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Effect of different kinds of gibberellin on temperate fruit crops: A review

Subham Ghosh and Shuvadeep Halder

Abstract
Gibberellin is a group of plant hormones that occur in seeds, young leaves, and roots. The name is derived from *Gibberella fujikuroi*, a hormone-producing fungus. Evidence suggests that gibberellins stimulate the growth of main stems, especially when applied to the whole plant. It has a great effect in seed germination, breaking dormancy, seedling growth, flowering, delay flowering, fruit development and fruit quality improvement etc. in many fruit crops and specially temperate fruit crops i.e apple, pear, peach, cherry, apricot etc.

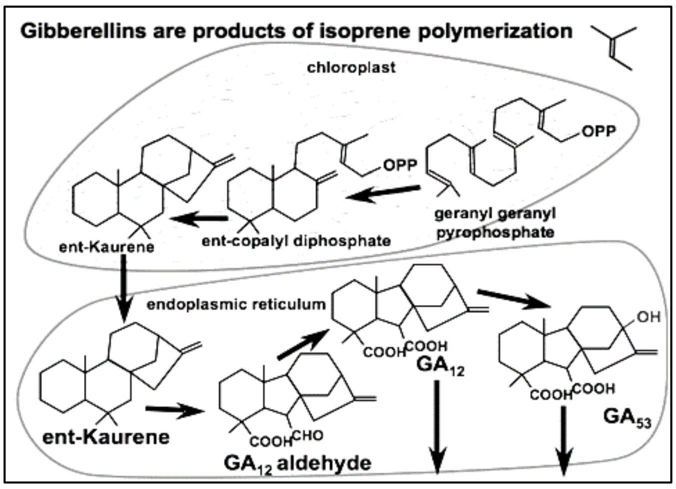
Keywords: GA, flowering, fruit set, germination, temperate fruit

Introduction
Gibberellins (GAs) are plant hormones that regulate growth and influence various developmental processes. Including stem elongation, germination, dormancy, flowering, sex expression, enzyme induction and leaf and fruit senescence.
Gibberellin was first recognized in 1926 by a Japanese scientist, Eiichi Kurosawa, a plant pathologist, studying bakanae the 'foolish seedling' disease in rice. It was first isolated in 1935 by Teijiro Yabuta and Sumuki from fungal strains (*Gibberella fujikuroi*) provided by Kurosawa. Yabuta named the isolate as gibberellins.

Occurrence
Soon after the work done by the Japanese, American and British groups, gibberellins were found to occur in higher plants and to be one of the most important classes of plant hormones that control plant growth. Immature seeds are usually the best source of naturally occurring gibberellins (Skene, 1970) [30].
At present there are more than 112 gibberellins (GAs) have been identified to date and the list grows almost every year. Some gibberellins are found only in the *Gibberella fujikuroi* fungus, some are found only in higher plants and some are found in both. At least 16 of the known gibberellins have been isolated from fungus and 27 have been isolated from the higher plants (Lang, 1970 MacMillan privet communication) [18]. At least 7 gibberellins occur both in the fungus and in some higher plants.

Chemical nature
Synthesis: Gibberellins have been defined as compounds that contain a gibbane skeleton and have appropriate biological properties. All known gibberellins are diterpinoid acids that are synthesized by the terpenoid pathway in plastids and then modified in the endoplasomic reticulum and cytosol until they reach their biologically-active form. All gibberellins are derived via the ent-gibberellane skeleton, but are synthesised via ent-kaurene. The intermediate precursor of gibberellins is a diterpene that contains four isoprene units (Arteca, 1996) [1]. The mevalonic acid pathway is used for the biosynthesis of gibberellins.

