertilizer, effective weed management practices, harvest and postharvest management affected the production, productivity and quality of spices (Fissaha & Negash, 2015; Hiranya, 2013; Lupi et al., 2016; Tariku et al., 2016).

In Ethiopia, the cultivation practices being practiced by smallholder farmers is not improved and the technique is highly based on the knowledge that passed from generations and as a result production level is low. Except pepper (Capsicum annum) spices cultivation practices are traditional and no improved seed or planting material is available in Ethiopia (ACP (Agricultural Commodities Programme), 2010; Vijayalaxmi & Sreepada, 2014). According to Habtewold et al. (2017), limited production technologies developed for spices so far have yet not multiplied and popularized to farmers. Disease like: fusarium wilt, blight, powdery mildew, downy mildew, leaf spot, root rot, damping-off, rust, stem gall, grain mold, and pests such as aphids, mites, stick-bugs, leaf eating caterpillars are also constraints that led to overall reduction in productivity and quality of spices in Ethiopia. Moreover, Dagnaygebaw and Tariku (2019) also reported a high frequency of weeding, high input need, different diseases and pests, wild animal competition are some of the constraints affecting production of spices in Ethiopia.
Fresh horticultural crops mainly vegetables and fruits are high in water content and subjected to desiccation and to mechanical injury (Mulualem et al., 2015). Likewise, most of the freshly harvested spices are very high in their moisture content, highly perishable and susceptible to microbial contamination. Harvesting at optimum stage, proper transportation to processing units, cleaning, blanching, treating with recommended chemicals, dehydration, packaging and storage or processing leading those to value-added products etc. are very much crucial as far as reduction of post-harvest losses of spices is concerned (Ankan & Amit, 2018).

Good post-harvest handling is crucial in ensuring a quality product. Good practice in cultivation, harvest, and particularly postharvest operations, is critical in ensuring a good quality and a safe end-product (Melanie & Michael, 2011). The quality of spices depends upon the practices adopted in processing, packaging, storing and transportation. Injudicious harvest and inappropriate postharvest operation may be potential threat for low quality (Meena et al., 2013).

Scientific studies have focused on production mainly whilst neglecting postharvest issues. More than 95% of resource allocation in agricultural research in developing countries is on production. Only 5% of resource is allocated on postharvest issues (Kader, 2005). In today’s scenario, real challenges confronting us are not only on how to sustain the productivity of spices but also on how to minimize their losses. The paradox is that due to lack of proper knowledge, awareness and improper technology dissemination, the postharvest management, especially in the developing countries is still not up to the mark (Ankan & Amit, 2018).

By using improved cultivation and postharvest handling practices and reducing constraints of spices, it is possible to boost production and productivity and reduce postharvest losses within a limited period. It is so important to know the existing cultivation and postharvest handling practices and constraints of major spices to increase production and productivity, quality and shelf life, thereby increasing profitability for growers. The purpose of this review was therefore to give a comprehensive information on some cultivation and postharvest handling practices that can be used by smallholder farmers and the real challenges/constraints smallholder are facing and how they can be affected the production and productivity and postharvest qualities and shelf-life of major spices crops cultivated in Ethiopia.

2. Review of relevant literature

2.1. Uses, cultivation practices and constraints of ginger

2.1.1. Uses of ginger
Ginger (Zingiber officinale) is valued for its medicinal values. It is a popular warming spice, a digestive aid and sometimes used to treat flatulence and colic (Girma et al., 2016). Ginger is a common ingredient as appetizer in many of the Ethiopian food stuffs. Ginger is also an ingredient in many of the common food served by Ethiopians, Misir wet (spiced red lentil curry), Gomen (Ethiopian collard green), Berbere (Ethiopian spice mix) and Ethiopian spiced tea (Girma et al., 2016). Dry ginger is used for the manufacture of several products, such as ginger oil, ginger essence, ginger oleoresin and vitaminised effervescent ginger powder used in soft drinks, local foods and drinks (Idris et al., 2010).

2.1.2. Cultivation practices and constraints of ginger
Production and productivity of ginger significantly reduced to a minimal due to various facts; traditional farming practices, shortage of high yielding, lack of irrigation facilities, disease resistant and high quality varieties, shortage of suitable crop management recommendations such as seed rate/population density, effective weed management practices, harvest and postharvest management affect the yield and quality of ginger during production (Hiranya, 2013; Tariku et al., 2016).
2.1.3. Distribution, climate and soil requirement
Ginger is cultivated in many places in Ethiopia. The major ginger production is in East and West Gojjam, Kefa, Illubabor, Jimma, North and south Omo, Gamo

Gofa, Wolaita, Bale, Sidamo and wolega (Asfaw & Demissew, 2009; Hailemichael & Tesfaye, 2008). However, the commercial production of ginger is limited to SNNPR (Southern Nations, Nationalities, and Peoples’ Region) where much of the country’s production and marketing activities are located. Even in the SNNPS region cultivation is mainly confined to two zones namely Wolaita Bolaso and Kambata-Tambaro (Girma et al., 2016).

Ginger thrives best at mean annual temperature of 20–32°C with altitudes from sea level up to 1500 m, and with total rainfall greater than 1200 mm. Well-drained and fertile soil with enough humus and neutral pH is the ideal soil for the production of ginger (N. Asfaw & Demissew, 2009; Hailemichael & Tesfaye, 2008).

2.1.4. Land preparation
The yield of spice crops is greatly influenced by land preparation. Except for certain spice crops like capsicum, alliums, fenugreek, black and white cumin farmers do not well prepare their farm lands. In general, farmers give little attention for spices crops while giving prior attention to food crops (Tiru et al., 2017).

Different land preparation techniques are used for the production of ginger in major ginger producing countries of the world. In Ethiopia farmers commonly plant ginger on flat land. A trial was conducted at Bebeka Coffee Plantation Project for five consecutive seasons by comparing six different techniques of land preparation to determine the best ones to obtain high yield under Ethiopian condition (Table 1).

According to Endrias and Asfaw (2011), most ginger growing farmers of the South Western Ethiopia (major producing regions) started preparing the land at the end of the rainy season (from late September to early October) after harvesting previous crop. They plow the same unit of land repeatedly for about three to five times. By doing so, seeds of weeds get exposed to the sun periodically and most of them die until dry-planting of ginger takes place 2–3 months after land preparation (February/January). Based on the soil type and the moisture content of the soil as well as the capacity of the farmer to use oxen power, the total number of tillage frequency ranges between 3 and 10, with the highest tillage frequency being more productive (Endrias & Asfaw, 2011).

2.1.5. Planting material
Among the major production problems of ginger in Ethiopia, crucial shortage of planting material is one of the major bottlenecks (MoARD (Ministry of Agriculture and Rural Development), 2008). Using rhizomes as a sole planting material is bulky and difficult to obtain when one require

| Table 1. Fresh rhizome yield of ginger as influenced by different land preparation techniques at Bebeka (Source: IAR, 1996) |
|------------------------------------|-----------------------------|
| Land preparation method            | Fresh rhizome yield (q ha⁻¹) |
| Flat land                          | 192.6                       |
| Planting on open ridges            | 148.7                       |
| Planting on open ridges after emergence | 195.1                   |
| Planting on raised bed             | 207.7                       |
| Planting on tide ridges            | 173.9                       |
| Tide ridges after emergence        | 192.8                       |
| Mean                               | 185.2                       |
establishing a new farm or expanding its area of cultivation. Therefore, the use of in-vitro propagation techniques becomes imperative to alleviate the shortages of planting material (Biruk et al., 2012).

In the SNNPRS farmers used larger pieces/sets of ginger rhizomes which is approximately larger than the recommended range of 2.5–5 cm. The reason that some farmers used larger pieces in Wolaita area is to re-harvest a mother rhizome, which they call; Kenna’, together with the daughter rhizomes since it is economically profitable when they sell it after sun-drying (Endrias & Asfaw, 2011). Hailemichael and Tesfaye (2008) also reported that an increase in seed rhizome size of 9.1 cm will significantly increase the major growth parameters and dry rhizome yield and using large seed rhizome was also found to be economically profitable.

