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Spices Research Achievements, Challenges and Future Prospects in Ethiopia

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National spices research team of Ethiopia, with limited capacity achieved several results on germplasm enhancement, crop management, post-harvest handling and quality management on spices. Lowland spices and highland seed spices were given special research attention. Performances of most of these spices were proved promising in yield and quality. From evaluation, two black pepper, two ginger, one cardamom, one turmeric, one vanilla, three black cumin, three coriander and three fenugreek varieties had been registered or released and promoted to their respective agro ecologies. The average yield of lowland spices was proved promising as presented in table (Table 1) while yield of seed spices such as black cumin, coriander and fenugreek ranged from 1.5 to 1.7t/ha. Quality parameters were also promising except in turmeric, cardamom and vanilla that require further improvement. Studies on planting time, multiplication methods, management practices as well as harvesting and processing techniques had also been conducted and important information recommended. Multiplication and distribution of planting materials of spices had already been underway in the past for the released varieties. The devastating case of ginger bacterial wilt has also been an urgent issue in the research. However, special attention had recently been given for the use of modern tissue culture for rapid multiplication and dissemination of disease-free planting materials of elite materials of the various spices.

Key words: germplasm, collection, spices, yield, quality, evaluation, ecology, extraction, variety, accession

INTRODUCTION

The national spices research team in collaboration with Institute of Biodiversity and Conservation of Ethiopia (IBC) has been carrying out significant number of collections and introductions of high valued spices of different agro ecologies. Main actors of the collection team were researchers from Tepi National Spices Research Center (TNSRC), Jimma Agricultural Research Center (JARC) and expertise from IBC. The collection team planned a type of specialization or target spices crops as more of the lowland and mid altitude area spices grow in partly South, Southwestern in Southern Nation and Nationality Regional State and partly from Northwestern of Oromiya Regional State of Ethiopia. The collection target areas of highland seed spices were highlands of Oromiya Regional State such as Bale, Arsi, more of the Shoa highlands and of Amhara Regional States such as Gondar (Kola-Diba), highlands in Wollo areas and highlands in Tigray Regional State.

Once germplasms attained, consecutive evaluation for adaptation, yield and quality performance had undergone in the respective agro ecologies. Similarly, introduction of various invaluable spices varieties has been continued and incorporated to the evaluation program according to the agro ecological domains. Main evaluation centers are research fields of TNSRC, Bonga Research Center, JARC, research fields of Tepi, Kabo and Bebeka Coffee Plantation Projects (currently private farms), IBC testing sites and also research plots of Kulumsa, Sinana, Gondar, DebreZeit Agricultural Research Centers. In addition to main centers, evaluation of these invaluable crops of economic importance had been undertaken at different sub-centers and testing sites of JARC such asMugi, Metu, Agaro. A number of promising improvement works had thus been carried out and considerable achievements attained on black pepper (*Piper nigrum* L.), cardamom (*Elettaria cardamomu* M.), ginger (*Zingeber officinale* Rosc.), turmeric (*Curcuma domestica* Val), vanilla (*Vanilla planifolia syn. Vanilla fragrans*), black cumin (*Nigella sativa* L.), coriander (*Coriandrum sativum*), white cumin (*Trachayspermum anni)*, fenugreek (*Trigonella foenumgraecum),* korarima *(Aframomum corrorima* Braun Jansen) and long pepper (*Piper capense*). The research also included spices such as cinnamon (*Cinnamomum zeylanicum), annatto (Bixa orellana*), cocoa (*Theobroma cacao*), chilies (*Capsicum spp*) and noni (*Morinda citrifolia*). These spices crops have diverse uses for Ethiopian people with a culture of more spicy foods.