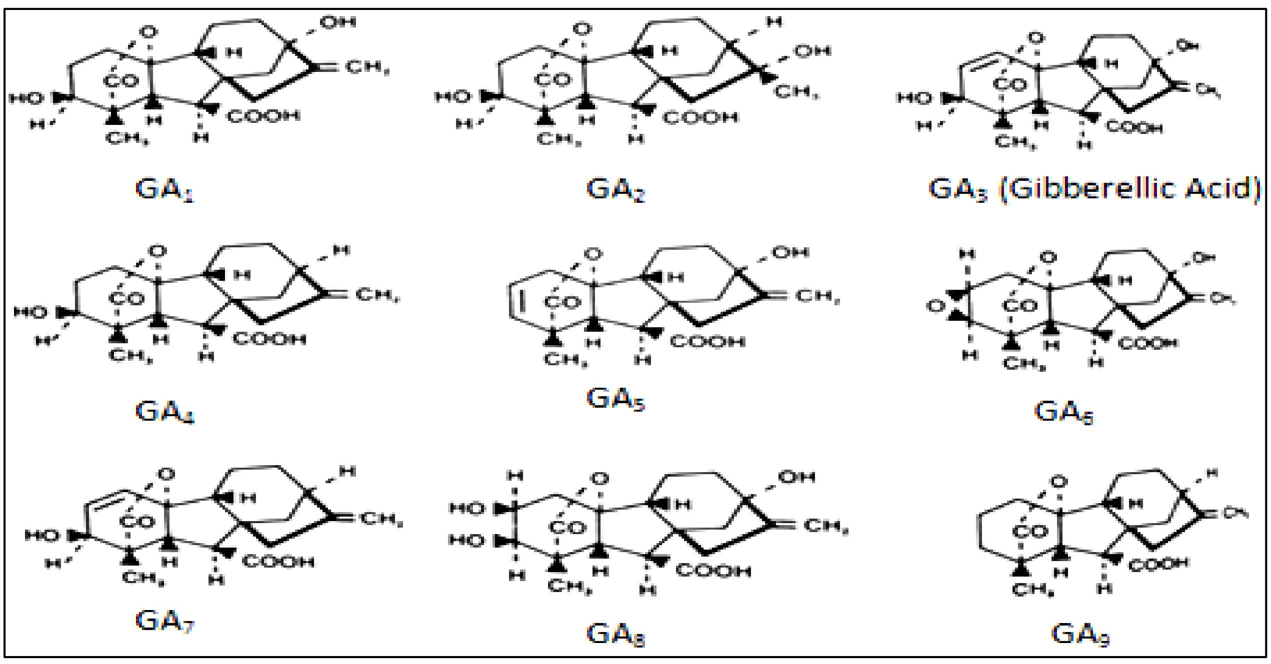
Structure: All the structure of many gibberellins are almost identical. Gibberellins are tetracyclic diterpene acids. All the gibberellins with 19 carbon atoms are monocarboxylic acids, have the –COOH group in position 7, and have a lactone ring. The major differences are that i) some gibberellins have nineteen carbon atoms and others have twenty and ii) hydroxyl groups may be present or absent in position 3 and 13 (ent-gibberellin numbering system). Only few GAs are bioactive, where others are precursors or deactivated GAs. The bioactive GAs are GA_1, GA_3, GA_4, and GA_7. There are three common structural traits between these GAs: i) a hydroxyl group on C-3β, ii) a carboxyl group on C-6, and iii) a lactone between C-4 and C-10. The 3β-hydroxyl group can be exchanged for other functional groups at C-2 and/or C-3 positions. GA_5 and GA_6 are examples of bioactive GAs that do not have a hydroxyl group on C-3β. The presence of GA_1 in various plant species suggests that it is a common bioactive GA.



Mode of Action

Germinating Seeds: One of the best examples of enzyme induction by hormone is the gibberellins induced production of α-amylase in barley aleurone.GA_3 can replaced an α-amylase inducing factor that produced by germinating barley seeds. The naturally occurring gibberellin is produced by the barley embryo and translocated into the alurone layers of the endosperm where synthesis of enzyme is occur. These enzymes, including amylase, proteases and lipase rapidly break down the cell walls of the endosperm and subsequently hydrolyze embryo the starches and proteins, thus liberating the nutrients and energy needed for the embryo development (Filner and Varner 1967) [11].

