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Review

Research achievements and recommendations in crop management for enhancing the productivity of spices: A review

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Spices are invaluable crops in Ethiopia and research. Just like coffee, their production started many years ago. Availability of diverse agro ecology allowed the country to cultivate different spices. Lowland (ginger, turmeric, black pepper, cardamom, and vanilla) and highland seed spices (black cumin and white cumin, fenugreek, and coriander) were some of the target in research. Appropriate crop management practices, next to varieties are very mandatory to improve productivity and production of spices. Suitable field management recommendations of the released spices varieties have been effected and because of that, productivity and production increased significantly. Spices such as korarima and long pepper are indigenous and special attention is needed to prepare their production packages. Cultural practices such as appropriate planting material preparation, planting time, propagation method, nursery and field management practices (shade/support management, pruning practices, and fertility requirement on some of the spices) have been conducted and important information is available for users. In addition, multiplication and distribution of planting materials has been underway for the released varieties. Also, attention has been given to the multiplication and dissemination of disease-free planting materials of ginger. This review paper summarizes the status of crop management practices, achievements, challenges and future prospects of spices.

Key words: Spices, varieties, management, yield, quality.

INTRODUCTION

In the past, Jimma Agricultural Research Center (JARC) in Ethiopia took the lead mainly with Tepi Agricultural Research Sub-Center (TARSC) to run a number of research activities on these economically invaluable low land spices. Adaptation researches were conducted at Melko (JARC), Tepi, Bebeka, Kabo, Mugi, Anfilo, Metu and significant results were obtained. Similar to this, research on highland seed spices had been conducted in Kulumsa, Sinana, Gondar, Sirinka, and Debrezeyit Agricultural Research centers in Ethiopia, etc. and

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appreciable results were achieved. It is clear that variety is one of the basic inputs to improve productivity and production and more results are attained in this aspect. However, next to variety, suitable cultural practices are very mandatory. Major activity was germplasm enhancement and variety development by evaluation and adaptation, and development of suitable crop management practices. A number of suitable cultural practices were applied on black pepper (*Piper nigrum* L.), cardamom (*Elettaria cardamomum* M.), ginger (*Znigebere officinale* Rosc.) and turmeric (*Curcuma domestica* Val) (Girma et al., 2008) similar to the recommendations given by Purseglove et al. (1981), Borget (1993), and Pruthi (1998). The seed spices in Ethiopia mainly grown in highland areas of the country (Bale, Arsi, Wello, Gondar and Shewa) and research on these spices was conducted at Kulumsa Agricultural Research Center (KARC), Debrezeit Agricultural Research Center (DZARC), Sirinka Agricultural Research Center (SARC) and Gondar Agricultural Research Center (GARC). Research on seed spices mainly focused on black cumin, fenugreek, coriander and white cumin.

Assessment on the ecological requirement of these spices: black pepper, cardamom, ginger, turmeric and vanilla had been conducted. And almost all of these spices were thus found well adapted to the hot-humid and lowland agro ecologies of Southwestern Ethiopia (Edossa, 1998a; Girma et al., 2008). The recommendations from Purseglove et al. (1981) also are almost similar to the findings. On the average, these high value spices plants were observed to perform best in areas with altitudes ranging between 500 and 1500 m, annual rainfall of 1200 to 7000 mm, and mean temperatures of 20 to 35°C (Purseglove et al., 1981; Borget, 1993; Edossa, 1998a; Pruthi, 1998). Fertile or alluvial soils rich in humus were also identified to be highly suitable for the production of the lowland spices (Purseglove et al., 1981; Borget, 1993; Pruthi, 1998; Uhl, 2000). Likewise, cardamom requires humus-rich forest covered soils that could sustain prolific and luxurious growth of crop plants. Forest coffee chocolate, red colored soil rich in humus has been proved to be very suitable for the successful production of these spices (Edossa, 1998a; Girma et al., 2008). Under small-scale production, cardamom, black pepper, ginger, and turmeric were found to be intercropped successfully with other horticultural crops like enset, banana, and coffee (Girma et al., 2008). These technologies well adapted to most parts of Southwestern Ethiopia, where the farming system is commonly characterized by the growth of one or more of these complementary species.

This time, a number of seed spice varieties are released and recommended for production in suitable agro ecologies. In that, six black cumin varieties (Gemechis, Soressa, Silingo, Eden, Dershaye and Derbera), seven fenugreek varieties (Jama, Wereillu, Burka, Bishoftu, Chala, Ebisa and Hundaol), three coriander varieties (Denkenesh, Walta'i and Indium01) and two white cumin varieties (Takusa-01 and Dembia-01) from Gondar were released and distributed for users. In addition to variety improvement, different researches on management practices were conducted and results were incorporated to enhance their production and productivity.

From long time practical observation, the highly successful growth and effective integration of the different indigenous and/or exotic high valued spice plants with Arabica coffee in Southwestern region of the country could be attributed to the prevailing conducive agro ecologic conditions of the area. Of the exotic spices, black pepper, ginger, turmeric and cardamom were proved to fit well with the existing coffee-based farming system of the area. As this particular area is commonly characterized by mixed and/or multiple cropping system, integration of these crops within the system has been successful, as most of these spices require either shade and/or support for their growth (Edossa, 1998b; Girma et al., 2016). Such unique characters and/or growth requirements make these crops the best candidates in the coffee diversification endeavour, thereby contributing to the national economy, through export and/or import substitution.

