INTRODUCTION

The aroma-yielding plants or their distilled volatile oils are known to have been, and in many cases, still are in use in various human activities, from religious ceremonies and adornments, to remedies and personal use, even before the recorded history of mankind (Hay and Waterman 1993). The Vedic literature, written in India around 2000 BC, lists hundreds of aromatic substances including cinnamon, ginger and sandalwood, and the Rig Veda describing their uses for religious and medical purposes. Over 3,000 plants have been identified as essential oil-bearing plants out of a large number of plants belonging to 87 angiospermic families. The essential oil in these plants, contained in leaves and/or reproductive structures and sometimes in the stem and roots, is usually recovered by steam distillation of the relevant plant parts. Commercially, these plants are traded as fresh or dried herbs or as the oil distilled from them, depending upon local agro-technology, or depending on the specifics end uses of the drug. Besides this, the essential oils extracted from some of the medicinal plants are used in synthesis of organic compounds of high economic value (The Wealth of India 1992; Sangwan et al. 2001). Because of bearing active flavour and fragrant ingredients of perfumery and cosmetic concoctions, the demand for the essential oils is rapidly increasing. These oils are also used in hygiene and health care formulations including fringe medicines (e.g. aromatherapy). The world trade regarding essential oils is expected to continue to expand tremendously in the foreseeable future, as a consequence of the growing number and preferences of consumers and a wide spectrum of the uses of these compounds (The Wealth of India 1992; Weiss 1997; Sangwan et al. 2001; Rogachav et al. 2006).

Among various plants evaluated for essential oil, Japanese mint (Mentha arvensis L.) and lemongrass [Cymbopogon flexuosus (Staud.) Wats.] have been recognized as rich source of essential oil. Mentha arvensis, commonly known as menthol mint, corn mint or Japanese mint, is a species of mint family (Lamiaceae) and is considered native of the temperate regions of Europe and Western and Central Asia, and that of Eastern Siberia. Mentha species are known as kitchen herbs from time immemorial. Japanese mint constitutes the most important source of therapeutic agents used in the modern and traditional systems of medicine. It is a stimulant, tonic,
vermifuge, anti-spasmodic, diaphoretic, stomachic, carminative, antiviral, antifungal, antibacterial and choleretic agent. Mint oil has wide applications in pharmaceutical, agrochemical and flavour industries all over the world (The Wealth of India 1992; Duriyaprapan et al. 1986; El Keltawi and Croteau 1987; Farooqui and Sharma 1988). Mentha oil is the main source of menthol (Fig. 1) that is a waxy and crystalline substance widely used to relieve minor throat irritations, and sunburns as it provides cooling sensation. It is used in oral hygiene products like mouthwash, toothpaste, mouth and tongue-spray, and also as a food flavour agent.

Lemongrass is a perennial, multi-harvest and sweet-smelling grass. It is the resource of lemongrass oil, which is an excellent source of natural citral (Fig. 2). The natural citral is used as an essential raw material for the synthesis of β-ionone that is used for the synthesis of a number of useful aromatic compounds, including vitamin-A. Lemongrass oil is also used as a key substitute for ‘Cod liver oil’, as flavour agent for soft drinks. The oil is also used as disinfectant to wash vegetable or salads. Utilization of lemongrass in Ayurvedic preparations like balm is also increasing. The crop is cultivated to obtain citral-rich essential oil used in the perfumery, cosmetic and pharmaceutical industries (Singh et al. 1989; Misra and Srivastava 1991; The Wealth of India 1992; Thomas 1995; Samiullah et al. 1998). Moreover, lemongrass oil has a promising anticancer activity and causes reduction in tumor cell viability by activating the apoptotic mechanism (Sharma et al. 2009).

Plants, whose secondary metabolites are valued for their characteristic aromatic or therapeutic attributes are more worth trading than the traditional food, forage or fibre crops (Sangwan et al. 2001). There is good demand for the essential oils from USA, UK, France, Germany, and also from far eastern countries like Japan, Singapore and Hong Kong. The estimated demand for the essential oils for the year 2009-2010 is 28, 900 tons. The growth rate of essential oil trade normally is of 9% and 25% for domestic and export market, respectively. In India, the supply gap is of about 12,000 tons (Weiss 1997). This pressure is worth attracting the attention of plant scientists to increase the essential oil production of these plants.
Figure 1. Structure formula of menthol

Figure 2. Structure formula of citral
Thus, the only dependable and sustenable alternative appears its large scale cultivation on agro-scientific lines. Regarding cultivation of lemongrass, the application of mineral nutrients and PGRs has reached its maximum extent in order to realize the potential of plants. At present, an ultra-recent radiation-mediated technique has emerged to increase the productivity of these plants. According to this technique, gamma rays irradiations are employed to degrade and lower down the molecular weight of some natural polysaccharides like alginates, chitosan and carrageenan into small sized oligomers. These oligomers, when applied to plants in the form of foliar sprays, elicit various kinds of biological and physiological activities, including promotion of plant growth, seed germination, shoot elongation, root growth, flower production, suppression of heavy metal stress, etc. Furthermore, application of these oilgomers can shorten the harvesting period of various crops and helps in reducing the use of insecticides and chemical fertilizers. (Hadwiger 1994; Zakaria et al. 1995; Ohta et al. 1999; Hien et al. 2000; Ahni et al. 2001; Kume et al. 2001; Cabalfin 2002; Hafeez et al. 2003; Luan et al. 2003).

Out of several natural polysaccharides, sodium alginate (SA) is a polysaccharide with its large quantity available in nature. It is a linear polyuronic acid hydrocolloid produced by some brown sea-weeds and certain species of bacteria (Day 1998). SA is the major structural polysaccharide of marine brown algae. It has combined features of linear copolymers of L-guluronic acid and D-mannuronic acid units (Xu et al. 2006) (Fig. 3). Its radiolytically (using gamma rays) degraded oligomers are also reported to have been used as plant growth promoters in the form of foliar sprays (Kume 2006; Mollah et al. 2009; Khan et al. 2010; Idrees et al. 2010a; Sarafaraz et al. 2010).

Keeping in mind the amazing properties and usefulness of essential oil of Mentha and lemongrass and effect of the irradiated polysaccharides on the crops, there arises a question “Could we enhance the foliage, essential oil and production of active constituents of these plants by using this novel technique?” Owing to the paramount significance of application of irradiated sodium alginate (ISA) in radiation biology and agriculture, the author decided to study the effect of these degraded oligomers as dilute aqueous foliar sprays on proposed plants to test whether ISA could augment the plant performance in terms of essential oil and its active constituents?
Figure 3. Structural formula of sodium Alginate (a) Polysaccharide form (b) Oligosaccharide form and Monomeric form (c)
To achieve this goal, two pot and two field experiments were conducted on these crops.

The aims of these four experiments were as follows:

1. To investigate whether the foliar application of dilute aqueous solution of irradiated sodium alginate (ISA) could enhance growth, yield and quality attributes of *Mentha arvensis* L. in pot culture (Experiment 1).
2. To find out whether foliar application of ISA could enhance growth, yield and quality attributes of *Cymbopogon flexuosus* (Steud.) Wats. in pot culture (Experiment 2).
3. To confirm whether foliar application of ISA could enhance growth, yield and quality attributes of *Mentha arvensis* L. under field condition (Experiment 3).
4. To confirm whether foliar application of ISA could enhance growth, yield and quality attributes of *Cymbopogon flexuosus* (Steud) Wats. under field condition (Experiment 4).