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Review on Agronomic Managements for Improving Fenugreek (*Trigonella foenum-graecum* L.) Production and Productivity in Ethiopia

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Abstract: Fenugreek (*Trigonella foenum-graecum* L.) is an annual crop belonging to family Fabaceae. It is a diploid species with the chromosome number of 2n=16 except *T. neoana* (2n=30), had 2n=16 chromosomes. It is regarded as the oldest known medicinal plant in recorded history. This plant use for blood lipids and sugar decreasing in diabetic and non-diabetic peoples and have antioxidant and antibacterial activity. Poor agronomic practices are among the major constraints limiting the production and productivity of this crop. Improving agronomic practices such as seedbed preparation, sowing date, planting methods, seed rate, weed control and pest management will enhance the production and productivity of fenugreek seed crops including its quality parameters. Concerning with fertilizer application higher nodulation due to increased phosphorus fertilizer might be due to symbiotic nitrogen fixation requires higher phosphorus for the maximum activity in reduction of atmospheric nitrogen by nitrogenase system. The recommended seed rate is 20-25 kg ha^{-1} kg per hectare depending on soil fertility, germinating capacity of the seed, type of variety and planting method. Planting date is dependent on the availability of soil moisture, altitude, soil type and maturity period of the specific crop cultivar. For fenugreek, two to three hand-weeding, 15 and 30 days after sowing (critical period), resulted in the highest seed yield. Application of herbicides, fungicides and insecticides was also recommended for control of weed, fungus and insect pests of fenugreek on large scale farming respectively.

Key words: Agronomic Practices · Productivity · Fenugreek · Medicinal Plant

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is the annual herbaceous legume crop, used as leafy vegetable, fodder and condiment [1]. It is widely used as a spice and condiment to add flavor in various foods [2]. Nursing mothers consumes fenugreek for the maintenance of breast milk. Infants after the age of 4-6 months are also fed with extracts of fenugreek seed [3]. Farmers in some parts of Ethiopia such as Hararghe as 'Lafiso' and Harari people as 'Hulbat Meraq' used as their best dish [4]. Feysal [5] reported that Ethiopia is recognized as the original homeland of *Trigonella foenum-graecum* subspecies Mediterranean, ecotype Abyssinian with its distribution extending to neighbor countries. Study reported presence of fenugreek genetic variability as well as the production and distribution in Ethiopia as nearly similar to those of other cool season food legumes [6]. According to the CSA [7] estimation, from total cultivated land in Ethiopia, fenugreek occupies 32,587 ha with productions and productivity of 43637.39 tons and 1.33 tons ha^{-1}, respectively, in 2017. In Ethiopia, Oromia Region State shared most of the production with productivity of 1.31 t ha^{-1}.

The productivity of fenugreek both nationally and regionally during 2017 cropping season was too low as compared to its potential yield 1.8 ton ha^{-1} reported by MoA [8]. One of the primary production constraints of fenugreek is poor soil fertility like P deficiency and incomplete packages of agronomic managements. According to Fairhurst [9], phosphorus deficiency is one of the largest constraints to crop production, owing to low native content of P coupled with high P fixation capacity of many tropical soils. The soil fertility map made over 124 Districts of Oromia showed that most soils lack NPK [10].

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Botanical Description: Fenugreek is also known as one of the oldest medicinal plants recognized in recorded history [11-13]. Linnaeus has described the species *Trigonella foenum-graecum* first [14- 16]. Fenugreek is an annual dicotyledonous plant belongings to the subfamily Papilionaceae, family Leguminacae (= Fabacecae). A morphological description of the plant is presented by Sinskaya [17], Hutchinson [18], Tutin and Heywod [19], Fazli and Hardman [20], Petropoulos [14, 21], and Basu [15] in Table 2 [22]. In general, two types of flowering shoots are observed [14, 21]. The common type bears axillary flowers showing an indeterminate growth habit, whereas the less common or so called "blind shoots" have both axillary and terminal flowers, each of which become "tip bearers". Two types of fenugreek flowers also have been described [14, 21] i.e., cleistogamous (closed) and aneictgamous (open) flowers. However, the majority of fenugreek flowers are cleitogamous; aneictgamous flowers are not common in fenugreek [15]. There are firm indications that there is a linkage of the quantitative character of diosgenin content with the morphological character of the number of pods per node near the top of stem, and that high content of diosgenin is inherited together with the formation of twin pods. So, the phenotype of twin pods in comparison with that of solitary pods is a good index of selection and should provide a reliable basis to predict the performance of their progenies for a higher diosgenin content of seed, from very early generations [14, 15, 21].