The major uses include food seasoning, applications in pharmaceuticals, perfumery, and/or cosmetics, as a whole or somehow processed. On top of these, some of these spices, like turmeric, are widely used in Ethiopia and elsewhere in the world for food coloring (Purseglove *et al*., 1981; Pruthi, 1998).The coloring power of turmeric is also used for industrial purpose such as in garment and coloring of pharmaceutical products. Uses of highland seed spices such as black cumin, coriander and fenugreek in the Ethiopian community has also been so diverse. A drop of black cumin fatty-oil or smell of 10 to 15 black seeds knotted in a small clean cloth is very common curative for headache. Fruits/capsules of coriander as a spice and tender branches/leaves of coriander is very common medicinal plant used as fresh vegetable. Vegetative part of fenugreek is also used as vegetable food and the flour of the fenugreek seeds is used as food (protein source) and as food flavoring. Almost all of these spices are commonly used for food and/or beverages flavoring in Ethiopia(Jansen, 1981). In addition to such uses the extract products of more of the spices crops discussed have high potential for generating alternative export products for the country. Till present, ginger, turmeric, pepper, black pepper, korarima, seeds of black cumin, coriander and fenugreek are exported either in their dried forms and/or as oleoresin or essential oils extract, thereby fetching some foreign currency to the country (Roukens *et al.*, 2005; Masresha, 2010).

From long term evaluation results attained, almost all of the lowland spices such as black pepper, ginger, turmeric, cardamom, korarima, long pepper, vanilla were thus found well adapted to the hot-humid and lowland agro ecologies of Southwestern Ethiopia and in some parts of Oromiya Regional State. Some of these like korarima and long pepper also performed well in mid altitude areas such as Jimma zone, Dawuro, Wolayita zones. According to review of different scientists (Purseglove *et al*., 1981; Borget, 1993; Pruthi, 1998) on average, the crops were observed to perform best in areas with altitudes ranging between 500 and 1500 m, annual rainfall of 1200-7000mm, and mean temperatures of 20-35 ºC. Virgin soils or alluvial soils rich in humus were also identified to be highly suitable for the production of more of the lowland spices. However, well-drained, fertile, and friable soils having sufficient humus, and neutral pH were reported ideal for the growth and production of ginger and turmeric (Purseglove *et al*., 1981; Borget, 1993; Pruthi, 1998; Ragham, 2007). Likewise, cardamom requires humus-rich forest covered soils that could sustain prolific and luxurious growth of crop plants. Under small-scale production, cardamom, black pepper, ginger, and/or turmeric were found to be intercropped successfully with other horticultural crops like enset, banana, and/or coffee. These technologies were hence proved well adapted to most parts of Western and Southwestern Ethiopia. The farming system is commonly characterized with the growth of one or more of these complementary crop species.

Improved varieties of highland seed spices: black cumin, coriander and fenugreek were proved performing very well in highlands of Ethiopia with average altitude of 1500-2300 meter above sea level, annual rain fall 120-400 mm. All require well prepared land ploughed at least 3 times and the soil should be fine, light, and free of logging, loam and with enough nutrient composition which can be improved by fertilizer application. Production areas of these spices in Ethiopia are very similar to that of teff (*Eragrostis tef*), guizotia (*Guizotia abyssinica*), chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) and more of the time mixed cropping of these spices is common with various cereals or legumes which are harvested annually. Average temperature of 12-20 ºC is very suitable for optimum flowering, pollination and fruit setting of these spices. Excessive moisture has a negative effect on vegetative and yield performance of these spices and also it aggravates the incidence and severity of various diseases. In this case sowing time is always a serious issue to stagger with the moisture period of the growing season. Cool and dry season areas of Ethiopian highlands are suitable for production of the seed spices.

The areas with coffee-based farming system of Ethiopia are commonly characterized with mixed and/or multiple cropping system, and integration of the lowland spices crops within the system had been successful, as most of these spices require either shade and/or support for their growth (Edossa, 1998a, Girma *et al*., 2008). The unique characters and/or growth requirements make these crops the best candidates in the coffee diversification endeavor, thereby contribute to the national economy, through export, and/or import substitution. Equivalent to this, the highland seed spices have high integration of cultural practices with various annual crops and more of the field activities are organized and managed accordingly. Their contribution as alternate cash generation in foreign exchange has also been very high.With the achievements obtained so far regarding to generation of improved technologies for these diverse crop species, more gaps still require further research attention. Among others, these include, widening of germplasm through exhaustive collection and/or sufficient introduction, as well as studies related with soil nutrition and harvesting and post-harvest technologies. To this end, pertinent fertilizer recommendations as well as improved postharvest handling and processing technologies are still lacking for most of these crops, especially for turmeric, cardamom, ginger and vanilla. In general, production of more of these plant species has been frequently reported below the level of their potential due to insufficient package. Seed multiplication and distribution of the various spices has also remained unbalanced.Ginger bacterial wilt which has been important emerging issue and the like are also priority of the research. Therefore, this paper reviewed the research achievements and available improved technologies for lowland and highland seed spices in their respective agro ecological conditions. It also presents the existing gaps that require research attention and tries to pin point future directions thenational spices research team should follow to avail full package recommendations for the producers.

