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Review Article

CUMULATIVE ROLE OF POLYSACCHARIDES IN MEDICINAL PLANTS : CURRENT UNDERSTANDING & FUTURE PROSPECTS

Abu Bakr Ahmad Fazili[1], Mohammad Afaan Fazili[2] , Samee Ullah[1,3], Eijaz Ahmed Bhat[4] and Yuanda Song[1*]

[1]Colin Ratledge Center for Microbial Lipids, School of Agriculture Engineering and Food Science, Shandong University of Technology, Zibo 255049 China.

[2]Advanced Plant Physiology Section, Department of Botany, Aligarh Muslim University, Aligarh, Uttar Pradesh, 202002, India.

[3]University Institute of Diet and Nutritional Sciences, The University of Lahore, Lahore, 54000, Pakistan.

[4]Life science institute, Zhejiang University, Hangzhou, Zhejiang, 310058, P.R. China

*Author for Correspondence: ysong@sdut.edu.cn

Abstract

Polysaccharides play a very vital role in plant's life. Different marine polysaccharides like sodium alginate, chitosan, and carrageenan have proved to be economical in enhancing the productivity of agricultural crops. Radiation degraded polysaccharides act as elicitor molecules for enhancement of various biological and physiological roles in plants. However, the exact mechanism underlying the role of degraded polysaccharides as elicitor molecules in plants body is still unknown to the scientific world. This review cites the role of various degraded polysaccharides in ameliorating the productivity and growth of specific medicinal plants with special reference to mint family.

***Keywords* :** Polysaccharides, sodium alginate, chitosan, carrageenan, elicitor, medicinal plants

Introduction

Medicinal plants are used as a source of natural medicines. This practice has been in use since prehistoric times. They may be used directly on large scale as therapeutic agents, dyes, or organic compounds for the synthesis of drugs, teas or in other extracted forms for their natural chemical constituents (Qureshi *et al.,* 2005). For medicinal purposes from towering trees to lichens it's anticipated that approximately seventy thousand plant species have been used. Plants (e.g. mint, garlic, turmeric, fennel, etc.) are directly used as a medicine by number of countries around the world. Plant metabolites include primary metabolites and secondary metabolites. Isolation and production of traditional drugs is provided by herbs. Presence of diverse chemical constituents of secondary metabolites contributes to establishment of curative properties of medicinal plants. Essential oils (EO's), alkaloids, glycosides and corticosteroids form different groups of plant metabolites based on their composition. On these bases demand of medicinal plants has exponentially enhanced in the global markets. (Weiss, 1997). Although there is rich biodiversity in various countries around the world, the mounting demand is putting a grave pressure on the currently available resources. Hence growing of medicinal plants is to be encouraged in order to meet upcoming future needs. Due to the important uses of the essential oil (EO's) of these plant, efforts must be made to increase the content of the oil of these plants. In this review we focus on role of polysaccharides naturally present in plants in enhancing and polishing the agricultural productivity of medicinal plants with special focus on plants belonging tolabiatae (mint) family. Therefore, we start with description and scientific classification of labiatae family. Polysaccharides, which are our burning focus in this review, include sodium alginate, chitosan and carrageenan with special emphasis on their elicitor mechanism for enhancement of plant growth, morphological aspects of plant, defense responses, biosynthesis of secondary metabolites and crop productivity in agriculture.

Description of Labiatae family

The Labiatae family has several members with significant essential oil content. Some of the members belonging to this family include *Mentha arvensis* L., *Mentha piperita* L., *Mentha spicata* L., *Mentha longifolia* L., *Mentha rotundifolia* L. *Mentha aquatica* L. *Mentha arvensis* L., being one among the important medicinal plant due to its high essential oil composition. Hence, the enhancement of EO's is very important and marine polysaccharides are known to enhance the essential oil composition in mint species. Scientific Classification Kingdom: Plantae Clade: Angiosperms Order: Lamiales Family: Lamiaceae Sub Family: Nepetoideae Tribe: Mentheae Genus: Mentha

Role of Polysaccharides in Labiatae (mint) family

The role of natural polymers has been a point of interest to the scientists since a long time ago, the application of which can do value addition in improving demands of agriculture industry. Moreover, radiation processed polysaccharides have further enhanced the quality traits in agricultural crops (Sabharwal, 2004). Some important natural polysaccharides include sodium alginate, chitosan and carrageenan which undergo radiation degradation for their breakdown into lower molecular weight structures, which act as an elicitor for ameliorating the productivity of plants. Progress of development of the plants is regulated by signal molecules constituted of biologically active oligosaccharides (Albersheim and Darvill, 1985). These carbohydrates also facilitate immune reactions in plants. Growth accelerating effect of irradiated oilgosachharide polymers has also been confirmed by Mollah *et al.*, 2009; Idrees *et al.,* 2012; Aftab *et al.,* 2011a; Naeem *et al.,* 2012 in *Mentha arvensis* L, *A. cruentus, Cymbopogon flexuosus and , A. annua.* Radiation processed alginates (usually by Co-60 gamma rays) prove beneficial, cheap, economical and provide safe way for the production of oligomers with low molecular weight (Nagasawa *et al.*, 2000; Lee *et al.*, 2003). Variety of factors which may be exogenous like plant growth regulators or endogenous like plant hormones and the elicitors controls numerous processes of development and growth in plants (Taiz *et al.*, 2014; Srivastava *et al.*, 2007). Plant growth regulators have also shown positive responses in enhancing the essential oil yield in mint (Table 1).