Gibberellin probably causes changes at the gene level; in turn stimulate synthesis of enzyme in the cell (Osborne, 1965) [22]. Gibberellin results in the stimulation of RNA synthesis in the alurone layers, which may be required for expression of the gibberellin effect (Varner and Chandra, 1964) [35]. One theory is that gibberellin is related to the DNA direct synthesis of the messenger RNA in the nucleus. It is now believed that gibberellins modifies the RNA produce in the nuclei and thus can exerts its control over cell elongation as well as other growth and developmental activities of the plant.



General Biological Effects

1. The most striking effect of spraying plants with gibberellins is the stimulation of growth. Stems of sprayed plants usually become much longer than normal (Stowe and Yamaki 1959) [33]. Growth is stimulated in the younger internodes and tissues and frequently the length of the individual internode is increased while the number of internodes remains unchanged. A temporary lightening of the leaves of many treated plants often is associated with the increase in leaf area, but normal green colour returns within ten days.
2. Gibberellin can induce flowering in many species requiring cold temperatures, such as carrot, endive, cabbage and turnip.
3. The application of gibberellins to stems produces a pronounced increase in cell division in the subapical meristem (Sachs *et al*. 1960) [29] and causes bolting in rosette plants. The rapid growth that occurs is a result of both the greater number of cells formed and an increased elongation of the individual cells.
4. One of the most remarkable effects of gibberellins is that occurring in dwarf plants. When some dwarf varieties, such as dwarf pea (Brian and Hemming, 1955) [3] and certain dwarf maize (Phinney, 1956) [23] are treated with gibberellins they grow to normal height. Since as little as 0.001µg suffices to increase stem elongation, some dwarf varieties are of value for gibberellin bioassays.
5. Gibberellin can terminate rest in the seeds of many species. In early work, the seeds of some species were not affected by exogenous gibberellins; subsequent research indicated that the cause frequently was the failure of the substance to penetrate the seed coat.
6. In many plants apical dominance is enhanced by treatment with gibberellins. Some bushy dwarf plants grow with a single stem after such treatment.
7. Gibberellins increase the size of many young fruits, such as grape and fig. The fact exogenous gibberellins can increase the berry size of seedless grape two or threefold is the basis of an important commercial practice. In such plants as grasses and celery, gibberellins application results in greater yield increases than that produced by untreated plants.

Practical Application

1. Effect of Gibberellins in rooting and propagation in temperate fruit crops

- These growth regulators are antagonistic to root initiation (Brine *et al*. 1960) [4]. Gibberellin probably prevents the cell division in mature tissues that is a prerequisite for creation of the meristematic condition and formation of root initials. The effect of gibberellins may also be a part of nutritional because shoot growth is stimulated and thus competes for the assimilates required for root initiation.
- GA_3 foliar application at 50 mg/l in Gaviota strawberry plants, increased runner which help us to produce strawberry plant.

2. Termination of seed rest of temperate fruits by application of Gibberellins

Seeds of many plants often require an extended period of after ripening at low temperature before they will germinate. Consequently, some means of terminating rest would definitely be of value to accelerate breeding programs.

There are so many work on seed rest by application of gibberellins temperate fruits like.