2.1.6. Weed, disease and insect pests
In SNNPR, farmers followed nonchemical weed management practices that included deep plowing and frequent cultivation. Farmers began to prepare seedbed at the end of the rainy season, before the season of planting comes. They plow the same unit of land as frequently as three to five times. While doing so, seeds of most weeds get exposed to the sun and die periodically and until dry-planting will take place 2–3 months after land preparation (Endrias & Asfaw, 2011). According to Tiru et al. (2017), recommendations on critical weeding period for different spice crops are not available in Ethiopia. List of noxious and important weed species of ginger in Ethiopia is indicated in table 2.

| Botanical name | Family        | Growth nature | Eco-physiology | Economic     |
|----------------|---------------|---------------|----------------|--------------|
| Cynodon spp.   | Poacea        | Perennial     | C4             | Noxious      |
| Cyperus spp.   | Poacea        | Perennial     | C4             | Noxious      |
| Digitaria      | Poacea        | Perennial     | C4             | Noxious      |
| Gyzotia scabra | Asteraceae    | Annual        | C3             | Noxious      |
| Bidens pilosa  | Compositae    | Annual        | C3             | Important    |
| Commelina      | Commelinaceae | Annual        | C3             | Noxious      |
| benghalensis   |               |               |                |              |
| Ageratum       | Compositae    | Annual        | C3             | Important    |
| caryzoides     |               |               |                |              |
| Plantago       | Plantaginaceae| Annual C3     | C3             | Important    |
| lanceolata     |               |               |                |              |

Source: Habetewold et al. (2015b) and Tadesse et al. (2015)

In Ethiopia, ginger is prone to many diseases of which rhizome rot, bacterial wilt, phyllosticta leaf spot, storage rot, etc. (Habetewold et al., 2015 and Tariku et al., 2016). Recently, ginger bacterial wilt is the most destructive disease that causes qualitative and quantitative rhizome yield losses in Ethiopia (Merga et al., 2019). In Ethiopia, almost 90% ginger production had been devastated because of this disease (Habetewold et al., 2015; Tariku et al., 2016).

Combined application of diverse methods such as host resistance, cultural practices, and biological and chemical control in integrated disease management schemes is recommended to control some level of bacterial wilt (Merga et al., 2019). Also, Nybe et al. (2007) reported that, selection of disease free rhizomes, soil and rhizome solarization, crop rotation, hot water treatment of rhizome (50°C for 10 min or 40°C for 15 min), using animal dung (farmyard manure), etc. was recommended for management of ginger bacterial wilt.
2.1.7. Fertilizer management
To get high yields, ginger needs well balanced fertilizer. Farmyard and poultry manures as well as compost are three types of organic fertilizers that have been used in ginger production. Using organic fertilizers results in better rhizome yield on sandy than clayey soils, because it is quite sticky. Sandy soils will not fall apart as easily as manures are added; therefore, they will be able to hold more water (K. Asfaw & Brihanu, 2013).

Farmyard is a major organic fertilizer used for ginger production in Southern Nation, Nationalities and peoples region. However, it cannot support large scale production of the crop, since the availability of farmyard manure is limited. In addition, for large scale production, farmers complain as working with farmyard manure is labor intensive and the cost of transportation is very high. In the Southern Nation, Nationalities and peoples region, some farmers who plant ginger at large scale also use compost, coffee pulp and husk as a source of nutrient for producing ginger at commercial level. They purchased the coffee pulp and husk from the wet and dry coffee processing plants operating in their vicinity and even from the neighboring Woreda and transport to their farm (Endrias & Asfaw, 2011). According to Abraham et al. (2014), the use of chemical fertilizers particularly nitrogen increased progressive increment for all ginger yield components. Therefore, application of N and P (92 kg N along with 30 kg P/ha) is recommended for higher yields at the Kindo-Koyisha, Wolaita Zone, South Ethiopia.

2.2. Harvesting and postharvest handling practices of ginger
Harvesting stage is governed by the demand of the end users of the produce; if the produce is for extraction, harvesting 7–8 months after planting is recommended while for the home use of dry ginger, harvesting 8–10 months (Girma et al., 2008). In SNNPR, two forms of ginger harvesting; that is, one-season harvesting and perennated harvesting. One-season harvesting comprised harvesting of matured rhizomes within one growing season. Perennated harvesting involved deliberately leaving the matured ginger rhizomes in the field for two or more consecutive seasons without harvesting (Endrias & Asfaw, 2011).

Care should be taken to ensure that no foreign matter is mixed with the harvested plant materials during harvesting. The harvested material should be transported immediately to a drying shed if harvesting occurs in wet conditions. All equipment’s like cutting devices, harvesters and other machines should be kept clean and adjusted to reduce contamination from soil and other materials (Douglas et al., 2005).

According to Hiranya (2013), lacking awareness about variety, irrigation, washing and storage management are the important factors affecting the quality of ginger in the export chain. Likewise, improper storage is affecting the quality of ginger, storage in a house or room not having any cooling facilities decays the ginger, which results in the loss of quantity and infection of diseases, shrinking of rhizomes and so storage in the cold store can maintain the quality, and increases the shelf-life of the ginger.

2.2.1. Pre-cooling and trimming
Pre-cooling should be done to remove the field heat of ginger to withstand transport better. Cooling in the shade under trees or covering the stake with the dry leaves of ginger (Sharma, 2009).

Trimming is the removal of undesirable stems, roots and other portions, diseased, insect pest infected parts should be cut with a sharp knife to protect from decay of rhizomes during storage and supply. According to Yiljep et al. (2005) and Belay et al. (2012), the injured, damaged and cut ends (if not carefully cured), may be served as starting point for mold growth and rot and also as inoculums sources for the spread of deteriorating and pathogenic fungi to the whole/stock ginger and hence facilitate spoilage and deterioration.
2.2.2. Washing/cleaning
Washing of harvested rhizomes is one of the important postharvest handling practices in order to get best market price and quality product of ginger (Belay et al., 2012). According to Belay et al. (2012) found that farmers at Hadaro put fresh harvested ginger with sock on unclean ground which initiated mold growth that further facilitates spoilage of fresh ginger.

Fresh rhizomes should be washed from dirt, parts of the plants and soil attached to roots. If available the pressure washing is recommended, which is more efficient and tended to reduce the microbial loads. After the harvest, cleaning is essential to ensure minimum loss from microbial contamination, mold growth and decay. The mechanical washers or hot air dryers may help to minimize contamination from dust during postharvest handling operations (FAO, 2002).

Unwashed rhizomes which not only deteriorating physical appearance, it also affected the whole quality of ginger during storage, packaging and transportation, which increase post-harvest loss during this period. The lack of awareness about the washing techniques and its importance for export markets is one of the main reasons the traders are supplying ginger without washing in the markets (Hiranya, 2013).

2.2.3. Curing, sorting and grading
Curing helps to heal the injured, scratched and cut rhizomes wounds by keeping for 3–4 days under the shade at a desirable temperature (22°–26°C). The periderm formation is favored by high temperature (70°–75°C) and relative humidity. Curing helps to increase the storage life and check the attack and spread of diseases (Acharya, 2012). Remove all damaged and injured rhizomes during sorting. The remaining marketable rhizomes should be stored according to size and overall performance (USAID, 2004). Generally grading is done based on the size, color and freshness, while sorting is carried out to the diseased, injured and decayed rhizome. The rhizomes that look fresh, big size and good pale yellow color are regarded as high grade and small, shrink rhizomes regarded as low grade. According to report of Agrisnet (2011), in India grading is generally done only in Himachal Pradesh. The first grade is popularly known as “Gola” having the maximum dry matter and low fiber contents. Second grade is known as “Gatti” included smaller size than the first grade. The third and the fourth grade are small amount of dry matter and high fiber content.

2.2.4. Packaging and storage
Adequate packaging is also another important postharvest practices used to reduce the postharvest losses and maintain quality of ginger (Gautam & Acharya, 2009; Zakir et al., 2018). Packaging is an important process by which the intrinsic quality of the spices and its product is preserved and spoiled due to microbes and insect infestation is prevented. Fresh ginger for export is usually packed in brace boxes (wire balance crates) to ensure maximum ventilation and is shifting under refrigeration at 13°C (Gautam & Acharya, 2009). Fresh and dry ginger is packed in gunny bags for local and distance market (Gautam & Acharya, 2009). In the Ethiopian context, clean sisal sacks can be used as alternate packing materials for dried ginger (Zakir et al., 2018).

Ginger may be successfully stored for several months if the correct postharvest handling and storage procedure are utilized, and healthy, undamaged rhizomes are initially selected. The optimal temperature for storing and transportation ginger is 12°C. At this temperature, the rhizomes will be remained in marketable condition for at least 3 months. On the other hand, surface mold will be began to grow at RH above 90% and sprouting will be stimulated, especially if the temperature is above 16°C. In order to minimize weight loss with avoiding surface mold, a comprise RH from 70 to 75% is recommended for storing ginger. Ginger stored at 22°C and 70% RH for 3 months will lose about 20% of its initial weigh (USAID, 2004).

Storage of the dried ginger is necessary until transport to market areas and the following important points should be given a due attention in the storage. The storage area should be free
from domestic or wild animals, dry, cool, ventilated and should not be in front of the long sunny hour at the day time (Girma et al., 2016).