Despite the achievements recorded on spices so far, there are still gaps demanding further research attention with regard to generation of improved technologies. These include fertility requirement of most of the spices, suitable irrigation recommendation and water requirement for some spices like korarima (*Aframomum corrorima*) and cardamom (*E. cardamomum* M). Suitable intercropping of these spices with potential crops needs a due attention in the future. Therefore, this paper attempts to highlight the agronomic research and achievements and available improved technologies for black pepper, ginger, turmeric, cardamom and korarima, specifically for Southwestern Ethiopia and areas having similar agro ecology. In the same trend, technologies available and available gaps on highland seed spices are revised. It also presents the existing gaps that require research attention and tries to indicate future directions the spices research team should follow to avail full package recommendations.

ECOLOGICAL REQUIREMENT OF SPICES

Lowland spices such as black pepper, ginger, turmeric, cardamom, korarima, long pepper, and vanilla were found to adapt well to the hot-humid and lowland agro-ecologies of Southern, Southwestern Ethiopia and in some parts of Oromiya Regional State. Korarima and long pepper also perform well in mid-altitude areas such as Jimma zone, Dawuro, Wolayita, North and South Omo zones. From different previous reviews (Purseglove et al.,

Table 1. Environmental requirement for seed spices.

Crop	Altitude (masl*)	Temperature (°C)	Rain fall (mm)	Soil type
Black cumin	1750 - 2200	12 - 14	120 - 400	Vertisol
Fenugreek	1750 - 2200	12 - 14	120 - 400	Vertisol
Coriander	1750 - 2200	12 - 14	120 - 400	Vertisol
White cumin	1500 - 2200	29.5 - 13.5	220 - 400	Vertisol

*masl= meter above sea level, mm= millimetre.
Source: Habtewold et al. (2017).

Table 2. Performance of Korarima (*A. corrorima* Braun Jansen) plant under different shade levels.

Shade level (%)	Plant height (cm)	No. of leaves/pseudostem	Capsule length (cm)		Weight of capsule (g)		Yield (kg/ha) dry capsule
			Fresh	Dry	Fresh	Dry	
0	-	-	-	-	-	-	-
43	89.05	16.07	25.38	3.82	25.35	4.31	223
47	102.45	19.87	27.70	3.92	27.67	4.71	539
55	118.45	19.77	27.42	4.36	27.42	5.02	639
63	131.10	19.77	26.99	4.05	26.99	5.61	811
72	134.47	20.67	25.83	4.19	25.83	5.01	569
Mean	115.10	19.23	26.66	4.07	26.65	4.77	556

Source: Jimma Research Center Progress Reports (1984/85, 1985/86 and 1986-1991).

1981; Borget, 1993; Pruthi, 1998), these spices were confirmed to perform best in areas with altitudes ranging from 500 to 1500 masl, annual rainfall of 1200 to 7000 mm, and mean temperatures of 20 to 35°C. 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). In general, most of the lowland spices adapted well to most parts of Western and Southwestern Ethiopia. Details of list of the type of spices varieties and suitable agronomic recommendations are shown in Table 1.

In Ethiopia, seed spices are produced in mid to highland areas and the crops require low water/residual moisture for growth (Table 1). These spices are usually dry and cold weather crops of the semiarid areas, which can grow in well drained black vertisols with residual moisture. Excessive moisture harms the vegetative and yield performance of these spices, and it also aggravates the incidence and severity of various diseases. The plants need relatively cool temperature during their early stages for better vegetative growth, while a dry and relatively high temperature favors better ripening and high seed production (Habetewold et al., 2017).

Shade requirement and management

Shade is very obligate in production of economically important spices like cardamom (*E. cardamomum* M.), Korarima (*A. corrorima* Braun Jansen), long pepper (*Piper capense* and *Piper umbellatum*) species and with optional condition for black pepper (*Piper nigrum* L.) (Purseglove et al., 1981; Edossa, 1998a; Pruthi, 1998; Girma et al., 2008). Research on optimum shade requirement of spices like cardamom (*E. cardamomum* M.) and korarima (*A. corrorima* Braun Jansen) has been undertaken and suitable recommendation was obtained. IAR (1985), cited in Edossa (1998a), reported that the study result indicated that shade level of 55 to 63% is very promising for the production of cardamom and korarima (Table 2). Similarly, this recommendation works for long pepper (*P. capense*) which has become an economically very important indigenous spice in Southwestern Ethiopia. Among others, the most common coffee shade tree species including *Albizzia*, *Millettia*, and *Gravellia* species could also be used for the provision of suitable shade to cardamom, korarima and long pepper. To this end, intercropping of cardamom with coffee had been successful, while its integration with "enset" and/or banana gave poor results. Edossa (1998a) also discussed that shade creates a suitable microclimate for cardamom and korarima and regulate moisture and

Table 3. Fresh rhizome yield (kg/ha) of ginger and turmeric from different land preparation methods.