Apple

For commercial production of apple seedlings, the seeds are usually stratified under moist conditions at a temperature of 5 °C for seventy to eighty days. However, when ruptured seeds or excised embryos from nonstratified seeds are exposed to temperatures favorable for germination, a few embryos do grow but they fail to elongate norm ally. Such plants are termed “physiological dwarfs.” Gibberellin was the first chemical shown to stimulate the growth of physiological dwarfs. In 1956 Barton applied lanolin preparations or aqueous solutions of GA_3 to physiological dwarfs from embryos of Malus arnoldiana that had not been after-ripened. Treatment resulted in extension of the seedlings’ internodes and consequent elimination of the dwarfed condition. Although gibberellin accelerates the germination of dormant rosaceous seeds when the seed coat has been removed, it fails to have any effect when the coat structures are intact (Nekrasova, 1960) [21]. This observation was confirmed by Using seeds of apple (Malus) cultivars Red Stoke’ and ‘Medailic d’Or,’ he found gibberellins stimulates isolated embryos to germinate but has no effect if the endosperm is left intact, even the testa is first removed.

Peach

The standard amount of time required for stratification of peach seeds is sixty to one hundred days at 5 °C. Gibberellin treatment can replace at least some of the low-temperature requirement. Donoho and Walker (1957) [8] tested the effect of gibberellin on seeds of ‘Eibetra' peach that had received only thirty-five days of stratification, during which they were placed in a moist medium and stored at a near freezing temperature.

Cherry

Poor germination of seed of cherry (Prunus avium). Particularly those of early maturing varieties of sweet cherry, has been a major problem for the breeder, as well as for the nurseryman using Mazzard seedlings as rootstocks for cherry varieties. Seeds of sweet cherry require an after-ripening period of at least six months at 3 °C for germination. Gibberellin can substitute for part of this after-ripening period. Soaking the seeds for twenty-four hours in gibberellin at a concentration of 100 ppm immediately after collection substitutes for two or three months of the after-ripening period (Fogle. 1958) [12]. Pillay *et al* (1965) [24] experimented with Mazzard and Mahaleb cherry two species that differ distinctly in endocarp thickness. Mazzard seeds were found to require between 120 and 150 days of after ripening at 7 ^{0}C in a moist medium Mahaleb seeds require 79 to 90 days. Soaking seeds in giberellin at a concentration of 100ppm increases the rate of germination and partially replaces the chilling requirements. The investigators found that chilling seeds for twenty-four and thirty-four days at 7 ^{0}C and then soaking them In gibberellin at a concentration of 100ppm results In 75 to 100 percent germination. It was also found that seeds whose endocarp was left intact produced better germination on than seeds whose endocarp had been removed and that were subsequently treated with gibberellin.

3. **Termination of bud rest of temperate fruits by application of Gibberellins**

Peach

A period of chilling is necessary to terminate the rest period of peach buds. The Elberta peach requires 930 hours of chilling at temperatures below 7 °C. Donoho and Walker (1957) [8] demonstrated that gibberellins is effective in terminating rest in this cultivar. The trees which received 164 hours below 7 °C are growing rapidly. Shoot length increased with higher concentration of gibberellin. Trees that had received gibberellin at concentrations of less than 100ppm remained dormant.

4. **Effect of flowering of temperate fruits by application of Gibberellins**

These compounds are the only chemical substances capable of inducing flower formation in plants that are representative of well-defined physiological classes when such plants are grown under experimental conditions in which they otherwise would stay completely vegetative. Gibberellin thus appears to be capable of replacing certain specific environmental conditions that control flower formation. Application of GA_3 induces the majority of long-day and cold- requiring plants to form flowers; it also induces flower formation in certain long-short-day plants when it is substituted for the long-day requirement. Gibberellin usually enhances flowering in short-day plants growing under inductive conditions, but its effect is generally negative when these plants are grown under noninductive conditions. The flower formation of long-day or long-short-day plants can be controlled by regulating the endogenous level of gibberellin-like substances through the use of such growth retardants as CCC that inhibit gibberellin synthesis. In many short-day plants or in plants that do not require variations in light for flowering, gibberellin application usually delays flower initiation or blocks it entirely. This delay may be caused by rapid shoot growth, which results in much competition between vegetative growth and floral development.