2.2.5. Processing
In Ethiopia, there are two categories of ginger processing techniques. The first category is preparation ginger in dried form and the second is extraction of ginger oleoresin. The former has been mainly performed by ginger producing farmers. The latter has been carried out by two factories known as Ethiopian Spices Extraction Factory and KASK. These two companies which are engaged in oleoresin extraction could not operate to their full capacity due to; dried ginger has been full of impurity as it is prepared traditionally by local farmers and there is low percentage of oleoresin content per unit volume of ginger as a result of perenniated/extended harvest, long storage period, over drying and/or redrying due to dampness. Moreover, the factories which were designed to extract pepper oleoresin formerly require high cost for modification of parts (Endrias and Asfaw, 2012).

2.3. Uses, practices and constraints of turmeric

2.3.1. Uses of turmeric (Curcuma domestica Val.)
Turmeric (Curcuma domestica Val) is one of the spices produced in Ethiopia entirely by smallholder subsistence farmers in southwestern part of the country. It composed a significant proportion of smallholders’ income and offered a good scope for diversification of the existing Arabica coffee based cropping system of Southwestern Ethiopia. Its commercial cultivation in Ethiopia is picking up and is likely to become a cash crop with good economic return especially for resource poor farmers. It has also been commercialized in large private farm and huge investment projects at national level, which indicated the bright future of the crop in Ethiopia (Derese, 2009; Masresha, 2010).

Turmeric is well known a component in many Ethiopian dishes (local stew, wot) (Girma et al., 2008a; Hailemicheal et al., 2008). It has a characteristic flavor and yellow in color and also used in cosmetics (facial preparation and creams) and ayurvedic drug preparations, antiseptic and also anti-inflammatory (Habetewold, 2018). In addition to the rhizome’s richness in curcuminoid pigments (6%) and essential oils (5%), it also contained 69.43% carbohydrate, 6.30% protein, 3.50% mineral and other important nutrients on dry weight basis (Olojede et al., 2005). It has also used as coloring power in different foods and beverages preparations; color extracts from turmeric are employed in textile industries, soap and cosmetic factories as well as in pharmaceutical preparations (Girma et al., 2008).

2.3.2. Cultivation practices and constraints of turmeric
2.3.2.1. Origin, distribution and ecological requirement. Turmeric is the dried rhizome of Curcuma longa L., herbaceous plant and native of South Asia. It is one of exported spice in Ethiopia, Southwest Ethiopia produce turmeric as a cash crop and many lively hood had been depend on it for a living. India is the world biggest exporter and producers of turmeric, whereas, Ethiopia is the biggest exporters and producers of turmeric in Africa.

Tepi national spices research center (TNSRC) has commenced several research experiments and developments since the introduction of the crop to Ethiopia in 1970s with the objective of identifying best turmeric production and processing technologies and practices that could be served as the best alternatives crop for export diversification and alleviation of poverty in Ethiopia (Olojede et al., 2005). In Ethiopia, turmeric production is mainly concentrated at southeastern part of the country (Sheka, benchmaji and keffa zones). However, recently major ginger producing areas including Wolayta zone shifts the land to turmeric production because of ginger bacterial wilt and good demand for turmeric (Habetewold, et al., 2018).

Turmeric is tropical plant and thrives well from sea level to 1500 m above sea level, at a temperature range of 20–35°C with an annual rainfall of 1500 mm or more. Though it can be
grown on different types of soils, it thrives best in well-drained sandy or clay loam soils with a pH range of 4.5–7.5 with good organic matter status (Jayashree et al., 2015).

2.3.2.2. Propagation technique. The propagation technique is vegetative and particularly the divisions of its rhizomes. Three types of planting materials can be prepared from the rhizomes. These are mother rhizome (arises from the original planting material), daughter rhizome (secondary rhizomes) and finger rhizomes (split rhizomes). Land for turmeric planting should be well prepared and ploughed to produce loose and friable seedbed. Based on soil type and rainfall condition of the area; planting can be in furrow, on flat beds and on ridges (Girma et al., 2008).

2.3.2.3. Nutrient management. Turmeric is a nutrient exhaustive crop, particularly nitrogen (Agere & Shiferaw, 2015; Singh et al., 2001). The high nutrient requirement of turmeric is due to their shallow rooting, prolonged growing period (up to 9 months) and the potential to produce large amount of dry matter per unit area (Singh et al., 2001). Nutrients uptake in turmeric is also depends on stage of development, i.e., a phase of moderate vegetative growth, a phase of active vegetative growth, a period of slow vegetative growth and a phase approaching senescence (Ravindran et al., 2007).

The major turmeric growing areas, southwestern Ethiopia, is well known for its high rainfall area where nutrient loss through leaching is very common. This makes the nutrient unavailable during the critical stages of crop growth (Agere & Shiferaw, 2015). Behailu and Weyessa (2019) reported that maximum rhizome yield and better oleoresin content was obtained from the application of 115 Kg ha\(^{-1}\) N rate in three equal splits (1/3rd at emergence, 1/3rd at lag growth stage and 1/3rd at tillering) as compared to the commonly used two times split application practiced in many crops in Tepi, and Southwestern Ethiopia.

2.3.2.4. Weed management. Deshmukh et al. (2018), investigated that in India integrated use of either Pendimethalin 1 kg/ha or by Metribuzin 0.7 kg/ha (0–5 DAP) followed by straw mulch 10 t/ha (10 DAP) followed by one hand weeding (75 DAP) was adjudged very effective for weed control and for attaining the highest productivity and profitability in turmeric.

2.4. Harvesting and postharvest handling practices of turmeric

Turmeric reaches harvestable stage after 8–9 months. Harvesting takes place usually when the lower leaves of the plant dry and turn yellow and pseudo stems withers and start to lodge. After removing the upper leaves, the rhizomes will be removed from the soil by use of fork or other appropriate tool (Girma, 2008).

The total production and productivity of turmeric is very low compared to its potential in Ethiopia. Its contribution to the spice export compared to its potential is yet unexploited due the weak link of production and marketing. Farmers used low yielding varieties and traditional harvesting and processing techniques (Derese, 2009). According to Addisu (2014), the national productivity of turmeric in Ethiopia was 2.4 tones ha\(^{-1}\) in the contrary to 4.0 tones ha\(^{-1}\) in India. Yield potential of turmeric in the research stations was reported as high as 310 q/ha fresh turmeric which is within the acceptable range of world turmeric productivity (Girma et al., 2008).

Turmeric, before entering the market as a stable commodity, undergoes several postharvest handling practices viz. curing, drying, and polishing, coloring and milling of rhizomes. Conventionally, mother and finger rhizomes are separated and cooked (45–60 min) in boiling water (±100°C), sometimes with the mixing of alkaline solution (Gitanjali et al., 2014; Shinde et al., 2011).

2.4.1. Washing/cleaning the rhizomes

The rhizomes are separated after digging out from the soil and washed, so that particles of soil spray residues and nonuseful particles attached to the rhizomes are removed. This process can be achieved by soaking and spraying equipment. Spraying of water is done at low pressure and wide angle jet or high pressure jet. At the times of washing rhizomes are divided in two parts. First part
from the middle is called the mother rhizome. The second part of it which is long and thin is called finger rhizome (World, 2016). In Ethiopia, cleaning the rhizomes is done following harvesting in December and January so as to make turmeric free from soil. In the meantime, roots are also removed from the rhizomes (Derese, 2009).

2.4.2. Boiling the rhizomes
According to Derese (2009), boiling required about 45–60 min in Ethiopia. Short and open barrel filled with water will be put on burning flame to boil the water. The turmeric is filled in the water. More fuel wood is added to produce more and more heat. The rhizomes are turned over and over continuously with spade. Rhizomes are spread on a prepared material. All the harvested turmeric rhizomes are boiled in the same manner. Farmers use many sets of barrels at a time. Farmers have labor exchange called “Dado” especially for boiling. They usually rent in barrels for 12 birr per day. Boiling one set of barrels for 45–60 minutes is called locally “tidosh.” One farmer can have on average about 250 “tidash” per season. To carry out the operations safely, farmers do the boiling at night, when the weather is cool. Shibru et al. (2017) reported that most farmers in Ethiopia boil mother and finger rhizomes together and give less concern to boiling temperature levels and durations that probably lead to loss of biochemical and physical qualities of turmeric. The same author further noted that, dry matter content was highest for finger rhizome sets at 100°C for 60 min. Crude protein was at its peak when rhizomes boiled for 30 min, at 80°C and for mother rhizome sets whereas the smallest values were recorded from 75 min at 100°C and finger rhizome sets. Moreover, crude fiber content was highest at 80°C for 30 min in mother rhizome sets, whereas minimum at 100°C, for 75 min in finger rhizome sets (Shibru et al., 2017).