Ginger		Turmeric	
Treatment	**Yield fresh (kg/ha)**	**Treatment**	**Yield fresh (kg/ha)**
Flat land	19260	Flat land	20907
Planting on open ridges	14870	Planting on open ridges	31240
Planting on open ridges, after emergence	19510	Planting on open ridges, after emergence	30240
Planting on raised beds	20770	Planting on raised beds	33550
Planting on tide ridges	17390	Planting on tide ridges	26790
Tide ridges after emergence	19280	Tide ridges after emergence	28440
Mean	18520	Mean	28540

Source: Jimma Research Center Progress Reports (1984/1985, 1985/1986 and 1986-1991).

temperature. Such microclimate is necessary for favourable root development of both cardamom and korarima, easier decomposition of organic plant products, enhancement of nutrient and water absorption and prevention of exposure of the surface to direct sun and soil erosion. From field observation long pepper also requires at least 50% shade in the natural forest, while black pepper (*P. nigrum* L.) requires very minimum or no shade level; it is a support obligate vine crop (Purseglove et al., 1981; Borget, 1993; Pruthi, 1998). During the unexpected and longer dry season than normal, some level of shade from the support trees is very advantageous for black pepper. According to the evaluation result of support trees in Tepi Agricultural Research Sub-Centre, *Erythrina indica* was better and effective support and shade tree for black pepper under more intensive management (Edossa, 1998a). However, from long period practical observations in the Research Center in Tepi areas and Bebeka coffee plantation sites had revealed *Gravellia robusta* as the best live support for black pepper vines. In case of shade trees for support and shade of vine spices, the following important points need high attention. There is need to plant those species that maintain their leaves throughout the seasons. Maintenance of optimum shade level by appropriate management likely reduces over shade by pruning during appropriate season as it can affect flowering, pollination, fruit set and maturity. It is important to maintain more shades by reducing pruning practices if it is under the recommended level. Under planting of additional shade plants when the original shade level is reduced is also a very important cultural practice.

Land preparation, planting material and seed rate

Important cultural practices of these spices like suitable land preparation, suitable planting materials or seeds and preparation, suitable seed storage and economizing of seeds of ginger and turmeric have been studied. Suitable planting time was also studied and recommended. Also for black pepper and cardamom, the suitable propagation methods/part and suitable nursery media, nursery and field management were studied and recommended.

LAND PREPARATION OF GINGER AND TURMERIC

In both spices, land preparation (orientation of the farm land and how it is prepared before planting) is very critical for the success of the spices next to sowing (Purseglove et al., 1981). In a report from IAR (1985) cited in Edossa (1998a), the highest fresh rhizome yield (20770 kg/ha) of ginger was obtained from raised bed type of land preparation and maximum fresh rhizome yield (33550 kg/ha); turmeric was obtained from the same type of land preparation (Table 3).

Appropriate land preparation is the main agronomic practice in seed spice production and it should be ploughed more than 3 times to facilitate better seed germination. If the land is heavy clay/vertisols the beds should be prepared by draining the excess water from the field by using broad bed maker (BBM) and reduce potential for diseases and water logging. Seeds of black cumin could be soaked in warm water overnight to enhance germination and reduce emergence period and partially dried under sun. Suitable spacing (population or seed rate) and recommended time for sowing the seeds of the spices are shown in Table 4.

Seed preparation and aftercare practices

Ginger and turmeric are propagated by rhizomes known as seed setts or seed rhizomes. For rhizomatous/ tuberous crops such as ginger and turmeric, the issue of economizing seed is very critical as the seed itself is a commercial product. In ginger and turmeric cultivation,

Table 4. Spacing and seed rate.

Spices type	Spacing (cm) between row and plant	Seed rate (kg/ha)	Sowing time
Black cumin	30×10	5-6	August-October
Fenugreek	30×10	25	August-October
Coriander	23-76 between row	18-28	August-October
White cumin	45×30	3-4	August-October

Source: Seed spice production guideline 2017. http://www.publication.eiar.gov.et (accessed on March, 2022).

Table 5. Fresh rhizome yield of turmeric as influenced by different types of planting materials and status of the planting materials

Type of planting materials	Mean fresh yield (kg/ha)	Status of planting material	Mean fresh yield (kg/ha)
Mother rhizome (whole)	14750	Un sprouted rhizome	16820
Mother rhizome (cut)	8770	Sprouted rhizome	19420
Primary finger	11030	Transplanted rhizome	17260
Mean	11520	-	17830

Source: Jimma Research Center Progress Reports (1984/85, 1985/86 and 1986-1991).

Table 6. Fresh rhizome yield (Kg/ha) of ginger from different spacing between rows and within plants.

Spacing (cm) between plants	Spacing between rows (cm)				Row mean
	20	30	40	50	
15	20000	16180	17430	19310	18230
20	18880	17570	15970	14450	16770
25	17710	17570	13400	13400	15520
30	18950	17970	15760	13330	16510
Mean	18880	17320	15640	15120	6740

Source: Jimma Research Center Progress Reports (1984/85, 1985/86 and 1986-1991)

there are 3 to 4 months between harvesting in January to February and next planting (middle March to middle April). A report by Girma and Mesfin (2016) indicated that seed rhizomes can be stored: in pits covered with thin grass mulch, under tree shade covered with mulch materials, or kept (partially buried) in pits. Types of planting material of turmeric and seed size/seed rate of ginger were also studied and recommended. According to IAR (1985) cited in Edossa, 1998a, maximum fresh rhizome yield (14750 kg/ha) and 19420 kg/ha were recorded, respectively, when mother rhizome (whole) and sprouted rhizome of turmeric were planted (Table 5). For ginger seed, rhizome size/seed rate was also studied and the result indicated that as the seed size increased, yield increased in parallel; but economical and recommended seed size identified was greater than 9 cm or approximate equal to 30 g (Girma and Kindie, 2008). A seed rate from minimum of 1700-2500 kg/ha can be used for ginger or turmeric.

Studies on turmeric have also been conducted to determine the appropriate planting method and planting density with suitable planting material. Results showed that maximum fresh rhizome yield (63825 Kg/ha) was obtained from mother rhizome planting material (Temtme et al., 2017). This is an extraordinary result.

