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Effect of photoperiod and gibberellic acid (GA_3) on flowering and fruiting of strawberry- A review

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Abstract
The use of plant growth regulators is exceptionally common practice in present day cultivation. They give a few benefits rearranging and improving fruit production. In commercial production of strawberry, the most development controller utilized and researched is GA_3 for the most part altering the beneficial characteristics of plants. Such as increasing fruit weight, plant height, early flowering, petiole length, fruit set, leaf area, yield and improve quality of fruit and also help in stem elongation and cell division. Photoperiodism plays an essential role in flower initiation. The photoperiod promoted plant growth, but also enhanced runner growth, runner formation and ramet growth. It could encourage a stronger runner plant to multiply. The light irradiation during the nursery season accelerated the harvest due to the ongoing flowering.

Keywords: strawberry, flower, photo period, gibberellic acid, fruit

Introduction
The gibberellins were discovered by Japanese scientist, who studied the foolish rice disease caused by fungus *Gibberella fujikuroi* (asexual stage) in 1920. Later on, the active substance, which was quite heat static, was isolated from the fungus and named as gibberellin by Teijiro Yabuta in 1935. Further work on gibberellins led to the identification, synthesis and crystallization of gibberellic acid in 1950s (Brian and Hemming, 1955). Gibberellic acid (GA_3) is a phytohormone, which is naturally present in plants in very small amounts. So for good growth, development and for more yield of plant, exogenous applications of gibberellins have proved to be beneficial for the crops. The commercial product of gibberellic acid is synthesized artificially which is available in various forms but mainly in liquid form for exogenous sprays. Gibberellic acid helps to improve the fruits in many different ways such as, it increases fruit marketable demand. All known gibberellins are diterpenoic acids, synthesised in plastids via the terpenoid route and then modified in the endoplasmic reticulum and cytosol until they enter their biologically active form. All gibberellins come from the *ent*-Giberellin framework, but are synthesized by *ent*-Kauren. Gibberellins have two groups based on the existence of 19 or 20 carbon atoms. But only few GAs are bioactive while others are deactivated. Bioactive GAs occurs both in the fungi and bacteria and consists GA_1, GA_3, GA_4, GA_7, which are used in all over the world. There are three common structural features among these Gas *viz*. hydroxyl group, carboxyl group and the lactone ring. GA_5 and GA_6 are examples of bioactive Gas but do not have a hydroxyl group. The presence of GA_1 in several plant species suggests that, this is a common bioactive GA. The physiological response of species to the length of the day or night is termed as photoperiodism. Photoperiods and light quality has profound impacts on the flowering in strawberries, while the intensity of light has a lower influence. Strawberries are categorized according to their photoperiodic flowering responses: short day, long day and day-neutral. June bearing plants are ever bearing plants, initiate flower buds under short day and long day respectively. In day-neutral plants, flower induction is relatively in different day duration. Others, however, consider true day-neutral genotypes distinct from the other classes genetically and physiologically (Ahmadi *et al.*, 1990). Most researchers accept that, due to the spectrum of photoperiodic responses found in various genotypes, categorization is difficult. The photoperiodic response is quantitative and, for cultivars within a class, the response curve varies. When the photoperiod is less than 14 h, SD genotypes initiate flowers, whereas LD genotypes typically require photoperiods greater than 12 h (Darrow 1936). Photoperiod and light quality help to increase the plant growth, flower initiation and increase leaf area.

Effect of gibberellic acid (GA_3) on the growth and development of strawberries

Gibberellins have been shown to affect the growth and development in strawberry to a greater extent. In a study conducted to evaluate the influence of plant growth regulators on strawberry cv. Chandler, GA_3, IAA and NAA (25, 50 and 100ppm, respectively) were applied in triplicate. Application of these growth regulators resulted in enhancement of the vegetative characters in strawberry. However, for vegetative characters including runner production, GA was found to be the most responsive among other plant growth regulators. NAA @ 100 ppm was effective in alleviating the yield characters in strawberry (Suvalaxmi *et al*., 2016). Gibberellic acid results in higher cell division which enhances the vegetative growth in plants. In strawberry, GA_3 diminishes blooming and as a result vegetative development counting generation of runners increases (Arteca, 1995) [31].