2.4.3. Curing
Curing of fresh rhizomes is the next unit operation in processing of turmeric to get dry turmeric. Curing is a process that killed the vitality of fresh rhizomes, served to obviate the raw odor, reduced the drying time, gelatinized the starch and disperses the pigment uniformly so that it provided a more uniformly colored produce. After the rhizomes have been removed from the ground, curing must be completed within 10 days to secure maximum usable product. Although, the curing quality of turmeric is mostly a varietal character, factors such as moisture content and maturity also determine the final percentage of cured raw turmeric. Short duration types have the highest curing percentage (24–26%) and medium duration types provide the lowest curing percentage (14–20%) and long duration has medium curing percentage (21–24%). The curing percentage is reported to increase with increasing the maturity of rhizomes (World, 2016).

2.4.4. Drying turmeric rhizomes
Drying is carried out using sun or mechanical dryers at a temperature of 60°C. The cooked fingers are spread on an open yard or on bamboo mats to thickness of 5–7 cm. It is avoided to spread as thin layer as it leads be bleaching of color. During night hours the dried fingers are heaped and drying is carried until it is completely dried and it takes 10–12 days. The dry, product yield will be varied from 10–15 percent depending on the variety and location where crop is grown up (World, 2016). In Ethiopia, the average drying time can take about 15 days and can also extend to a month depending on the existing weather condition (Derese, 2009).

2.4.5. Turmeric polishing
The dried rhizomes are polished to remove the scales and root bits. In traditional method the dried rhizomes are loaded in a bag and beaten on a hard surface. In the improved method hand operated barrel or a drum mounted on a central axis is used for polishing. The barrel or drum has an expanded metal mesh into which dried rhizomes are loaded and rotated. Polishing is carried out by the action of abrasion of the surface against the mesh and rubbing between the rhizomes (World, 2016).
In Ethiopia, farmers grind uncooked turmeric rhizomes with mortal (mukecha) and pestle. They mix the grinded turmeric juice with lemon juice and apply on the boiled rhizomes. The purpose of coating turmeric with such solution is to produce the yellow color of the turmeric and to protect the rhizome from weevil attack and increase storage time. This step of adding solutions on rhizomes is a value adding mechanism for farmers. This process is not currently practiced by farmers as traders have resisted buying such coated turmeric rhizomes. The big traders are processing by themselves at their warehouses after they buy the dry rhizomes from farmers. This has its own implication for reduction of price (Derese, 2009).

2.4.6. Coloring
The colour of the processed turmeric will fetch high price in the market. So to get an attractive product, turmeric powder is sprinkled in the last phase of polishing. CFTRI, Mysore has recommended to produce an emulsion with the following materials: Alum—0.04 kg, turmeric powder—2.00 kg, castor seed—0.14 kg, sodium bisulfate—30 g and concentrated hydrochloric acid ~ 30 ml. The prepared emulsion is poured on the half polished turmeric where it is shaken well in a wicker basket. Once the coating of half polished turmeric is over, it is dried in sun, the quantity given above is sufficient to coat 100 kg of half polished turmeric (World, 2016).

2.5. Uses, practices and constraints of black cumin (Nigella sativa)

2.5.1. Uses of black cumin
Black cumin (Nigella sativa), rarely known as black caraway, is a short-lived annual flowering plant that belongs to the family Ranunculaceae. In Amharic, it is known as “Tikur azmud” (Shewaye, 2011; Habtewold et al., 2017). Black cumin is used predominantly to flavor food, either as whole grain or in powdered form or as an oleoresin extract. In Ethiopia, its main use is as a spice, which is typically ground and mixed with other spices (Orgut, 2007). Black cumin seed oil was used traditionally in different countries for many medical complaints. The seeds are used for culinary purposes, medicinal treatment and also used as food additives (Shimeles, 2017).

2.5.2. Cultivation practices and constraints of black cumin
Yousif (2008) reported that several problems including lack of improved seed, recommended fertilizer rate, lack postharvest handling; improved agriculture practices and extension system, marketing system, etc. Reduced productivity and production of black cumin. According to Habtewold et al. (2017), the major crop management practices in black cumin are proper land preparation or hoeing before sowing, weeding, manuring, thinning and hoeing.

2.5.3. Distribution, climate and soil requirement
Black cumin is known to be native to the South and Southwest Asia. It is one of the most important species cultivated in various parts of the world in Egypt, Middle East, Russia, Kenya, Sudan, Yemen, China, Turkey, India and middle Asian countries being the major producers (Shewaye, 2011; Habtewold et al., 2017). It ranked second among the seed spices produced in Ethiopia in terms of production and area coverage. It is mainly cultivated in Amhara, Oromia, Tigray and SNNPRS, although for own household consumption, it is as well grown in various places (Habtewold et al., 2017).

Black cumin is mainly produced in mid to highland areas with altitude ranges of 1750–2200 m a s l. It is usually a dry and cold weather crop of the semiarid areas, which can grow in well drained black vertisols with residual moisture. A rainfall of 120–400 mm during its growing season could be enough for its optimum production. It grew in temperature ranges of 5–25°C, with 12–14°C is being the optimum (Habtewold et al., 2017).

2.5.4. Land preparation and sowing
According to Habtewold et al. (2017), the land should be frequently plowed two to three times, at least one month before sowing the crop. Then, the beds should be prepared with 120–130 cm
spacing using the broad bed maker in order to be ready for planting. This helped to drain the excess water from the field and reduced potential soil borne diseases like wilt and damping off. For one hectare, seed rate of 15 kg could be enough if broadcasted method of planting is used or 5–6 kg if row spacing is used. A spacing of 25–30 cm between rows and 10–15 cm between plants and a sowing depth of 3 cm is generally recommended. Soaking seeds in water and then dried under sun prior to sowing for about 12–15 hours, is used to reduce time for germination. After establishment, thinning is done if required, when the plants attained a height of 15 cm and removed plants may be used for transplanting into other fields. The planting time varies based on different climatic conditions. For example, in Arsi, Chefe Donsa and Debre Zeit areas, planting is done at the beginning of August whereas in Bale and Gondor areas, it is done from September to October.

2.5.5. Agricultural inputs

Wubeshet and Dessolegn (2019) assessed that the production and utilization of black cumin at Oromia Regional state, Bale Zone. The authors reported that farm input like fertilizer and improved seed help farmers to increase the production and productivity of black cumin. The results of the study revealed that the majority (73.33% and 68.33%) of the respondents were using fertilizer and improved seed for their farm production activities, respectively (Table 3).

| Variable            | Frequency | Percentage |
|---------------------|-----------|------------|
| Fertilizer use      | Yes       | 142        | 73.33     |
|                     | No        | 48         | 26.67     |
|                     | Total     | 180        | 100.00    |
| Improved seed       | Yes       | 123        | 68.33     |
|                     | No        | 57         | 31.67     |
|                     | Total     | 180        | 100.00    |

Source: Wubeshet and Dessolegn (2019)

2.5.6. Nutrient management

Application nitrogen is crucial to get optimum growth and productivity of the crop. Application of farm yard manure (FYM) at the rate of 10–15 tons/ha and 50:40:20 kilograms of NPK per hectare are sufficient for good yield. Similarly, Research carried out at Debere Zeit Research Center indicated that 60 kg of nitrogen per hectare is sufficient to get optimum yield (Habtewold et al., 2017)

2.5.7. Weed management

Due to its slow growth and short stature, the open canopy nature of black cumin often favors the grow up of weeds, which caused significant reduction in yield. Weed results in 60–85% yield loss if the crop is left for weed competition throughout its growing season. Weed competition is more severe during the early stage of crop growth, i.e., up to 40 days. At least three to four times hand weeding is advisable during the critical period. Two hoeing and weeding periods (30 and 60 days after sowing respectively) are generally needed for effective control of weeds. Thinning should also be done in addition to the first weeding session (30 days after sowing). Although, it required adequate soil moisture for the system to be effective, the pre-emergence herbicides application is reportedly very effective in other countries. Terbutryn or Oxadiazon at 0.5–1.0 kilogram per hectare is recommended for effective control of weeds (Habtewold et al., 2017). According to Jibat et al. (2019), Cynodon dactylon and Solanum nigrum are most dominant and the most frequent weeds in black cumin field.
2.5.8. Disease and pest management
According to Habtewold et al. (2017), the most important disease of black cumin is fusarium wilt, black cumin blight and powdery mildew. Use of resistance variety, crop rotation, strict phytosanitary measure, biological control and using of appropriate fungicides were reported to control the disease. In addition, Aphids and Mites were also reported as the major insect pests of black cumin. They can be managed through pruning infested leaves and shoots, use of tolerant varieties and use of insecticides if the infestation is very high (Habtewold et al., 2017). Tiru et al. (2017) also reported that occasionally, both black and white cumin are affected by rust, root rot, aphid, and boll worm and cut worm in South Wollo.