Suitable spacing of ginger and turmeric rhizomes was also studied; the recommended spacing of these ginger and turmeric spices is 30 cm×15 cm between rows and within plants. In Table 6, high rhizome yield (20000 kg/ha) was obtained from 20 cm×15 cm combination between rows and within plants but due to various factors. It is recommended to use spacing with enough opening 30 cm×15 cm. For turmeric, suitable spacing of seed rhizome is 30 cm×15 cm giving maximum yield of 30590 kg/ha (Table 7).

Research was conducted to determine the suitable planting time of ginger and turmeric as it is very mandatory for the improvement of yield. In that, maximum mean fresh rhizome yield of ginger and turmeric was obtained when planted from 5th March to 5th

Table 7. Fresh rhizome yield (Kg/ha) of turmeric from different spacing between rows and within plants.

Spacing (cm)	Spacing between rows (cm)			Row mean
	30	40	50	
15	30590	30090	27460	29380
20	27720	30120	27680	28510
25	28700	28460	25920	27690
30	28610	28310	24180	27040
Mean	28910	29250	26310	28150

Source: Jimma Research Center Progress Reports (1984/85, 1985/86 and 1986-1991).

Table 8. Mean fresh rhizome yield (kg/ha) of ginger and turmeric as planted in different times.

Planting time	Fresh yield (kg/ha)	
	Ginger	Turmeric
5th March	34090	18480
5th April	30380	9350
5th May	27120	6160
5th June	22250	3040
5th July	16040	3540
5th August	10210	2140
5th September	5390	1120
Mean	20780	6260

Source: Jimma Research Center Progress Reports (1984/85, 1985/86 and 1986-1991).

April. It is recommended to plant from middle of March to middle of April for Tepi area and similar agro ecologies (Table 8).

In addition to the aforementioned recommendations, fertilizer requirement of ginger and turmeric had been studied. According to Palous (1986) cited in Edossa (1998a), the result indicated that though there was no significant difference in mean fresh rhizome yield of both ginger and turmeric, there was an increasing trend of fresh rhizome yield as the NP (Nitrogen, Phosphorous) applied per hectare increased (Tables 9 and 10). Of course, these results are so out dated, and a revisit of fertilizer recommendation has been an important agenda of the research this time.

Similarly, growth and yield of ginger linearly increased when the applied nitrogen fertilizers increased, as reported by Abraham et al. (2014). According to Abraham et al. (2014), the maximum results of growth and yield-related parameters of ginger were recorded from the plot which had received about 92/30 kg/ha of N/P fertilizer rate. The authors reported no yield data were recorded due to the outbreak of bacterial wilt disease. However, the recorded results of the growth and yield-related parameters indicated the possibility of promoting higher ginger yield by increasing the use of N and P fertilizers at the application rate of 92 and 30 kg/ha, respectively (Table 11).

The response of nitrogen and phosphorus fertilizer on fresh rhizome yield of turmeric was studied by Lupi and Temtme (2015). The authors reported that, the growth and fresh rhizome yield of turmeric were significantly influenced by the interaction effects of N and P fertilizer rates. The highest fresh rhizome yield of turmeric was obtained from the plot that received 69 and 10 kg/ha of N and P fertilizer rates, respectively (Lupi and Temtme, 2015). Similar to the research findings of Paulos (1986), there was a linear increase of fresh rhizome yield of turmeric when the amount of N fertilizer applied increased (Tables 12 and 13).

Besides the fertilizer rate of application, the time of applying fertilizer on turmeric was studied and reported by Mekonnen and Garedew (2019). They reported that the timing of N fertilizer application had a significant effect on the growth, yield, and quality of turmeric. Accordingly, three splits (1/3rd at emergence, 1/3rd at the lag growth stage, and 1/3rd at the tillering stage) application of 115

Table 9. Effect of N and P on the fresh rhizome yield (Kg/ha) of ginger at Tepi.

Coffee husk (t/ha)	N (kg/ha)	P (kg/ha)			Mean
		0	33	66	
0	0	41030	43050	45440	43180
	75	47080	49270	48000	48110
	150	42780	44270	47420	44820
	Mean	43230	45530	46960	45370
45	0	43400	41910	46200	43840
	75	49100	48000	51460	49620
	150	46820	53820	43960	48180
	Mean	45440	47910	47180	47180
90	0	42520	40310	42680	41840
	75	43320	41840	42510	45890
	150	49840	45820	50090	48580
	Mean	48650	42660	45090	45440
	Overall mean	42610	45360	46410	45990

Source: Paulos (1986).

Table 10. Effect of fertilizer treatments on the fresh rhizome yield (kkg/ha) of turmeric at Bebeka.

N (kg/ha)	P (kg/ha)				Mean
	0	22	44	66	
0	53500	49300	47800	48500	49800
50	54900	41200	46900	57200	50100
100	45800	51200	64700	48500	52800
150	49400	65600	64000	56200	58800
Mean	50900	52100	55900	52600	52880

Source: Paulos (1986).

fertilizer per hectare gave the highest fresh rhizome yield of turmeric (Table 14).

Some studies of nitrogen and phosphorus fertilizer on highland seed spices were conducted, mainly on black cumin and white cumin. According to Ebrie et al. (2015), enhanced growth and yield of black cumin were observed when a fertilizer rate of 60/40 N/P_2O_5 (kg/ha) was applied. However, they recommend a fertilizer rate of 45/40 kg N/P_2O_5 (Kg/ha) as an economical and agronomical rate of application for black cumin (Table 15). Similarly, white cumin also positively responded to nitrogen and phosphorus fertilizer as reported by the research works of Tesfaye (2017). The author reported that nitrogen and phosphorus fertilizers with the application rate of 45/30 kg/ha were found an economical and recommendable for enhanced growth and yield of white cumin (Table 16).

