International Journal of Farm Sciences **8(2):** 1-7: 2018; doi: 10.5958/2250-0499.2018.00032.0

Review

Influence of gibberellic acid on onion production- a review

OMESH THAKUR and VIJAY KUMAR

Department of Vegetable Science
Indira Gandhi Krishi Vishwavidyalaya, Raipur 492012 Chhattisgarh, India
Email for correspondence: omithakur10@gmail.com

Received: 6.11.2017/Accepted: 18.12.2017

ABSTRACT

Plant growth regulators are new generation agrochemicals and are expected to play an important role in overcoming the hurdles in manifestation of biological yield. Role of plant growth regulators in crop production is a well known phenomenon. Their use in crop promotes growth along the longitudinal area, number of branches, early flower initiation, fruit set and fruit quality and subsequently contributes towards higher production when applied at various concentrations. Due to this it is possible to achieve the desirable standards and norms in terms of quality for exportable production. GA_3 application brings metabolic changes that affect both quality and quantity of the desired product. It stimulates the synthesis of hydrolic enzymes which are secreted and act on starchy endosperm in turn affecting physiology of seed germination and establishment of seedlings. Gibberellic acid is considered as a tool in chemical regulation of the pattern of growth and development in plants.

Keywords: Gibberellic acid; plant growth regulators; growth; development; onion

INTRODUCTION

Onion (*Allium cepa* L) is one of the important underground bulbous vegetable crops of Alliaceae family. It is successfully grown in tropical, subtropical and temperate parts of the world. Onion is rich in carbohydrates and minerals like phosphorus and calcium (Aykroyd 1963). The growth and yield of crop plants are mainly influenced by genetical and cultural factors. The first factor deals with the various plant breeding techniques used for the improvement of crop varieties. The second factor deals with the supply of adequate nutrition, growth substances, plant protection etc. Plant growth regulators are known to regulate and modify various physiological processes within the plant and thereby help to increase the yield (Weaver 1972). The growth regulators are applied as seed treatment, root dipping, foliar application etc to improve yield and quality of the produce. Growth hormones regulate the physiological processes and balance the source and sink thereby increasing the productivity and quality.

Growth, development and yield analysis in crop plants helps in understanding the contribution of various growth and yield components. Plant growth regulators are considered as new generation agrichemicals as when added in small amounts they modify the growth of plants usually by stimulating or modifying one part of the natural growth regulatory system and thus the yield is enhanced. Higher production through breeding is a continuous endeavor of mankind. But these methods are however not only time consuming but also costly. The growth regulators have therefore been known to be one of the quick means of increasing production. Similarly nutrients are inorganic substances necessary for the normal growth and development of plants and have important role in various enzymatic processes, assimilation, oxidation and reduction reactions and help in increasing the biomass and yield.

Classes of plant growth regulators

Plant growth regulators are grouped into 2 main types:

Growth promoters: They have a positive effect on a process and thus promote it. These are auxin, gibberellins and cytokinin.

Growth inhibitors: They have a negative effect and cause inhibition. A particular hormone may promote

Principal groups of phyto-hormones

Hormone	Synthesis location	Target tissue
Auxins	Stem apex, developing fruits	Primary cell wall
Gibberellins	Immature seeds	Internodes, seeds, fruits
Cytokinins	Actively growing regions	Roots, stem, phloem, xylem
Ethylene	Fruits, flowers, leaves, roots	Buds, seeds, fruits
Abscisic acid	Leaves	Stomata

Plant growth regulators and their associated functions

Plant growth regulator	Associated function
Auxins	Create apical dominance; induce rooting; control fruit drop; induce parthenocarpy, phototropism and geotropism; act as herbicides
Gibberellins	Stimulate cell division and elongation, germination of seeds, bolting/flowering in response to long days; prevent genetic dwarfism; increase flowers and fruits size and dormancy; induce maleness in dioecious flowers and extend self-life
Cytokinin	Promotes cell division, cell enlargement and cell differentiation; prevents chlorophyll degradation
Abcisic acid	Acts as plant stress hormone; induces dormancy of buds and seeds, seed development and germination
Ethylene	Induces uniform ripening; creates senescence of leaves

certain processes, inhibit some others and not affect many others. They act synergistically (cooperative and beneficial) or antagonistically (acting in opposition) with one another. These are ethylene and abscisic acid (ABA).