Plant growth regulators *viz*. BAP, GA_3 & Kn in different composition produced different crave response *in vitro*. The treatment [BAP (1.5mg/l) + Kn (0.1mg/l)] given after 30 days of culture, gave the highest number of shoot (3) with 5.5cm shoot length, highest number of leaves (7) and maximum survival rate of explants (70%-75%) and thus it was found to be the best among the various treatment combination (Bhat *et al*. 2012) [3].

Effect of gibberellic acid (GA_3) on the flowering and fruiting of different strawberry cultivars

Ozgüven and Yilmaz, (2000) [41] examined the effect of GA_3 on the flowering and fruiting of strawberry and determined that GA_3 caused the early blossoming and fruiting of cv. Camarosa, particularly at 10 ppm and 20 ppm doses but in low freezing temperature, the effectiveness of the treatments on fruit yield was failed. Similarly, Thakur *et al*., (2017) [56] disclosed that treatment of strawberries with 15 ppm GA_4 + GA_7 applied two weeks before blooming, increased the flowering, fruit diameter, fruit set, fruit length, fruit weight and yield while, promalin gave best results at 6 ppm concentration with increased yield (137.92%) and fruit weight (51.81%).

Narayan, (2014) [37] analysed that two foliar sprays of 100 ppm GA_3 at one month after planting and 15 days after flowering gave the highest value of leaf numbers, crown per plant, plant height and runners per plant in the strawberry cv. Chandler.

Effect of photoperiodism on the growth, development and flowering of the strawberry varieties

Strawberry plants act as donor or receptor units. The effect of long photoperiods or a light-break treatment increased petiole length, leaf size and the flower initiation in the donor plants and short photoperiod treatment delayed flower initiation in receptor plants (Guttridge, 1956) [17]. Wu *et al*., (2009) [58], described that, LED was found to be the best light source for runner generation. Similarly, Yoshida *et al*., (2016) [61] observed that blue light from the different peak LED type encouraged more blooming as compared to red light as well the photosynthetic pace under the blue light was higher than under the red light. Likewise, Hidaka *et al*., (2013) [25] reported that the leaf photosynthesis was altogether higher in plants illuminated with tall irradiance LEDs than in those lighted with fluorescent lights, as a result, supplemental lighting (more t12h per day) given by LEDs driven to superior in the fruit quality and higher marketable value of strawberry fruits.

The photoperiod from 11 to 17 h increased flower bud induction by 2-, 5-, and 20-fold in three different long day (LD) cultivars while, floral induction in day-neutral (DN) genotypes occurs independently of day length (Downs and Piringer, 1955) [10]. The minimum number of photo inductive cycles required for flower bud induction in strawberry ranges from 7 to 24 (Hartmann, 1947; Heide, 1977; Hancock, 1999) [19, 22, 18]. The photoperiod response of flower bud induction in strawberry is well described in terms of day length, little is known regarding the effect of quality. The far-red extension delayed induction but red- light increased the flower induction in strawberry (Zahavi and Ephrat, 1974; Guttridge, 1985) [62, 17].

The Frigo plant of 'Elkat' strawberries were examined, beneath diverse light-emitting diode treatment: (red and a combination of red and blue LEDs). Results revealed that, red LED initiated prolongation of flowering stem and entire plant; this brought about in higher shoot/root proportion whereas, a blend of red & blue LED spectral components is fundamental for the improvement of Frigo strawberries (Samuoliene *et al*., 2010) [50]

GA_3 and photoperiod regimes, long and short days, using 16 hours and 10 hours light respectively were applied in different quantity in different varieties of the strawberry. As a result, the leaf area and the length of the petiole were increased by GA_3. Application of GA_3 at high concentration (200mg/l) increased the petiole concentration duration to a greater degree (50mg/l) than at a lower concentration. The leaf increased with the distinct GA_3 application dose to a similar extent, region (Paroussi *et al*., 2002) [44].

