INDIAN JOURNAL OF
ARID HORTICULTURE
2016, Vol. 11 (1-2):15-21

Plant growth regulators in onion-A review

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(Received: 07.11.2016, Accepted: 15.12.2015)

Abstract

Indian horticulture becomes more mechanized and science increases the possibilities for using inputs to enhance production. The discovery of plant growth substances has proved revolutionary in increasing the production of different vegetable crops. In recent years, their use becomes more vital as they provide an immediate impact on crops and are less time consuming. There is a great potentiality of various plant growth substances in different concentration for improving vegetative growth, yield and quality of onion. Further, theses can also be used to prevent sprouting and rotting of bulbs in storage. This paper reviews the research work done on use of various plant growth substances like auxins, gibberellins, cytokinin, ethylene, growth inhibitors and growth retardants in onion production.

Key words: Onion**,** Plant growth regulators, Growth, Yield, Quality, Bolting, Shelf-life.

Introduction

Onion (*Allium cepa* L.) is one of the most important bulbous vegetable crops of India belonging to family Alliaceae and consumed worldwide. It is considered as the queen of kitchen (Selvaraj, 1976) and characterized by its distinctive flavour and pungency, which is the due to sulphur containing compounds allyl propyl-disulphide, a volatile oil. Onion contains carbohydrates, protein, vitamin A, thiamine, riboflavin, niacin and ascorbic acid. It is used as salad, cooked in various ways of fried, boiled, soup making, sauces and pickles. Now-a-days white onion is also widely used in dehydrated powder form and has several medicinal properties. India is a leading producer of onion supporting 20.2% of the world production. During 2013-14, India ranked second in area (12.03 lakh ha) and production (19.40 lakh MT) after China and third in export (18.22 lakh MT) after Netherlands and Spain, with foreign exchange earnings of 1966.6 crores (Anonymous, 2014). Despite the importance of this crop it is suffering from several problems like low vegetative growth, low yield, bolting, doubling of bulbs, bulb sprouting, *etc*. Now-a-days the use of plant growth substances in onion has proved as a boon for improving the growth, yield, quality and shelf life of bulbs. Most of the physiological activities and growth in plants are regulated by action and interaction of some chemical substance called hormones and by some naturally occurring inhibitors. With the gradual increase of population the demand for onion is increasing day by day. To enhance onion production per hectare, improved and modern agronomic practices should be applied properly. In this connection, application of plant growth regulators (PGRs) might be useful in increasing onion production. Recently, there has been global realization for important role of PGRs in vegetable production, better growth of crop and yield (Isalm *et al.*, 2007; Bose *et al.*, 2009 and Prajapati *et al.*, 2015).

PGRs considered as a new generation of agrichemicals when added in small amounts, modify the growth of plants usually by stimulating or modifying one part of the natural growth regulatory system, thereby the yield is enhanced. The growth regulators have therefore, been known to be one of the quick means of increasing production and used in different forms like liquid, powder, paste, *etc*. Application of plant growth regulators in optimum concentration have given favourable impact on growth, yield and quality of onion (Maurya and Lal, 1975; Nirmal *et al.*, 1994; Singh *et al.*, 2003; Patel *et al.*, 2010; Sisodia *et al.*, 2012; Choudhary *et al.*, 2015 and Choudhary *et al.*, 2016). PGRs in onion provides professionals and researchers with the information needed to enhance production, shelf-life and quality of onion. Hence, the relevant and important published work available on onion has been reviewed and presented in this review article.

Categories and function of plant growth regulators

PGRs are organic chemical substance, other than nutrients and vitamins which regulate the growth of plant when applied in small quantities. 'Hormone' is derived from a Greek '*hormao*', which means to stimulate (Bayliss and Starling, 1902). Thimann (1948) suggested the use of term phytohormones as the organic substances, which are produced naturally in plants, synthesized in one part and usually translocated to other part where in every small quantity affect the growth and other physiological function of the plants. They played an important role in horticulture and their function is given in Table 1.

