Vol. 17(8), pp. 1096-xxx, August, 2021
DOI: 10.5897/AJAR2020.15409
Article Number: FC428EB67486
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Review

Pre- and post-harvest practices influencing yield and quality of turmeric (*Curcuma longa* L.) in Southwestern Ethiopia: A review

Girma Hailemichael* and Mohammedsani Zakir

Horticulture/Spices Department, Jimma Agricultural Research Center, P. O. Box 192; Jimma, Ethiopia.

Received 15 December, 2020; Accepted 14 June, 2021

Turmeric (*Curcuma longa* L.) is one of the spices produced by smallholder farmers in Ethiopia. It becomes one of income sources and acceptable for diversification of coffee. Turmeric and ginger have wider adaptation, perform in similar ecologies. Reports indicated that 3962.03 t produced in Ethiopia in three years, and values of USD 1.26 million, export of 1233 MT rhizomes in different seasons. Turmeric becomes best alternate as ginger devastated by wilt disease and demand increased. Also, more processing centers are emerging in Southwestern Ethiopia as approved promising business. On other hand, there are two released varieties: Dame and Tepi-1, with production package. However, still the production is low and not such satisfactory. Therefore, the objective of this review paper is to organize/present all pre and postharvest practices (variety development, planting materials, land selection, land preparation, planting date, seed rhizome storage, spacing/seed rate, nutrient management, weed management and intercropping of turmeric with another crop) that help improve production/productivity. It also focused on post-harvest practices (washing, boiling, drying and polishing rhizomes) responsible for quality improvement. Products and end uses and factors affecting the quality of turmeric are also discussed to support optimization of yield and quality of turmeric and benefit producers.

Key words: Coloring, harvesting, turmeric, quality, yield, rhizomes, seed.

INTRODUCTION

Turmeric (*Curcuma longa* L.) is one of the spices produced in Ethiopia entirely by smallholder subsistence farmers in southwestern part of the country. It composed of a significant proportion of smallholders' income and offered a good opportunity for diversification of the existing Arabica coffee-based cropping system of Southwestern Ethiopia. This region has very suitable agro ecology for turmeric production. 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 a well-known component in many Ethiopian

*Corresponding author. E-mail: girmah2003@gmail.com. Tel: + 251 947 65 19 29.

Table 1. Pedigree of Turmeric accessions evaluated.

No.	Acc. code	Origin
1	HT3/2002	Ethiopia
2	Bonga.51/71 (Tepi-1)	Ethiopia
3	PAK6/82	Pakistan
4	KT14/2004	Ethiopia
5	HT2/2002(B)	Ethiopia
6	Ind.48/72 (Dame)	India
7	SODO07/2004	Ethiopia
8	HT1/2002(A)	Ethiopia

Source: Habetewold et al. (2018).

dishes (local stew, "wot") (Girma et al., 2008; Edossa, 1998). 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 et al., 2018; Purseglove et al., 1981). In addition to richness of rhizomes in curcuminoids 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 is 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; Purseglove et al., 1981).

Turmeric is one of the exported spices from Ethiopia; Southwest Ethiopia produce turmeric as a cash crop and many livelihoods are dependent on it. India is the world biggest exporter and producers of turmeric, whereas, Ethiopia is the exporter and producer of turmeric in Africa. Tepi National Spices Research Center (TNSRC) 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 alternative crop for export diversification and alleviation of poverty in Ethiopia (Olojede et al., 2005). In Ethiopia, turmeric is mainly produced in southwestern 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 devastation of ginger by bacterial wilt and good demand for turmeric (Habetewold et al., 2018).

Turmeric is a tropical plant and thrives well from sea level to 1500 m above sea level, at a temperature range of 20 to 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 to 7.5 with good organic matter status (Jayashree et al., 2015).

VARIETY DEVELOPMENT

In 1972, two turmeric accessions were introduced from abroad for adaptability study at Jimma, Metu, Bebeka, Tepi, Wenago, Awasa, Mugi and Bako (Edossa, 1998). In the next research activities, eight accessions were included in the evaluation process and two improved varieties namely Ind.48/72 (Dame) and Bonga.51/71 (Tepi-1) were released in Ethiopia. The released varieties showed high yield (250-300 quintal fresh yield per ha) and qualities standards such as oleoresin and essential oil contents were in the range of the international standard. List of accessions evaluated in the national variety trial is shown in Table 1. Maintenance of these materials continued as the germplasm will be useful for future research.