Origin and Distribution: Fenugreek, (*Trigonella foenum-graecum* L.), is an ancient and annual legume crop mainly grown for multiple uses in many parts of the world. Landraces and species of Trigonella have been found on the continents of Asia, Europe, Africa and Australia. Fenugreek was also cultivated in parts of Europe, northern Africa, west and south Asia, North and South America and Australia [11, 15]. Asia is positioned in 1st place among continents in terms of fenugreek production and acreage. Different authors have widely divergent opinions about the probable ancestry of *T. foenum-graecum*. Vavilov [23] has suggested that fenugreek is native to the Mediterranean region, while Fazli and Hardman [20] proposed an Asian origin for the crop [11]. De Candolle [22] believes that the origin of fenugreek should be Asia rather than Southern Europe, because if a plant of fenugreek nature was indigenous in Southern Europe it would be far more common and not be missing in the insular floras of Sicily, Ischia and the Balearic Isles [14]. Many authors maintain that the direct ancestor of cultivated fenugreek is the wild *T. gladiata* Ste. that differs from *T. foenum graecum* in respect of the entire aggregate of characters, of which seed tuberculation and the small size of the pods are only the most striking. It is possible that the species *T. foenum graecum* evolved from *T. gladiata*, which had possibly given rise to some new extinct forms of *T. foenum-graecum* [14, 21] Scientists have widely debated the probable ancestry of *Trigonella foenum-graecum* (L.), although the divergent schools of opinion identify three probable centers of origin for the plant i.e. Mediterranean region, Asian/India and Turkey [24-27]. Fenugreek is now cultivated in all habitable continents of the world. Some of these continents have a long history of use, while other continents only started cultivating the crop during the past 2-3 decades [28].

Production and Productivity of Fenugreek: A Scientific Journal of Krishi Foundation Indexed Journalis leading in fenugreek seed production, producing about 90 % of the world fenugreek production [24]. Among other Asian countries; Iran, Israel, China and Pakistan also have high levels of production. A wide range of medicinal properties has been attributed to fenugreek such as wound-healing, bust enhancement, enhanced lactation in weaning mothers, as an aphrodisiac, anti-diabetic, anti-hyperthyroidism, anticancer, gastro-protective, antioxidant, antipyretic, antimicrobial, anthelmintic, anti-sterility, anti-allergy and anti-inflammatory effects [24,29].

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The productivity of fenugreek both nationally and regionally during 2018 cropping season was too low as compared to its potential yield (1.8 ton ha^{-1}) reported by [8]. One of the primary production constraints of fenugreek is poor soil fertility like P deficiency.

Ecological Requirements: Although the main area cultivated with fenugreek is concentrated in some countries of Asia and Africa, however it has been distributed in many countries throughout the world under different environments. This wide distribution of its

Table 1: Improved fenugreek varieties, accession and recommended agro-ecology in Ethiopia

Cultivars/Accession	Maintaining Research Center*	Released Year	Yield ton ha^{-1}	Recommended agro-ecology
Bishoftu	DZARC/EIAR	2017	1.19	Mid and high altitude
Chala (FG -47-01)	DZARC/EIAR	2005	0.9-1.65	Mid and high altitude
Ebbisa	SARC/OARI	2012	1.38	Mid and high altitude
Hunda - 01 (FG-18	SARC/OARI	2006	1.22	Mid and high altitude
28605	EBI	2016	-	1954 m.a.s.l.
28606	EBI	2016	-	1966 m.a.s.l.

Source: Abera *et al*., 2019

*DZARC=Debrezeit Agricultural Research Center, EIAR=Ethiopian Institute of Agricultural Research, SARC=South Agricultural Research Center, OARI=Oromia Agricultural Research Institute. EBI=Ethiopia Biodiversity Institute. Source: (Ministry of Agriculture and Natural Resources, 2016)