RESULTS AND DISCUSSION

Collection, Introduction and Germplasm Enhancement

Acquiring sufficient types and number of germplasm is the corner stone to achieve the desired goals of improvement in any crop species. Thus it is imperative to give peculiar attention to this aspect to succeed in the endeavor. In that, evaluation and identification of the best performing crop species and/or varieties that could serve as the best alternatives for coffee diversification in the South and Southwestern part and various agro ecologies of the country was the major goal set by the national spices research. Consequently, several accessions from each crop species of lowland and highland seed spices were collected and/or introduced from different corners of the country and from other countries and evaluated under the prevailing agro ecologic conditions of the area. In the course of this evaluation, strong emphasis was given to their performance in adaptation measured by their vegetative performance, yield, quality, as well as disease and pest resistance.

Of the different crop species that Ethiopia is known to be the center of origin and/or diversity, korarima and long pepper were given special research emphasis by the national spices research team. On the other hand, ginger was among the crops that had been introduced in the 13th century (Jansen, 1981), and it is currently found growing in wider parts of the country, with more distribution inthe Southwestern Ethiopia. Consequently, though it is not as diverse as that of the indigenous species, the variability within the ginger accessions in the country was so high. Therefore, collection of germplasm from different parts of the country had been one of the main areas given research attention for improving these three species; korarima, long pepper and ginger. On top of this, introduction of potential ginger accessions from elsewhere in the world had also been undertaken through FAO to widen the local genetic base. On the other hand, considerable efforts have been made for introducing other spice crops of economic importance. Of these high valued spices, accessions of black pepper, turmeric and cardamom were introduced before some two and half decades mainly through individual efforts. The collected or introduced materials were thus subjected to rigorous evaluation for adaptation, yield, quality, and resistance to diseases and pests under different agro ecologies.

The findings obtained had thus indicated the existence of enormous potential for the production of these invaluable crops in the country as a diversification option for coffee especially for lowland spices. Concomitantly, the research findings for highland seed spices were very promising in more of the cereal-based farming system of mid-altitude and highlands of Ethiopia. Therefore, highly promising varieties of black pepper, ginger, turmeric, cardamom and vanilla from lowland spices and black cumin, coriander and fenugreek for highland seed spices had been identified based on their adaptation, yield, extraction quality and chemical composition that could meet the international standards, provided they are produced following appropriate agronomic and postharvest handling techniques. Subsequently, best accessions from each crop species that are highly adaptable and productive under the stated agro ecologies were identified. Potentials of these varieties for high economic return to producers were clearly observed from the results of many year evaluation. Ethiopian export performance (values ‘000 Ethiopian Birr (ETB); 1 USD= 20 ETB) of dry spices: ginger, turmeric, black cumin and chili from 2002/03 to 2012/2013 was 1,586,938.2; 188,624.78; 353,704.19 and 317,849.08, respectively (Feleke Sebhatu presentation, 2015). As a result, their contribution for boosting the national economy through import substitution and/or export, were evident.

