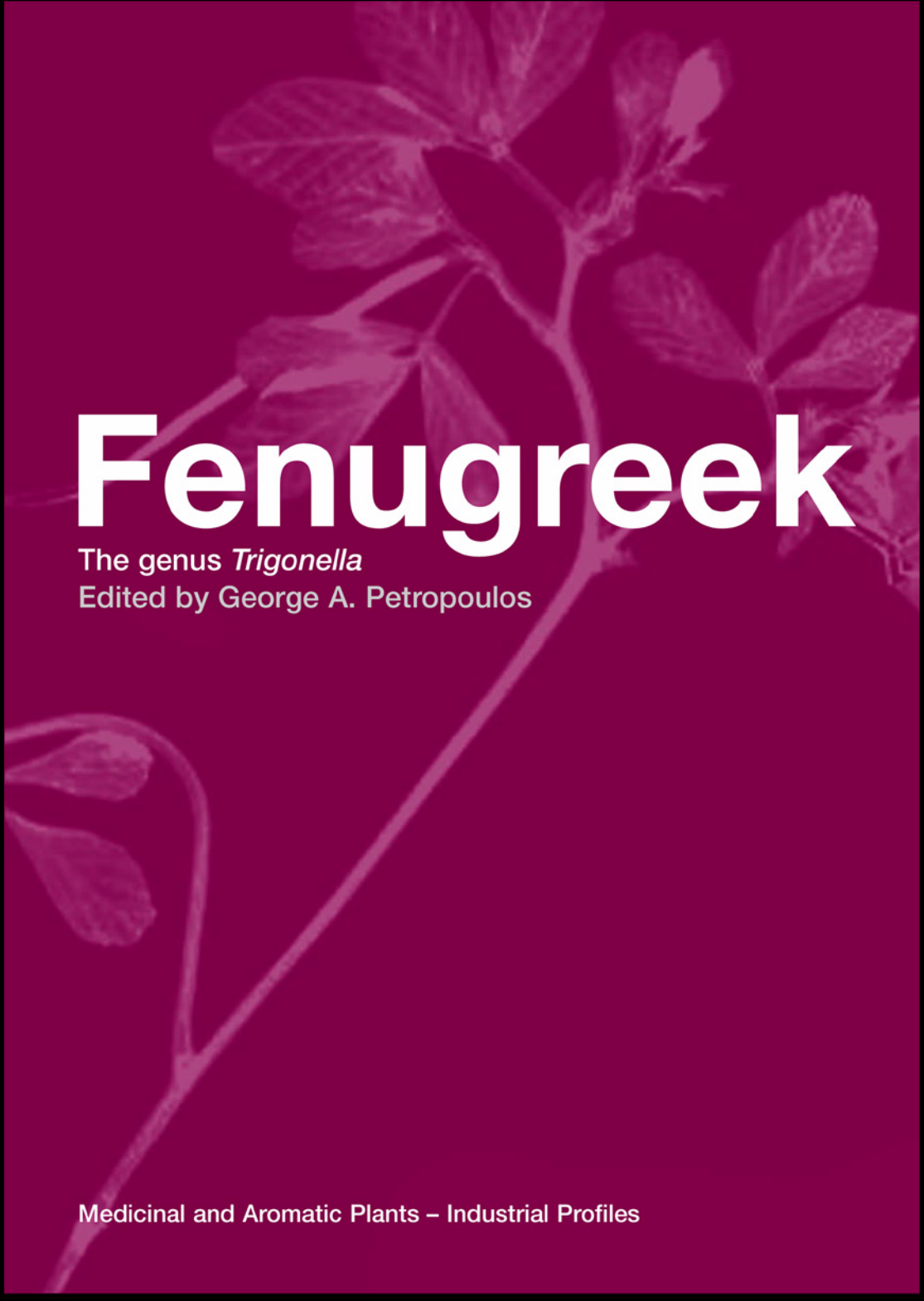

Fenugreek

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Fenugreek

The genus *Trigonella*

Edited by
Georgios A. Petropoulos

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Preface to the series

There is increasing interest in industry, academia and the health sciences in medicinal and aromatic plants. In passing from plant production to the eventual product used by the public, many sciences are involved. This series brings together information which is currently scattered through an ever increasing number of journals. Each volume gives an in-depth look at one plant genus, about which an area specialist has assembled information ranging from the production of the plant to market trends and quality control.