Auxins have been used variously in horticulture which was extracted from maize kernels and identified as Indole Acetic Acid (IAA). IAA is the principal naturally occurring auxin of all higher plants and fungi. The precursor of IAA is tryptophan, an amino acid. The major sites of auxin production are the shoot tips, developing seeds and buds. There are a number of synthetic chemicals which are similar to IAA in their biological activity however, they do not occur in any plant.

Gibberellins are one of the main regulators of plant growth and development which repress the growth and promoting cell division and elongation (Tomas *et al.*, 2009). Gibberellin was first extracted from the fungus *Gibberella fujikuroi* (*Fusarium moniliforme*), the causal organism of '*foolish seedling of rice*' or commonly called '*bakanae disease of rice*'. It is well known that GA_3 promotes plant growth and its secondary metabolite production. They promote seed germination, leaf expansion, stem elongation and flowering initiation. Gibberellins play a major role in diverse growth processes including seed development, organ elongation, senescence and control of flowering time (Ouzounidou *et al.*, 2011). Gibberellins are designated as GA_1, GA_2 and so on. The common gibberellic acid is GA_3. At present 112 types of gibberellins are known. Gibberellins are synthesized in the young leaves (major site), shoot tip, root tip and immature seeds (embryo). Precursor of gibberellin is kaurene.

Cytokinins play a key role in the life of higher plants and responsible for cell division. Usually *Zeatin* is the most abundant naturally occurring free cytokinin. Zeatin is synthesized from mevalonic acid and adenine. Root tip is an important site of cytokinin synthesis. However, developing seeds and cambial tissues are also the site of its biosynthesis. Functional activity of cytokinins occurs in the presence of auxins.

Ethylene is the simplest organic compound which affects plants. It is a natural product of plant metabolism and active in trace amounts. Ethylene is highly effective in inducing fruit ripening and called as ripening hormone. Methionine (an amino acid) is an immediate precursor of ethylene. Meristematic and nodal regions are most active in ethylene biosynthesis. Its production increases during leaf abscission and flower senescence, as well as during fruit ripening.

Growth inhibitors are synthetic or natural substances which suppress the growth of plants. They inhibit the transport of auxins and also called anti-auxins. Abscisic acid (ABA) is one of the wide spread and naturally occurring inhibitor found in plants. ABA is known as dormancy inducing and abscission accelerating substance. It is found in all parts of the seed namely the seed coat, embryonic axis, cotyledons and endosperm. ABA is synthesized in mature leaves and fruits.

The terms growth retardants is used for all chemicals that retard cell division and cell elongation in shoot tissues and regulate plant height physiologically without formative effects (Pgrsa, 2007). The formation of leaves, flowers and fruits remain unaffected. Growth retardation is primarily induced by inhibition of gibberellin biosynthesis and therefore also called anti-gibberellins. These are synthetic only. Cycocel (CCC) is an important plant growth retardant used for inducing dwarfism in plants and shorter internodes, stronger stems and green leaves. The response of CCC can vary depending on the dose or concentration, method, site of application, species and cultivar and also growing season (Taiz and Zeiger, 2006).

Table 1. Important plant growth regulators and their function

Class of PGRs	Important PGRs	Function
Auxins	Indole-3-acetic acid (IAA), Indole butyric acid (IBA), 2-Naphtalene acetic acid (NAA), Para chlorophenoxy acetic acid (PCPA)	Apical dominance, root induction, control of fruits drops, flowering regulation, parthenocarpy, phototropism, geotropism, herbicides, inhibit abscission, increase female flowers and induce rooting.
Gibberellins	Gibberellic acid (GA_3)	Stimulate cell division, cell elongation and germination of seeds. Stimulates bolting/ flowering in response to long days. Prevent genetic dwarfism, increase flower and fruit size. Break dormancy. Induces maleness in dioecious flowers. Extend self life.
Cytokinins	Kinetin, Zeatin	Promotes cell division, cell enlargement and cell differentiation. Stimulate bud initiation and root growth. Help in translocation of nutrients. Prolong storage life of flowers and vegetables. Prevent chlorophyll degradation, morphogenesis, lateral bud development and delay senescence.
Ethylene	Ethrel	Induce uniform ripening in vegetables, promotes abscission and senescence of leaf.
Growth	Abscisic acid (ABA), 2,3,5-tri-	Act as plant stress hormone. Inhibit mitotic cell division. Induce

