GRAIN YIELD AND QUALITY IMPROVEMENT IN FENUGREEK : A REVIEW

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SUMMARY

Fenugreek (*Trigonella foenum-graecum* L.) is traditionally used as a spice and forage crop in parts of Asia, Europe, Africa, North and South America and Australia. This crop is now being cultivated as an annual forage legume crop and spice crop in India. Its green leaves and seeds are used for multipurpose. 100 g of seeds provide more than 65 per cent of dietary fibre due to its high fibre content and it has an ability to change food texture. It is well known for its gum, fibre, alkaloid, flavonoids, saponin and volatile contents. It is used as food stabilizer, adhesive and emulsifying agent due to its fibre, protein and gum content. Without enough variability and successive judicial selection, development of suitable cultivar(s) with high seed yield and quality under prairie conditions will not be possible.To reach its full potential, high yielding, early maturing fenugreek cultivars that produce good seed yield and quality need to be developed. Variants showing improved seed yield and yield attributing traits that can be used for cultivar development.

Key words : Fenugreek, yield, quality improvement

The fenugreek *(Trigonella foenum-graecum* L.) is a member of the family *Fabaceae* in the order *Leguminosae.* It is a self-pollinating dicotyledonous plant with branched stems, trifoliate leaves, which bears white flowers and produces golden yellow seeds (Petropoulos, 2002; Acharya *et al.*, 2010). Although fenugreek cultivation is mostly concentrated in Asia and the Mediterranean region, it is now widely cultivated in northern Africa, central Europe, North America and Australia (Fotopoulos, 2002).

Fenugreek is primarily used as a spice in countries where it is grown (Acharya *et al.*, 2006). Especially in India and countries in the Mediterranean regions both seeds and leaves of fenugreek are widely used as a culinary spice to enhance the taste of many meat, poultry and vegetable dishes (Mary, 2009). Seeds and leaves of fenugreek are well characterized with a distinctive, pungent scent that has made it highly desirable in culinary applications (Max, 1992).

The seed is frequently used in Indian sub-continental cuisine as an ingredient of various curry powders, and in the preparation of pickles and pastes (Srinivasan, 2006). Fenugreek seed is the main condiment in Yemen and the Arabian Gulf (Weiss, 2002). In south Asia and Egypt young leaves and sprouts of fenugreek are eaten as green vegetables, while dried leaves are used to flavour soups and curries (Duke, 1981).

In India fenugreek seed powder is one of the ingredients in making a specialty type of bread (Al-Habori and Raman, 2002; Leela and Shafeekh, 2008). Leafy stems of fenugreek are ground to produce an organic powdered food colour product to colour steamed pastries (Hu, 2005).

Fenugreek is also grown for forage. It is regarded as traditional forage in Egypt, India, Turkey and the Mediterranean region (McCormick *et al*., 2009). Many researchers have suggested that it has been used extensively in the past as hay, green fodder and silage, and as a supplement with other animal feed (Rouk and Mangesha, 1963; Hardman, 1969; Smith, 1982).

In addition fenugreek, mixed with cotton seed is fed to weaning cows to increase flow of milk (Hidvegi *et al*., 1984). It is also used to mix with inferior hay and sour hay (mildewed hay) to increase palatability (Petropoulos,

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2002). It is recommended as alternative leguminous forage in alfalfa based cattle farms since it can prevent bloating in cattle which is a disadvantage associated with use of alfalfa fodder (Acharya *et al*., 2007).

Fenugreek is reported to provide similar rumen conditions, digestibility and weight gain in cattle in comparison to alfalfa (Mir *et al*., 1998). Acharya *et al*. (2008) stated that fenugreek forage yield was identical to two cuts of alfalfa. As well, it is capable of retaining its quality profile throughout the season.

Fenugreek has a long history of use as a medicinal herb. It is extensively used in both Indian Ayurvedic medicines and traditional Chinese medicines (Tiran, 2003). In herbal medicine it is used in the treatment of diabetes (Leela and Shafeekh, 2008).