Accordingly, promising black pepper varieties; Gacheb and Tato with average dry peppercorn yield (2.4 t/ha) and with international standard extraction quality were registered for users (Edossa, 1998b; NVRC, 2006; Girma *et al*., 2008).Similarly, productivity of more than 20 t/ha fresh rhizome yield of ginger and turmeric had been recorded from ginger and turmeric, which explicitly indicates the potential for the production of these spices in Southwestern Ethiopia. However, the turmeric accessions at hand have quality problem that calls for further improvement (Fantahun and Teklu, 1995). Likewise, two superior varieties of ginger, Yali and Boziaband one variety of turmeric (Dame), one variety of cardamom (Gene) had been registered and distributed for users (NVRC, 2006, 2007)**.**Similarly varieties of highland seed spices: Darbera, Eden and Dershaye (black cumin), Walta-I and Indium 01 (coriander), Chala, Hunda 01 and Ebbisa (fenugreek), Melka-Zala, Oda-Haro, Melka-Awaze and Melka-Shote (chili pepper) and Tsedey-92, Bishoftu-Netch, Qoricho, Kuriftu and Chelenko-I (Garlic) (NVRC, 2012, 2013, 2014) had been released and supplied for users. More of the released and/or registered spices varieties had been proved highly promising giving high yieldas well as quality standards in international market (Table 1).

Crop Management Practices

Black pepper is a climber vine and it requires live support (Purseglove *et al*., 1981; Borget, 1993; Pruthi, 1998). Based on the evaluation in Tepi National Spices Research Centre, *Erythrina indica* and *Gravellia robusta* were proved the most effective support and partial shade trees (Edossa, 1998b; Girma *et al*., 2008). On the other hand, cardamom, korarima and long pepper are shade loving plants, thus, as their original habitat is the tropical rain forest regions of the equator, provision of ideal shade level (55 to 63%) is critical to maximize production in potential areas (Tepi, Bebeka, and Jimma). Common coffee shade tree species including *Albizzia* spp, *Millettia* spp, and *Gravellia* spp could also be used for provision of shade to cardamom, korarima and long pepper. Gliricidia (*Gliricidia sepium*) has also been proved to satisfy the perforated light and support requirement for vanilla (YEKI-1) variety. Intercropping of cardamom with coffee had been successful, while its integration with "enset" and/or banana gave poor results and need further investigation as the intercropped components gave poor yield (Institute of Agricultural Research; IAR, 1985a, 1985b, and 1987). It could be justified the coffee plant gave optimum shade while other two were not. Intercropping of ginger with coffee was found effective under recommended agro ecologies (Tepi, Anfillo and the like) (Zenebe and Bereke-Tsehay, 1991) while no significant yield reduction was recordedfrom the integration of turmeric with coffee. These findingsrevealedthat turmeric can perform well under moderate shade levels (IAR, 1997b). On the other hand, supplementary irrigation was proved to increase ginger rhizome yield by 72% over non-irrigated plot (IAR, 1985a).

Vine (10-30cm long) with 3 nodes cutting was proved to be highly effective for conventional propagation of black pepper in Ethiopian context while 60 cm length (7 to 10 nodes) was recommended by different authors (Borget, 1993; Purseglove *et al*., 1981; Pruthi, 1998). Similar propagation technique was also recommended for vanilla. The use of clumps with one old and another young shoots had proved ideal for cardamom and korarimaclonal propagation (Borget, 1993; Purseglove *et al*., 1981; Pruthi, 1998, Girma *et al*., 2008). The effects of different ginger planting materials (sprouted, un-sprouted, and transplanted rhizomes) were not statistically significant; however, sprouted rhizomes followed by those transplanted ones gave higher yields(IAR, 1996). Similar results were also obtained from turmeric that high fresh yield (19.4 t/ha), while the un-sprouted rhizome produced (17t/ha) (Edossa, 1998b).

As reported by various groups, appropriate planting type and time, spacing and different cultural practices were identified and recommended from periods of research results (IAR, 1985b, 1987, 1995, 1997a, 1997b; Zenebe and Bereke-Tsehay, 1991; Edossa, 1998b; Girma *et al*., 2008). Summary of the important cultural practices recommendations are presented in tables (Table 2).