Similar results were also reported by Ali et al. (2015) on black cumin.

Weed management practices

Yield and quality of spices are highly constrained by many factors among which weeds are the major ones. All spices highly suffer from weed infestation especially for water and nutrient competition. The Southwestern part of the country is characterized as high weed diversity and fast weed growing area which makes weed control difficult. According to Tadesse et al. (2015), about 95.5% of ginger yield could be reduced when the weeding was ignored totally throughout their growing period.

Research results reported by Habetewold et al. (2015) and Habetewold and Wakjira (2017) indicated the critical time of weed competition for ginger and turmeric is between 30 and 60 days after planting (DAP) at Tepi

Table 11. Mean values of yield and yield components of ginger at Kindo-Koyisha during 2012/2013.

Treatment	No. of Leaf/plant)	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	No. of tillers/hill	No. of plants/plot
				Nitrogen (kg/ha)			
0	13.12[d]	41.21[d]	15.57[c]	1.78[d]	39.91[d]	3.70[d]	34.33[d]
23	16.53[c]	49.57[c]	18.57[b]	2.12[c]	56.05[c]	4.85[c]	50.13[c]
46	18.11[b]	51.29[c]	19.39[ab]	2.25[b]	62.28[b]	5.74[b]	52.75[bc]
69	18.79[b]	53.21[b]	19.78[a]	2.30[b]	64.57[b]	6.31[a]	54.18[ab]
92	20.42[a]	55.13[a]	20.27[a]	2.56[a]	74.05[a]	6.49[a]	56.25[a]
CV (%)	8.24	4.55	6.1	6.53	9.70	9.63	6.94
SEm	±1.17	±1.86	±0.93	±0.12	±4.70	±0.43	±2.81
				Phosphorus (kg/ha)			
0	16.25[b]	46.68[c]	17.27[c]	2.12[b]	53.18[c]	4.91[c]	46.73[c]
10	17.23[ab]	49.65[b]	18.55[b]	2.19[ab]	58.15[b]	5.35[b]	48.60[bc]
20	17.77[a]	51.29[ab]	19.33[ab]	2.23[ab]	-	5.57[ab]	49.87[b]
30	18.32[a]	52.70[a]	19.72[a]	2.27[a]	64.29[a]	5.85[a]	52.90[a]
CV (%)	8.24	4.55	6.10	6.53	9.70	9.63	6.94
SEm	±1.17	±1.86	±0.93	±0.12	±4.70	±0.43	±2.81

Source: Abraham et al. (2014).

Table 12. Interaction effects of N and P fertilizer rates on fresh rhizome yield (Kg/ha) of Turmeric at Tepi in 2012/13 Cropping seasons.

N (kg/ha)	P (kg/ha)			
	0	**10**	**20**	**30**
0	45503[bc]	51322[abc]	50529[abc]	41402[c]
23	44974[bc]	49206[bc]	46963[bc]	43123[c]
46	42857[c]	48679[bc]	51852[abc]	49767[bc]
69	52381[abc]	56984[ab]	51985[abc]	62963[a]
CV (%)		9		
LSD (0.05)		131.4*		

Source: Lupi and Temtme (2015).

Table 13. Interaction effects of N and P fertilizer rates on fresh rhizome yield (Kg/ha) of Turmeric at Tepi in 2013/14 Cropping seasons.

N (kg/ha)	P (kg/ha)			
	0	**10**	**20**	**30**
0	49735[cdefg]	44444[fg]	46032[efg]	48677[cdef]
23	43386[g]	52381[bcdef]	49206[cdefg]	52910[abcdef]
46	53968[abcde]	51852[bcdefg]	47090[defg]	55026[abcd]
69	57143[abc]	59788[ab]	58730[ab]	61376[a]
CV (%)		9.9		
LSD (0.05)		89.09*		

Source: Lupi and Temtme (2015).

condition. Accordingly, a hand weeding between 30 and 45 DAP or weeding at 30, 60 DAP plus mulching would be advisable to avoid or reduce severe competition and obtain the maximum yield of ginger and turmeric

Table 14. Interaction effects of N rates and time of application on fresh rhizome yield (kg/ha) of Turmeric grown at Tepi, southwestern Ethiopia.

N Split	N (kg/ha)				
	0	46	69	92	115
Full dose	31764.70^{pq}	38853.21^{lm}	43345.07^{j}	48962.47^{fgh}	51280.73^{e}
Two splits	34258.55^{no}	40652.50^{kl}	47597.16^{ghi}	54612.93^{d}	60659.77^{c}
Three splits	32940.21^{op}	41989.43^{jk}	47284.31^{hi}	62644.16^{b}	69251.83^{a}
Four splits	34914.66^{n}	40142.79^{l}	45869.06^{i}	50368.40^{ef}	55285.89^{d}
Five splits	30974.58^{q}	37168.03^{m}	40135.21^{l}	43585.00^{j}	49218.45^{fg}
CV (%)			1830.20		
LSD (0.05)			5.43		

Source: Mekonnen and Garedew (2019).

Table 15. Seed yield (kg/ha) of black cumin as influenced by nitrogen and phosphorus application.

N (kg/ha)	P (kg/ha)		
	0	20	40
0	636.67^{i}	716.60^{hg}	756.60^{fg}
15	680.00^{hi}	810.00^{fe}	836.60^{e}
30	800.00^{fe}	920.00^{d}	1036.60^{c}
45	993.30^{c}	1013.30^{c}	1216.60^{b}
60	1060.00^{c}	1273.30^{ab}	1336.67^{a}
CV (%)		4.3	
LSD (0.05)		67.8	

Source: Ebrie et al. (2015).