The crop species has long been used as a galactogogue to promote lactation in weaning mothers and to promote weight-gain in women (Tiran, 2003; Rgubi and Belahsen, 2006). In early times, it has been used to get diverse medicinal benefits that include wound-healing, aid in digestion, treatment of sinus and lung congestion, inflammation and infection mitigation, hair treatment, bust enhancement and aphrodisiac effects (Tiran, 2003; Leela and Shafeekh, 2008). These have led to identification of specific health benefits of this novel crop through extensive research and clinical trials (Acharya and Thomas, 2007). Health benefits that can be obtained using fenugreek comprise anti-inflammatory (Langmeade *et al.*, 2002), anti-carcinogenic (Amin *et al*., 2005; Raju and Bird, 2006), anti-nociceptive (Sur *et al.*, 2001; Hibasami *et al.*, 2003); antioxidant (McCue and Shetty 2003; Langmeade *et al.*, 2002), anti-microbial (Thomas *et al.*, 2006), anti-ulcer (Pandian *et al.*, 2002), antiobesity (Handa *et al*., 2005), anti-hyperglycemic (Basch *et al*., 2003; Ruby *et al*., 2005), anti-diabetic (Saxsena and Vikram, 2004) and hypocholesterolemic (Basch *et al*., 2003) effects.

Most of the laboratory studies and clinical trials have focused on three bioactive compounds found in fenugreek, namely, galactomannan, diosgenin and 4hydroxyisoleucine. The results of these studies indicate that most health benefits of fenugreek can be attributed to these three key biochemical components. Fenugreek as a crop provides other environmental, economic and social benefits (Moyer *et al*., 2003; Acharya *et al*., 2011).

Incorporation of the plant into the soil after harvest can serve as a nitrogen source for subsequent crops; thus fenugreek also can lower the need for application of nitrogenous fertilizers in the field; it can successfully be used in short term rotations to help maintain soil productivity (Moyer *et al.*, 2003; Acharya *et al*., 2006; 2008). Fenugreek oil is used in flavouring for many canned food and syrups.

Artificial maple syrup is flavoured with fenugreek seed extract as it imitates a maple syrup smell (Acharya *et al.*, 2008). It also has attracted the interest of the perfume trade. It is considered as a secret ingredient in some French perfumes (Petropoulos, 2002). Most fenugreeks have an indeterminate growth habit where the plants grow continuously at the shoot apex and keep producing new shoots, flowers and seed pods that mature slowly (Basu *et al.*, 2009). However, some fenugreek plants can exhibit a determinate growth habit where the shoot apices fail to branch and redirect plant resources into flowering and seed development resulting in early plant maturation. Increase in ploidy levels of somatic chromosomes often results in an increase in plant vigour, size of the plant and seeds due to larger cell size (Fehr, 1987). Basu (2006) treated "Tristar" fenugreek with colchicine. He reported that the tetraploid plants produced had larger leaves, a longer pod length, vigorous growth and larger seeds in comparison of untreated "Tristar" plants. In my study it is hypothesized that as the seeds of the tetraploid plants are larger in size than the diploid plants, the seeds may contain more oil than the seeds of diploid plants. If these tetraploid seeds are found to contain more oil, the tetraploid plants may be used to develop a cultivar suitable for commercial use for its oil.

Origin and Centre of Diversity

The divergent schools of opinion identify three probable centers of origin for the plant (Acharya *et al.*, 2008). Vavilov (1926, 1951) suggested that fenugreek originated from the Mediterranean region. However, according to De Candolle (1964) and Fazli and Hardman (1968) fenugreek has an Asian/Indian center of origin. Dangi *et al.* (2004) also proposed that the species originated in Turkey. Collections of fenugreek from different countries have been made for the purposes of taxonomic investigation and characterization. Results of these studies have revealed other probable centers of diversity for fenugreek; *e.g.*, Serpukhova (1934) proposed that Yemen and Abyssinia are centers of diversity for fenugreek, while Moschini (1958) suggested that Sicily, Tuscany and Morocco were centers of diversity for fenugreek. In another study, Yemen, the Transcaucasia region of Eurasia, Africa, Afghanistan, the China-Iran region, and India also have been proposed as diversity centers for fenugreek (Furry, 1950).