CROP MANAGEMENT

Planting materials

Determination of appropriate rhizome part (whole rhizome, mother rhizome (cut) planting, or primary finger) is the decisive factor in planning turmeric production. Since it is the commercial product (rhizome) to be used as seed, over size or under size will have a negative effect. Generally, in rhizomatous crops (spices) the bigger the seed size, the higher will be the final product. Highest fresh rhizome yield (14.8 t/ha) was obtained from mother rhizome (whole) followed by 11.03 t/ha from using seed of primary finger (Edossa, 1998). Moreover, selection of planting materials from unsprouted, sprouted and transplanted rhizomes was conducted and out of these, the sprouted rhizome gave the highest fresh rhizome yield (19.42 t/ha) followed by transplanted rhizome (17.26 t/ha) (Girma et al., 2008).

Land selection

Turmeric should not be cultivated on sloppy area as

Table 2. Fresh rhizome yield of turmeric obtained from different land preparation methods.

Treatment	Yield (t/ha)
Flat land	20.97
Open ridges, before planting	31.24
Open ridges, after planting	30.24
Raised beds	33.55
Tide ridges	26.79
Tide ridges, at interval	28.44
Mean	28.54

Source: IAR (1996) JARC Progress Reports (1983/1984, 19484/1985, 1985/1986).

Table 3. Fresh rhizome yield of turmeric planted in different periods (months).

Planting dates (months)	Mean yield (t/ha)
5 March	18.48
5 April	9.35
5 May	6.16
5 June	3.04
5 July	3.54
5 August	2.14
5 Sept	1.12
Mean	6.26

Source: Edossa (1998).

down moving water can erode and can deplete the soil around the plant and exposing seed or sprouted rhizome significantly reduce the growth, production and quality of turmeric. The land should be thoroughly ploughed three to four times before the rainy season.

Land preparation

Before planting the prepared seed rhizomes, the land should be free of any obstacle (roots, stones or gravels, etc.) that could hamper the free horizontal expansion of the rhizomes. The soil should be very fine and workable, free of marshy condition. Studies on identification of suitable land preparation methods indicated that raised bed preparation gave maximum fresh rhizome yield (33.55 t/ha) while the lowest fresh rhizome yield (20.97 t/ha) recorded from flat land (Girma et al., 2008) (Table 2).

Propagation technique

Commercially, turmeric is vegetatively propagated particularly with 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 rhizome (split rhizomes). Seed rhizomes need preparation before planting; select healthy, reasonable size and weight and at least with one or two buds. Based on soil types and rainfall condition of the area, planting can be in furrow, on flat beds and on ridges (Girma et al., 2008; Purseglove et al., 1981).

Planting date

Turmeric is rhizomatous spice that requires high moisture particularly higher and longer rainfall distribution from time of planting to maturation. Therefore, determination of suitable planting time to get enough moisture is an important issue. Study on suitable planting time in Southwestern Ethiopia was conducted and mid of March to first week of April was recommended as the highest rhizome yield (18.48 t/ha) recorded in this period (Table 3). This recommendation can work for various agro ecologies with some modifications in specific areas.

Seed rhizome storage

Three to four-month time gap between harvesting and

Table 4. Mean fresh rhizome and dry rhizome yield at different spacing (t/ha).