2.5.9. Harvesting and postharvest handling practices of black cumin
Black cumin matures, often in around 135–150 days and the color of the inflorescence turned to brown. Since late harvesting often caused fruit splitting and shattering, timely harvesting with hands or sickles is essential. Harvesting is done early morning or late afternoon to reduce yield loss due to shattering (Habtewold et al., 2017). After harvesting, the bundles are stacked in sun for drying. The seeds are separated by rubbing or stick beating the bundles. The seeds are thereafter winnowed and dried (Habtewold et al., 2017). The packing is done in gunny bags and stored in cool and dry places. The national average of black cumin productivity is 0.79 tons per hectare, but the released varieties of “Dershaye” and “Eden” give 0.9–1.6 tons per hectare (Habtewold et al., 2017).

Ermias et al. (2015) evaluated that the adaptability study of improved black cumin varieties (Dirishaye, Eden, and Deribera with the local check) in the mid- and high-land areas of Kaffa zone, South West Ethiopia in order to diversify their production and to maximize the income of the farmers in the area. The results revealed that the local check showed significantly higher grain yield (612.98 Kg ha⁻¹) than Eden, Dirishaye, and Deribera (473.06, 451.9 and 449.62 Kg ha⁻¹, respectively) at the study area. Thus, such a potential suggested that the local check or the land race could be used for variety development program which would later be supported by agronomic and pathological studies (fertilizer rate, sowing date and reaction to insect pests and diseases) (Ermias et al., 2015).

Due to the increased demand of black cumin seed for local consumption and other importance, such as oil and oil resin for medicinal purposes, its export market, its potentiality in crop diversification, income generation and its importance to reduce the risk of crop failure and others made black cumin as a best alternative crop under Ethiopian smaller land holdings (Dessalegn & Wubeshet, 2018).

2.6. Postharvest handling practices of black cumin
According to Larrousse (2007), black cumin required extensive labor in collection and harvesting as the capsules (fruit) tend to shatter at maturity. The mature fruits do not require much attention as they are self-preserving and their essential oil is a great deterrent to fungal attack as well as rodent infestation.

2.7. Use, practices and constraints of korarima (Aframomum corrorima)

2.7.1. Uses of korarima
Korarima (Aframomum corrorima) is one of the indigenous important spices used in Ethiopian cuisine and medicinal purposes (Girma et al., 2009b). Korarima seeds (dried or fresh) are used in Ethiopia to flavor all kinds of “wot,” for which they are ground and usually mixed with other spices. Sometimes they are used to flavor a special kind of local food, bread and butter. In addition, korarima is an important plant for soil conservation as the rhizomes and leaves spread on the ground covering and protecting the soil from erosion in mountainous areas. The primary used part of Korarima is the red fruits, but other parts of the plant can also be used (Eyob et al., 2009). The seeds of korarima contained different types of essential oils having typical odour (S. Eyob et al., 2007). In southern Ethiopia korarima seeds, pods, leaves, rhizomes and flowers are used as traditional medicine for human and animal ailments (Eyob et al., 2008). Dried capsule and seeds of korarima also provide a great economic value by supporting local income and used as an export commodity (Israel et al., 2019).
2.7.2. Cultivation practices and constraints of korarima

2.7.2.1. Origin and distribution. The altitudinal distribution of korarima ranged from 1000 to 2000 m above sea level. As indigenous spice, Aframomum Korarima grew in various parts of the country mainly in Kaffa, Jimma, Bale, South and North Omo, Sidamo, Illubabour, East and West Gojam and Gamugofa, East and West Wollega (Braun, 2011; Simegn et al., 2016; Zakir et al., 2018).

2.7.2.2. Climate and soil requirement. Korarima thrives well at annual rainfall varies from 1300 mm to more than 2000 mm and annual average temperature of about 20°C. Soil has high organic matter and rooting media containing forest soil is needed for the growth of seedling of Korarima (Jafer et al., 2014; Lupi et al., 2016).

Jafer (2016) determined that biomass production and distribution on seedling of korarima under media and watering frequency at the Jimma Research Center, southwest Ethiopia and concluded that watering frequency every 2–3 days and media of top soil and compost combinations improved both dry mass and dry matter partitioning of seedling. The results revealed that mixed top and compost soil media in 3:1 > 1:1 ratios > blended forest and top soil with compost media in 1:1:1 and watering frequency every two or three days significant for biomass production and distribution.

Acidic soils (5.5–6.5 pH), deep to medium soils (50–150 cm), well drained but with high water holding capacity is excellent for korarima production (FAO Food and Agriculture Organization, 2007). Korarima is an obligate shade loving plant similar to cardamom as it created suitable microclimate and regulated moisture and temperature, which facilitates optimum growth and root development particularly when rhizomes produced very shallow roots at each node (Girma et al., 2016).

2.7.2.3. Planting material. Korarima can be propagated using seed or by cutting of its clumps. Cutting of clumps is the most common method, as it yields earlier and ensures a true-to-type propagation than using the seed. However, this technique is always accompanied with lack of a steady supply of quality planting material. In recent times, development of micro propagation like in-vitro propagation technique is proven to overcome the lack of a steady supply of quality planting material. These techniques enable production of sufficient amounts of planting material of a desired clone and also the basis for future improvement through genetic engineering, as well as modern germplasm conservation tasks (Eyob et al., 2009; Wondyifraw & Wannakairoj, 2004). According to Teferi (2016), large-scale propagation of korarima by tissue culture techniques is feasible and several plantlets can be produced in short period of time.

2.7.2.4. Agricultural inputs. The production of A. corrorima in Ethiopia has been affected by poor access to agricultural inputs such as fertilizer and planting materials (Fissinya & Negash, 2015). In addition, absence of improved varieties and weak agronomic practices are also major production constraints in the country (Lupi et al., 2016).

The study conducted at Western Ethiopia in Wollega Zone, Nekemte and Shambu woredas identified that 86%, 74.50%, 41%, 35.95%, 62.10%, 52.25% and 32.75% of sampled farmers confirmed that inadequate fertilizer supply, planting materials, shortage of access to credit, wild animal competition, price setting, scale and demand, respectively, are the major factors affecting korarima production negatively (Fissinya & Negash, 2015).

2.7.2.5. Disease and insect pests. According to (Jansen, 2008), there was no serious diseases or insect pests known for korarima except the natural enemies like, ape, monkey and mice, but current reports show that the rust Puccinia aframomii has been observed on korarima leaves in Ethiopia.

Conversely, Teshale et al. (2018) identified that pests were known to affect the production of korarima in southwestern part of Ethiopia. The authors identified different insect pests of korarima including the green stink bug (Acrosternum spp.), korarima flower thrips (Sciothrips spp.), motted tortoise beetle (Chelymorpha spp.) and cardamom white fly (Dialeurodes spp.) were extensively distributed and recorded relatively with high infestation rate. Black leaf beetle (Chrysochus spp.),
brown spotted grasshopper (Cyrtacanthacris spp.), spice grasshopper (Catantops spp.) were considered as intermediary due to medium infestation and damage level in all surveyed areas. Moreover, the author concluded that it is imperative to design control options for these major insect pests to ensure plant health.

2.7.2.6. Genetic diversity. In Ethiopia, the genetic diversity of korarima is being affected due to threats in its natural habitat and other limiting factors such as nonimproved variety, nonadapted agronomic practices and loses caused due to biotic and a biotic stresses. The humid mountain forest of southwestern Ethiopia which is known by korarima diversity has been destroyed at an increasing rate (Girma et al., 2008). In addition, Manmade and Natural calamities are also caused depletion to the biodiversity of medicinal plant including Korarima (Regassa, 2013).

To reduce genetic loss of korarima and destruction of its diversity; collecting germplasms for yield, adaptation and quality from different locations and conserving them at in-situ and ex-situ conservation sites, maintaining the natural habitat from deforestation, awareness creation for the society on forest conservation is the best strategy for conservation, sustainable utilization of the crop (Chombe & Bekele, 2018; Jansen, 2008; Zakir et al., 2018).

2.8. Harvesting and postharvest handling practices of korarima

Maturity and harvesting time of Korarima varies in different areas of Ethiopia but generally harvesting is done between August and September. Capsules or seeds are the economic parts of korarima plant (Girma et al., 2008). The ideal time for harvesting korarima plant is when the capsules attain maximum size or when the capsules are red or yellowish green in color or when the upper tip of capsules are dried and easy to be detached from the mother plant (Fissiha et al., 2014; Girma et al., 2016). Capsules which are free from insect or physical damage, unbleached, uniform in color for the particular stage is considered during the harvesting time (Fissiha et al., 2014).