Effect of GA_3 on quality parameters

Paroles *et al*., (2018) [42] described that the application of plant growth regulators (RDF + 75 ppm GA_3) was expected to be the best way to increase the quality parameters, i.e. TSS: acid ratio, total sugar, reduction of sugar, non-reducing sugar and the content of ascorbic acid, compared to control, while fruit acidity decreased with the same treatment.

Effect of GA_3 on ripening of strawberry

Gibberellin sprays can be used to increase the amount of fruit picked during the picking season. An analysis of the effect of this compound on 'Sparkle strawberry suggested that gibberellins at a concentration of 10 ppm should be applied three times at weekly intervals beginning in the autumn when the flowers are first launched for better performance (Smith *et al*., 1961).

Effect of GA_3 on strawberry disorders

Experiments have been conducted to study the impacts of foliar application of gibberellic acid on vegetative development, flowering, fruiting and disorders of the 'Chandler' strawberry. Results indicated that application of GA_3 @ 75 ppm improved vegetative and reproductive growth of strawberries with a lower proportion of malformed and button berries with higher marketable fruit yields, and without any adverse effects on fruit quality (Sharma and Singh, 2018) [51].

Effect of GA_3 on ripening of Strawberry

The effect of GA_3 was evaluated by different biochemical parameters on post-harvest maturation in strawberry fruit. Strawberry slices were incubated with GA_3 at various ripening levels. Studies suggested that GA_3 has an inhibitory effect on the maturation of strawberry fruits, evidenced by decreased respiratory activity and delayed synthesis of anthocyanin and degradation of chlorophylls (Martínez *et al*., 1994) [35].

Conclusion

GA_3, photoperiod and essential elements are vital components of plant (crop) life cycle affecting quality and quantity of fruits and their optimized usage can improve production, promote plant health and increase yield. The alteration in the photoperiodism (light) along with GA_3 applications found to decrease the time duration required for inflorescence initiation & bud formation as well as enhance runner growth, development, vegetative growth and yield in strawberries. Applications of growth regulators (GA_3) also help to reduce physiological disorders of strawberry to some extent but their role is quite unknown.