inhibitors	iodobenzoic acid (TIBA), Chlorpropham (CIPC)	bud and seed dormancy. Induces seeds to synthesize storage proteins. Stomata regulation.
Growth retardants	Cycocel (CCC), Phosphon-D, Alar, AMO-1618, Paclobutrazol (Cultar)	Slows cell division and cell elongation of shoot tissue and regulate plant height physiologically without formative effects.

Effect on growth parameters

The application of plant growth regulators has been found effective in promoting the different growth parameters in onion. Foliar application of NAA 50ppm gave the highest plant height, number of leaves, neck diameter, bulb weight, bulb diameter and yield per hectare which might be due to the fact that growth regulators stimulated the plant growth and bulb development, which has given more opportunity for carbohydrate assimilation needed for better yield (Nandekar and Sawarkar, 1992; Nirmal *et al.*, 1994; Rizk *et al.,* 1996; Singh *et al.,* 2001; Mandal *et al.,* 2003; Amin *et al*., 2007 and Islam *et al*., 2007). Bose *et al*. (2009) recorded the highest plant height (61.63 cm), number of leaves/ plant (l0.25) with NAA 50ppm over control.

Bio-regulators like gibberellins (GA_3) have been known to play a vital role in building of plants. Overall, only GA_3 supply leads to a vigorous onion growth and yield (Ouzounidou *et al*., 2011) those found that GA_3 promoted the total plant length of onion by 35% of the control and number of leaves/ plant of onion increased significantly under GA_3. Foliar application of gibberellins and ethrel 100ppm have also been resulted in greatest increase in plant growth of onion (Nagwa *et al*., 2013), GA_3 50 or 60ppm (Shaikh *et al*., 2002; Kumar and Shashidhar, 2016). Furthermore, bio-regulators had the superior effect in various growth traits of onion (Shukla *et al*., 2007; Tyagi and Yadav, 2007; Yamaguchi, 2008; Yu *et al*., 2009; Sisodia *et al*., 2012 and Ouzounidou *et al*., 2011). Lokhande *et al.* (2014) recorded increased seedling biomass due to pre-sowing soaking treatments of GA, methionine and cysteine, while, SA, 6-BA and CCC pre-treatments slightly decreased the seedling biomass.

Although, the vegetative characters like plant height, number of leaves, leaf length, percentage of fruit set and bulb size of onion have been found inhibition with paclobutrazol 80ppm (Ashrafuzzaman *et al*., 2009), CCC 500 or 1000ppm, ethephon 2000 or 2500ppm and paclobutrazol 1000 or 2000ppm (Choudhary *et al*., 2016). The reduction in growth parameters might be due to anti-gibberellin action of other growth retardants, which might have negated the endogenous GA level, thereby hindering vital cell activities like apical growth, cell growth and elongation (Jones *et al.,* 2009).

Effect on yield parameters

PGRs have been reported to increase the bulb yield of onion. The treatment with GA_3 and their physiological action was found to enhance vegetative growth, yield and dry weight (Islam *et al*., 2007). The GA_3 and NAA induced cell division and rapid cell elongation in growing portion causing increase in bulb size. NAA 30ppm resulted in maximum neck diameter (1.98 cm), fresh weight of bulb (78.71g), bulb diameter (5.08cm) and yield/ ha (337.17 q) over control (Bose *et al*., 2009). An increase in onion bulb yield after the application of GA_3 was observed by Shakhda and Gajipara (1998), Anant and Maurya (2001), Poonam *et al*. (2002) and Subimal *et al*. (2003).