cultivation in the world is characteristic of its adaptation to variable climatic conditions and growing environments [14, 21]. Duke [24] reports that fenugreek, ranging from cool temperate steppe to wet through tropical very dry forest life zone, is reported to tolerate an annual precipitation of 3.8-15.3 dm and an annual mean temperature of 7.8-27.5°C. There are indications of the possible benefit of colder nights on the sapogenin content of the seed [20]. Depending on the geographical source of the seed its sapogenin content, calculated as diosgenin, varied from 0.8-2.2 percent expressed on a moisture free basis [20]. The highest sapogenin content was found in an Ethiopian sample and the lowest in a sample from Palestine [14]. As a legume crop, it can condition the soil by fixing nitrogen from the atmosphere and can reduce the need for nitrogen fertilizer for subsequent crops. Because fenugreek is a nitrogen-fixing legume, seeds must be inoculated with appropriate Rhizobium species for optimal growth [14, 15, 30]. As a dry-land crop, its water requirements are low; use of fenugreek can reduce the cost of irrigation, save water and reduce eutrophication of surface water and limit contamination of ground water source. These properties also make fenugreek a useful legume crop for incorporation into short term rotations [13, 15].

Agronomic Practices: Higher yield per hectare will be obtained through superior varieties and better management practices of production. In the old times, a fenugreek yield of 1 ton of seeds per hectare was considered very well, but nowadays yields of more than 2 tons per hectare are being obtained. The large yields of fenugreek are mainly dependent to suitable cropping and agronomic practices. A significant increase in yields through the suitable use of irrigation and adequate levels of soil fertility could make an immediate and important contribution to farm income [14, 21]. Fenugreek is a dry-land crop which responds even to minimal levels of irrigation. Interest in cultivating fenugreek in temperate climates, has increased because of its rain-fed adaptation [11, 13]. Baricevic and Zupancic [31] reported lower diosgenin yield from drought stressed fenugreek cultivars. However, when grown under optimal irrigation regime (35% depletion of available soil water) diosgenin yield increased in comparison to normal irrigated plants, suggesting that the plant does well under minimal irrigation [14, 31].

Soil Preparation: The land should be well prepared for better germination of seeds and growth of plant. A total of 3-4 ploughing are required. The first ploughing should be done by soil turning plough followed by 2-3 ploughing with harrow to bring the soil to a fine tilth [32]. At the time of sowing there should be good moisture in the soil for better germination of seed. When fenugreek follows most cereal crops or soil moisture was limited and low cost, plowing may not be necessary [14, 15].

Spacing: A spacing of 20 cm to 30 cm between rows and 10 cm to 15 cm between plants, at a planting depth of 2 cm to 3 cm should be maintained not to affect the germination rate. Seeds germinate and emerge from the soil in 4 to 10 days depending on planting season, growing conditions and planting depth.

Sowing Methods and Seed Quality: Namely broadcasting on the surface of the soil and drilling are applied, also seed quality should possess at least 95% seed purity and 80% germination ability [14].

Seed Rate: The quantity of seed required for the sowing of unit area depends on the purpose for which the crop is sown. Also it varies from place to place depending on soil fertility, germinating capacity of the seed, and type of variety. To raise a healthy crop and to obtain better yield with quality produce, proper seed rate should be maintained. On average, seed rate requirement for fenugreek in Ethiopian is 20–25 kg ha^{-1} [33].

Sowing Time: It is generally grown as a winter crop in areas with mild winter and as spring crop in areas with soil that keeps moisture in the summer. However, spring sowings are recommended for all areas with prolonged periods below freezing [14, 34].

Irrigation: Methods of application are both flooding and spraying [13, 14]. It is estimated that a water quantity of 200 m^3/ha every time for sandy soils, and 250 m /ha for heavier soils replicated every fortnight [14].

Fertilizers: The main source of N fertilization is nitrate ammonia for acid soils and sulfate ammonia for limey soils [14]. The N×P interaction can significantly increase the yield per hectare. The highest seed yield and seed weight can be obtained from plants receiving N: P at 30:60 kg/ha but it reduces the diosgenin content from 0.35% to 0.12% with NP treatment [34]. Nodule number and nodule dry weight per plant was significantly ($P<0.01$) affected due to genotype, phosphorous application and interaction effect of these two factors (Table 2). Higher nodule number was obtained at combined effect of variety Ebbisa with 26 kg ha^{-1} and variety Bishoftu with 26 kg ha^{-1} (Table 2). The lowest nodule number was recorded from accession 28606 with no phosphorous application. The nodule number showed successive improvement as phosphorous level increased from control to 26 kg ha^{-1} with Ebbisa, Bishoftu and Hunda varieties (Table 2).