Land preparation plays critical roles in production and productivity of ginger and turmeric and a little bit slant land orientation to avoid water logging and well pulverized soil for fast rhizome expansion is necessary. Water logged, stony and marshy areas are not suitable for the production of ginger or turmeric.Planting on flat land had given the highest rhizome yield, as compared to the use of ridges and/or raised beds in ginger (Zenebe and Bereke-Tsehay, 1991). However, fresh rhizome yield of turmeric was highly enhanced by planting on raised beds (34 t/ha) under Tepi conditions (Edossa, 1998b). Fertilizer application on ginger and turmeric was not effective (Paulos, 1986). In general, raising of black pepper vine cuttings in nursery starts inMarch and could be ready for planting in July and August. However, in the case of ginger and turmeric, harvesting commences in early March, thus planting could be carried out between March and mid-April. Likewise, seeds of cardamom could be collected and sown between October and November, thus, the seedlings could be ready for transplantingduring the main rain season (June and August).

Table 1. Physical characteristics and extraction outputs of the spice accessions in our research center

Name		No. of Accessions	Varieties Released	Physical characteristics at 20°C			Color	% Yield	
Common	Scientific			Refractive Index	Specific Gravity	Optical rotation		Oleoresin (w/w)	Essentialoil (v/w)
Black pepper	*Piper nigrum* L.	13	Gacheb	NA	NA	NA	LY	9.1	3.20
			Tato	NA	NA	NA	LY	10.0	2.29
Ginger	*Zingeber officinale Rosc.*	92	Yali	1.4929	0.9145	NA	LY	6.53	1.33
			Boziab	1.4897	0.8838	-34.221	Yish	9.22	1.27
Cardamom	*Elettaria cardamomum*	3	Gene	1.4655	0.9494	+16.799	PY	8.2	6.1
Turmeric	*Curcuma domestica*	8	Dame	NA	NA	NA	NA	18.0	NA
Vanilla	*Vanilla planifolia*	4	YEKI-1	NA	NA	NA	NA	NA	NA
Korarima	*Aframomum corrorima*	71	Pipeline	NA	NA	NA	NA	NA	NA
Long pepper	*Piper capense*	20	Pipeline	NA	NA	NA	NA	NA	NA

LY= Light yellow; PY= Pale yellow; Yish= Yellowish, NA= not available
Source: Edossa, 1998b

Harvesting and Postharvest Handling

Major quality parameters considered in black pepper were boldness and color uniformity of the peppercorns and the best harvesting and postharvest techniques recommended were those that could result in un-shriveled seeds with full body and quite uniform dark-brown to black color (Purseglove *et al*., 1981). On the other hand, the quality status, i.e. essential oil and oleoresin contents, of most ginger accessions at hand is reported to meet the international market standards. However, in some cases farmers retain their rhizomes in the field for more than a year, to increase the bulk rhizome yield. Such malpractices usually reduce the product quality, resulting in fibrous rhizomes with low oil content (Purseglove *et al*., 1981)**.** Turmeric is highly valued for its deep-yellow-orange color which is attained from timely stepwise application of the major processing steps (boiling, drying, peeling, and polishing) (Purseglove *et al*., 1981; Pruthi, 1998). However, turmeric farmers in Southwestern Ethiopia do not follow these important steps strictly and they commonly bypass the peeling and/or polishing steps of the process, which are the most basic and key procedure to ensure quality. To the contrary, they rather try to coat the dried rhizomes with external coloring materials than working appropriately to develop the inherent color of the rhizomes through peeling and polishing, thus, resulting in the poor quality product. In the case of cardamom, variety Car 82/72 (Gene) has an erect or arching type of panicle, unlike that of Car 14/79, which has prostrate panicle types (IAR, 1996). This directly affects market quality, as it is associated with capsule color that is mainly ascribed to the prevalence of soil contact that could bring about discoloration of the capsules in Car 14/79. Therefore, this will affect quality of the final product, since the ultimate aim of whole cardamom production is to obtain as clean and white capsules as possible (Borget, 1993). In addition, Car 82/72 (Gene) had also been promoted as it gives the best large sized and prominent green or white straw colored capsules, fulfilling the most primary quality parameters at the international market. On top of these, the variety is also known to give relatively higher yields of essential oil and oleoresin (Edossa, 1998b; Girma *et al*., 2008).