5. **Prevention or delay flowering by application of gibberellins of temperate fruits**

Peach

In New York State, trees of 'Redhaven’ and 'Golden Jubilee’ were sprayed with potassium salt of GA_3 at concentrations of 50 or 200 ppm in late July (Edgerton, 1966) [9]. Examination of sections of buds in September showed that the gibberellin treatment had delayed the initiation of flower buds at the shoot tips and retarded flower bud development toward the bases of the shoots. Gibberellin delayed full bloom of Elberta peach up to six days in trials conducted in Washington State (Proebsting and Mills. 1964) [25]. A high percentage of the flowers on gibberellin-treated trees usually set fruit. The high set is probably a result of the sharp reduction in the number of flower buds per shoot. Application of gibberellin at a concentration of 50 ppm produced a nearly optimal set of fruit (Edgerton, 1966) [10]. If too high a concentration of gibberellln is used, no fruitful buds are formed (Hull and Lewis, 1959) [15]. In experiments in which trees of 'Redskin' peach were sprayed with gibberellin after bud differentiation but before leaf fall, bud development was retarded and some buds were killed (Stembridge and La Rue, 1969) [32].

Apricot, Almond, and Plum

Spraying apricot cv. ‘Royal’, almond cv. ‘Jordanolo’, and plum cv. ‘President’ during the floral initiation period with GA_3 at concentration of 100 to 1000 ppm at the initiation of the pit-hardening stage of the fruit growth that generally occurs during this period inhibits development of both floral and vegetative buds (Bradley and Crane. 1960) [2].

Blossoming in almond may be retarded for several days by application of gibberellins the preceding fall in order to reduce the frost hazard. Another advantage of gibberelline treatment is that it facilitates better cross pollination among varieties having non synchronous bloom periods (Hicks and Crane, 1968) [14].

Cherry

Post bloom applications of gibberellin at a concentration of 100 ppm to branches of mature, bearing trees of ‘Montmorency’ cherry was found to result in weak flowering the following year (Hull and Lewis, 1959) [15]. Flowers appeared on the distal portion of the shoots of treated branches. Spurs on the treated trees were entirely vegetative, but many non treated trees were fruitful. One post bloom application of gibberellin at a concentration of 500 ppm or two applications at a concentration of 250 ppm caused complete inhibition of flower bud development in sweet cherry cv. ‘Bing’ (Bradley and Crane, 1960) [2].

Pear

In California, September sprays of gibberellin at concentrations of 10 to 500 ppm failed to effect flowering in the following spring. However, higher concentration applied in March when flower bud scales were separating reduced flower bud formation. The greatest reduction in flower buds resulted when highest concentrations were applied at full bloom or petal fall (Griggs and Iwakiri, 1961) [13].

6. **Effect of gibberellins in physiology of fruit set**

Fruit set

Many fruits that can be set with auxins can also be set with gibberellins. However, gibberellins have also been effective for setting fruit in several species that do not respond to auxins.

Attempts to induce parthenocarpy in apple by applying auxins have produced rather poor results, but gibberellins have yielded positive results (Luckwill, 1959; Dennis and Edgerton. 1966) [19, 7]. However the induced fruit set has been generally low and application of gibberelline to open pollinated trees at petal fall has resulted in reduced yields. GA_3 usually has little effect on fruit set in seeded commercial varieties of apple unless pollination is prevented. Dennis (1970) [6] treated the blossoms of six apetalous clones with gibberellins to ascertain their response. He found that GA_3 was effective in increasing fruit set in only two of the six clones, and he confirmed that GA and the mixture of GA_4 and GA_7 were much more potent than GA_3 in inducing fruit set.

Auxins fail to fruit set in Rosa avensis, but GA_3 is very effective, it has been shown to induce a 71 percent parthenocarpic set compared with a 45percent set of pollinated blossoms (Prosser and Jackson, 1959) [27]. In Rosa spinosissima a synergic action occurs between GA_3 and NAA that promotes parthenocarpy (Prosser and Jackson, 1959) [27]. Two growth regulators together resulted in a 94 percent set. GA_3 alone and NAA alone resulted in sets of 70 and 65 percent respectively.