Gibberellins commonly known as gibberellic acids (GAs) first came to the attention of western scientists in 1950s. They had been discovered much earlier in Japan. Rice farmers of Japan had long known of a fungal disease called foolish seedling or bakanae disease in Japanese that causes rice plants to grow taller and eliminate seed production. Plant pathologists found that these symptoms in rice plant were induced by a chemical secreted by a pathogenic fungus, *Gibberella fujikuroi*. Culturing this fungus in the laboratory and analyzing the culture filtrate enabled Japanese scientists in the 1930s to obtain impure crystals of two fungal compounds possessing plant growth promoting activity. One of these because it was isolated from the fungus *Gibberella* was named gibberellin. GA_3 is considered as a tool in chemical regulation of the pattern of growth and development in plant. GA_3-stimulated stem elongation increases dry matter accumulation (Hore et al 1988). GA_3 promotes cell division and a number of plant development mechanisms and encourages numerous desirable effects such as plant height, uniform flowering, reduced time to flowering and increased flower number and size (Srivastava and Srivastava 2007).

Influence of gibberellic acid on growth of onion crop

Watson (1947) reported that total dry matter of a crop is the output of net photosynthesis. It is mainly dependent on the size of photosynthesis system or its activity as well as the length of its growth period during which photosynthesis continues. Simao et al (1958) reported that application of GA_3 increased the leaf size and number of lettuce. Jauhari et al (1960) noted increase in number of leaves in spinach with the use of GA_3.

As per Okazawa (1959) GA_3 inhibits tuberisation in potato whether applied to whole plant or to stem cutting. Magsino (1961) observed the effect of GA_3 on garlic and reported that application of 100 ppm GA_3 to the tip of ground leaves induced leaf elongation and increased plant height and bulb growth. Humphries and Wheeler (1963) observed that gibberellic acid enhanced the growth of vein as well as mesophyll cells resulting in enlargement of leaves. Halevy and Shoub (1964) obtained reduced bulb yield when iris bulbs were subjected to 50 and 500 mg gibberellic acid. Mathur (1971) reported that growth substances like NAA, IAA and IBA at 100, 200 and 300 ppm respectively increased leaf number and weight of onion bulbs.

Kaushik et al (1974) found that GA_3 at 100 ppm increased the number and weight of fruits. Application of GA_3 at vegetative stage increased fruit size which increased individual fruit weight.

Maurya and Lal (1975) carried out an experiment on onion cv Pusa Red seedlings. When soaking of seedlings continued for 12 hours in water and different levels of GA_3 (20, 40 and 60 ppm) before transplanting, plant height and leaf and root growth as well as bulb growth were improved by treatment at 20 ppm over water. However higher rates were less effective and sometimes harmful. Lipe (1975) found that gibberellic acid increased the number of leaves per plant by initiating multiple growing points when bulbs of onion cv New Maxico (medium day) and Yellow Spanish Colorado # 6 (long day) were treated with GA_3 at 10-15 ppm. Takagi and Aoba (1976) found that garlic cloves treated with 50-80 ppm GA_3 and spraying 200-400 ppm solution of GA_3 at different stages of crop improved bud formation in both the cases over water soaking.

Shishido and Saito (1984-1985) obtained more number of leaves and hastened flower bud initiation through GA_3. It also shortened total growth period of onion by 20 days under low temperature conditions. The GA_3 appears to hasten the flower bud initiation through the activation of meristematic tissues (Miyazaki et al 1986). They stated that inflorescence contained flowers and florets but no pollen was formed from gibberellic acid-induced inflorescence.