Patel *et al.* (2010) observed significantly increased volume of bulb, equatorial and polar diameter of bulb as well as bulb yield with GA_3 50ppm while average weight of bulb was significantly increased in GA_3 100ppm applied as root dipping + foliar spray. Foliar spray of GA_3 80ppm and NAA 50ppm at 40 and 60 DAT produced significantly higher bulb yield of 316.7 and 311.5 q/ha, respectively, which was 24.7 and 22.7% higher over control (Sharma *et al*., 2013). Shafeek *et al.* (2013) found the highest plant growth and total yield of onion with application of ethrel 200ppm. Nagwa *et al.* (2013) recorded superior effect of GA_3 or ethrel @ 100ppm on total yield of onion. The root dipping and foliar spray of GA_3 50 or 100ppm as significantly increased bulb weight, equatorial and polar diameter of bulb as well as bulb yield (Patel *et al*., 2010), GA_3 500ppm (Safdari *et al*., 2014). Similar effect of different PGRs was also reported by various researchers in onion (Demiral and Turkan, 2005; Hussein and El-Greadly, 2007; Shukla *et al*., 2007; Tyagi and Yadav, 2007 and Sisodia *et al*., 2012).

GA_3 promoted increased the fresh and dry weight of onion significantly under GA_3 (Ouzounidou *et al*., 2011). Furthermore, Choudhary *et al*., 2016 obtained the decreased bulb yield with foliar application of CCC (500 or 1000ppm) and ethephon (2000 or 2500ppm). The reduction of yield is might be due to the decreased vegetative growth, bulb weight, bulb diameter and bulb size due to exogenous application of growth retardants to restrictive growth, less nutrient conceptions and low carbohydrate synthesis by the plant and subsequently reduced yield (Deore and Bharud, 1990; Hye *et al*., 2002). Singh *et al.* (2003) recorded significantly highest plant height, bulb diameter, bulb size index, bulb weight, gross yield and marketable yield with Cytozyme 0.2% applied as root dip + spray of CCC 500ppm at 75 DAP.

Effect on quality parameters

Plant growth regulators have also been found to affect bulb quality of onion. Sharma *et al*. (2013) reported that foliar spray of GA_3 80ppm and NAA 50ppm improved of quality parameters of onion. Wei *et al.* (2011) also reported that GA_3 500ppm increased soluble sugar in onion. The foliar applications of growth regulators results in increase in carotenoid content of onion leaves might be playing important role in the protection against oxidative stress. The increased level of carotenoids will help to protect the chlorophylls and to maintain better growth and productivity of onion bulb (Kojo, 2004). The increased level of carotenoids will help to protect the chlorophylls and to maintain better growth and productivity of onion bulb.

Singh *et al.* (2003) noted remarkable improvement in total soluble solids and dry matter contents with ethephon and cytozyme over the control. The N, P and K as well as Fe, Mn, Zn and Cu contents in onion bulb tissues was highest with application of ethrel 200ppm (Shafeek *et al.*, 2013). Ganie and Solanki (2010) reported the application of 1500ppm CCC increased quality characters *viz.*, TSS, sulphur and protein content in bulbs of *kharif* onion. Furthermore, the paclobutrazol, ethephon and CCC decreased reducing sugars, soluble proteins but increased leaf chlorophylls, proteins and sugars (Arvin and Banakar, 2002). Foliar application of gibberellins and ethrel 100ppm has also been resulted in greatest increase in quality and nutrient content of onion (Nagwa *et al.*, 2013). Shafeek *et al.* (2013) also noticed the effect of ethrel on bulb quality of onion. Lokhande and Gaikwad (2014) also obtained the significantly increased chlorophylls in response to GA, CCC, methionine and cysteine application. The chlorophyll a/b ratio was slightly altered due to PGR application while the overall carotenoid content was slightly decreased in leaves of onion. The total carbohydrate content was slightly decreased, while total sugars were slightly elevated. Choudhary *et al.* (2016) obtained highest TSS content in onion with paclobutrazol 2000ppm.