Sodium alginate

Alginates produced from some bacteria and brown algae are hydrocolloids of linear polyuronic acid. (Day; 1998). Alginate the main marine-brown algal structural polysaccharide which has collective feature of high resources of D mannuronic acid and L-guluronic acid linear copolymers (Xu *et al.*, 2006). Alginic acid, which is a homopolymeric of linear copolymer for (1-4)-β-D-mannuronate (M) and α-L-guluronate (G) which is a C-5 epimer of M, connected to each other in various sequences or chains respectively by covalent bonds. Monomers are formed of alternating M and G-residues (MG blocks), consecutive M-residues (M-blocks) and consecutive G-residues (G-blocks). (Fig. 1). Scientists from various countries have recently been working on polysaccharides isolation viz. sodium alginate, chitosan and carrageenan from the seaweed for being used as plant growth promoter, foods preserver biomedical products and healthcare, etc. In bioengineering, food, drink, pharmaceutical industries alginates have wider application spread (Gacesa, 1988).

Elicitor mechanism of sodium alginate for enhancement of growth in mint

I t has been observed by many scientists that radiation –processed polysaccharides such as sodium alginate, has a very promising effect on the morphological aspects of plant such as enhancement in, fresh weight, dry weight, root length and shoot length (Hegazy *et al.,* 2009: Ali *et al.,* 2014). Significant increase in the plant growth qualities has been reported by use of alginate radiation derived oligosaccharides (Idrees *et al.*, 2011, 2012), Khan *et al.* (2011) and Fazili *et al.* (2017). Gamma irradiated sodium alginate is suggested to play a significant role in improving the biological activity of plants (Luan *et al.,* 2003). The main processes that exhibit the quantity and quality of development and plant growth are cell division, cell enlargement and cell differentiation. These processes are widely influenced by numerous external and internal factors, including supply, nutrient absorption, which play a important role in the metabolism of cells and the involvement of plant growth regulators/phytohormones to maintain a strong source sink relationship (Taiz and Zeiger, 2006; Patel and Golakia, 1988). The Plant growth regulators are involved by modifying the gene expression like transcription or translation or differential sensitivity of the tissue. Irradiated sodium alginate is used as a substance that controls plant growth. The nitrogen role in development, plant growth and the biomass production is widely known (Davies *et al.,* 2009). Increase of nitrogen levels have proven in advanced utilization and absorption, which inturn was responsible for higher accumulation of photosynthetic assimilates for rapid plant growth (Gautam *et al.,* 2008).

Drought induced damage because of ROS (Reactive Oxygen Species) was observed to be reduced by significant elevation in catalase activities, peroxidase and superoxide dismutase enzymes in tomato seedlings, showing that alginate based oligosaccharides may stimulates the antioxidant enzymes synthesis to catabolize ROS rapidly, thus protecting the cell membranes damage. Mollah *et al.* (2009) reported that like other plant growth promoters, irradiated sodium alginate may promote growth and serve as biofertilizer. The depolymerized alginate showed growth that promoted elongation of the barley root, particularly radical (Taiz and Zeiger, 2006). They found the effective alginate concentration (100-300 μg /ml) for root elongations without inhibition. Iwasaki and Matsubara (2000) using a mixture of sodium alginate in their study demonstrated that development in sodium alginate behavior with respect to lettuce root elongation at a concentration range of 200-3000 μg/ml

Elicitor mechanism of chitosan for enhancement of growth in mint

Chitosan (ß-(1, 4)-D-glucosamine polymer), being one of the largest natural marine polysaccharide is extracted from chitin deacetylation and precisely found in pathogenic microorganism's cell wall (Agrawal *et al.*, 2002). It can induce plant defense responses as well as stimulate biosynthesis of secondary metabolites. The detailed structure of chitosan is given in Fig 2. As per literature cited, only a few researchers have examined the impact on secondary metabolite production of foliar applied chitosan (Khan *et al.*, 2003; Al-Tawaha *et al.,* 2005). The plant growth is affected by foliar application of irradiated chitosan (chitosan oligmers) which has altered various physiological and biological aspects of plants (Nge *et al.*, 2006; Chmielewski *et al.,* 2007; Hossain *et al.*, 2013). Chmielewski *et al.*, 2007 showed that in the field of agriculture the plants supplied with chitosan had developed better shoots and roots. Ali *et al.*, 2014 concluded that irradiated chitosan has profoundly influenced the biological perspectives of Eucalyptus citriodora Hook. The 70-150 kGy dose level increases the of wheat and rice growth in plants and in effect minimizes the vanadium harm (Tham *et al.*, 2001).