Inappropriate capsules collection of korarima reduce the product quality. Therefore, collectors in all korarima growing areas of Ethiopia better to be aware of the quality issues and may be used the recommendations for better oleoresin and essential oil (Fissiha et al., 2014). The capsules are harvested mostly at immature green stage due to the competition among competitive spice collectors from the natural forest and wild animals (monkeys, squirrels and snakes) (Zakir et al., 2018).

Therefore, well ripened korarima capsules are selected and collected during the peak harvest season and its seeds are removed and rubbed with ash to facilitate their drying and protect fungal development, as well as to ease their handling during sowing (Endashaw, 2007). After harvesting to maintain better physical quality of the dried capsules, mature deep red capsules are dried on wire mesh for 10 days in open sun (Girma et al., 2016).

2.8.1. Drying

Drying is a critical process whereby moisture levels are reduced to prevent deterioration. Drying can be done by spreading the crop in the sun (direct solar), or in drying rooms, or tunnels, sometimes using solar or solar assisted drying systems (indirect solar) (Melanie & Michael, 2011).

In the course of drying, the seeds are kept under shade for four to five or more days, prior to sowing in polyethylene bags filled with forest soil or directly on seed beds (Endashaw, 2007). Korarima capsules harvested from natural forests in the south and southwestern parts of Ethiopia are processed or dried in traditional ways. As indicated in table 4, drying is performed in two ways; sun-drying: capsules are spread on clean ground or on materials prepared for this purpose. Drying in this way takes 10–15 days depending on the length of sunny hours and the intensity of sunlight. Drying with smoke: Drying with smoke involves spreading the capsules on a wooden bed over chimneys under the roof for 15–20 days. In some cases, both methods
could be employed depending particularly on weather condition. Both methods of drying have advantages and disadvantages (Fantahun & Teklu, 1995).

Korarima product quality is influenced different factors; harvesting stages, drying structures and durations. It faces severe market challenges, due to its inferior oleoresin and essential oil content, with Indian Cardamom (Eyob et al., 2007). The study was conducted by Fissiha et al. (2014), on influence of harvesting stages, drying structures and drying durations on oleoresin and essential oil content of korarima. The results revealed that maximum oleoresin content (10.04% w/w) was recorded from mature green capsules dried on wire mesh for 10 days and next to this oleoresin content (9.16% w/w) was obtained still from seeds of mature green capsules dried on the ground for 10 days. In contrast, the minimum oleoresin content (4.87%) was recorded from mature deep-red capsules dried on cement floor for 20 days (Table 5).

### 3. Conclusion and recommendation

Agriculture remains the backbone of Ethiopian economy with traditional practices that have been handed down through generations still practiced in many parts of Ethiopia. Spices, being a cash crop, have an immense potential for developing countries economy through enhancing the purchasing power of the smallholder farmers, creation and expansion of employment opportunities and distribution of income and foreign exchange earnings and thus helping in poverty reduction and ensuring food security in Ethiopia. It has diverse agro climatic condition, abundant cultivable and irrigable land and cheap labor and favorable policy environment that support growing a wide variety of spice crops in Ethiopia. Chili/pepper, ginger, turmeric, black cumin and korarima are the leading spices crops cultivated in Ethiopia.

Even though, there is potential to produce and export spice crops, Ethiopia could not boost production and quality and hence, could not be competitor in the world spices market. This could be due to traditional cultivation practices and inappropriate postharvest handling practices. In Ethiopia, the cultivation practices being practiced by smallholder farmers is not improved and the technique is more of traditional and as a result production level is low. Except chili/pepper (*Capsicum annuum*) spices cultivation practices are traditional and no improved technology is available in Ethiopia. Therefore, by using improved cultivation practices, reducing different production constraints and using the available opportunity and policy of the countries it is possible to boost production and productivity and benefited from this sector within a limited period.

Post-harvest handling practices are also one of the concerns of spices growers in Ethiopia as most of the fresh harvested spices crops are very high in their moisture content, highly perishable and susceptible to microbial contamination. As a result, improved modern processing method and appropriate postharvest handling practices is required to increase the shelf life and quality of spices to meet international standards. Failure to adhere to the improved cultivation and appropriate postharvest handling practices will result in a reduction in production and productivity and a high amount of losses.
| Drying Structures | Mature Green (MG) | Mature Semi-Red (MS) | Mature Deep Red (MR) |
|-------------------|------------------|---------------------|---------------------|
|                   | 10 Days | 15 Days | 20 Days | 10 Days | 15 Days | 20 Days | 15 Days | 15 Days | 20 Days |
| Cement            | 0.526jkl | 0.516jkl | 0.423 n | 0.576 g hij | 0.463 mn | 0.476 l mn | 0.640fg | 0.520ijklm | 0.493 k lm |
| Ground            | 0.773bc | 0.713 cd e | 0.53ij k | 0.720 c d | 0.553ij k | 0.523ij kl | 0.650ef | 0.583 g hi | 0.533jkl |
| Wiremesh          | 0.933a | 0.770bv | 0.630fg | 0.833b | 0.673def | 0.626 fgh | 0.766 c | 0.626f gh | 0.563hij |
| LSD (0.05)        |         |         |         | 0.067 |         |         |         |         |         |
| CV (%)            |         |         |         |         | 6.593 |         |         |         |         |

Source: Fissiha et al. (2014)
Funding
The authors received no direct funding for this research.

Author details
Tsegaye Shimeles Hordofa1
E-mail: tsegayeshimelis5@gmail.com
ORCID ID: http://orcid.org/0000-0002-0418-1852
Tasisa Temesgen Tolossa2
E-mail: tasisatemesgen@gmail.com
1 School of Plant Sciences, Haramaya University, Dire Dawa, Ethiopia.
2 School of Natural Resources Management and Environmental Sciences, Haramaya University, Dire Dawa, Ethiopia.

Competing interests
The authors declare no competing interests.

Citation information
Cite this article as: Cultivation and postharvest handling practices affecting yield and quality of major spices crops in Ethiopia: A review, Tsegaye Shimeles Hordofa & Tasisa Temesgen Tolossa, Cogent Food & Agriculture (2020), 6: 1788896.