Harvesting, Drying and Processing

Stages of maturity at harvest and subsequent processing/drying steps followed are among the most critical factors affecting product quality in spices, next to variety, environment and soil type (Purseglove *et al*., 1981; Borget, 1993). Therefore, identifying the appropriate stage of maturity for harvest, together with most effective and best techniques of harvesting, drying, and processing of the produce is mandatory.

Table 2. List of recommended spices and relevant agronomic information

List of Spices	Propagation Method	Recommended			Requirements (shade/support)	Commercial Product	Yield (t/ha)
		Planting/sowing	Harvesting	Spacing			
Black pepper	Cutting	June – July	February – March	2.4 m X 2.4 m	Support	Fruits/berries	2.4 (dry)
Ginger	Rhizomes	March – mid April	Dec. – January	30 cm X 15 cm	Open sun	Rhizomes	19.6 (fresh)
Cardamom	Seed (capsule)	June - July	Nov.- Dec.	3 m X 3 m	Shade	Capsules	0.16 (dry)
Turmeric	Rhizomes	March – mid April	Dec.– January	30 cm X 15cm	Open sun, intercrop shade	Rhizomes	23 (fresh)
Vanilla	Cutting	July, August		3 m X 2 m	Support, shade	Pods	
Black cumin	Seed	August, Sept. (rain fed) April, May (irrigation)	164 days to maturity	5 to 7.5 Kg/ha seed rate		Seed	1.5 (dry)
Coriander	Seed or capsule	Mid July to early August	130 days to maturity	20 to 30 Kg/ha seed rate		Seed	1.7 (dry)
Fenugreek	Seed	First week of September	146 days to maturity	20 to 25 Kg/ha seed rate		Seed	1.5 (dry)
Garlic	Bulb	Year round (rain fed, irrigation)	132 days to mature	30 cm X 10cm		Bulb	9.8 (fresh marketable)
Hot pepper (chili)	Seed	Mid April to early May	114 days to maturity	600 to 700 gram/ha		Pod	2.1 (dry)

Source: Edossa, 1998b, Girma *et al*., 2008, NVRC, 2005, 2006, 2007, 2008, 2012, 2013 and 2014, Dec.=December, Nov.= November.

Consequently, the national spices research team had devoted most to come up with appropriate harvesting time for black pepper, ginger and turmeric rhizomes, cardamom capsules, vanilla pods and seeds and capsules of seed spices. Accordingly, suitable recommendations had been availed regarding these aspects of product development for these spices in Ethiopian condition. In that, the best time of harvest, as well as the most appropriate harvesting, drying and/or processing techniques were found to vary depending on the type of final marketable product. Accordingly, each of the spices discussed in this paper have their own recommended durations and conditions of drying.

Black pepper is the major product of *Piper nigrum* and the ultimate color of the produce needs to be dark brown or black in color. To attain this, harvesting of green immature berries that are changing their color to light yellow and subsequent drying under the sun is essential to produce this product (Purseglove *et al*., 1981; Borget, 1993; San Lin, 1994; Pruthi, 1998, Ragham, 2007, Girma *et al*., 2008). Mixed berries with red ripe and immature green are not acceptable in commercial market. In the process, the green yellow colored fruits will be detached from the spikes and dried under the sun on a clean cemented surface or on a raised bed until 11% moisture level is achieved. This process mostly takes 7 to 8 days with continuous steering (Purseglove *et al*., 1981; Borget, 1993; Pruthi, 1998; Girma *et al*., 2008). In general, black pepper takes 6 to 8 months from flowering to maturity and harvesting, depending on the prevailing environmental condition (Purseglove *et al*., 1981; Borget, 1993). Therefore, if the product is intended for extraction, it is recommended to harvest the berries after around 3.5 to 4 months from the time of 70% fruit setting under Tepi condition. However, if the final product is to be sold and consumed in whole or ground form harvesting should commence after nearly 5.5 to 6 months of 70% fruit setting (Girma and Digafie, 2008).