References

1. Asrey R, Jain RK, Singh R. Effect of plant growth regulators on growth and survival of strawberry runners under semi-arid region of Punjab. Indian Journal of Plant Physiology 2003;8(2):196-198.
2. Ayesha R, Fatima N, Ruqayya M, Qureshi KM, Hafiz IA, Khan KS *et al*. Influence of different growth media on the fruit quality and reproductive growth parameters of strawberry (*Fragaria* x *ananassa* Duch.). Journal of Medicinal Plants Research 2011;5(26):6224-6232.
3. Bhat RP, Devi KM, Jayalaxmi H, Sophia I, Prajna PS. Effect of plant growth regulators on establishment and growth of strawberry (*Fragaria* x *ananassa* Duch.) var. chandler *in vitro*. Agricultural Science Research Journal 2012;2(12):623-32.
4. Dale A, Elfving DC, Chandler CK. Benzyladenine and gibberellic acid increase runner production in day-neutral strawberries. HortScience 1996;31(7):1190-1194.
5. Danial GH, Ibrahim DA, Omer MS. Response of running shoot tips of strawberry (*Fragaria* x *ananasa*) for *in vitro* propagation in Kurdistan Region of Iraq. International Journal of Environment, Agriculture and Biotechnology 2016;1(2):238-516.
6. Darnell RL, Cantliffe DJ, Kirschbaum DS, Chandler CK. The physiology of flowering in strawberry. Horticultural Reviews 2003;28:325-349.
7. Davière JM, Achard P. Gibberellin signaling in plants. Development 2013;140(6):1147-1151.
8. Debeaujon I, Koornneef M. Gibberellin requirement for Arabidopsis seed germination is determined both by testa characteristics and embryonic abscisic acid. Plant physiology 2000;122(2):415-424.
9. Demirsoy L, Demirsoy H, Uzun S, Ozturk A. The effects of different periods of shading on growth and yield in Sweet Charlie strawberry. European Journal of Horticultural Science 2007;72(1):26.
10. Downs RJ and Piringer AA. Differences in photoperiodic response of everbearing and June-bearing strawberries. Proceedings of the Amwerican Society of Horticultural Science 1955;66:234-236.
11. Dubey V, Meena ML, Tripathi VK, Meena DC, Meena JK, Rai T. Response of foliar application of NAA, GA_3 and boric acid on vegetative growth and yield of strawberry (*Fragaria* × *ananassa* Duch.) cv. chandler. Annals of Horticulture 2017;10(1):40-44.
12. El-Shabasi MSS, Ragab ME, El-Oksh II, Osman YMM. Response of strawberry plants to some growth regulators. In VI International Strawberry Symposium 2008;842:725-728.
13. Eshighi S, Safizadeh MR, Jamali B, Sarseifi M. Influence of foliar application of volk oil, dormex, gibberellic acid and potassium nitrate on vegetative growth and reproductive characteristics of strawberry cv. Merak. Journal Biol. Environmental Science 2012;6(16):35-38.
14. Ghosh S, Halder S. Effect of different kinds of gibberellin on temperate fruit crops: A review. The Pharma Innovation Journal 2018;7:315-319.
15. Gomes F, Simões M, Lopes ML, Canhoto JM. Effect of plant growth regulators and genotype on the micropropagation of adult trees of *Arbutus unedo* L. (strawberry tree). New Biotechnology 2010;27(6):882-892.
16. Gulen H, Eris A. Effect of heat stress on peroxidase activity and total protein content in strawberry plants. Plant Science 2004;166(3):739-744.
17. Guttridge CG. *Fragaria* x *ananassa*. In CRC Handbook of Flowering. (Halevy, A.H., Ed.). Volume III. CRC Press, Inc., Boca Raton, FL, USA 16-33.
18. Hancock JF. Strawberries. CAB International, Wallinford, Oxon., UK 237.
19. Hartmann HT. Some effects of temperature and photoperiod on flower formation and runner production in strawberry. Plant Physiology 1947;22:407-420.
20. Hasan SMZ, Al-Madhagi I, Ahmad A, Yusoff WAB. Effect of photoperiod on propagation of Strawberry (*Fragaria* x *ananassa* Duch.). Journal of Horticulture and Forestry 2011;3(8):259-263.
21. Hazarika TK, Ralte Z, Nautiyal BP, Shukla AC. Influence of bio-fertilizers and bio-regulators on growth, yield and quality of strawberry (*Fragaria* × *ananassa*). Indian Journal of Agricultural Sciences 2015;85(9):1201-5.
22. Heide OM. Photoperiod and temperature interactions in growth and flowering of strawberry. Physiologia Plantarum 1977;40:21-26.
23. Heide OM, Stavang JA, Sønsteby A. Physiology and genetics of flowering in cultivated and wild strawberries-a review. The Journal of Horticultural Science and Biotechnology 2013;88(1):1-18.
24. Hidaka K, Dan K, Imamura H, Takayama T, Sameshima K, Okimura M. Variety comparison of effect of supplemental lighting with LED on growth and yield in forcing culture of strawberry. Environmental Control in Biology 2015;53(3):135-143.
25. Hidaka K, Okamoto A, Araki T, Miyoshi Y, Dan K, Imamura H *et al*. Effect of photoperiod of supplemental lighting with light-emitting diodes on growth and yield of strawberry. Environmental Control in Biology 2014;52(2):63-71.
26. Hideo ITO, Saito T. Studies on the flower formation in the strawberry plants I. Effect of temperature and photoperiod on the flower formation. Tohoku journal of agricultural research 1962;13(3):191-203.
27. Hytönen T, Elomaa P, Moritz T, Junttila O. Gibberellin mediates daylength-controlled differentiation of vegetative meristems in strawberry (*Fragaria* × *ananassa* Duch). BMC Plant Biology 2009;9(1):18.
28. Ikram S, Qureshi KM, Khalid N. Flowering and fruiting responses of strawberry to growth hormone and chilling grown under tunnel conditions. Pakistan Journal of Agricultural Science 2016, 53(4).