References
Abraham, B., Toye, B., & Mesfin, K. (2014). The Effect of NP fertilizer rates on the yield and yield components of ginger (Zingiber officinale Roxb.) in Kindo Kaysha Woreda; Wolaata, South Ethiopia. Journal of Natural Sciences Research, 4 (16), 2224-3186 (Paper) 2225-0921 (Online).
Acharya, B. (2012). Sustainable ginger production, protective storage and dried ginger processing technology. Protective storage of ginger. Nepal Agricultural Research Council, National Ginger Research Program.
ACP (Agricultural Commodities Programme), (2010). Spice sub-sector strategy for Ethiopia submitted to the government of Ethiopia by the Spice Sector Strategy Coordinating Committee.
Addisu, A. (2014, January 23). Spice, herbs and aromatic plants subsector platform. 1st Ethiopian Spice Platform Stakeholders Meeting.
Agere, L., & Shiferaw, T. (2015). Determination of optimum rate of nitrogen and phosphorous fertilizers for the yield and yield components of turmeric (Curcuma longa L.) on Nitosals at Yoki Woreda Southwestern Ethiopia. Journal of Agricultural Science Research, 3 (10), 289–295.
Agrisinet, (2011). Sikkim agriset, market and export potential. Ginger. Post-Harvest (online). Department of Agriculture. Government of Sikkim. http://www.sikkimagrisnet.org/General/en/Ginger.aspx
Ankan, D., & Arit, B. S. (2018). Post-harvest technology and value addition of spice. Indian Spices, 269–276.
Asfow, K., & Birhanu, S. (2013). Ginger (Zingiber officinale Roxb.) production, postharvest handling, processing and marketing: A comprehensive extension package manual Tadesse Fikre and Asfow Kifle (editors). Organized by Farm Africa.
Asfow, N., & Demissew, S. (2009). Aromatic plants in Ethiopia. Shoma books.
ATA (Ethiopian Agricultural Transformation Agency). (2017-18). Annual report. Foreword from the chief executive officer.
Behailu, M., & Weyessa, G. (2019). Nitrogen fertilizer rate and time of application affected yield and quality of turmeric (Curcuma longa L.) at Tepi, Southwestern Ethiopia. American Journal of Agriculture and Forestry, 7(4), 126–132. https://doi.org/10.1164&j.qaf.20190704.11
Belay, B., Kebede, A., Tameru, A., & Fasil, A. (2012). Isolation, characterization and identification of post-harvest spoilage fungi of ginger (Zingiber officinale) at Hadaro Tunto and Boloso-Bamboe, Southern Ethiopia. International Journal of Life Sciences, 1(2), 19–27.
Biruk, A., Wendifraw, T., & Kassahun, B. (2012). In vitro propagation of Ethiopian ginger (Zingiber officinale Rosc.) cultivars: Evaluation of explant types and hormone combinations. African Journal of Biotechnology, 11(16), 3911–3918.
Braun, A. (2013). Aframomum corromora was published in spices, condiments and medicinal plants in Ethiopia, their taxonomy and agricultural significance. national germplasm resources laboratory, USDA, ARS, National Genetic Resources Program.
Chombe, D., & Bekele, E. (2018). Genotypic diversity analysis of cultivated Kororima (Aframomum corromora (Braun) P.C.M.) populations from southwestern Ethiopia using inter simple sequence repeats (ISSR) marker. Journal of Biological Research-Thessaloniki, 25(1), 1–12. https://doi.org/10.1186/s40709-017-0073-z
Dognaygebaw, G., & Tairku, A. (2019). Review on factors affecting production and marketing of spices in Ethiopia. Journal of Agricultural and Healthcare, 9(6), 13–17.
Derese, T. M. (2009). Practices and constraints of turmeric (Curcuma domestica Val) Production and marketing by smallholder farmers: The case of Yeki Woreda, Shaka zone in southwestern Ethiopia (Unpublished data). A Thesis submitted to the School of Graduate Studies ofAddis Ababa University for the requirement of degree in Master of Arts (MA) in Development Studies.
Deshmukh, J. P., Kakade, S. U., Ingole, P. G., Shingup, P. V., & Solanke, M. S. (2018). Integrated weed management in turmeric. International Journal of Current Microbiology and Applied Sciences, 6, 1894–1899.
Dessalegn, A., & Wubeshet, T. (2018). Economic value of black cummion (Nigella sativa L.) conservation at Bale Zone of Oromia Region, Ethiopia. American Journal of Business, Economics and Management, 6(4), 104–109.
Douglas, M., Heyes, J., & Small, F. (2005). Herbs, spices and essential oils: Postharvest operations in developing countries. NZ Institute for Crop and Food Research Ltd New Zealand, FAO.
EMI (Ethiopian Ministry of Industry). (2015). Spice industry strategic plan (2015-2025) Ethiopia.
Endashaw, B. (2007). Study on actual situation of medicinal plants in Ethiopia. Prepared for Japan Association for International Collaboration of Agriculture and Forestry, JAICAF.
Endrias, G., & Asfaw, K. (2011). Production, processing and marketing of ginger in Southern Ethiopia. Journal of Horticulture and Forestry, 3 (7), 207–213. 2006-9782 http://www.academicijournals.org/jhf
Ermias, A., Addis, A., & Teshome, M. (2015). Adaptability Study of Black Cumin (Nigella sativa L.) Varieties in the Mid and High Land Areas of Kaffa Zone, South West Ethiopia. Agriculture, Forestry and Fisheries, 4 (1), 14–17. https://doi.org/10.1164&j.aff.20150401.13
Eyob, S., Appelgren, M., Rohloff, J., Tsegaye, A., & Messele, G. (2007). Traditional medicinal uses and essential oil composition of leaves and rhizomes of kororima (Aframomum corromora (Braun) P.C.M. Jansen) from Southern Ethiopia. South African Journal of Botany, 74(2), 181–185. https://doi.org/10.1016/j.sajb.2007.10.007
Eyob, S., Martinsen, K., Tsegaye, A., Appelgren, M., & Skrede, G. (2008). Antioxidant and antimicrobial activities of extract and essential oil of korarima (Aframomum corrorima (Braun) P.C.M. Jansen). African Journal of Biotechnology, 7(15), 2585–2592.

Eyob, S., Tsegaye, A., & Appelgren, M. (2009). Analysis of korarima (Aframomum corrorima (Braun) P.C.M. Jansen) indigenous production practices and farm based biodiversity in southern Ethiopia. Genetic Resources and Crop Evolution, 56(4), 573–585. https://doi.org/10.1007/s10722-008-9387-x

Fantoahun, L., & Teklu, N. (1995, February 27 - March 1). Spices crops processing: Constraints and Possibilities. Workshop on Coffee and Associated Crops. (unpublished)

FAO. (2002). Ginger: Post-harvest Compendium. Post-production management for market access (pdf). Retrieved August 28, 2013, from http://www.fao.org/fileadmin/user_upload/infoph/docs/post_harvest_Compendium-Ginger. Pdf.

FAO (Food and Agriculture Organization). (2007). Eco crop of Food and Agriculture Organization of the United Nations.

Fissiha, G. G., All, M., & Girma, H. (2014). Influence of harvesting stages, drying structures and drying durations on oleoresin and essential oil content of korarima (Aframomum corrorima (Braun) P.C.M. Jansen) capsules grown in Ethiopia. Agricultural Science, Engineering and Technology Research, 2 (4), 1–8. 2333 – 0953 http://ieter.org/

Fissiha, G. G., & Negash, Z. M. (2015). Analysis of major factors affecting production and marketing of korarima (Aframomum Corrorima (Braun) P.C.M. Jansen) in Ethiopia. Journal of Economics and Sustainable Development, 6(19), 72–79.

Gautam, K. G. J., & Acharya, B. (2009). Ginger and turmeric production, improved technology. Nepal Agricultural Research Council, Ginger Research Program.

Girma, H., Digafe, T., Edossa, E., Beloy, Y., & Weyessa, G. (2008). Spices research achievements EIAIR (Reviseded.).

Girma, H., Digafe, T., & Tekeleigne, T. (2009a). Physical parameters, oleoresin and volatile oils content of five pepper (Piper nigrum L.) cultivars as influenced by maturity. Haramaya University, Ethiopia. East African Journal of Agricultural Sciences, 3(2), 189–192.

Girma, H., Haimanot, M., & Habteewold, K. (2016). In search of spices and herbs in Ethiopia. Zinjibel in Ethiopia. Tepi National Spices Research Center.

Girma, H. G., Digafe, T., Edossa, E., Beloy, Y., & Wondifraw, G. (2008a). Spices research, achievements (Revised ed.). EIARO.

Gitanjali, J., Venkatachalama, P., & Subramanian, P. (2014). Development of high efficient combustion system for turmeric boiling. Journal of Environmental Research and Development, 9(1), 67–74.

Habteewold, K., Bekele, K., Kasahun, S., & Tariku, H. (2015a). Prevalence of bacterial wilt of ginger (Z. officinale Rosc.) caused byRalstonia solanacearum (Smith) in Ethiopia. International Journal of Research Studies in Agricultural Sciences (IJRAS), 1(6), 14–22.

Habteewold, K., Dejene, B., Lemi, Y., Abukjya, G., Wokijira, G., Girma, H., & Haimanot, M. (2018). Result of turmeric variety trial in Ethiopia. International Journal of Research Studies in Agricultural Sciences (IJRAS), 4(9), 34–38. https://doi.org/10.20431/2454-6224.0409005

Habteewold, K., Tadesse, E., & Hailieramariam, A. (2016). Critical time of weed competition and evaluation of weed management techniques on ginger (Zengiber officinale) at Tepi in South West Ethiopia. International Journal of Research Studies in Agricultural Sciences (IJRAS), 3(3), 5–10.

Habteewold, K., Demes, F., Tewodros, L., Dejene, B., Haimanot, M., & Wokijira, G. (2017). Seed spices production guideline: Ethiopian institute of agricultural research. http://www.ublication.eior.gov

Hailmichael, G., & Tesfaye, K. (2008). The effects of seed rhizome size on the growth, yield and economic return of ginger (Zingiber officinale Rosc.). Asian Journal of Plant Sciences, 7(2), 213–217. https://doi.org/10.3923/ajps.2008.213.217

Hailmichael, G., Tilahun, D., & Etiso, E. (2008). Spices research achievements (Revised ed.). Ethiopian Institute of Agricultural Research.

Herms, S. (2013). Business Opportunities Report Spices #6 in the series written for the “Ethiopian Netherlands Business Initiative”.

Hiranya, B. S. (2013). An assessment of pre & post-harvest factors affecting quality of ginger in the export chain. A case study of Salyan District and Nepalgunj City, Mid-Western Development Region, Nepal.

IAE. (1998). Institute of agricultural research, Jimma national coffee research center horticulture division progress report for the period 1986–1991.

Idris, G. L., Omojowo, F. S., Omojosola, P. F., Adetunji, C. O., & Ngwu, E. O. (2010). The effect of different concentrations of ginger on the quality of smoked dried catfish (Clarias gariepinus). Nature and Science, 8 (4), 59–63. 11545-0740

Israel, P., Menbere, F. A., & Samuel, P. M. (2019). Socio-economic and environmental values of korarima (Aframomum corrorima (Braun) P.C.M. Jansen). International Journal of Agriculture Innovations and Research, 7 (4). (Online) 2319-1473.

Jafer, D. (2016). Effect of potting media and watering frequency on dry matter production and distribution of seedling of korarima (Aframomum corrorima (Braun) P.C.M. Jansen).