Table 16. The seed yield (Kg/ha) of white cumin as affected by nitrogen and phosphorus application.

N (kg/ha)	P (kg/ha)			
	0	10	20	30
0	730^{l}	940^{k}	1060^{jk}	1160^{hij}
15	1050^{jk}	1150^{hij}	1090^{ij}	1290^{fgh}
30	1310^{ef}	1230^{ghi}	1480^{de}	1600^{cd}
45	1440^{ef}	1740^{bc}	1790^{ab}	1940^{a}
CV (%)		14.17		
LSD (0.05)		150		

Source: Tesfaye (2017).

(Habtewold et al., 2015). Similar to these findings, hand weeding between 30 and 45 DAP or mulching at planting followed by two consecutive hand weeding at 60 and 90 DAP were the best practices at Metu for higher ginger yield (Tadesse et al., 2015).

Intercropping/multiple cropping

Growing two or more crops on the same land at the same time can increase crop yield per unit area, reduce risks associated with crop failure and price fall. Also, it helps farmers to get balanced nutrition and an additional income. Several authors indicated that intercropping helps for efficient use of farm inputs including family labor, growth resources (Aggarwal et al., 1992), and weed control (Baumann et al., 2002). In the Southwestern part of Ethiopia, the farming system is commonly characterized by the growth of one or more of these complementary crop species. Previous studies have reported successful intercropping of cardamom, korarima, turmeric, ginger, and other lowland spices with

Table 17. Rooting percentage, root number, and root length of black pepper cuttings raised on different growth media compositions.

Rooting media	Rooting percentage	Root number	Root length (cm)
FS	63.3	3.83	14.91
ForS	47.7	3.94	13.36
PDCH	26.3	2.82	11.22
FS:ForS (1:1)	51.9	4.74	14.61
FS:PDCH (1:1)	45.4	3.69	13.04
ForS:PDCH (1:1)	37.5	3.58	12.65
FS:ForS:PDCH (1:1:1)	51.4	4.50	14.18
LSD (0.05)	2.25	0.89	2.48
CV (%)	22.93	26.44	21.03

FS=fine sand, ForS= forest soil, PDCH=partially decomposed coffee husk.
Source: Digafie (2006).

coffee (*Coffea arabica* L.) (Girma et al., 2008; Anteneh and Taye, 2015; Behailu et al., 2020). According to Girma et al. (2008) and Behailu et al. (2020), the best results of the system could be attributed to the optimal shade level that the coffee plant gave to the cardamom and korarima during their growing periods.

During the early growth stage of coffee, intercropping of ginger and turmeric with coffee was also found to be a possible practice to increase the productivity of the component crops yield as reported by Anteneh and Taye (2015). Intercropping of turmeric (T) and soybean (S) plants could increase total productivity of curcuma and soybeans. In row relay T-K cropping patterns, turmeric plants generated growth and yield parameters as well as higher per-unit area yield than other cropping pattern, so as to produce higher land equivalent ratio (LER=1.09) and revenue to cost ratio (R/C ratio=2.36) than other cropping patterns (Ellis et al., 2017).

Propagation methods and nursery management of black pepper and cardamom

Commercial black pepper and vanilla propagation is carried out using vine cuttings, while cardamom and korarima can be propagated either by seed or clumps. The first technique is proved the best, as it helps to avoid the katte viral disease in cardamom, and overcome planting material shortage in both species (Purseglove et al., 1981; Borget, 1993; Pruthi, 1998; Wondyifraw and Surawit, 2004; Girma et al., 2008). Vine cuttings of 60 cm long (7 to 10 nodes) were recommended for black pepper propagation by different authors (Purseglove et al., 1981; Borget, 1993; Pruthi, 1998). However, practical observations under the Ethiopian condition had proved 30 to 40 cm long (3 to 4 nodes) cutting to be highly effective for propagation (Girma et al., 2008). In clonal propagation of cardamom and korarima, the use of clumps with one old and another young shoots is ideal (Purseglove et al., 1981; Borget, 1993; Pruthi, 1998). Suitable rooting medium is also a very important agronomic practice for successful establishment of black pepper, cardamom, korarima and vanilla from nursery to field. According to Purseglove et al. (1981), Borget (1993) and Pruthi (1998), media combination with a 3:2:1 composition (forest soil, decomposed animal manure and sand) is recommended for successful propagation of black pepper, cardamom korarima and vanilla. In Ethiopia, practical observation proved that an ideal forest soil which has enough nutrients and with typical characteristics of forest soil alone can be utilized for efficient propagation of these spices including vanilla. According to Digafie (2006), forest soil with fine sand with 1:1 ratio or fine sand, forest soil and partially decomposed coffee husk with 1:1:1 ratio can be used for efficient rooting of black pepper cuttings in nursery (Table 17).

Seed treatments and rooting media

Regarding seed treatments, it was observed that seed soaking had effect on the emergence and subsequent growth of cardamom seedlings. According to Hassen et al. (2019), a significant seed emergence and subsequent growth of cardamom seedlings were observed from seeds sown after being soaked in alcohol (80%) for 30 min (Table 18). Like cardamom, the highest total dry weight of korarima seedlings was observed from seed sown on a mixed media of forest soil and compost (1:1 ratio) after being soaked in pure water for 24 h as reported by the research works of Jafer (2019). Regarding nursery rooting media, the growth and biomass production of the korarima seedlings were significantly influenced by the type of nursery rooting

Table 18. Effects of seed treatments on seed germination and seedling growth of cardamom.