Effect on bolting

Bolting is one of the major constraints in the production of onion as it directly affects the bulb yield and quality however; it is desirable for seed production. It is frequently caused by adverse weather conditions especially low temperature. Flowering in onion was mainly induced by low atmospheric temperature ranging from 4 to 15ºC. Further, higher temperature after floral initiation sometimes prevents normal development of flower stalks due to abortion of flower initials (Brewster, 1994). Growth retardants reduce bolting which might be due to the active movement of these substances from the leaves into the bulb tissues at the time of bulb maturity thereby lowering down GA_3 levels, responsible for transition for vegetative to reproductive stage (Kielak and Bielinska-Czarneckzarnika, 1987). Helaly *et al.* (2016) found decreased in earliness of bolting and bolting period with the application GA_3 at 1000ppm and CCC at 100ppm in onion. Foliar application of paclobutrazol and ethephon reduced bolting and shoot length but CCC increased bolting (Arvin and Banakar, 2002), paclobutrazol 2000ppm showed lowest bolting in onion (Choudhary *et al.*, 2015).

Effect during storage

Post harvest handling of onion a major issue throughout the world. Onion bulbs contain about 89% water which may be harmful in post harvest life. Moisture loss itself is a major concern in post harvest life because loss in weight during storage is directly related to economic loss. Moreover, physical injury, rotting and sprouting (re-growth) are also cause deterioration of onion bulbs, because it increases respiration rate, which consequently increase moisture loss and reduce the shelf life. In India, post harvest losses in onion are over 40% (Bhagachandani *et al.*, 1980) and could be as high as 40-50% (Maini *et al.* 1984). In general, the losses due to reduction in weight, sprouting and rotting (decay) were found to be 20 to 25, 4 to 5 and 10 to 12 per cent, respectively (Pandey, 1989).

Pre-harvest sprays PGRs/ chemicals like ethrel, CCC, carbendazim and aureofungin have been widely applied without impairing the keeping quality of onion. These compounds greatly facilitate the maintenance of quality of onion bulbs in storage with respect to inhibition of sprouting, rooting and reduction in the physiological loss in weight. Several chemicals have been tried so far to prolong the shelf life of onion and a few among them are ABA, GA_3, auxin, cytokinin, MH, CCC, ethrel and paraquat (Pandey, 1989). Ethylene can suppress sprouting while the ethylene binding inhibitor 1-methylcyclopropene (1-MCP) can also suppress sprout growth and has been found to increase shelf life of onion (Cools *et al.*, 2011), with ethylene and 1-MCP in combination after curing for 24 hour (Johnson, 2006), with 1-MCP for 24 hour after curing (Chope *et al.*, 2007). Application of ethephon to onion plants 2 week prior to harvest was found to reduce sprout incidence (Adamicki, 2004).

Benkeblia and Selselet-Attou (1999) found that sprouting of the control bulbs and the non-cooled bulbs treated with ethephon were normal during storage, with a level of 50% after 3 month and 100% after 6 month. Sprouting occurred earlier for cooled bulbs treated with ethephon, 50% after 2 month and 100% after 4 month. Patel *et al.* (2010) observed the significantly reduced physiological loss of weight, spoilage loss and finally total loss with NAA 100ppm as root dipping treatment. Anbukkarasi *et al.* (2013) also reported that with CCC, ethylene and fungicides play a crucial role in delaying sprouting and enhancement of shelf life in onion. Anbukkarasi *et al.* (2013) and Banuu Priya *et al.* (2014) reviewed the work done on pre and post-harvest treatments in onion to extend shelf-life. The maleic hydrazide (MH) was banned by government of India during the year 2009.

So application of MH for postharvest handling of onion is not included in this review.

Effect on male sterility

Some PGRs induce male sterility in plants and called as gametocides. Gibbrellin was found to act as gametocide and application of GA_3 induced male sterility in onion which can be used for F_1 hybrid seed production (Prajapati *et al*., 2015).

Conclusion

The available literature reveals that application of plant growth regulators enhances growth, yield, quality and shelf-life of onion when applied suitable dose at proper stage. Thus, it can be concluded from this review that the use of plant growth regulators in onion improve different growth, yield and quality parameters. Further, post harvest losses like rotting and sprouting of onion are major issues which can also be reduced with the application of PGRs at appropriate stages.

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