Many industries are involved such as forestry, agriculture, chemical, food, flavour, beverage, pharmaceutical, cosmetic and fragrance. The plant raw materials are roots, rhizomes, bulbs, leaves, stems, barks, wood, flowers, fruits and seeds. These yield gums, resins, essential (volatile) oils, fixed oils, waxes, juices, extracts and spices for medicinal and aromatic purposes. All these commodities are traded worldwide. A dealer's market report for an item may say 'Drought in the country of origin has forced up prices'.

Natural products do not mean safe products and account of this has to be taken by the above industries, which are subject to regulation. For example, a number of plants which are approved for use in medicine must not be used in cosmetic products.

The assessment of safe to use starts with the harvested plant material which has to comply with an official monograph. This may require absence of, or prescribed limits of, radioactive material, heavy metals, aflatoxin, pesticide residue, as well as the required level of active principle. This analytical control is costly and tends to exclude small batches of plant material. Large scale contracted mechanized cultivation with designated seed or plantlets is now preferable.

Today, plant selection is not only for the yield of active principle, but for the plant's ability to overcome disease, climatic stress and the hazards caused by mankind. Such methods as *in vitro* fertilization, meristem cultures and somatic embryogenesis are used. The transfer of sections of DNA is giving rise to controversy in the case of some end-uses of the plant material.

Some suppliers of plant raw material are now able to certify that they are supplying organically-farmed medicinal plants, herbs and spices. The Economic Union directive (CVO/EU No 2092/91) details the specifications for the *obligatory* quality controls to be carried out at all stages of production and processing of organic products.

Fascinating plant folklore and ethnopharmacology leads to medicinal potential. Examples are the muscle relaxants based on the arrow poison, curare, from species of *Chondrodendron*, and the anti-malarials derived from species of *Cinchona* and *Artemisia*.The methods of detection of pharmacological activity have become increasingly reliable and specific, frequently involving enzymes in bioassays and avoiding the use of laboratory animals. By using bioassay linked fractionation of crude plant juices or extracts, compounds can be specifically targeted which, for

example, inhibit blood platelet aggregation, or have anti-tumour, or anti-viral, or any other required activity. With the assistance of robotic devices, all the members of a genus may be readily screened. However, the plant material must be *fully* authenticated by a specialist.

The medicinal traditions of ancient civilizations such as those of China and India have a large armamentaria of plants in their pharmacopoeias which are used throughout South-East Asia. A similar situation exists in Africa and South America. Thus, a very high percentage of the World's population relies on medicinal and aromatic plants for their medicine. Western medicine is also responding. Already in Germany all medical practitioners have to pass an examination in phytotherapy before being allowed to practise. It is noticeable that throughout Europe and the USA, medical, pharmacy and health related schools are increasingly offering training in phytotherapy.

Multinational pharmaceutical companies have become less enamoured of the single compound magic bullet cure. The high costs of such ventures and the endless competition from 'me too' compounds from rival companies often discourage the attempt. Independent phytomedicine companies have been very strong in Germany. However, by the end of 1995, eleven (almost all) had been acquired by the multinational pharmaceutical firms, acknowledging the lay public's growing demand for phytomedicines in the Western World.

The business of dietary supplements in the Western World has expanded from the health store to the pharmacy. Alternative medicine includes plant-based, products. Appropriate measures to ensure the quality, safety and efficacy of these either already exist or are being answered by greater legislative control by such bodies as the Food and Drug Administration of the USA and the recently created European Agency for the Evaluation of Medicinal Products, based in London.

In the USA, the Dietary Supplement and Health Education Act of 1994 recognized the class of phytotherapeutic agents derived from medicinal and aromatic plants. Furthermore, under public pressure, the US Congress set up an Office of Alternative Medicine and this office in 1994 assisted the filing of several Investigational New Drug (IND) applications, required for clinical trials of some Chinese herbal preparations. The significance of these applications was that each Chinese preparation involved several plants and yet was handled as a *single* IND. A demonstration of the contribution to efficacy, of *each* ingredient of *each* plant, was not required. This was a major step forward towards more sensible regulations in regard to phytomedicines.

My thanks are due to the staffs of Harwood Academic Publishers and Taylor & Francis who have made this series possible and especially to the volume editors and their chapter contributors for the authoritative information.

Roland Hardman

Preface

In recent decades increasing attention has been paid in utilization and consumption of natural and traditional products (foods, flavours, colours, perfumes, phytotherapeutics etc.), because modern scientific knowledge and technologies have revealed that many chemical products of synthetic origin of this kind are responsible for a lot of new hazards and disorders for human beings.