Spacing within plants (cm)	Spacing between rows (cm)			Fresh between plants mean	Dry rhizome mean
	30	40	50		
15	30.59	30.09	27.46	29.38	6.17
20	27.72	30.12	27.68	28.51	5.99
25	28.70	28.46	25.92	27.69	5.82
30	28.61	28.31	24.18	27.04	5.68
Row mean	28.91	29.25	26.31	28.15	5.91

Source: IAR (1996) JARC Progress Reports (1983/84-1985/86).

next planting of ginger can lead to significant loss of planting materials and this necessitated devising appropriate storage method(s) of seed rhizome turmeric. Ginger and turmeric have similar seed rhizome preparation and management technique as they have almost same morphology and similar storage practices can be applied. For ginger, the following experiences of storage of ginger were investigated:

(1) Under thatched roof shelter on the ground
(2) Under thatched roof shelter on one meter raised structure or bed
(3) In pits covered with thin grass mulch
(4) Buried in pits
(5) Under tree shade covered with mulch materials

According to the result obtained from this research, less percent of shriveled rhizomes and maximum fresh rhizome yield of 28.24 and 27.52 t/ha were obtained from seed rhizomes kept under tree shade covered with mulch materials and from seed rhizomes kept under thatched roof shelter on the ground (Hailemichael and Seyoum, 2016). The results disclosed that there are more safe options to keep seed rhizomes of turmeric and ginger which could be designed and constructed easily at farmers' level. The various options can be applied based on the environmental condition.

Spacing or seed rate

An experiment with three different spaces between rows and four different spaces between plants was conducted at Tepi. Accordingly, spacing of 30 cm × 15 cm between rows and between plants that yield 30.59 t/ha (fresh) equivalent to 6.17 t/ha dry, has been recommended (Table 4).

The researchers also indicated that this issue should be further studied to have location specific recommendations. The amount of seed rhizome or seed setts required to sow 1 ha of land varies based on the spacing, size and type of the seed rhizomes used for planting. Conversion of ginger is that, fresh 100 kg ginger is 21 kg dry.

Nutrient management

Turmeric is a nutrient exhaustive crop, particularly nitrogen (Agere and 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 also depends on stage of development, that is, 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 and Shiferaw, 2015). Behailu and Weyessa (2019) also reported that maximum rhizome yield and better oleoresin content were obtained from the application of 115 kg/ha 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, Southwestern Ethiopia.

This study was conducted to fix the fertilizer requirement of N × P. A factorial experiment of N × P each at four levels was added at Bebeka to study the response of turmeric to N and P fertilizers. Urea and DAP (0, 50, 100, 150 and 0, 22, 44, 66) kg/ha, respectively were applied with the variety Tu.48/72 (Dame) with a spacing of 15 × 30 cm. According to Paulose (1986), as reported by Edossa (1998), there was a slight improvement in yield at higher combinations of N and P but statistically no significant effect was obtained. Maximum mean fresh rhizome yield (64.0) t/ha of turmeric was obtained at 150 and 44 Q/ha N and P combinations. This report indicated that in areas with similar soil types like Tepi, application of fertilizers may not be recommended. To maximize the fresh rhizome yield of turmeric with high fertilizer rate, it should be supported by cost benefit analysis. However, as soil is influenced by different environmental factors throughout time, it is required to run another fertilizer study after a certain period (Girma et al., 2008).

Table 5. Estimated gross field benefit [Ethiopian Birr (ETB)/ha] from coffee and turmeric and ginger over three consecutive crop years.

Crop type	4th year			5th Year			6th year		
	Sole	Intercrop	Mean	Sole	Intercrop	Mean	Sole	Intercrop	Mean
Coffee	9747	8665	9206	8398	6892	7645	9982	8298	9140
Turmeric	6659	3509	5084	3185	1438	2312	9675	3647	6661
Ginger	12394	1933	7164	6442	1474	3958	4392	1145	2768
Total	28800	14107	21454	18025	9804	13914	24049	13090	18569

*20 ETB = 1 US Dollar; Field prices of dry coffee for the respective crop years were 225, 475 and 591 ETB/100 kg. The respective field prices of processed turmeric and fresh ginger yields were 150, 100 and 200 and 100, 75 and 50 ETB/kg-during the 1st, 2nd and 3rd crop years, respectively.
Source: Anteneh and Taye (2015).

Weed management

Turmeric and ginger are very sensitive to weed competition. The first two to three or four months of planting rhizomes are very critical to manage weed. If the field left un weeded in the mentioned periods, the weeds will be very competent and affect the full establishment of the turmeric plant. And, the reverse will be observed if timely and appropriate management practices are applied (Girma et al., 2008; Purseglove et al., 1981).