Treatments	Days of 50% germination	Seedling length (cm)	Root number	Root length (cm)	Leaf area (cm^2)	Normal seedlings (%)
Control	40.33^{cd}	2.16^{d}	3.33^{c}	2.46^{ab}	2.63^{d}	52^{cd}
H_2O for 12 h	42.00^{cd}	2.18^{cd}	4.78^{ab}	1.85^{bc}	3.03^{bc}	64^{bc}
H_2O for 24 h	47.66^{b}	2.10^{de}	4.84^{ab}	1.75^{c}	2.95^{cd}	54^{bc}
H_2SO_4 (5%) for 10 min	44.66^{bc}	2.23^{bcd}	3.63^{c}	2.27^{abc}	3.37^{b}	59^{bc}
H_2SO_4 (10%) for 5 min	53.00^{a}	1.98^{e}	4.31^{b}	2.18^{abc}	2.97^{bcd}	42^{f}
HNO_3 (25%) for 10 min	48.00^{b}	2.36^{a}	4.55^{ab}	1.96^{bc}	3.11^{bc}	51^{cd}
HNO_3 (50%) for 15 min	52.66^{a}	2.33^{ab}	3.55^{c}	2.35^{abc}	3.07^{bc}	47^{cd}
Acetic acid (25%) for 10 min	38.00^{d}	2.37^{a}	4.94^{a}	2.01^{bc}	3.87^{a}	68^{ab}
Alcohol (80%) for 30 min	31.66^{d}	2.40^{a}	5.00^{a}	2.85^{a}	3.92^{a}	78^{a}
LSD (0.05)	4.44	0.13	0.54	0.67	0.39	11
CV (%)	5.71	6.47	7.28	7.85	7.13	7.86

Source: Hassen et al. (2019).

Table 19. Vegetative and yield parameters of black pepper (*P. nigrum* L.) variety Gacheb as influenced by different pruning practices.

Treatments	No. of fruiting branches per all main stem	Length of main stem (m)	Fresh yield (kg/ha)
No pruning (check)	97.8	4.0	6870
Pruning + two orthotropic shoots allowed to grow	80.9	2.9	6290
Pruning + three orthotropic shoots allowed to grow	85.2	2.8	4960
Pruning + four orthotropic shoots allowed to grow	111.2	3.1	7180
Pruning + free growth	111.3	3.1	5490
Mean	97.3	3.2	6160

media and frequency of watering (Jafer, 2016, 2019). The emergence and growth of korarima seedlings were enhanced when the seed was sown on a mixed media of topsoil and compost (1:1 ratio) and watered in every one or two days interval (Jafer, 2016). The author also reported that the highest produced biomass of korarima seedlings was observed from a mixed rooting media of topsoil and compost (3:1 ratio) with a watering frequency of 2 or 3 days interval. In another study, a rooting media of forest soil alone was also suggested as an alternate nursery media for enhanced growth of korarima seedlings (Lupi et al., 2016). Bhardwaj (2014) also reported similar finding; vermicompost and cocopeat, due to their suitable physical, chemical and biological properties could be used successfully in preparation of papaya seedlings.

In the cultivation of spices such as cardamom, black pepper, korarima and vanilla, cultural practices like pruning and field sanitation are very important for the improvement of their yield. Especially, in black pepper and cardamom, growth and final yield of the crop is significantly influenced by pruning practice (Purseglove et al., 1981; Pruthi, 1998). There are various practices of pruning in black pepper. Selective pruning that eliminates weak, non-productive branch parts will aid in channelling the plants energy in to flowering and fruiting. Generally, pruning pepper vine promotes the fruiting of lateral branches and induces a greater stem thickening with view to enlarge vascular system and strong framework, greater bushiness of canopy and larger cropping points, so that when matured the vine will have the maximum number of fruiting branches (Purseglove et al., 1981). As it is a new technology in Ethiopia, pepper cultivation has not been well developed; pepper is planted under the foot of the support without pruning, which can adversely affect the performance of the vines. The number of vines maintained per point is also the critical factor depending on the soil, climatic factors and the field management. Since most of the vines can climb high over 8 m on the supporting trees, fruit picking at maturity was found too difficult. A result from a trial in Tepi Agricultural Research Sub-center, comparing five different methods of pruning on variety Gacheb showed no significant yield difference, while highest mean fresh yield (7180 kg/ha) was obtained from the vines pruned and four orthotropic shoots maintained (Table 19). This research agenda need to be conducted again for the optimal recommendation.

Table 20. Major pests of seed spices

Crop	Major Disease	Major insect pests	Major weeds
Black cumin	Wilt, Blight and powdery mildew	Pod borer and Aphid	*Cynadon dactylon* and *Solanum nigrum*
Fenugreek	powdery mildew and Wilt	Aphid, Pod borer and Thrips	*Chenopodium album* and *Drymaria cordata*
Coriander	Root rot and wilt	Aphid and Cushiony	*Chenopodium album*

Source: Tepi Agricultural Research Center (TARC) progress report, 2020.

Table 21. List of released varieties of major spices and relevant agronomic information.