29. Kano Y, Asahiras T. Effects of some plant growth regulators on the development of strawberry fruit in vitro culture. Journal of the Japanese Society for Horticultural Science 1978;47(2):195-202.
30. Koskela EA, Mouhu K, Albani MC, Kurokura T, Rantanen M, Sargent DJ *et al*. Mutation in TERMINAL FLOWER1 reverses the photoperiodic requirement for flowering in the wild strawberry *Fragaria vesca*. Plant Physiology 2012;159(3):1043-1054.
31. Kumakura H, Shishido Y. Effects of temperature and light conditions on flower initiation and fruit development in strawberry. Japan Agricultural Research Quarterly 1995;29:241-250.
32. Kumar R, Tripathi VK. Influence of NAA, GA3 and boric acid on growth, yield and quality of strawberry cv. Chandler. Progressive Horticulture 2009;41(1):113-115.
33. Kumra R, Saravanan S, Bakshi P, Kumar A, Singh M, Kumar V. Influence of plant growth regulators on strawberry: A review. International Journal of Chemical Studies 2018;6(1):1236-1239.
34. Liu C, Guo Z, Park YG, Wei H, Jeong BR. PGR and Its Application Method Affect Number and Length of Runners Produced in Maehyang and Sulhyang Strawberries. Agronomy 2019;9(2):59.
35. Martinez GA, Chaves AR, Anon MC. Effect of gibberellic acid on ripening of strawberry fruits (*Fragaria* x *annanassa* Duch.). Journal of Plant Growth Regulation 1994;13(2):87.
36. Nadalini S, Zucchi P, Andreotti C. Effects of blue and red LED lights on soilless cultivated strawberry growth performances and fruit quality. European Journal Horticulture Science 2017;82:12-20.
37. Narayan S. Effect of foliar application of nitrogen and plant growth regulators on vigour, yield and generative characters of strawberry. Journal of Natural Resource and Development 2014;9(1):1-4.
38. Nishizawa T, Ito A, Shishido Y. Effects of Light Intervals on Flower-Bud Formation, Leaf Growth, and Chlorophyll and Carbohydrate Concentrations in Nyoho Strawberry Runner Plants during Storage under Cool Conditions. Environment Control in Biology 1999;37(1):43-48.
39. Nishizawa T. Effects of photoperiods on the length and number of epidermal cells in runners of strawberry plants. Journal of the Japanese Society for Horticultural Science 1994;63(2):347-352.
40. Özdemir E, Kaşka N, Gündüz K, Serce S. Effects of short-day conditioning, chilling and GA3 treatments to yield and fruit quality in strawberry plug transplants aiming early fruit production. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 2013;41(1):263-268.
41. Ozgüven AI, Yilmaz C. The effect of gibberellic acid treatments on the yield and fruit quality of strawberry (*Fragaria* x *ananassa*) cv. Camarosa. In IV International Strawberry Symposium, July 2000;567:277-280.
42. Paikra S, Panigrahi HK, Chandrakar S. Effect of NAA and GA3 spray on quality parameters of strawberry (*Fragaria* x *ananassa* Duch.) cv. Sabrina under net tunnel. Journal of Pharmacognosy and Phytochemistry 2018;7(6):393-395.
43. Palei S, Das K, Sahoo KA, Dash DK, Swain S. Influence of plant growth regulators on strawberry Cv. Chandler under Odisha condition. International Journal of Scientific Research 2016;7(4):9945-48.
44. Paroussi G, Voyiatzis DG, Paroussis E, Drogoudi PD. Growth, flowering and yield responses to GA3 of strawberry grown under different environmental conditions. Scientia Horticulturae 2002;96(1-4):103-113.
45. Paroussi G, Voyiatzis DG, Paroussis E, Drogoudi PD. Effect of GA3 and photoperiod regime on growth and flowering in strawberry. In IV International Strawberry Symposium July 2000;567:273-276.
46. Pipattawong N, Fujishige N, Yamane K, Ijiro Y, Ogata R. Effects of growth regulators and fertilizer on runner production, flowering, and growth in day-neutral strawberries. Japanese Journal of Tropical Agriculture 1996;40(3):101-105.