The exact number of species of the genus *Trigonella* is also unsettled. Petropoulos (2002) indicated that Linneaus suggested that about 260 species of fenugreek existed, while 97 species and 128 species have been described by Fazli (1967) and Vasil'chenko (1953), respectively. Hutchinson (1964), and Rouk and Mangesha (1963) placed about 70 species under the *Trigonella* genus. This decline in specie's number between the 18^{th} and 20^{th} centuries suggests that many species of *Trigonella* may have been lost due to lack of conservation and species domestication. Recently, Acharya *et al.* (2008) suggested that a total of 18 different currently recognized species of fenugreek may still exist.

Biological Studies

The genus *Trigonella* is made up of many species, many of which are diploid. Darlington and Wylie (1945) reported that the haploid chromosome number *(n)* of most species of the genus *Trigonella* was 8, 9, 11 or 14. However, *T. hamosa* from Egypt was found to have 16 and 44 chromosomes; *T. geminiflora* from Iran and Asia Minor, and *T. grandiflora* from Turkey also had 44 chromosomes, while *T. polycerata* which was collected in areas around the Mediterranean and in Asia was reported to have 28, 30 and 32 chromosomes, and *T. ornithopodioides* was reported to possess 18 chromosomes in its genome (Petropoulos, 2002). According to Darlington and Wylie (1945) fenugreek has a diploid chromosome number of $2n=16$ chromosomes. Singh and Singh (1976) isolated primary trisomics along with five double trisomics from the progeny of autotetraploid fenugreek which had 18 ($2n+1+1$) chromosomes. Joshi and Raghuvanshi (1968) looked for the presence of ß-chromosomes in fenugreek and demonstrated that chromosome number in the plant could increase due to their presence. Roy and Singh (1968) also produced tetraploid fenugreek by treating shoot apices with colchicine, while Basu (2006) also reported that he had produced tetraploid fenugreek ($2n+2n=32$) by treating seeds with colchicine. Fenugreek seeds require 3-10 days for germination and, follow an epigeal process where in the presence of sufficient moisture, oxygen and heat, the emergent cotyledon is bent over as it is pulled from under the surface of the soil during germination; i. e. imbibition of water into the seed results in swelling of the seed endosperm. As the cells absorb water they elongate, extending the radicle to form a primary root in the soil which eventually will develop secondary roots. According to Petropoulos (2002) protrusion of the radicle by more than 5 mm is considered a sign of fenugreek seed germination. As the hypocotyl elongates, the cotyledons are pulled above the soil to form a seedling; an epicotyl is characteristically absent. Release of the cotyledons leads to growth of the first simple leaf, followed by emergence of the first trifoliate leaf. Development of stems, flowers, pods and seeds occurs after seed germination and growth of the seedling (Petropoulos, 2002).

Fenugreek stems are erect, hollow, and circular to slightly quadrangular. The colour of the stems is dark green or dark bluish-green due to anthocyanin accumulation. Two types of stems are found in fenugreek; a monostalk without secondary shoots, and a multistalk where many shoots extend from the basal and higher nodes. In some cases where secondary shoots extend from the basal nodes, the main shoot does not differ markedly from the secondary shoots. In general, two types of flowering shoots are observed in fenugreek. The most common type shows an indeterminate growth habit and bears axillary flowers; occasionally "blind shoots" form which produce both axillary and terminal flowers which develop seeds at the tip (Petropoulos, 2002). Leaves from fenugreek are simple, distinctly petiolate and consist of three leaflets. The leaflets of fenugreek are slightly dented over the edge, oval to orbicular in shape and green in colour. The leaves are arranged in an alternate array throughout the plant (Slinkard *et al*., 2006). The root system of the fenugreek plant consists of a tap root and branched side roots arising from the main root. Like other leguminous plants fenugreek is also capable of forming root nodules containing nodule-forming bacteria (Acharya *et al*., 2006).