The plant species of the genus *Trigonella* and especially that of *T. foenum-graecum* L. (fenugreek) is a good example, which has been used traditionally to cover such human needs. Fenugreek is cultivated all over the world and mainly in India and the Mediterranean countries as chemurgic, cash and good renovator of soil crop and as a multi-purpose legume, is used as forage, food, spice, perfume, insect repellent, dye, herbal medicine etc.

The biological and pharmaceutical actions of fenugreek are attributed to the variety of its constituents including steroids (diosgenin), alkaloids (trigonelline), flavonoids (luteolin), coumarins, aminoacids (hydroxyisoleucine), mucilage (galactomannan), volatile constituents (HDFM), fixed oils and other substances.

Species of the genus *Trigonella* and particularly fenugreek are well known for their pungent aromatic, high nutritive and multi-therapeutical properties and serve culinary, medicinal and industrial purposes.

As there is today an emerging change in food habits preference for natural colouring, flavouring and revolution in packaging, fenugreek could contribute to this direction, as its seeds are a component of many curry preparations and are used to colour and flavour food, stimulate appetite and help digestion.

Fenugreek is one of the oldest known medicinal plants from ancient times and even Hippocrates thought highly of it. Fenugreek seeds which are described in the Greek and Latin Pharmacopoeias are said to have anti-diabetic activity and hypocholesterolaemic effects and have been reported to possess a curative gastric anti-ulcer action and anti-fertility and anti-nociceptive effects. The therapeutic efficacy of fenugreek extracts in providing sedation has been proved by many pharmacological and clinical experiments. So, many of its actions as remedy have been confirmed and the mechanisms of their activity are being studied. Also, some other properties of fenugreek which have been reported but received less attention include anti-cancer, anti-bacterial, anthelmintic, anti-cholinergic, wound healing activities, etc.

Fenugreek seed as a source of diosgenin, that is the base for the production of the oral contraceptives and rich in protein and fixed oils, could make a two-fold economic contribution to the world's increasing population problems, by assisting in birth control and at the same time, providing additional food, especially for people, where meatless diets are customary for cultural and religious reasons.

Finally, it is doubtful if any other plant crop, while saving energy by fixation of atmospheric nitrogen, has such potential for making a major contribution to the world's food supply, to reduce hunger, improve health care and help population control.

Georgios A. Petropoulos

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I would like to thank the numerous people who helped to make this work possible. In particular I appreciate Dr R. Hardman for his continuous advice and helpful suggestions, Dr Anthony Dweck, Research Director of Peter Black Toiletries and Cosmetics Ltd. for providing a data base of references on the use and history of fenugreek and Demetrios Cotarides for his assistance with the drawings.

Finally I am indebted to my family for their continuous encouragement.

1 Introduction

Georgios A. Petropoulos

This introductory chapter deals with a brief analysis of the history, world cultivated area, main uses, needs for research and future trends of the most important species of the genus *Trigonella* and especially that of *T. foenum-graecum* (fenugreek).

History

Plants of the genus *Trigonella* and particularly of the cultivated species *T. foenum-graecum* (fenugreek) were known and used for different purposes in ancient times, especially in Greece and Egypt (Rouk and Mangesha, 1963). In North Africa it has been cultivated around the Saharan oases since very early times (Duke, 1986).

Hidvegi *et al*. (1984) report that references to the utilization of fenugreek are found as far back as 1578, when detailed information on the plant is given in the famous Kolozsvar Herbarium compiled by Melius (1578). In this Transylvanian Herbarium the 'warming and very drying' nature of fenugreek and its antique sources are emphasized. Fenugreek seeds were found in the tomb of Tutankhamun (Manniche, 1989). Portius Cato, a Roman authority on animal husbandry in the second century BC ordered *foenum-graecum*, that was today's fenugreek, to be shown as fodder for oxen (Fazli and Hardman, 1968). Antiochus Epiphanes, King of Syria, and all those who entered the gymnasium to witness the games were anointed with perfumes from golden dishes that contained fenugreek and other aromatic plants (Leyel, 1987). Leaves of fenugreek were one of the components of the celebrated Egyptian Incense *Kuphi*, a holy smoke used in fumigation and embalming rites (Rosengarten, 1969). Miller (1969) reports that fenugreek was a spice plant mentioned in classical texts.