Foliar application of GA_3 (5 and 10 ppm) increased the length of stems and stolons and decreased the tuber fertility but caused elongation of the stolons (Burton 1989, Chapman 1958). Mishriky et al (1990) observed that GA_3 significantly increased stem length and number of leaves per plant while CCC (a growth retardant) reduced all these parameters of vegetative growth in pea. Nandekar and Sawarkar (1992) tested the effect of IAA, NAA and GA_3 each at 0, 20, 30 and 40 ppm for 24 hours by root dipping of onion seedlings. Treatments with GA_3 at 40 ppm significantly increased the number of leaves, length and weight of bulbs, number of roots, size and weight of bulbs, number of scales and percentage of grade A (more than 4.5 cm diameter) bulbs of onion.

Nehara et al (1992) opined that in onion the better performance of GA_3 might be attributed to the production of healthier plants, higher splitting of bulbs and increased number of scapes per plant. Mulge et al (1998) reported beneficial effect of GA_3 spray on shoot length and seedling growth in onion. Hisamatsu et al (1998) showed that GA_3 stimulated both cell division and cell elongation.

Dixit et al (2001) reported significant increase in vegetative growth as a result of GA_3 treatment. Hye et al (2002) reported that GA_3 200 ppm induced maximum 3 number of leaves and there was a gradual increase in leaf number with the concentration of GA_3. Tiwari et al (2003) observed that application of 50 ppm GA_3 produced the highest number of leaves per plant both as spray (12.33) and as root dip (12.53). Ud-Deen et al (2005) reported that number of leaves per plant, pseudostem length, leaf length and plant height were increased with the increase of the duration of treatment of growth promoting hormone GA_3.

Shukla et al (2007) applied 18 different plant growth regulator treatments comprising two PGRs (GA_3 and NAA) each in three doses (20, 40 and 60 ppm of GA_3 and 200, 300 and 400 ppm of NAA) through three different application methods (seed soaking, root dipping and foliar spray). Results indicated that growth characters viz plant height, leaf length and culm width were influenced by different doses and application methods of PGRs. Root dipping with GA_3 at 40 or 60 ppm was found superior than other treatments for above characters. Number of leaves, culm length, bulb length and bulb diameter were not influenced by different treatments.

Influence of gibberellic acid on yield and quality of onion crop

Lopper and Waller (1982) showed that GA_3 as foliar spray treatment at higher rate significantly increased bolting and yield. Abd-El-Gawad et al (1986) observed that GA_3 slightly increased pungency in onion bulbs. GA-stimulated stem elongation increased dry matter accumulation (Hore et al 1988) and enhanced vegetable seed yield. It was noticed that both the fruit number and fruit yield significantly affected hormones. Bankar and Prasad (1990) also found that TSS content was significantly increased by GA_3 when applied as foliar spray. The increase in TSS due to GA_3 application may be attributed to the reason that the plant remains physiologically active to build up sufficient food material for the developing bulbs with better quality.

GA_3 can increase fruit size with consequent enhancement in seed yield. It also increased the flowering and fruit set (Gurudev and Saxena 1991). It has its particular role in induction of flowering and seed setting. It helped to produce healthier plants and initiated splitting of bulbs (sprouts) and thus helped in increased number of escapes per plant as well as seed yield per umbel and per bulb which finally lead to higher seed yield per hectare (Nehara et al 1992). Thus it can be said that higher concentration of GA_3 plays an important role in increasing the yield. It increases fruit size with consequent enhancement in seed yield.

Sharma et al (1998) reported that bulb yield per plot showed positive and significant correlation with plant height, leaves per plant, neck girth, bulb diameter length, bulb diameter width, cloves per bulb and biological yield per plant.

Kale et al (2000) reported that maximum ascorbic acid content was obtained by GA_3 application @ 80 ppm (12.85 mg/100 g). Singh (2003) revealed that higher seed yield (789.41 kg/ha) was recorded in the large size bulbs which was significantly superior over medium and small size bulbs. Minimum seed yield (721.52 kg/ha) was observed in the small size bulbs.

Raifa et al (2005) have reported that the maximum total phenol content was increased with the application of GA_3.