The flowers of fenugreek are complete, papilionaceous and triangular in shape. The genus name *'Trigonella'* comes from Latin, meaning 'little triangle' in reference to the triangular shape of the flowers (Rosengarten, 1969). The calyx consists of five sepals fused together to form a calyx tube with five teeth about as long as the tube. The corolla consists of a large standard or banner, two lateral wing petals, and two fused petals that form the keel. Each flower contains ten stamens and one pistil. The stamens are arranged on a stamen tube where nine stamen anthers are grouped and one stamen anther is free. Flower setting in fenugreek leaf axils is generally paired but, more rarely solitary and usually starts 35-40 days from seed sowing. Two types of flowers are observed in fenugreek : (i) cleistogamous flowers and (ii) aneictogamous flowers. A majority of fenugreek flowers are cleistogamous in which the keel of the flower remains closed in order to favour self-pollination. Aneictogamous flowers represent less than 1 per cent of the total number of flowers found on a plant, and offer opportunities for cross-pollination since parts of the corolla remain open (Petropoulos, 2002).

The fruit structure in fenugreek is the pod. Fenugreek pods are long, erect, pointed, sickle-shaped and slender. They have a sharp beak, 2-3 mm in length at the end (Duke, 1981). The pods are green in colour during growth of the plant but, turn yellow to yellowish brown at maturity. Fenugreek plants can be divided into two classes on the basis of number of pods per node. When there is only one pod per node the plants are considered to possess a "single" or "solitary pod", whereas if there are two pods per node a plant is referred to as having a "double" or "twin pod". In "double podded" plants the two pods project in opposite directions from the same node of the stem. In ancient Greece, fenugreek was called "ox horn" or "goat horn", probably because of the two seed pods projecting in opposite directions which resembles an ox or goat horn (Rosengarten, 1969). Each pod carries approximately 10-20 seeds and, each pod-bearing branch can produce about 2-8 pods (Petropoulos, 2002). Fenugreek seeds are yellow to golden-yellow in colour when mature, although some varieties can produce mature seeds which are green or yellow-green in colour (McCormick *et al.*, 2009). The seeds have a rectangular, square or irregular rhomboidal shape with grooves situated between the radicle and the cotyledons (Slinkard *et al.*, 2006). Fenugreek seeds are surrounded by a seed coat which is separated from the embryo by a dark translucent endosperm (Fazli and Hardman, 1968). A single layer of living tissue known as the aleurone layer lies between the seed coat and the endosperm. In mature seeds, a majority of the cytoplasm found within cells of the endosperm is made up by storage reserves consisting of 'galactomannan' (Petropoulos, 2002). Botanical and morphological characteristics of fenugreek are summarized in Table 1.

TABLE 1
Botanical and morphological aspects of fenugreek

Feature	Organ/part	Description	Dimension
Ploidy level		Mostly diploid (2n=16)	
Germination		Epigeal	
Plant habit		Erect, Straight Or Profusely branched	20-130 cm in length
Root	Main root and side root	Tap root system	15-30 cm in length
Stem	Primary shoot and secondary shoot	Branched, circular to quadrangular, green or bluish green	0.5-1.0 cm in diameter
Leaf	Leaf lamina	Simple, trifoliate, toothed on tip	1.5-4.5 x 0.8-1.5 cm
	Petiole	Pale green often anthocyanin tinged, very small	
0.5-1.1 mm			
Flower	Calyx	Five fused green sepals	6-8 x 13-19 mm
	Corolla	Papilionaceous, white, papery	
		Mono carpellary	1.5-1.9 mm
	Gynoecium	Pale green, pale bluish green	
	Stigma	Style single, pale green, pale	
	Style	bluish green	1.5-2.1 mm
	Ovary	ovary superior,	
	Androecium	Ten stamens (9+1) diadelphous	0.2-0.5 mm
Pod		Long, slender, erect, beaked at the end	0.2-0.6 × 10-19 cm
Seed		Rectangular to oval, pale brown to yellow in colour	3-5 x 2-3 mm