With regard to nodule dry weight; variety Ebbisa with 26 kg ha^{-1} and Bishoftu with 26 kg ha^{-1} produced the highest nodule dry weight numerically. Accession 28606 produced numerically lower nodule dry weight particularly as planted without phosphorus (Table 2). Higher nodulation due to increased phosphorus fertilizer might be due to symbiotic nitrogen fixation requires higher phosphorus for the maximum activity in reduction of atmospheric nitrogen by nitrogenase system. The other reason might be due to genetic factors that the genotype nature to nodulation as long as non nodulating and nodulating genotype existed, irrespective of agronomic practices available [35]. The above result is in agreement with Abbasi [36] who stated increasing in phosphorus application increased the total of root nodules and dry weight. Increased nodulation due to application of 40 to 60 kg P_2O_5 ha^{-1} has been reported [37].

Seed Yield of Fenugreek: Seed yield showed significant variation due to genotype, phosphorus application and interaction ($P<0.01$) effect of two factors (Table 3). The combined effect of Chala variety with 17 kg ha^{-1} resulted in significantly higher seed yield followed by the same variety combined with both 9 and 26 kg ha^{-1}. Accession 28605 combined with both control plot and 9 kg ha^{-1} as well as Ebbisa variety combined with control plot was those treatments generated lower seed yield statistically (Table 3). Seed yield of a crop is a function of yield attributes such as number of pods per plant, number of seeds per pod and 1000-seed weight that increasing in growth due to enhanced nutrient uptake and utilization which have direct and positive effect on seed, straw and biological yields of fenugreek. The increment in seed yield due to increase in plant growth attributes and yield components were reported [38]. Higher dose of phosphorus helped in increase the number of pod per plant and filled pods. This might be due to higher response of genotype to applied phosphorus as long as the initial soil available phosphorus was low. The existence of capable genotype to respond and produce higher grain yield might be a reason. The above research findings confirmed with Khiriya [39] who stated as significant increase in seed yield of fenugreek up to 17 kg ha^{-1}.

Weed Management: Hand weeding twice, 15 and 30 days after sowing (critical period), resulted in the highest seed yield [40]. Pre-sowing treatments; paraquat, and glyphosate (non-selective herbicides). Preemergence treatments; trifluralin, fluchloralin, chlorpropham, and pendimethalin (soil-acting). Post-emergence treatments; bentazon, MCPB, diclofop-methyl, and alloxydim [14, 21].

Rotation: A very good two year rotation crop is fenugreek-wheat, which is widely practiced [22]. The usefulness of fenugreek as a commercial crop is now being recognized and also as a break-crop for cereal areas [14]. Fenugreek can be successfully grown in conservation tillage systems in rotation with a wide range of crops [11, 13].

Harvesting: In most of the cases, especially under wet conditions, harvesting starts when most of the pods are mature. For spring sowing, ripens usually 3-5 months after planting and for fall sowing, this time exceeded 7 months [14]. The best harvesting time of fenugreek for green fodder should be when the pods of the base are in the first stage of their development, where the plants are a well formed mass and are very tender [14].

Table 2: Nodule number and dry weight of fenugreek as affected by interaction effect of genotype and P application

	Nodule number per plant				Nodule dry weight per plant(mg)			
	P (kgha^{-1})				P (kgha^{-1})			
Genotype	0	9	17	26	0	9	17	26
Bishoftu	14.9^{hi}	18.3^{fg}	24.6^{cd}	34.3^{a}	19.$^{7e-g}$	22.4 ^{ef}	33.3^{cd}	47.8^{a}
Chala	10.8^{jk}	14.6^{hi}	15.9^{hi}	24.0^{c-e}	17.8^{f-i}	19.3 $^{f-h}$	43.5^{ab}	28.2^{de}
Ebbisa	18.7^{f}	23.0^{de}	31.5^{b}	35.2^{a}	12.5^{g-j}	19.1^{f-h}	44.8^{ab}	50.1^{a}
Hunda	14.4^{i}	19.0^{f}	21.7^{e}	25.9^{c}	10.5^{h-j}	15.0^{f-j}	16.2^{f-i}	46.5^{ab}
28605	9.5^{k}	11.2^{j}	22.1^{e}	16.3^{gh}	8.9^{ij}	17.2^{f-i}	21.8^{ef}	38.3^{bc}
28606	7.2 ^{l}	9.6^{jk}	13.6^{i}	15.0^{hi}	6.5^{j}	14.0^{f-j}	15.0^{f-j}	15.6^{f-i}
MS		23.06**				196.86***		
EMS		1.91				7.59		
CV (%)		7.35				11.3		