47. Qureshi KM, Chughtai S, Qureshi US, Abbasi NA. Impact of exogenous application of salt and growth regulators on growth and yield of strawberry. Pakistan Journal of Botany 2013;45(4):1179-1185.
48. Rademacher W. Chemical regulators of gibberellin status and their application in plant production. Annual Plant Reviews online 2018, 359-403.
49. Robert F, Risser G, Pétel G. Photoperiod and temperature effect on growth of strawberry plant (*Fragaria* x *ananassa* Duch.): development of a morphological test to assess the dormancy induction. Scientia Horticulturae 1999;82(3-4):217-226.
50. Samuolienė G, Brazaitytė A, Urbonavičiūte A, Šabajevienė G, Duchovskis P. The effect of red and blue light component on the growth and development of frigo strawberries. Zemdirbyste-Agriculture 2010;97(2):99-104.
51. Sharma RR, Singh R. Gibberellic acid influences the production of malformed and button berries, and fruit yield and quality in strawberry (Fragaria x ananassa Duch.). Scientia Horticulturae 2009;119(4):430-433.
52. Sønsteby A, Heide OM. Dormancy relations and flowering of the strawberry cultivars Korona and Elsanta as influenced by photoperiod and temperature. Scientia Horticulturae 2006;110(1):57-67.
53. Sønsteby A, Heide OM. Long-day control of flowering in everbearing strawberries. The Journal of Horticultural Science and Biotechnology 2007;82(6):875-884.
54. Sønsteby A, Heide OM. Quantitative long-day flowering response in the Perpetual-flowering F1 strawberry cultivar Elan. The Journal of Horticultural Science and Biotechnology 2007;82(2):266-274.
55. Sood MK, Kachawaya DS, Singh MC. Effect of Bio-Fertilizers and plant growth regulators on growth, flowering, fruit ion content, yield and fruit quality of strawberry. International Journal of Agriculture, Environment and Biotechnology 2018;11(3):439-449.
56. Thakur Y, Chandel JS, Verma P. Effect of plant growth regulators on growth, yield and fruit quality of strawberry (*Fragaria* x *ananassa* Duch.) under protected conditions. Journal of Applied and Natural Science 2017;9(3):1676-1681.
57. Uematsu Y, Katsura N. Changes in endogenous gibberellin level in strawberry plants induced by light breaks. Journal of the Japanese Society for Horticultural Science 1983;51(4):405-411.
58. Wu CC, Hsu ST, Chang MY, Fang W. Effect of light environment on runner plant propagation of strawberry. In VI International Symposium on Light in Horticulture, November 2009;907:297-302.

59. Xu X, Hernández R. The Effect of Light Intensity on Vegetative Propagation Efficacy, Growth, and Morphology of Albion Strawberry Plants in a Precision Indoor Propagation System. Applied Sciences 2020;10(3):1044.
60. Yadav I, Singh J, Meena B, Singh P, Meena S, Neware S *et al*. Strawberry Yield and Yield Attributes after Application of Plant Growth Regulators and Micronutrients on Cv. Winter Dawn. Chemical Science Review and Letters 2017;6(21):589-594.
61. Yoshida H, Mizuta D, Fukuda N, Hikosaka S, Goto E. (Effects of varying light quality from single-peak blue and red light-emitting diodes during nursery period on flowering, photosynthesis, growth, and fruit yield of everbearing strawberry. Plant Biotechnology 2016;33(4):267-276.
62. Zahavi AK, Ephrat E. Opposite response groups of short-day plants to the spectral composition of the main light period and to end-of-day red or far-red irradiations. Plant and Cell Physiology 1974;15(4):693-699.
63. Zheng J, He D, Ji F. Effects of light intensity and photoperiod on runner plant propagation of hydroponic strawberry transplants under LED lighting. International Journal of Agricultural and Biological Engineering 2019;12(6):26-31.