Surendra et al (2006) indicated that among the growth regulators and micronutrients the foliar application of GA_3 (25 and 50 ppm) at 60 DAS registered significantly higher fresh fruit yield over other treatments. The increase was due to increase in yield attributing components viz total number of flowers and fruits per plant, fruit length, seed number per fruit, seed weight and harvest index. The benefit-cost ratio was higher with application of GA_3 (50 ppm) over all other treatments. Dandena et al (2010) stated that for increase in TSS in tomato the assimilates' export from the leaves, import by fruits and the fruit carbon metabolism were the factors.

Graham and Ballesteros (1980) also reported that GA_3 increased proteins, soluble carbohydrates, ascorbic acid, starch and alpha-carotene in tomato.

Rashid (2010) reported that application of GA_3 100 ppm gave the maximum bulb yield while the minimum value was observed from control.

Waghmode et al (2010) concluded that 100 ppm GA_3 was effective in increasing the seed production of onion. Biofertilizer doses (6 kg/ha *Azospirillum* + PSB and 10 kg/ha VAM) gave maximum seed yield of onion. Shukla et al (2007) reported that root dipping with GA_3 at 20 ppm produced highest bulb weight (43.90 g). Marketable yield and total yield of onion bulbs were significantly higher in root dipping with GA_3 at 40 ppm followed by root dipping with GA_3 at 60 and at 20 ppm.

Singh et al (2013) reported that GA_3 application @ 80 ppm recorded maximum TSS content (12.62%). The TSS content was increased with higher levels of GA_3. This could be due to the reason that the plant remained physiologically active to build up sufficient food material for the developing bulbs with better quality. Maximum anthocyanin content (9.72 mg/100 g) was recorded with application of GA_3 80 ppm. The increase in anthocyanin content with increasing level of GA_3 might be attributed to the reason that gibberellins played a vital role in enhancing phenyl alanase (PAL) and tyrosine ammalyase (TAL) synthesis that in turn increased the anthocyanin content.

Govind et al (2015) suggested that GA_3 30 ppm + liquid manure (LM) 100 ppm may be used for better growth and yield of garlic cv G-282 under Lucknow subtropical condition having high soil pH.

Influence of gibberellic acid on quality seed production

El-Habbasha et al (1985) carried out a field experiment to evaluate the effect of different concentrations of GA_3 and IAA on flowering and seed production of onion during the growing seasons of 1978-1979 and 1979-1980. It was found that the applications of GA_3 at 500 ppm three times caused an increase in onion flowering rate and early bolting by 30 days and high concentration (500 ppm) increased the seed stalk height and number per plant and seed production.

Al-Shdiefat (1992) reported that there was significant effect of GA_3 application at concentrations of 10, 25, 50, 100, 200, 300, 400, 500 and 1000 ppm on flowering and seed production of onion during 1989/90 growing season. Application of GA_3 significantly affected average number of seed stalks, main seed stalks and secondary seed stalks per plant, average number of small size umbels per plant and seed vigour. The concentration of 10 ppm GA_3 produced higher number of seed stalks and main seed stalks per plant; 300 and 1000 ppm treatments gave the highest number of secondary seed stalks per plant; 100 ppm treatment gave the highest number of small umbels per plant and 25 ppm treatment resulted in the highest seed vigour in onion.

Thiruvelavan et al (1999) reported that GA_3-treated bulbs of onion showed early sprouting, umbel emergence and flowering and had better umbel characters and higher seed yield compared to the control. There was higher seed yield per plant treated with 100 ppm GA_3 which was correlated with the increased scape length, umbel per plant and umbel diameter. Lovato et al (2000) reported that foliage spraying with 20 ppm GA_3 before bolting induced a slight earliness in seed maturity and increased seed yield. Reghin et al (2000) applied 4 different doses of GA_3 on three bolting-resistant varieties of lettuce and reported increased flowering percentage, seed yield, earliness of the anthesis and seed maturation.

Influence of gibberellic acid on cost economics

The higher net profit and benefit-cost ratio in GA_3-treated plants are due to higher marketable yield that ultimately results in higher value.