Historically, fenugreek is one of the oldest known medicinal plants and even Hippocrates thought highly of it (Lust, 1986; Schauenberg and Paris, 1990). There is a prescription for the rejuvenational properties of fenugreek of Pharaonic date (Manniche, 1989). Fenugreek was first introduced into Chinese medicine in the Sung dynasty, AD 1057 (Jones, 1989). Dioscorides, a greek physician of Anazarbus in Cilicia, father of Pharmacology, at AD 65, in his examination of the definition and function of spices in his Materia Medica, writes that fenugreek is an active compound of ointments (Miller, 1969). He also describes a concoction of fenugreek seeds to treat the vulva. In the seventeenth century fenugreek seeds were recommended to help expel the placenta of women after giving birth (Howard, 1987). The herb has long been a favourite of the Arabs and it was studied at the School of Salermo by Arab physicians (Stuart, 1986). Fenugreek was known and cultivated as forage in ancient Greece. Theophrastus had given it the greek names *Βουκέρας* (Voukeras) and *Τήλις* (Tilis) and the oil produced from it was called *τήλιον έλαιον* (oil of Tilis). Probably fenugreek is one of the forages known to have been cultivated before the era of recorded history. As a fodder plant, it is said to be the Hedysarum of

Theophrastus and Dioscorides (Leyel, 1987). Dioscorides also says that the Egyptians called it 'itasin' (Manniche, 1989). In the Middle Ages it is recorded that fenugreek was added to inferior hay, because of its peculiar pleasant smell (Howard, 1987).

Fenugreek was introduced into Central Europe at the start of the ninth century (Schauenberg and Paris, 1990), according to Fazli and Hardman (1968) Charlemagne encouraged its cultivation in this area. Rosengarten (1969) reports that the Romans obtained the plant from the Greeks, and that it became a commercial commodity of the Roman Empire (Miller, 1969), while Stuart (1986) and Howard (1987) support the contention that Benedictine monks introduced the plant into medieval Europe. However, it is not mentioned in any herbal literature until the sixteenth century, when it was recorded as grown in England.

Cultivated area

Furry (1950) describes five cultivated species of the genus *Trigonella* as: *T. foenum-graecum, T. caerulea, T. polycerata, T. monspeliaca* and *T. suavissima*, while in Flora European (Ivimey-Cook, 1968) only two species to be cultivated are reported: *T. foenum-graecum* and *T. caerulea*; the last one has also been reported as cultivated by Uphof (1968). However, statistics of the cultivated area for forage and seed production are not available, except for the *T. foenum-graecum* (fenugreek). Fenugreek has been reported as a cultivated crop in Portugal, Spain, United Kingdom, Germany, Austria, Switzerland, Greece, Turkey, Egypt, Sudan, Ethiopia, Kenya, Tanzania, Israel, Lebanon, Morocco, Tunisia, India, Pakistan, China, Japan, Russia, Argentine and the United States of America (Rouk and Mangesha, 1963; Fazli and Hardman, 1968; Rosengarten, 1969). At the present time fenugreek is an important cash crop in India (the leading fenugreek producing country), Morocco, China, Pakistan, Spain, Tunisia, Turkey, Lebanon, Israel, Egypt, Ethiopia, Kenya, Tanzania etc. (Smith, 1982; Edison, 1995).

As far as the world cultivated area of fenugreek and the annual production of seed are concerned, statistics are very limited and scattered, as the area seeded with fenugreek is relatively small and not recorded by the agricultural statistics of different countries. In spite of this, the following analysis based on the exported quantities of the principal producing countries, the domestic use of fenugreek and the existing statistics of the cultivated area for some countries, represents a reasonably accurate assessment of the world production and cultivated area of fenugreek.

So, taking into consideration that:

1 The cultivated area of fenugreek in India, an average for the last twenty years (1975–95), accounts for 34,534 ha with a production of 41,530 tons and an export of 4203 tons, that is domestic use accounts for 90 per cent of the production (Anonymous, 1996).
2 Recently, there has been an increase in the export of fenugreek from India: in 1994–95 it accounted for 7,956 tons (Anonymous, 1996). According to Edison (1995) India claims 70–80 per cent of the world export in fenugreek. This means that the world export of fenugreek until 1995 fluctuated around 10,500 tons, and export from the other countries mentioned above can be estimated as approaching 2,700 tons. According to the forementioned considerations, the cultivated area from these countries accounts for about 22,000 ha with a production of 26,700 tons.
3 These considerations permit us to estimate that in the world, the annually cultivated area of fenugreek amounts to roughly 57,000 ha with a seed production of 68,000 tons.