Since turmeric is slow germinating and growing crop, repeated hand weeding is required to save the crop from noxious robust growing tall weed species such as *Gyzotia scabra*, *Bidens ploynchyma*, *Nicandra physaloides* and *Caylusia abyssinica*. The result has confirmed that early hand weeding between 30 and 45 days was critical for vigorous growth of turmeric. The finding reported by Tadesse et al. (2015) has proved that mulching at planting was found to be good agronomic practice in suppressing weed growth and reducing the frequency of hand weeding in turmeric under Metu condition which can be applied to similar agro ecologies. Hence, based on the present finding, turmeric can be mulched at planting and supplemented by two hands weeding at 60 and 90 days or at 45 and 75 days after planting for high yield of turmeric. Deshmukh et al. (2018) also investigated and reported that in India integrated use of either Pendimethalin 1 kg/ha or by Metribuzin 0.7 kg/ha (0-5 DAP=days after planting) followed by straw mulch 10 t/ha (10 DAP) followed by one hand weeding (75 DAP) was proved very effective for weed control and for attaining the highest productivity and profitability in turmeric.

Intercropping

In photosynthesis performance, turmeric is between C4 and C3 plants and can perform in medium shade condition. It can be intercropped with crops like chilli, onion, French beans, eggplant and maize. Turmeric can also be grown as intercrop in coconut and areca nut plantations. As a whole, turmeric intercropping with coffee was found appreciable to stabilize yield advantages and gross economic returns, particularly at the early year of stand establishment (Table 5). Hence, the small holding farmers can more or less buffer against crop failure and low market price of one crop.

Harvesting

Because of less awareness on quality aspects or other agendas, Turmeric farmers in Ethiopia sometimes keep the rhizomes not harvested at end of season. And, this type of practice can have significant negative influence on the quality of turmeric. So, farmers need to be trained and start to follow the suitable harvesting stage for yield and quality. Maintain the rhizomes underground for more than one season, meaning facilitation, the loss of quality. This type of farmers' practice is to maximize the rhizome yield, however, it has been reported (Purseglove et al., 1981; Girma et al., 2016) that the quality parameters of turmeric reduced and the produce is less competent in the local and foreign market.

Two types of research activities; four different harvesting cycles (1, 2, 3 and 4 years cycles) and five months of harvesting stages (7, 8, 9, 10 and 11) after planting were conducted at different years (Edossa, 1998; Girma et al., 2016). Late harvesting years or months resulted in high rhizome yield (29.32 and 19.344 t/ha) from first year and fourth year cycles, respectively, increased fiber and reduced extraction qualities. The results were supportive to the report by Purseglove et al. (1981). Although leaving turmeric rhizomes in field for more seasons resulted in continuous physical rhizome yield increase, the extraction quality that has a negative correlation to duration of maintenance and the production costs should be investigated and this type of activity is not recommended. The quality of turmeric is influenced by harvesting stage and variety. Extraction yields such as oleoresin from turmeric are the critical quality factors considered for industrial utilization.

The highest essential oil yield in dry weight basis of the turmeric rhizomes was 5.14 and 5.13% when the variety Bonga. 51/71 (Tepi-1) was harvested 8 and 7 months after planting, respectively. On the other hand, maximum oleoresin content was obtained in Bonga.51/71 (Tepi-1) and Ind.48/71 (Dame) (11.45 and 11.21% respectively) while the lowest (10.55%) was obtained in Pack.6/82. Harvesting of 7 to 9 months after planting is suitable for these varieties in order to maintain their quality as the varieties will get more fibrous as maintained for more months in the field.

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 another appropriate tool (Girma et al., 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 t/ha, while it is 4.0 t/ha in India. Yield potential of turmeric in the research stations was reported as high as 6.2 t/ha dry rhizome which is within the acceptable range of world turmeric productivity (Girma et al., 2008).

POSTHARVEST HANDLING PRACTICES AND QUALITY

A number of factors are responsible for quality of spices/turmeric; cultivar, environment where cultivated, and postharvest management activities are mentioned (Purseglove et al., 1981). Turmeric, before entering the market as a stable commodity, undergoes several postharvest handling practices viz. washing, curing, drying, polishing and packing.