Hence the application of GA_3 40 ppm applied as root dipping is economically better treatment of all treatments to enhance onion bulb production. Singh (2003) reported that the large size bulbs increased the cost of onion seed production and this increased cost of onion seed production was not compensated by its gross return that resulted in the least net return and benefit-cost ratio.

Patel et al (2009) reported that based on monetary return and B-C ratio application of GA_3 (50 mg/l) as root dipping + foliar spray and NAA (100 mg/l) as foliar spray gave higher B-C ratio of 1:3.50 and 1:3.48 with net realization of Rs 173328 and Rs 162466 per hectare respectively and was more remunerative than the rest of the treatments.

Kashyap (2012) obtained highest benefit-cost ratio of 3.80 under the treatment GA_3 (100 ppm) followed by NAA (100 ppm) (3.15) and NAA (200 ppm) (2.96) and the lowest (1.77) in treatment of ethrel (1000 ppm).

Precautions in application of plant growth regulators

Plant growth substances should be used at an appropriate stage of plant growth. Only fresh solutions of chemicals should be used and spraying in windy hours should be avoided.

CONCLUSION

Seed germination, stem elongation, meristmetic tissue development and differentiation of floral organs are highly dependent on GA_3 signaling system and mechanism. GA_3 is required to break the seed dormancy leading to its germination. Seed germination is a complex process controlled by both physical and internal regulating factors. When used on plants GA_3 produces bigger leaves and longer stems, enhances photosynthesis, stimulates seed germination and triggers transitions from the vegetative to the flowering stage. Thus the application of GA_3 has significant influence on growth, quality and yield of onion.

REFERENCES

Abd-El-Gawad AA, El-Tabbakh AM and El-Habal MS 1986. Effect of spraying onion plants with IAA and GA3 on yield and chemical composition of onion bulbs. Annals of Agricultural Sciences **31(2):** 1021-1031.

Al-Shdiefat SMM 1992. Effect GA_3 application on flowering and seed production in onion (number of tillers and leaves, plant height, seed stalks number and height at the different treatments). Arab Universities Journal of Agricultural Sciences **3(2):** 109.

Aykroyd WR 1963. The nutritive value of Indian foods and the planning of satisfactory diets. Special Report, Series # 42, 6th edn, Indian Council of Medical Research, New Delhi, India.

Bankar GJ and Prasad RN 1990. Effect of gibberellic acid and NAA on fruit set and quality of fruits in ber cv Gola. Progressive Horticulture **22(1-4):** 60-62.

Burton WG 1989. The potato. 3rd edn, John Wiley and Sons, Inc, New York, 742p.

Chapman HW 1958. Tuberization in the potato plant. Physiologia Plantarum **11(2):** 215-224.

Dandena G, Bekele A and Lemma D 2010. Effects of gibberellic acid and 2,4-dichlorophenoxyacetic acid spray on fruit yield and quality of tomato (*Lycopersicon esculentum* Mill). Journal of Plant Breeding and Crop Science **2(10):** 316-324.

Dixit A, Rai N and Kumar V 2001. Effect of plant growth regulator on growth, earliness and sex ratio in water melon. Indian Journal Agricultural Research **35(1):** 66-68.

El-Habbasha KM, Mahmoud HA, Thabet NG and Abdou FE 1985. Effect of GA3 and IAA application on the flowering and seed production of onion (*Allium cepa* L). Journal of Agriculture and Water Resources Research **4(2):** 13-26.

Govind, Maji S, Kumawat R, Pal A, Kumar S and Saha S 2015. Improvement of growth, yield and quality of garlic (*Allium sativum* L) cv G-282 through a novel approach. Bioscan **10(1):** 23-27.

Graham HD and Ballesteros M 1980. Effect of plant growth regulators on plant nutrients. Journal of Food Science **45(3):** 502-505.

Gurudev S and Saxena OP 1991. Seed treatments with bioregulators in relation to wheat productivity. In: New trends in plant physiology, Proceedings, National Symposium on Growth and Differentiation in Plants, New Delhi, India, pp 201-210.

Halevy AH and Shoub J 1964. The effect of cold storage and treatment with gibberellic acid on flowering and bulb yields of Dutch iris. Journal of Horticultural Science **39(2):** 120-129.