Jafer, D., Tesfaye, S., & Amsalu, N. (2016). Effect of nursery potting media and watering frequency on emergence and seedling growth of korarima (Aframomum corrorima (Braun) P.C.M. Jansen). Sky Journal of Agricultural Research, 3(10), 187–195.

Jansen, P. C. M. (2008). Aframomum corrorima (Braun). South African Journal of Botany, 74(1), 181–185.

Jayashree, E., Kandianan, K., Prasath, D., Sasikumar, B., Senthamarai, M., Srinivasan, V., Susela, B. R., & Thakonamani, C. K. (2013). Turmeric Extension Pamphlet. Indian Institute of Agricultural research, Manager, Agricultural Technology Information Centre.

Jibat, M., Getachew, W., Getu, A., & Kiflew, H. (2019). Survey and identification of major weeds of seeds spice in Ethiopia. Journal of Plant Pathology & Microbiology, 10(4), 477. https://doi.org/10.35248/2157-7471.10.477

Kader, A. A. (2005). Increasing food availability by reducing postharvest losses of fresh produce. Acta horticulure, 682(1), 2169–2176. https://doi.org/10.17660/ActaHortic.2005.682.296

Larrousse, L. (2007). Larrousse’s Gastronomique. Cold Spring Harbour Press.

Lupi, A., Temeteme, S., Mitiku, T., & Mekonen, B. (2016). Influence of Rooting Media on Nursery Performance of Korarima (Aframomum corrorima) in Southwest of Ethiopia. Academic Research Journal of Agricultural Science, 5(4). 51–60.

Masresha, Y. (2010). Market profile on spices in Ethiopia: A report to UNCATD ITC.

Meena, S. S., Balraj, S., Dheraj, S., Ronjan, J. K., & Meena, R. D. (2013). Pre and post-harvest factors
effecting yield and quality of seed spices: A review. *International Journal of Seed Spices*, 3(1), 1–11.

Melanie, M., & Michael, J. (2011). Spices and herbs for home and market. Rural Infrastructure and Agro-Industries Division Food and Agriculture Organization of the United Nations.

Merga, J. G., Hobtamu, T. Y., & Eshetu, D. K. (2019). Yield loss of ginger (*Zingiber officinale*) due to bacterial wilt (*Ralstonia solanacearum*) in different wilt management systems in Ethiopia. *Agriculture & Food Security*, 8(1), 5. https://doi.org/10.1186/s40066-018-0245-6

MoARD (Ministry of Agriculture and Rural Development). (2008, November 6). A proceeding report on status and challenges of spice production in Ethiopia. National Workshop in United Nations for Economic Commission for Africa. pp. 17–26.

Mulukdest, A. M., Jema, H., Kebede, W., & Amare, A. (2015). Determinants of postharvest banana loss in the marketing chain of central Ethiopia. *Food Science and Quality Management*, 37(52–63), 3.

Nybe, E. V., Raj, M. N., & Peter, K. V. (2007). Horticulture science series (Spices in). In K. V. Peter (Ed.). Vol. 5. 67–91. New India Publishing Agency

Olojede, A. O., Iluebbey, P., & Dixon, A. G. O. (2005). Collaborative germplasm and data collection on minor root and tuber crops in Nigeria IITA/NRCRI, in: Annual Report, National Root Crops Research Institute pp. 77–81.

Orgut. (2007). Market assessment study. Ethiopian Nile irrigation and drainage project, main report and annexes. Ministry of Water Resources.

Ravinndran, P., Ravindran, K., Nirmal, B., & Sivaraman, K. (2007). *Turmeric: The genus Curcuma; Medicinal and aromatic plants industrial profiles*. CRC Press, Taylor & Francis Group.

Regassa, R. (2013). Assessment of indigenous knowledge of medicinal plant practice and mode of service delivery in Hawassa city, southern Ethiopia. *Journal of Medicinal Plants Research*, 7(9), 517–535.

Sharma, B. P. (2009). Diseases and ginger and their management. Post-harvest consideration of ginger to control diseases. Nepal Agricultural Research Council, Ginger Research Program.

Shewale, L. (2011). Antifungal substances from essential oils. M.Sc. Thesis. Addis Ababa University. p. 8

Shibru, Z. F., Ali, M., Girma, H., & John, B. (2011). Effect of boiling temperature levels and durations on dry matter, total ash, crude protein and crude fiber contents of different rhizome set types of turmeric (*Curcuma Longa L*). *International Journal of Advanced Research*, 5(2), 2653–2662. https://doi.org/10.2147/IJAR.01/3470

Shimeles, M. (2011). Extraction and evaluation of fixed oil from black cumin (nigella sativa) using hexane and ethanol solvents. A Thesis Submitted to the School of Chemical and Bio-Engineering submitted in partial fulfillment of the Requirements for the Degree of Master of Science (Process Engineering). Addis Ababa University.

Shinde, G. U., Kamble, K. J., Harkari, M. H., & More, G. R. (2011). Process optimization in turmeric heat treatment by design and fabrication of blancher. *International Conference on Environmental and Agriculture Engineering*. IPCBEE, 15(2011), 36–41.

Simegn, K., Sentayehu, A., & Melaku, A. (2016). Genetic Diversity Studies on Yield and Its Related Traits in Korarima (*Aframomum korarima* (Braun) Jansen) germplasms. *Journal of Biology, Agriculture and Healthcare*, 6 (3), 1–7. 2224–3208

Singh, P., Srivastava, R., Sharma, A., Hore, D., & Panwar, B. (2001). Genetic variability and correlation in turmeric (*Curcuma longa L*). *Indian Journal of Hill Farming*, 14, 24–28

Todesse, E., Melaku, A., & Fantahun, A. (2015). Effect of weed management methods on the growth and yield of ginger in Metu, Illubabor, Ethiopia. *Developing Country Studies*, 5(13), 82–86.

Teriku, H., Kassahun, S., & Gezahegne, G. (2016). First report of ginger (*Zingiber officinale*) bacterial wilt disease in Ethiopia. *Research Journal of Agriculture and Forestry Sciences*, 4(4), 5–9

Teferi, M. B. (2016). In vitro propagation of korarima (*Aframomum korarima*) from shoot explants. An MSc Thesis Submitted to School of Graduate Studies, Addis Ababa University.

Teshaile, D., Haimanot, M., Girma, H., & Merga, J. (2018). Insect pests infesting korarima (*Aframomum korarima*) (Braun) P.C.M. Jansen in southwestern part of Ethiopia. *International Journal of Veterinary Sciences and Animal Husbandry*, 3(2), 10–13. www.veterinarypaper.com

Tiru, T., Wondimu, B., Arega, G., & Hassen, B. (2017). Spice production, marketing, and utilization in South Wollo, Ethiopia. *East African Journal of Sciences*, 11(1), 27–36.

USAID. (2006). Post-harvest handling series; technical bulletin no 23. Ginger post-harvest care and market preparation. Ministry of fisheries, crops and livestock, New Guyana’s marketing cooperation, National agriculture research institute (pdf). Retrieved August 28, 2013, from http://pdf.usaid.gov/pdf_docs/PNACY839.pdf

Vijayalaxmi, H., & Sreepada, H. (2014). An economic overview of ginger production in Ethiopia. *International Journal of Science and Research*, 3(12), 2052–2054.

Wondifraw, T., & Wannakairo, S. (2004). A micropropagation method for korarima (*Aframomum korarima* (Braun) Jansen), Katesats University, Kampangsaen, Thailand. *Science Asia*, 30 (1), 1–7. https://doi.org/10.2306/scienceasia1513-1874.2004.30.001

World, K. (2016, June). Farm level processing of turmeric. kisanworld@gmail.com

Wubeshet, T., & Dessalegn, A. (2019). Assessment of production and utilization of black cumin (*Nigella sativa*) at the Oromia Regional State, Ethiopia. *Asian Journal of Agricultural Extension, Economics & Sociology*, 31(3), 1–12.

Yiljep, G. A., Fumen, A., & Ajisegiri, E. A. (2005). The effects of peeling, splitting and drying on ginger quality and oil/aerosol content. *Agricultural Engineering International: The CIGR E Journal*, VII, 1–8.

Yousif, H. H. (2008). Effect of high levels of nitrogen and phosphorus fertilizer on growth, yield and yield components of Nigella sativa L. Horticulure Department College of Agriculture, Duhok University, Iraq. *Mesopotamia Journal Agriculture*, 36(1), 1815–316X

Zakir, M., Hollemichael, G., Seyoum, M., & Addisu, M. (2018). Status of ginger (*Zingiber officinale*) research and production challenges and future prospects in Ethiopia: A review. *Acdad. Res. J. Agri. Sci. Res.*, 6(5), 276–290.