List of spices	Propagation Method	Recommended			Special requirements (shade/support)	Commercial Product	Yield (kg/ha)
		Planting and/or nursery preparation time	Harvesting time	Spacing			
Black pepper (Gacheb & Tato)	Cutting	Cutting: March; Planting: June-July	Feb.-March	2.4 m × 2.4 m	Support	Fruits/Berries	1970-2850 (dry)
Ginger (Yali & Boziab)	Rhizomes	Planting: March-Mid April	Dec.-Jan.	30 cm × 15 cm	Open sun	Rhizomes	15000-24100 (fresh)
Cardamom (Gene)	Seed	Nursery: Nov.-Dec. Planting: June-July	Nov.-Dec.	3 m × 3 m or 2.5 m × 2.5 m	Shade	Capsules	140-180 (dry)
Turmeric (Dame, Tepi-1)	Rhizomes	Planting: March-Mid April	Dec.-Jan.	30 cm × 15cm	Open sun-partial intercrop shade	Rhizomes	20000-25000 (fresh)
Vanilla (Yeki-1)	Cutting	Cutting: March; Planting: June-July	Nov.- Dec.	2.4 m × 2.4 m	Shade	pod	204
Black cumin (Eden, Dershaye, Darbera, etc.)	Seed	July to end September	Jan.-Feb.	30 cm × 10 cm	Open sun	Seed	1500-1900
White cumin (Dembia-01 and Takusa-01)	Seed	July to end September	Jan.-Feb.	45 cm × 30 cm	Open sun	Seed and all plant	2220.1
Coriander (Denkenesh, Walta'i and Indium)	Seed	July to end September	Jan.-Feb.	23-76 cm between row	Open sun	Seed	1300-1700
Fenugreek (Jama, Wereillu, Burka, Bishoftu, Chala, Ebisa & Hundaol)	Seed	July to end September	Jan.-Feb.	30 cm × 10 cm	Open sun	Seed	1500-2210

***Source**: Edossa (1998a), Girma et al. (2008), Habtewold et al. (2017).

Summarized information of the released spices in low land spices is presented in Table 20.

There is limited research on disease and pest management; however, few years ago survey and identification of major disease and insect pest of seed spices were identified and the research on management approach is underway. Summary on list of major insect pests of the highland seed spices is presented in Table 21.

Gaps and challenges

Though the capacities of spices research (human power and research facilities) have been very limited, significant agronomic research achievements have been attained. Of course, many researchable areas are yet to be covered in no late times. With strategic widening of the gene pool of the economically important spices plants, very important cultural practices like suitable pruning in black pepper, fertilizer requirement of all spices, suitable nursery practices such as for cardamom, possible intercropping, etc., should be undertaken to come up with complete optimal packages. Shortage of planting materials of all spices has also been the bottleneck for sufficient scale up of the proved spices technologies. This call for establishment of government led specialized seed/planting material multiplication center. Finally, yet importantly, there is a serious gap in demonstration and popularization of available technologies for these invaluable spices. Productivity of seed spices continues to be very low as compared to the world average and majority is accounted to lack of improved production packages. The main constraints in seed spices production are: inherent nature of slow and non-uniform seed germination at initial growth for black cumin, high incidence of diseases such as wilt, blight and powdery mildew. In addition, absence of integrated pest management (IPM) approach developed for seed spices (black cumin, fenugreek, coriander and white cumin) can also be mentioned as main contributor to their low performance. Similar to other spices, serious shortage of quality seed material of seed spices varieties has been a challenge for the sub sector.

Prospects

Very conducive environmental conditions (rainfall, temperature, altitude and soil condition) and promising varieties of major low land spices (black pepper, ginger, turmeric and cardamom) identified and released for users in the Southwestern areas of the country point out there is high prospect for the nation in this corridor. Quality of the spices also proved very promising to fulfil the international standards indicating that the soil condition is very suitable. Therefore, it is a very good opportunity to disseminate and scale up the available technologies to suitable and recommended areas of the country. The government gave due attention to the development of the spices of this group and the research system has also gained strong attention to have national network. Thus, with the current support given to strengthen the research team, the problems of qualified human power are being resolved, thereby creating a possibility to address the areas that still require research attention. Finally, with the popularization of existing improved agronomic technologies and further generation, there is a high chance for the production of sufficient volume and quality products that can help the country to compete in the world market. Both domestic and international market demand of seed spices keeps increasing from time to time. Suitable agro ecology for the production of this group of spices and involvement of federal and regional research centres to generate technologies that can improve productivity and production are very promising for the future.

CONCLUSION AND RECOMMENDATIONS

So far, significant improved research results of cultural practices had been developed and recommended with respect to the different spices that were given research attention. These include technologies regarding suitable agronomic practices such as suitable nursery practices, seed preparation and seed rate, suitable propagation methods, appropriate pruning practices for some of the vine spices, suitable planting date, land preparation and so on. For some of the shade loving spices (cardamom and korarima), suitable shade level was studied and recommended. From practical observation, types of shade trees for these species were identified and support trees for vine crops like black pepper were studied and recommended. The prevalence of suitable climatic conditions for the production of these invaluable spices in the country is the other opportunity to be further exploited by smallholder farmers and private investors. The varieties of these spice crops that are currently available at hand had proved comparable in yield and/or quality with commercial varieties in other producing countries. Therefore, to exploit all these opportunities effectively and assist in further technology generation through research, it is imperative to strengthen the national spices research program with essential qualified human power and research facilities. Those outstanding research gaps such as those related with nutrient requirement, soil and water/natural resource management, intercropping and seed/planting material multiplication should be given prior attention. In addition the research team should give attention for protection and postharvest handling of these spices. The work of tissue culture multiplication for large-scale production of planting materials should be enhanced further to meet the ever-growing demand for quality planting materials. Strong attention should also be directed to the demonstration and popularization of the existing technologies on these spices of economic importance, to attract private investors and encourage small-scale farmers, thereby assist in the envisaged coffee diversification endeavour.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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