Ginger and turmeric rhizomes are harvested manually by fork or by tractor and the rhizomes should be washed and cleaned to remove all soil remnants and tiny roots. The best harvesting time for ginger and turmeric is 8-9 months after planting under the southwestern agroecologies of Ethiopia (Edossa, 1998b; Girma *et al*., 2008). Drying is carried out under the sun on clean cemented surface with frequent steering till the rhizomes reach 7-12% moisture content that takes 6-8 days. Curing is an additional processing step in turmeric and it helps to develop the desired deep-yellow orange color. The curing step comes before drying, and it involves boiling fresh rhizomes in water, sun drying and finally polishing or peelingto develop the color (Purseglove *et a*l., 1981; Borget, 1993; Pruthi, 1998; Girma *et al*., 2008). Boiling turmeric rhizomes helps to kill the live rhizome, gelatinize the starch and ensure more uniform coloring, obviate the raw odor, reduce the drying time(Purseglove *et al*., 1981; Pruthi, 1998). In the process, washed rhizomes will be put into a clean barrel filled with water for boiling leaving 5-7 cm space on top to be filled later with dry leaves of turmeric. Boiling will continue through providing uniform fire for some 45-60 minutes, until the boiling rhizomes start to release attractive smell of turmeric, and become easy for pinching using a stick (Purseglove *et al*., 1981; Borget, 1993; Fantahun and Teklu, 1995). After boiling, drying is performed in a similar manner to ginger which takes about 10-15 days under Tepi condition. The dried rhizomes will then be polished and peeled to develop the inherent deep yellow-orange color and the cured products deprived of bitter constituents (Purseglove *et al*., 1981; Pruthi, 1998).

Cardamom capsules of commerce are small, having either dark green, light green or white color, depending on the processing technique adopted (Ragham, 2007). Among others, color and appearance of the capsules are the major quality criteria in cardamom marketing. Under field condition, capsules are considered mature and ready for harvest in the months of October to December when their color changes to light yellow. Unlike that of other spice crops considered in this paper, special care should be taken while harvesting and/or drying cardamom capsules, since cracked and/or split capsules are stated poor in quality because of the resulting total loss of aroma and flavor through these cracks (Purseglove *et al*., 1981). Different techniques could be used to dry cardamom capsules, i.e. with hot air from furnace, on heated platforms, under sunlight, etc. (Purseglove *et al*., 1981). In any of these processes, all stalks and other remains of the floral partsshould be removed from the dried capsules, either by hand, when production is of a smaller scale and through rubbing the dried capsules over a coarse surface of wire mesh or bamboo trays, when having large production volumes.

Packaging and Storage

Suitable packaging practices for processed spice products are highly essential. Generally, the basic principles of proper packaging and storage involve retention of suitable moisture level, storage under clean and cool, well-ventilated area, free from any incidence of storage insect pests, rodents, as well as other domestic animals. Dried black pepper is hygroscopic by nature thus could absorb moisture from the environment if not protected well (Purseglove *et al*. (1981). Such conditions are common, especially during the rainy season, where the prevailing high humidity could enhance mould development and/or insect pest infestation in the case of whole pepper. It could also result in caking, which will lead to quality loss, i.e. aroma and flavor, or it may create unpleasant odor, thereby reducing its marketability. According to the guidelines of the American Spices Trade Association, ASTA (1999), it is essential to use sacks for packing pepper dried to 10 to 11% moisture level. Producers are required to use new, clean sacks that are dry and free from any contaminant. To prevent moisture re-absorption during storage, it is recommended to use wooden planks for stacking the pepper containing sacks at least 30cm away from the walls. Likewise, both dried ginger and turmeric should also be packed in new and clean bags. The products also require effective protection from dampness during storage, using dunnage of wooden crates to stack the packaged bags to prevent moisture ingress from the floor. In the meantime, the bags should also be stacked some 50 to 60cm away from the walls to avoid re-moistening. No insecticide applications should be carried out during storage, as these will affect the aroma and flavor of the spices. In general, the use of polythene laminated gunny bags are recommended for packing dried ginger and turmeric (ASTA, 1999). Dry products of black cumin, fenugreek and coriander with moisture content (10 to 11%) can be packed with sacks. Under the Ethiopian condition, all the spice crops given attention in this paper could be stored effectively making use of clean sacks, which could later be stacked in clean, dry, well-ventilated stores that are free from any sorts of pest infestations.