Washing/cleaning the rhizomes

The dug out rhizomes are separated from the soil and washed, so that particles of soil spray residues and non-useful 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 (Purseglove et al., 1981). 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 (Girma et al., 2008; Derese, 2009).

Boiling the rhizomes

In Ethiopia, even if it depends on different factors, boiling required about 45 to 50 min in Ethiopia (Edossa, 1998; Girma et al., 2008). In the process, short and open barrel filled with water will be put on burning flame to boil the water. Turmeric rhizomes are added into the water in the barrel. The barrel has 15 cm empty space at top direction for air. Boiling performed with continuous addition of fuel wood to intensify the heat that takes 45 to 60 min. Rhizomes are frequently turned by spade or small sticks for uniform boiling. Farmers operate this in group called “Dado” as the job is very tiresome. Shibru et al. (2017a) reported that most farmers in Ethiopia boil traditionally 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. Prior reports from Purseglove et al. (1981) supported by Shibru et al. (2017a) confirmed same effects.

Mother rhizome sets boiled at 100°C for 30 min yielded the highest values of oleoresin and essential oil similar and at par essential oil content was recorded from mother rhizomes boiled at 90°C for 30 min. Color value was the highest when mother rhizome sets boiled at 100°C for 45 min, 90°C for 60 min and finger rhizome sets boiled at 100°C for 30 min (Shibru et al., 2017b). It is recommended to aware farmers that for quality turmeric produce, mother and finger rhizomes need be separated in boiling and drying process and the boiling duration be given due attention.

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 (Purseglove et al., 1981).

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 to 7 cm. It is avoided to spread as thin layer as it leads to

Figure 1. Partial view of materials and processing steps of tumeric rhizomes.

bleaching of color. During night hours the dried fingers are heaped and drying is carried out until it is completely dried and it takes 10 to 12 days. The dry, product yield will be varied from 10 to 15% depending on the variety and location where crop is grown up (Purseglove et al., 1981). In Ethiopia, the average drying time can take about 15 days and can also extend to a month depending on the existing weather condition (Edossa, 1998; Derese, 2009). It is advisable to reduce the drying duration with frequent turning over as this helps to reduce drying period and improves quality. Slicing of rhizomes after boiling significantly reduces drying duration and improves quality. Researchers and extension agents give continuous practical training for farmers, private investors, etc., on processing and quality.

Turmeric polishing

The dried rhizomes are polished (Figure 1) to remove the scales and root bits. This helps remove the corck layer of dried rhizomes and enhance the deep inherent yellow orange colour (Purseglove et al., 1981). 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 polishing 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 (Girma et al., 2008). In Ethiopia, farmers grind uncooked turmeric rhizomes with mortal and pestle ("mukecha"). 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 as 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). Results of comparison of the effect of different polishing or peeling practices and techniques exercised around Tepi areas were evaluated and presented in Table 6.

From the evaluation of various polishing or 'peeling' techniques, the best preferred yellow orange colour was obtained when the cured turmeric fingers were rotated in a polishing drum. Though very laborious, polishing or 'peeling' using mortar and pestle with the addition of citrus was found to yield products comparable with a rotating drum resulting deep-yellow coloured products, while other practices resulted in a bit inferior products (Fantahun and Teklu, 1995) (Table 6). Manual polishing drum could be adopted by farmers, may be through cooperatives. With this, farmers can benefit from the

Table 6. Effect of different peeling or polishing techniques on colour and outer skin of cured turmeric.

Peeling or polishing techniques	Colour of the cured turmeric	Outer skin removed/intact
Using mortar and pestle	Yellow	Removed
Using mortar and pestle with the addition of lemon juice	Deep yellow	Removed
Polishing using rough sacks	Yellowish-brown	Removed
Coating (painting) with freshly crushed turmeric	Dull brown	Intact (un removed)
Painting with freshly crushed turmeric mixed with lemon and sour orange juice	Yellowish-brown	Intact (un removed)
Polishing using manually operated polishing drum	Yellow-orange	Removed

Source: Fantahun and Teklu (1995).