Cultivation

Fenugreek grows best on well-drained loamy and/or sandy soils (Petropoulos, 2002). Fenugreek is fairly salt tolerant and, can be grown in low to moderate saline soils (Abdelmoumen and Idrissi, 2009). Most favourable productivity has been obtained when fenugreek seeds are planted using a row spacing of 15-30 cm (Baswana and Pandit 1989; Gill *et al*., 2001; Korla and Saini, 2003; Slinkard *et al*., 2006). Various seeding rates have been suggested for fenugreek ranging from 15 to 25 kg/ha (Duke, 1981; Petropoulos, 2002). Inoculation of fenugreek seeds with *Rhizobium*, an aerobic, non-sporulating Gram negative nodule-forming bacterium, can improve quality and quantity of seed produced by the plant (Abdelgani *et al*., 1999). Soil nutrient management is an important practice to achieve high crop yields from fenugreek. Poor supply of plant nutrients often results in insufficient plant growth, slow growth, poor grain quality and low biomass yields. These constraints can be removed by adequate application of a fertilizer and/or manure to the soil. Fenugreek is sensitive to mineral deficiencies mainly of nitrogen (N) and phosphorus (P) (Petropoulos, 1973; Yadav and Kumawat, 2003). Deficiencies in boron (B), magnesium (Mg), and manganese (Mn) can also result in a poor or reduced seed and biomass yield (Petropoulos, 2002). Fenugreek yield can be increased by applying manure and other organic and inorganic sources of nitrogen and phosphorus to the soil (Detoroja *et al*., 1995; Khiriya and Singh, 2003). When fenugreek crops are properly inoculated with *Rhizobium meliloti*, a small amount of nitrogen can be applied as 'infantile nitrogen" at the same time as the seed is sown. This infantile nitrogen dose helps promote rapid growth of fenugreek seedlings until the root nodules can form and the *Rhizobium* bacteria in the nodules are able to fix atmospheric nitrogen in large quantities (Petropoulos, 2002). Deora *et al*. (2009) also reported that application of 20 kg/ha nitrogen in areas of Rajasthan, India significantly increased yield and nitrogen uptake by the crop, while Singh *et al.* (2008) suggested that application of 40 kg/ha nitrogen significantly improved growth, seed yield and nitrogen uptake. Slinkard *et al.* (2006) reported that nitrogen requirement for fenugreek was similar to that of lentil. Phosphorus can play an important role in crop management of fenugreek as it accelerates maturity of the crop. It also promotes transfer of substances from the stalks, leaves and other growing parts of the plant to the seed increasing their size at maturity (Petropoulos, 2002). The rate of application of phosphorus fertilizer depends mainly on the amount of available phosphorus in the soil (Petropoulos, 2002). High yields of fenugreek have been obtained by application of 40 to 50 kg inorganic P_2O_5 /ha to the soil (Tiwari *et al*., 2006; Deora *et al*., 2009). Sulphur (S) levels of 50 kg/ha also can significantly increase plant biomass and seed yield. The number of irrigation varies depending on the region where the crop is being cultivated. Petropoulos (2002) reported that application of irrigation for five times for the whole growing period of fenugreek under Indian conditions was sufficient for a successful crop.