Qualitative Analysis

Gas chromatogram evaluations of essential oils of black pepper, ginger, turmeric, cardamom and long pepper samples collected from Tepi confirmed to be comparable with samples from Sri Lankan (Berhanu and Nigist, 1987). Analysis on oleoresin and essential oils of the varieties had also proved quality standards of the Ethiopian materials to be as per the international market requirements (Bahiru and Nigist, 1992). Therefore, they had confirmed the oil from the pepper samples collected from Tepi to contain a complex mixture of hydrocarbons such as monoterpenes (70-80%), sesquiterpenes (20-30%) and small amount of oxygenated terpene compounds. Likewise, the gas chromatogram data of the oils from the promising ginger varieties had also proved to be qualitatively similar with variety from Sri Lanka, with only some quantitative variation in individual components. On the other hand, the principal essential oil components of cardamom produced in Ethiopia were cineol (26-40%), α-terpinyl acetate (28-34%), Limonene (2-14%) and sabinene (3-5%) with several other minor components, such as linalool, α-terpineol, linalyl acetate, etc. (Berhanu and Nigist, 1987).

Research Gaps and Challenges

National spices research team has very limited resources while several research areas need immediate attention. Available accessions in some of the spices such as cinnamon and vanilla are insufficient to carryout extensive evaluations to come up with suitable varieties for specific agro ecologies of the country. Moreover, new spices accessions such as nutmeg, pimento, clove, etc. should be introduced to the evaluation process. On the other hand, researchers require special exposure to post harvest technologies elsewhere. Studies on crop protection and soil nutrition are the other areas of research that had not been given full research coverage. It is also very necessary to establish up-to-date laboratories to run quality evaluations. Shortage of planting material had also been a crucial bottleneck for wider dissemination of these crop species to farmers. Giving a prime attention to market promotion for these low-volume high-value crop species has also been essential. Finally, there is a serious gap in demonstration and popularization of available technologies of these invaluable crops of economic significance. Emerging issues such as ginger bacterial wilt that devastated the production should be given a prime attention. Extensive erosion of genetic resources of indigenous spices with destruction of the natural forest which is their habitat should also be given a due attention at higher officials and policy level.

Prospects

Conducive environmental condition and promising varieties of lowland and highland spices had been identified and released for users. Therefore, it is a very good opportunity to multiply and disseminate the available technologies within the recommended agro-ecologies of the country. The successes of *in vitro* protocol optimization of spice crops like cardamom, vanilla and black pepper could resolve the problem of clean planting material supply. Moreover, the research system is gaining strong attention due to the prime concern for the development of these crop species. Thus, with the current special support the problems of technical staff and research facilities will be resolved. Consequently, with popularization of available technologies, there is a high chance for production of quality products to compete in the world market. Improved management of indigenous spices applies for natural forest and this has high contribution in forest conservation. Technology shopping can be exercised as an alternate approach to satisfy part of the technology demand by shortening the time required to generate some of technologies.

CONCLUSION AND RECOMMENDATIONS

Several improved technologies had been generated and distributed to different agro ecologies of the country. These include improved varieties, suitable agronomic practices, drying or processing techniques, packaging techniques and quality standards. The suitable climatic conditions for the production of these invaluable spices in the country are the other opportunity to be further exploited by smallholder farmers and private investors. Therefore, to exploit all these opportunities effectively and assist in further technology generation through research, it is imperative to strengthen the national spices program with qualified human power and research facility. Those outstanding research gaps such as those related with crop protection, germplasm conservation, postharvest handling technologies, as well as soil and water management and conservation should be given prior attention. In vitro mass propagation of planting materials should be enhanced further to meet the ever-growing demand for quality planting materials. Peculiar attention should be given to promote marketing of these spices both at the local and international level. Maximum effort should also be directed for demonstration and popularization of the existing technologies on these spice crops of economic importance to attract private investors and encourage small-scale farmers, thereby assist in the envisaged production and export diversification endeavor.

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