The wide distribution of fenugreek is indicated by the large number of names that it has in several languages, with Arabic, Indian, Sanskrit, Greek and Latin roots. It has many local names (see Chapter 2).

Uses

Almost all the species of the genus *Trigonella* are strongly scented (Anonymous, 1994) and most of them are used as insect repellent (Chopra *et al*., 1949; Duke, 1986) for the protection of grains, cloths, etc.; while the essential oils of some of them are a very valuable raw material for the perfumery (Fazli and Hardman, 1968).

Most of these species (*T. foenum-graecum, T. caerulea, T. corniculata, T. hamosa, T. balansae, T. laciniata, T. marginata, T. occulta, T. anguina, T. arabica, T. glabra, T. stelata, T. coerulenses, T. spinosa, T. sibthorpii, T. spicata*, etc.) are rich in protein, vitamins and amino acids (Hidvegi *et al*., 1984), while the seeds and the fresh material are used as forage, especially for cattle, mainly in the eastern Mediterranean area. In particulars *T. arabica* and *T. stelata* are foraged by animals in the desert areas of the Sahara, Palestine and the Dead Sea (Allen and Allen, 1981).

Several species of *Trigonella* (*T. foenum-graecum, T. balansae, T. corniculata, T. maritima, T. spicata, T. coerulea, T. occulta, T. polycerata, T. calliceras, T. cretica*, etc.) contain some interesting, from the pharmaceutical point of view, phytochemical compounds belonging to steroids, flavonoids and alkaloids (Anonymous, 1994) and efforts are being made to use some of them as a source of these constituents, especially of the steroidal diosgenin (Hardman, 1969). Seeds of these species also yield choline, a semicrystalline white saponin, a lactation-stimulating oil and various gums (Allen and Allen, 1981).

The alkaloid trigonelline has been isolated from plant parts, mainly seeds of *T. caerulea, T. cretica, T. foenum-graecum, T. lilacina, T. radiata, T. spinosa* (Allen and Allen, 1981) and *T. polycerata* (Mehra *et al*., 1996). This pyridine alkaloid is known for its hypoglycemic and hypocholesterolaimic properties (Mehra *et al*., 1996).

Some of these species are also used in traditional as well as veterinary medicine for different diseases, alone or in combination with other remedies: *T. occulta, T. polycerata* and *T. uncata* are included among the Indian herbals along with *T. foenum-graecum* (Hardman and Fazli, 1972).

The well developed endosperm of most of the species is rich in the polysaccharide mucilage (galactomannan) that has wide uses in industry including in pharmaceuticals and cosmetics.

In some parts of Pakistan and India *T. corniculata* is used for different purposes: its young tops are currently used as a green vegetable, the dried herb as a flavouring agent and its seeds for the treatment of swellings and bruises (Hardman and Fazli, 1972).

Chopped foliage of the species *T. caerulea* (sweet trefoil) is used in Switzerland for flavouring green cheeses: *Schabzieger, Chapsiger* and *Serred Vert*. In some parts of Tirol sweet trefoil is used for flavouring the bread called *Brotw*^{n}*rze*. Sweet trefoil is also employed as a condiment in soups and potatoes, as a decoction for tea, and as flavouring in Chinese tea (Allen and Allen, 1981). Hardman and Fazli (1972) report that in Switzerland sweet trefoil has also been used in herbal medicine.

The varied and numerous special uses of the species *T. foenum-graecum* (fenugreek) are described in more detail in Chapter 4.

Need for research

This section reports on *T. foenum-graecum* (fenugreek), which is the only widely cultivated species of the genus *Trigonella*.

Fenugreek faces problems that keep it from reaching its full potential. Recently Edison (1995) reported that in India there are problems in improving the productivity of spices, one of which is fenugreek, due to:

- lack of advanced breeding methods for creation of high yielding varieties
- inherent inability expressed through poor and slow germination
- lack of adequate genetic variability
- lack of research based on crop rotation and cropping system
- inadequate techniques for diagnostic tests and screening for host resistance
- poor methods of nutrition and general management, particularly in light and sandy soils
- lack of incentives for seed production and poor storage facilities
- inadequate production and delivery systems of high quality planting material
- lack of facilitation of import genetic material for evolving new and improved varieties.

In order to overcome these problems, the following strategies have been under consideration (Edison, 1995):

- investigation of yield and loss forecasting models for both the producer and the trader
- import/exchange of valuable germplasm and promising varieties from the main regions of the Mediterranean in order to overcome the yield barrier
- production, distribution and delivery guaranteed planting material (certified seeds)
- identification on the basis of region suitable variety and choosing the best one together with the package of practices
- organization of demonstration fields
- motivating farmers to apply improved management techniques
- organizing cooperative markets and conducting producer–buyer–trader meetings in respective centres.