Source: Abera *et al*., 2019

MS=Mean Square, EMS=Error mean square, CV (%); Coefficient of variation. Means followed by the same letter(s) are not significantly different at 5 % probability level by DMRT

Table 3: Seed yield of fenugreek as influenced by interaction effect of genotype and phosphorous

	Seed yield (t ha^{-1})			
	P (kg ha^{-1})			
Genotype	0	9	17	26
Bishoftu	1.16^{e-g}	1.17^{ef}	1.32^{cd}	1.22^{de}
Chala	1.29^{cd}	1.48^{b}	1.62^{a}	1.52^{b}
Ebbisa	0.88^{j}	1.00^{i}	1.01^{i}	1.03^{hi}
Hunda	1.04^{hi}	1.14^{e-h}	1.15^{e-g}	1.16^{ef}
28605	0.82^{j}	0.89^{j}	1.06^{f-i}	1.07^{f-i}
28606	1.11^{e-i}	1.14^{e-h}	1.35^{c}	1.15^{e-g}
Mean	1.05	1.13	1.25	1.19
CV (%)		5.11		
MS		0.009**		
EMS		0.003		

Source: Abera *et al*. 2019

P=Phosphorus, MS=Mean square, EMS=Error mean square, CV (%) = Coefficient of variation, Means followed by the same letter(s) are not significantly different at 5 % probability level by DMRT

Disease and Insect Pests

Disease Pests

Powdery Mildew: The causal agents of the disease could be of Leveilua taurica, Levv, Erysiphe polygoni Dc. and Erysiphe tryphi. Severe occurrences of powdery mildew are often noted at temperature ranges between15 and 25°C together with a relative humidity range of 60-70%.

Downy Mildew: Downy mildew forms a cottony grayish white mycelium on the undersurface of the infected leaves. The management practices include the following: Use of healthy or disease free seeds, use of resistant varieties, seed treatment with Carbendazim plus Captan (1:1) @ 4g/kg seed, soil solarization to keep the level of inoculum low, organic amendments like neem cake (10q/ha) and Spry Biltox-50 (0.2%) or any copper fungicide or Zeneb (3g/lit).

Leaf Spot: The diseases is characterized by the presence of spots which are maphigenous, round to semi-circular, about 1cm in diameter and brown on periphery and white at center. Spraying of Febam or Eithane M-45 (0.2%) or Bavistin (0.05%) is often used to control the disease.

Root Rot: Root rot symptoms include appearance of varying degree of rotting of roots leading to foliage yellowing, plant withering and drying. The management practices include any of the following options and/or their combinations. Use healthy or diseases free seeds, use of soil amendments like neem cake @ 1.5-2.0 tones or FYM 10-25 tones/ha, soil solarization to keep the level of inoculums low, use of antagonistic fungi (e.g. Trichoderma Viride at 4 g/kg seed).

Damping off: Damping off infected seeds and seedlings appear as water soaked discolored, soft areas and emit bad odor. Seedlings also topple down and wither off. Some of the damping off management practices are: soil solarization to keep the level of inoculums low, spraying of brassicol or carbendazim (1g/l) along with crop rotation and removal of diseased plant, organic amendments like neem cake (10q/ha), treating seeds with benomyl (3g/ke seed) or carbendazim (3g/kg seed).

Insect Pest Management: Fenugreek is generally not frequently attacked by many insect pests, although some leaf eating caterpillars and pod borers can at times pose problems. Spray of Malathion (0.05%), Quinalphos (0.05%) or Endosulphan/Monocrotophos (0.04%) can control such pests. Aphids (pea, and cowpea aphids, Acyrthosiphon pisum) can also seldom damage the crop and these can be managed the same way stated above under black cumin.

CONCLUSIONS

Generally fenugreek grows best on well-drained soil and high in organic matter content Sand, silt and clay loam soils are recommended for commercial production. The rational use of phosphorous greatly promoted fenugreek growth, yield and obvious growth was undertaken due to symbiotic nitrogen fixation and ultimately, increased nitrogen economy. Fenugreek has three to five months duration to harvest, the best harvesting time of fenugreek for green fodder should be when the pods of the base are in the first stage of their development, where the plants are a well formed mass and are very tender. For this reason, using full packages of agronomic practices including disease and insect pests are advisable for small and large scale producer farmers to get high production, productivity and quality of fenugreek seeds.

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