Table 7. Qualitative parameters of turmeric as influenced by accessions and/or cultivar and harvesting stage after planting.

Accessions/cultivars	Moisture content (%)	Volatile oil content (%) v/w (wet basis)	Volatile oil content (%) v/w (dry basis)	Oleoresin content (%) w/w (wet basis)	Oleoresin content (%) w/w (dry basis)
1. Bonga.51/71	76.490	1.08	4.42	2.70	11.19
2. Pak.6/82	76.978	1.09	4.51	2.77	9.46
3. Ind.48/72 (Dame)	77.550	1.09	4.60	2.77	11.60
CV (%)	1.05	10.16	10.46	24.19	11.64
$LSD_{0.05}$	NS	0.247	NS	NS	NS
Harvesting stages (months)					
7	77.233	1.02	4.28	2.75	11.19
8	75.990	1.16	4.62	2.42	9.46
9	76.510	1.12	4.50	2.97	11.60
10	77.310	1.05	4.44	2.88	11.64
11	78.810	1.08	4.70	2.73	11.46
CV (%)	1.05	10.16	10.46	12.44	13.55
$LSD_{0.05}$%	NS	0.36	0.14	0.27	1.2
Cultivar × harvesting stages	NS	NS	NS	NS	NS

NS= non-significant.

turmeric product by producing standard quality turmeric (Habetewold et al., 2018). Currently, more turmeric processing factories are being established as the business confirmed promising. Partial view of postharvest process is as shown in Figure 1.

Quality

Quality of turmeric is influenced by a number of factors; type of cultivar planted, environment of production, field management, postharvest practice and processing (Purseglove et al., 1981; Girma et al., 2008). Quality parameters of turmeric can be physical (appearance, surface structure, content of extraneous matter, etc.) and extraction content of essential oil and oleoresin are important ones. So far, the varieties supplied to the production system in Ethiopia fulfil the major quality parameters set by the market. Harvesting stage of Turmeric rhizomes significantly influenced more of the quality parameters. In general, the varieties Dame and Tepi-1 showed higher extraction quality performances when harvested from 7 to 8 months after planting (Purseglove et al., 1981; Girma et al., 2008, 2016) (Table 7). Whereas, harvesting 9 to 11 months after planting improves the physical quality parameters; dried rhizomes look slender, large size, from yellow to deep yellow orange colour, double use (whole-home use, extraction) (Girma et al., 2016).

Products and end use

The primary product of turmeric is the cured dried rhizome. This is valued principally for its yellow-orange coloring power in textile industry. Second to this, it contains an appreciated aroma and flavour that makes it considered as a spice. Turmeric is used directly as a spice or colouring agent in the ground form and also for the preparation of the solvent extracted oleoresin (Purseglove et al., 1981). Turmeric is an important spice in every Ethiopian kitchen and commonly used as an ingredient in the preparation of local sauces 'Wot'. It is the most favoured spice by house-wives. As a characteristic of more of the spices plants and products, it has significant use in medicinal value (Purseglove et al., 1981). There are reports indicating that 3962.03 t of turmeric was produced in Ethiopia in three years, while Monika and Addisu (2018) mentioned values of USD 1.26 million as well as export of 1233 MT rhizomes in different seasons.

CONCLUSION

Ethiopia has wide agro ecology, and turmeric has wider adaptation from lowland to mid altitude areas. Currently, two improved varieties released with production packages and there is cheap labour and good experience of production and processing and attractive local and foreign markets. These all call for the active participation of the parties who involve in the value chain of turmeric from land to consumption. The recent devastation of ginger production from most part of Ethiopia lead farmers shift to turmeric. However, in spite of these, all such huge opportunities, production and productivity of turmeric remained low demanding implementation of all available technologies such as released varieties, suitable site selection, land preparation, harvest and postharvest management practices to benefit the society in the value chain. It is very important to put hands and all capacity together to avert this and benefit the society.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank the Ethiopian Institute of Agricultural Research (EIAR) for funding the study.

REFERENCES

Addisu A (2014). Spice, herbs and aromatic plants subsector platform. 1st Ethiopian Spice Platform Stakeholders Meeting. January 23.