In India, in the last fifty years, eight research and development plans have been established for spices, including fenugreek, through a wide network of research institutions and state universities under the All India Coordinated Research Project (A.I.C.R.P, Edison, 1995). Similar problems are faced by fenugreek growers in other fenugreek producing countries throughout the world. Further, the necessary research information is not available to help them make correct decisions regarding existing problems.

It is a safe assumption, however, that all these problems can be solved by approaches through a well planned research programme taking into consideration the research priorities for fenugreek.

Projections must relate to comparative high yields, lower production costs, development of improved and better adapted varieties characterized by higher quantity and better quality, investigation of technological changes in production and utilization techniques and development of improved management practices; in general, fenugreek is grown under poor management conditions (Paroda and Karwasra, 1975).

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. The very high yields recorded under experimental conditions (Petropoulos, 1973; Evans, 1989) and the reported big differences in seed yield among twenty-nine ecotypes (Banyai, 1973) suggest that it is not taking full advantage of the yield capacity of many fenugreek varieties.

Production cost is increasing and research must help the farmer, so that the money invested in increasing crop yields is reflected in the amount and the quality of collected seed or forage. Adaptable and improved genotypes and varieties are needed, suitable for: mechanization, no scattering of seed, high yielding and seed content characterized by high active constituents (diosgenin, protein etc., Cornish *et al*., 1983), resistant to diseases, pests and drought. However, fenugreek is generally considered an unpretentious plant and rarely subject to diseases and pests (Sinskaya, 1961; Hardman, 1969; Duke, 1986).

The creation of a genotype without the peculiar smell that causes the tainting of animal products (milk, meat) and its derivatives (Molfino, 1947; Talelis, 1967) for an unlimited parallel use as forage for better valorization of the crop, should be another research objective. This objective should be based on the condition that progress in this goal is not offset by losses in some other valuable crop attributes.

There is also a need for research in the investigation and adaptation of new, more rapid and accurate analytical methods, for isolation and characterization of steroids, for analysis and utilization of the flavour extracts, the nutritive value of protein, the bread making ability of seed, and in general for the analysis and utilization of the other active constituents of fenugreek. The increase of the diosgenin content during the growing period through fertilization (Kozlowski *et al*., 1982), use of herbicides (Mohamed, 1983) and other cultivation methods, as well as post harvest treatments through fermentation (Evans, 1989), incubation (Elujoba and Hardman, 1985), enzymes (Elujoba and Hardman, 1987), hormonal influence (Hardman and Stevens, 1978), tissue culture (Stevens and Hardman, 1974) and other biotechnological methods are some of the other critical areas.

The identification of the mechanisms of fenugreek galactomannan biosynthesis (during seed development) and hydrolysis (during germination) in order to produce transformed fenugreek plants, where the ratio Gal./Man. is appropriate for industrial use (Reid and Meier, 1970; Li *et al*., 1980), needs further research efforts. The complete mechanization of sowing, harvesting, threshing and cleaning of fenugreek seed to increase yields and reduce the cost of production are also critical areas for research. This will help scientists to develop, through integrated research management programmes, means to establish optimum levels of fenugreek production and to optimize the yield of active constituents per unit area for a wide range of environmental and other conditions and for specific farming situations.

Future trends

The usefulness of fenugreek as a commercial and chemurgic crop is now being recognized, not only as a break-crop for cereal areas, where it is a very good soil renovator (Duke, 1986), but as forage, medicinal plant, source of diosgenin (the most important raw material for the steroid industry) and other constituents (protein, fixed oils, mucilage), as well as for culinary uses: as a traditional and modern flavouring.

Fenugreek is grown in about 57,000 ha with a production of 68,000 tons. Higher seed yield per hectare will be obtained through superior varieties and better management practices and may contribute to an increase in the crop worldwide; however, in India during the eighth plan of research and development, the overall growth rate of spices, including fenugreek, was 8 per cent. Fenugreek with the other spices, is a major source of foreign exchange for India (Edison, 1995).

From the world production of fenugreek it can be estimated that more than half is produced in India. India consumes domestically 90 per cent of its own production and claims 70–80 per cent of the world exports in fenugreek (Edison, 1995). Although the market for fenugreek is considerably small, there is a world incremental growth rate in demand of 4 per cent