Hisamatsu T, Koshioka M, Kubota S and King RW 1998. Effect of gibberellin A_4 and GA biosynthesis inhibitors on growth and flowering of stock, *Matthiola incana* (L) R Br. Journal of the Japanese Society for Horticultural Science **67:** 537-543.

Hore JK, Paria NC and Sen SK 1988. Effect of pre-sowing seed treatment on germination, growth and yield of onion (*Allium cepa* L) var Red Globe. Haryana Journal of Horticultural Sciences **17:** 83-87.

Humphries EC and Wheeler AW 1963. The physiology of leaf growth. Annual Review of Plant Physiology **14(1):** 385-410.

Hye MA, Haque MS and Karim MA 2002. Influence of growth regulators and their time of application on yield of onion. Pakistan Journal of Biological Sciences **5(10):** 1021-1023.

Jauhari DS, Singh RD and Dikshit VS 1960. Preliminary studies on the effect of gibberellic acid on growth of spinach (*Spinacia oleracea*). Current Science **29(12):** 484-485.

Kale VS, Dod VN, Adpawar RM and Bharad SG 2000. Effect of plant growth regulators on fruit characters and quality of ber (*Zizyphus mauritiana* L). Crop Research **20(2):** 327-333.

Kashyap K 2012. Studies on effect of plant growth regulators on growth, yield and quality of onion. MSc (Agric) thesis, Inidra Gandhi Krishi Vidyapeeth, Raipur, Chhattisgarh, India.

Kaushik MP, Sharma JK and Singh I 1974. Effect of alpha naphthalene acetic acid, gibberellic acid, kinetin and morphactin on yield of tomato. Plant Science **6:** 51-53.

Lipe WN 1975. Influence of growth regulators on growth, bulbing and yield in onion. Horticultural Science **10(1):** 20-21.

Lopper GM and Waller GD 1982. GA3 incised bolting and seed production in late planted onion. HortScience **17(6):** 922-923.

Lovato A, Dellacecca V, Montanari M, Macchia M and Magnani G 2000. A three years research of lettuce (*Lactuce sativa* L) seed production in two environmental conditions. Sementi Elette **46(6):** 19-23.

Magsino HJ 1961. The effect of gibberellic acid on garlic. Araneta Journal of Agriculture **8:** 54-73.

Mathur MM 1971. Response of *Allium cepa* Linn transplants to different plant growth regulators. Indian Journal of Horticulture **28(4):** 296-300.

Maurya AN and Lal S 1975. Effect of plant growth regulators on growth and development of onion (*Allium cepa* L) transplants. Bangladesh Horticulture **3(2):** 11-16.

Mishriky JF, El-Fadaly KA and Badawi MA 1990. Effect of gibberellic acid (GA_3) and chlormequat (CCC) on growth, yield and quality of peas (*Pisum sativum* L). Bulletin of Faculty of Agriculture, University of Cairo, Giza, Egypt **41(3):** 785-797.

Miyazaki S, Tashiro Y, Kanozowa K and Tabaru M 1986. Promotion of flowering of taro by the treatment of seed cormel and young plants with gibberellic acid. Journal of the Japanese Society of Horticultural Science **54(4):** 450-549.

Mulge R, Chauhan M and Madalgiri MB 1998. Seedling germination and seedling growth as influenced by seed treatments in onion. South Indian Horticulture **46:** 206-208.

Nandekar DN and Sawarkar SD 1992. Note on effect of growth regulators on growth, yield and quality of kharif onion. Indian Journal of Horticulture **49(3):** 267-269.

Nehara BK, Pandita ML and Singh K 1992. A note on the effect of various chemicals on bolting and seed yield of onion under seed to seed method of seed production. Haryana Journal of Horticultural Sciences **21(1-2):** 103-105.

Okazawa Y 1959. Studies on the occurrence of natural gibberellin and its effect on the tuber formation of potato plants. Proceedings, Crop Science Society of Japan **28:** 129-133.