Improvement

The improvement of fenugreek requires several important considerations, such as the genetic variation, reproductive behaviour, environmental adaptability, mode of inheritance of desirable characters, and economical importance, determine the objectives and methods chosen for the genetic improvement of a crop. Fenugreek is normally diploid in nature and that is an advantage for genetic development of this plant species, as diploid genetics has been evaluated extensively. Plant breeding has provided a large number of varieties of fenugreek. The need for fenugreek varieties with higher productivity, increased vigour, elevated amount of essential biochemical products mainly with higher diosgenin content, has driven more breeding efforts in this crop (Petropoulos, 2002). Fenugreek is a highly self-pollinated plant, though cross-pollination is reported to occur in a very little extent. Most of the breeding endeavor for the genetic improvement of fenugreek has mainly concentrated on three approaches, namely, selection, hybridization and mutation used separately or in combination (Petropoulos, 1973, 2002; Green *et al*., 1981).

Selection

For different inherited traits of fenugreek, suitable morphological and physiological characters as an index of selection can provide a reliable basis for genetic improvement through selection. Petropoulos (2002) has reported that in fenugreek presence of twin pods is an indication of a high diosgenin content in the seeds. This readily detected phenotypic selection is useful to improve fenugreek cultivar with higher diosgenin content.

Knowledge of dominant and recessively inherited traits is considered very important as it would have a direct impact on progeny behaviour of selected plants. Ahmed *et al.* (1989) produced a variety with higher diosgenin content by passively selecting for plants bearing 'twin pods'. Two procedures are commonly used for the process of selection to develop improved varieties of fenugreek : the individual (also called pedigree and pure line selection) or simple plant selection and the mass selection. Selection method is very important for producing varieties in an area where the plant is recently introduced. The first North American forage fenugreek cultivar "Tristar" has been developed by selecting suitable genotype among fenugreek germplasm, and subsequent adapting the selected genotype in North American conditions (Acharya *et al.*, 2008). A group of investigators have evaluated fenugreek landraces for the assessment of drought tolerance in Iran. Suitable genotype(s) may produce good drought tolerant fenugreek cultivar in Iran by selection and adaptation in areas of fenugreek cultivation in Iran (Sadeghzadeh-Ahari, 2009; 2010). In Australia where fenugreek is a minor crop, McCormick *et al.* (2009) have evaluated a germplasm collection of 205 fenugreek accessions for a range of phenotypic traits including seed yield. Selection approach has produced many fenugreek cultivars for various desired traits (as reviewed in Petropoulos, 2002). The cultivar RH 2701 and RH 2698 with higher diosgenin content, RH 3128 with higher seed yield, the cultivar RH 2699 with higher per cent protein, and the cultivar RH 2701 for higher amount of fixed oil were created by continuous selection process among the mother cultivars (Petropoulos, 1973, 2002).

Hybridization

Hybridization involves crossing two or more varieties of genetically different individuals. Common methods of hybridization can involve a 2-parent cross, a 3-parent cross, a 4-parent cross, a back cross, a complex cross, a convergent cross and/or a polycross (Fehr, 1993). Hybridization offers high probability for increasing variability for further selection and the greatest possibilities for improvement of fenugreek (Petropoulos, 2002). Fenugreek is a highly self-pollinated in nature, and because of its flower structure (cleistogamous) hybridization is tedious, laborious in this plant species. In fenugreek, crosses are normally made by hand. Before pollination the flowers are emasculated to avoid the risk of self-pollination, and this step is considered an important step for hybridization in fenugreek. Emasculation and manual pollination has been used effectively for crossing different lines of fenugreek (Petropoulos, 2002). The fenugreek flower should be emasculated at the end of the first floral developmental stage when the stigma of the pistil is beginning to be receptive, while the anthers of the stamens are closed and lower than the stigma. Immediate after manual pollination, a bag should be placed over the fenugreek flowers to avoid any chances of unrestricted out-crossing (Cornish *et al.*, 1983). To find individual plants that possess unique and desirable combinations of characters, at times hundreds of crosses need to be made in order to generate a successful hybrid. Many fenugreek varieties have been produced by hybridization (Edison, 1995; Saleh, 1996; Petropoulos, 2002). For instance, the high seed yielding genotypes RH 3109/32, RH 3110/37, RH 3105/15 and 3111/8, and the genotypes RH 3109/42 and RH 3110/66 with high diosgenin content were produced by crossing Fluorescent and Kenyan cultivars (Petropoulos 1973). However, this method has a major disadvantage in that undesirable character combinations often are created; these can be difficult to select out and can take many generations of selection or back crossing to eliminate.