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 Nitisols at Yaki Woreda Southwestern Ethiopia. Journal of Agricultural Science Research 3(10):289-295.

Anteneh N, Taye K (2015). Intercropping of Arabica Coffee with Turmeric (*Curcuma longa*) and Ginger (*Zingiber officinale* Rose) at Tepi, Journal of Biology, Agriculture and Healthcare 5(7):65-68. www.iiste.org

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.

Derese TM (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 Art (MA) in Development Studies

Deshmukh JP, Kakade SU, Ingole PG, Shingrup PV, Solanke MS (2018). Integrated weed management in turmeric. International Journal of Current Microbiology and Applied Sciences (6):1894-1899.

Edossa E (1998). Spices research achievements and experiences. Research Report No. 33. Institute of Agricultural Research, Addis Ababa Ethiopia pp. 5-45

Fantahun L, Teklu N (1995). Spices crops processing: constraints and possibilities, Workshop on Coffee and Associated Crops, Feb. 27 - March 1/1995. Addis Ababa Ethiopia pp. 1-19.

Girma HG, Digafie T, Edossa E, Belay YB, Woyessa G (2008). Spices research achievements, revised edition. Ethiopian Institute of Agricultural Research, Addis Ababa Ethiopia

Girma H, Amsalu N, Ali M, Derbew B, Digafie T (2016). Effect of stage of maturity at harvest on the quality of different cultivars of turmeric (*Curcuma domestica*) in Southwestern Ethiopia. Sky Journal of Agricultural Research 5(5):087-090.

Habetewold K, Dejene B, Lemi Y, Abukiya G, Wakjira G, Girma H, Haimanot M (2018). Result of turmeric variety trial in Ethiopia. International Journal of Research Studies in Agricultural Sciences 4(9):34-38.

Hailemichael G, Seyoum M (2016). Influence of Different Storage Methods on the Viability and Field Establishment of Seed Rhizome Ginger (*Zingiber officinale* Rosc.) in Ethiopia. Academic Research Journal of Agricultural Science and Research 4(4):117-123.

IAR (1996). Institute of Agricultural Research, Jimma National Coffee Research Center horticulture division progress report for the period 1986-1991.

Jayashree E, Kandiannan K, Prasath D, Sasikumar B, Senthil KCM, Srinivasan V, Suseela BR, Thankamani CK (2015). Turmeric Extension Pamphlet. Indian Institute of Agricultural research, Manager, Agricultural Technology Information Centre.

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

Monika S, Addisu A (2018).Reopening the European spice market for Ethiopian exporters. The Ethiopian–Netherlands Trade for Agricultural Growth (ENTAG); review working document: https://knowledge4food.net/wp-content/uploads/2019/01/181200_creating-effective-case-studies_entag2.pdf

Olojede AO, Iluebbey P, Dixon AGO (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.

Paulose D (1986). Response of turmeric (*Curcuma domestica* Val.) and ginger (*Zingiber officinale* Rosc.) to fertilizer treatments. In: Desta B (eds) Proceedings of the first Soil Science Research Review Workshop, Addis Ababa Ethiopia pp 60-61.

Purseglove JW, Brown EG, Green CL, Robins SRJ (1981). Spices: Volumes 1 and 2. Longman Group Limited, London.

Ravindran P, Ravindran K, Nirmal B, Sivaraman K (2007). Turmeric: the genus Curcuma; Medicinal and aromatic plants-industrial profiles pp. 234-236. http://www.alaalsayid.com/ebooks/Medicinal%20and%20Aromatic%20Plants%20-%20vol%2045%20-%20Turmeric-%20The%20Genus%20Curcuma.pdf

Shibru ZF, Ali M, Girma H, John B (2017a). 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.

Shibru ZF, Ali M, Girma H, John B (2017b). Influence of boiling temperature levels and durations on the essential oil, oleoresin, colour value of different rhizome set types of turmeric (*C. longa* L.). Journal of Science, Agriculture 7(3):112-121.

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.

Tadesse E, Melaku A, Fantahun A (2015). Effect of weed management methods on the growth and yield of Turmeric in Metu, Illubabor, Ethiopia. International Journal of African and Asian Studies 11:115-119.