Patel HB, Kakade DK, Tomar RS, Kulkarni GU, Memane PG, Deshmukh NA, Sharma SJ and Patel CD 2009. Effect of plant growth regulators on sex expression and yield of sponge gourd, *Luffa cylindrica* (Roem) cv Pusa Chikni. Asian Journal of Horticulture **4(2):** 408-410.

Raifa AH, Hemmat KI, Hala MS and Sadak MS 2005. Increasing the active constituents of sepals of roselle (*Hibiscus subdariffa* L) plant applying gibberellic acid and benzyladenine. Journal of Applied Sciences Research **1(2):** 137-146.

Rashid MHA 2010. Effect of sulphur and GA_3 on the growth and yield of onion. Progressive Agriculture **21(1-2):** 57-63.

Reghin MY, Otto RF and Rocha A 2000. Flowering induction and seed yield in lettuce with different doses of gibberellic acid. Horticultura Brasileira **18(3):** 123-128.

Sharma DP, Verma BK, Mehta AK and Shrivastava RK 1998. Correlation and path analysis in garlic (*Allium sativum* L). Haryana Journal of Horticultural Sciences **27(4):** 277-280.

Shishido Y and Saito T 1984-1985. Effects of plant growth regulators on low temperature induction of flower buds in onion plants. Journal of the Japanese Society for Horticultural Science **53(1):** 45-51.

Shukla N, Mondal S, Dikshit SN, Trivedi J, Tamrakar S and Sharma P 2007. Effect of different concentrations of GA_3 and NAA and their methods of application on growth and yield of onion (*Allium cepa* L). Progressive Horticulture **42(1):** 111-113.

Simão S, Serzedello A and Whitaker N 1958. Ação do ácido giberélico sobre o tomateiro *(Lycopersicon esculentum* Mill). Revista de Agricultura **33(3):** 153-156.

Singh B 2003. Studies on seed production of onion (*Allium cepa* L) as influenced by bulb size and nitrogen levels. MSc (Agric) thesis, Inidra Gandhi Krishi Vidyapeeth, Raipur, Chhattisgarh, India.

Singh UR, Singh RP and Vishkarma SK 2013. Effect of gibberellic acid and sulphuron glycosides and phenolics on onion bulbs (*Allium cepa* L). Trends in Biosciences **6(4):** 363-365.

Srivastava NK and Srivastava AK 2007. Influence of gibberellic acid on $^{14}CO_2$ metabolism, growth and production of alkaloids in *Catharanthus roseus*. Photosynthetica **45(1):** 156-160.

Surendra PN, Awalagatti CM, Chetti M and Hiremath HM 2006. Effect of plant growth regulators and micronutrients on yield and yield components in okra. Karnataka Journal of Agricultural Sciences **19(2):** 264-267.

Takagi H and Aoba T 1976. Studies on bulb formation in garlic: effect of growth regulators on shoot growth and bulb formation. Journal of Yamagata Agriculture and Forestry Society **33:** 39-50.

Thiruvelavan P, Thamburaj S and Veeraragavathatham D 1999. Studies on flowering and seed yield of *Allium cepa* sp *aggregatum* onion in Kharif season. South Indian Horticulture **47:** 223-224.

Tiwari RS, Ankur Agarwal A and Sengar SC 2003. Effect of bioregulators on growth, bulb yield, quality and storability of onion cv Pusa Red. Indian Journal of Plant Physiology **8(4):** 411-413.

Ud-Deen MM, Kabir G, Rahman MA and Hossain MS 2005. Influence of plant growth regulators on morphological changes in onion (*Allium cepa* L). Bangladesh Journal of Environmental Science **11(1):** 94-96.

Waghmode HS, Patil RS and Pandure BS 2010. Effect of biofertilizer and gibberellic acid on yield contributing character of onion. International Journal of Agricultural Sciences **6(2):** 392-394.

Watson DJ 1947. Comparative physiological studies on the growth of field crops. II. The effect of varying nutrient supply on net assimilation rate and leaf area. Annals of Botany **11:** 375-407.

Weaver RJ 1972. Plant growth substances in agriculture. WH Freeman and Co, San Francisco, USA, 594p.