Mutation Breeding

Mutation breeding can be used when there is little variation in an existing gene pool for a certain trait (Fehr, 1993). Four types of mutations can occur and these are (1) genome mutation; (2) structural mutations; (3) gene mutations; and (4) extranuclear mutations. Among the above mentioned mutation types, gene mutations are most desired in plant breeding (Yadav *et al.*, 2007). Gene mutations cause an alteration of gene expression by substituting one nucleotide base for another or by adding or deleting a nucleotide to a gene. Potential lines that are generated from these mutations are used to generate mutant cultivars which can be inbred in order to stabilize a new trait, and then used in hybridization programmes to introduce the trait to other plants. Mutations can either occur spontaneously or may be induced artificially and, are a valuable tool for crop improvement. Mutation breeding has been successfully utilized to bring desirable genetic changes in cultivars of legume crops (Sigurbjornsson and Micke, 1974; Sigurbjornsson 1983; Toker *et al.*, 2007) e. g. Manha *et* *al*. (1994) used mutation breeding to increase the diosgenin content in *T. corniculata* (a close relative of fenugreek). Various mutagenic chemicals or irradiation processes can be used to introduce mutations into plants. Ionizing irradiation that includes electromagnetic radiation and particulate radiation (for example, x-rays, gamma rays, alpha particle and beta particle), is used to artificially increase the rate of spontaneous mutations. The chemical mutagens belong to different groups such as base analogs, acridine dyes, nitrous acid, hydroxylamine and alkylating agent. Mutation breeding is more adaptable for inducing recessive genes than dominant genes (Toker *et al*., 2007). Micke and Donini (1993) suggested that as mutations are mostly recessive, they cannot be selected for until the second generation, whereas dominant mutations occur at low frequencies and can be selected for in the first generation. Although mutations are beneficial for producing variability in populations, the treatments themselves can be detrimental and can cause a reduction in germination, growth rate, plant vigour, and pollen and ovule fertility in a plant. Singh (2005) stated that mutations could be recurrent and that the same gene(s) of a plant species may be induced to mutate again and again. Moreover, mutations generally have pleiotropic effects due to closely linked gene(s). Mutation breeding has been utilized to improve fenugreek genotypes for various traits. Both spontaneous and induced mutations have been exploited to generate suitable cultivars of fenugreek. A number of fenugreek mutants from spontaneous mutations have been isolated and are in use all over the world (Petropoulos, 1973; Singh and Singh, 1974; Laxmi *et al.*, 1980; Laxmi and Datta, 1987). The spontaneous mutant RH 3129, characterized with high proportion of twin pods and with high diosgenin content was isolated from the Moroccan cultivar. The cultivar RH 3112 with higher diosgenin content, RH 3112 with higher seed yield, the cultivars RH 3112 and RH 3118 with higher per cent protein, cultivars with higher amount of fixed oil and cultivars with early maturity trait were created by induced mutation process (Petropoulos, 1973, 2002; Laxmi *et al*., 1980). Basu (2006) has generated mutant populations by treating seeds from the North American cultivar “Tristar” with EMS. These populations were reported to exhibit variability in height, seed yield, seed number per pod, biomass yield, total number of pods and number of twin pods.

CONCLUSION

New fenugreek cultivars with improved seed yield and enhanced levels of chemical constituents can be developed for improving efficiency of its use both for cattle and humans. The variability can be produced in fenugreek through hybridization and mutation breeding and this variability can be used for production of new and improved cultivars or as a good germplasm source for improvement of fenugreek with desired trait(s) in India and other parts of the world.

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