In case of orchids, Nge *et al.*, 2006 observed that chitosan oligomers applied at a 15 mg/L concentration stimulate plant growth in orchid. Chitin and chitosan are responsible for induction of disease resistance of crops, lignification, ion flux variations, acidification of cytoplasm, protein phosphorylation, membrane depolarization and disease resistance (Barber, Bertram, & Ride, 1989; Doares *et al.*, 1995, Kuchitsu *et al.*, 1997, Kikuyama *et al.* 1997; Felix *et al.* 1998), activation of glucanase and chitinase enzymes (Roby *et al.*, 1987; Kaku *et al.*, 1997). Inducetion of phytoalexin biosynthesis (Yamada *et al.*1993), generation and regeneration of reactive oxygen species (ROS) (Kuchitsu *et al.,* 1995), systematic jasmonic acid biosynthesis (Nojiri *et al.*, 1996), as well as the unique expression of early responsive and defence related genes (Minami *et al.*, 1996). Chitosan finds wide application in medicine, waste water treatment and biotechnological applications (Kumar, 2001), material for coating leaf, seeds, fruit and vegetables (Devlieghere *et al.*, 2004). Therefore, further studies needs to be done in order to elucidate the elicitor mechanism of irradiated chitosan. Which actually influence the crop productivity for sustainable agriculture in near future.

Elicitor mechanism of carrageenan for enhancement of growth in mint

Carageenans originally belong to the Rhodophyceae family and are usually mixtures of water soluble, linear sulfated galactans extracted from many species of red algae. Three main types of carrageenan originate which include: iota (i-),kappa (j-), and lambda (k-) and are classified to the number and position of sulfate groups. Iota carrageenan is composed of alternating a(1,3)-D-galactose-4-sulfated and b(1-4)-3,6-anhydro-D-galactose-2-sulfate. Kappa carrageenan on the other hand is composed of alternating a(1,3)-D-130.galactose-4-sulfated and b(1-4)-3,6-anhydro-D-galactose. Lambda carrageenan differs from iota and kappa carrageenan by having a disulfated-D-galactose residue and no 4-sulfate ester group but has varying amounts of 2-sulfate ester groups (Fig 3). Degraded polysaccharides have played a vital role in ameliorating the crop productivity in agriculture. Besides, oligomers formed have been used tremendously in the field of medicine like lowering the cholesterol level, healing the wounds, anticancerous and antidiabetic properties (Qin *et al.*, 2002). Patier *et al.*, 1995 concluded that secretion of laminarinase from Rubus cells and protoplast induced by Oligo-kappa carrageenans.

Genetics related to terpene biosynthesis in mints

Hefendehl and Murray (1972) studied the biosynthesis of chemical constituents of various species of mint. The single Mendelian gene is responsible to control the absence or presence of main compounds such as carvone, menthol, menthone, and piperitenone or piperitone. Hefendehl and Murray (1972) revealed that *M. piperita* and *M. arvensis* perform almost similar conversions; pulegone menthone menthol methyl acetate. The main reason for the conversion of menthone into menthol indicated gene R in either in heterozygous (Rr) or homozygous (RR) form, was responsible for the reduction of menthone to menthol as well as carvone to carveol (Hefendehl and Murray 1973). The fundamental principal for biosynthesis of monoterpene in mint. The main enzymes responsible are as follows: (i) Geranyl bisphosphate synthase (ii) Limonene synthase (iii) CytP450 limonene-3-hydroxylase (iv) *Trans*-isopiperitenol dehydrogenase (v) Isopiperitonereductase (vi) *Cis*-isopulegoneisomerase (vii) Pulegonereductase (viii) Menthone reductase (modified from Crteau and Gershenzon, 1994; McConkey *et al.*, 2000).

Conclusion

It is a well established fact that irradiated polysaccharides act as an elicitor to ameliorate the growth, physiology and metabolism as well as essential oil content in various species of Mentha. In this review we have focused on three polysaccharides which include sodium alginate, chitosan and carrageenan and discussed about their elicitor mechanism to enhance the productivity, growth, defense and other aspects of plant. However, more studies needs to be done to further investigate the exact mechanism which is actually responsible for such effects. This study may inspire a number of agriculturists for the enhancement of oil quality in mint. Furthermore, this technique is economical and effective in enhancing the quality and yield of mint plants.

Table 1: Effect of plant growth regulators on essential oil production in various species of *Mentha*.

Plant Species	Growth Regulator	Related Factor	References
Mentha arvensis L.	Cytokinins	Biomass increment	Farooqi *et al.,* 2003
Mentha piperita L.	Cytokinins	Increase of enzyme activity	El- Keltawi and Croteau, 1987
Mentha spicata L.	Cytokinins	Acting on monoterpene metabolism	El- Keltawi and Croteau, 1987

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