Parthenocarpy has also been induced in Sultan plum by application of GA_3 and a mixture of GA_4 and GA_7 (Jackson. 1968) [16] mixture was found to be more effective.

Parthenocarpic development of fruits of sweet cherry resulted from application of gibberelline only when applied in conjunction with 2, 4- dichlorophenoxyacetyl methionine (Rebeiz and Crane, 1961) [28].

7. Fruit Development

Gibberellin enhances cell enlargement, thereby increasing size. It also has the effect of delay ripening, so that the fruit has a longer time to develop and therefore reaches a larger size. When the treatment or treatments are given during the fruit growth will determine which of these two effects will be primary. Cherries are generally sprayed with gibberellins 3 to 4 weeks before harvest (Looney and Lidster, 1980) [37]. The sprayed fruits are larger and firmer than the unsprayed cherries (Looney and Lidster, 1980) [37]. Similar response have been found in other stone fruits, such as apricots nectarins.

8. Changes in growth pattern and fruit set induced by application of gibberellins

Seedless fruits of apple that are induced to set by gibberellins usually produce much more elongated fruit than do normal seeded fruits. Similarly fully seeded fruits of apple respond application of GA_3 by producing longer fruit, just as do the parthenocarpic fruit set by the hormone. Application of GA_3 has also been reported to increase the depth of the stem cavity of ‘McIntosh’ apple.

Application of gibberellins develops parthenocarpic fruits of peach that are similar to those resulting from pollination.

Application of gibberellins has also resulted in production of mature parthenocarpic pears (Griggs and Iwakiri, 1961) [13]. Application of this growth regulator at concentrations of 10 to 50ppm at the pink-bud stage, at full bloom or at petal fall increases fruit set by approximately 25 percent. Because treated fruits and pedicels are long, the calyx end of the fruits are distorted, and fruit softening is hastened, commercial gibberellins application has not yet become a reality. In Holland several varieties set poorly, including ‘Triomphe de Vienne’ and ‘Beurre Hardy’ are commercially sprayed with GA_3 at bloom to produce a good set (Van Eijden, 1965) [34], other varieties such as ‘Doyenne du Comice’ don’t respond.

Application of GA_3 at a concentration of 500ppm to trees of apricot cv. ‘Moorpark’ significantly increased the size of fruit within 7 days after treatment and the increase in size over that of controls was maintained until maturity (Jackson 1968) [17].

9. Ripening of Strawberry

Gibberellin sprays can be used to increase the quantity of fruit harvested during the early part of the picking season. An investigation of the compound’s effect on ‘Sparkle’ strawberry indicted that for best results, gibberellins at a concentration of 10ppm should be applied three times at weekly intervals starting in the autumn, when the flowers are first initiated (Smith *et al*., 1961) [31].

Prevention of internal browning of fruit

Prune

Early ripening varieties of prune grown in the northwestern United States are subjected to internal browning, or the breakdown of the flesh to the pit. However, experiments with several growth regulators have shown that a pre harvest spray of gibberellins at concentration of 100ppm to ‘Demaris Early Italian’ and ‘Richard Early Italian’ substantially reduces internal browning and results firmer fruit (Proebsting and Mills, 1966) [26]. The shelf life of the fruit is extended by approximately three days. Firmer fruit can be handled more easily, and also better suited for mechanical harvesting. A disadvantage of applying gibberellins to prune is that there is sometimes a delay in development of skin colour and a reduction in the level of soluble solids.

Peach

Application of ethephon and GA_3 to peach trees has consistently prevented the browning of pureed and sliced peaches subsequently prepared from such fruit. Application of ethephon at a concentration of 50ppm to ‘Early Amber’ when the seed was approximately 12mm in length and application of GA_3 two weeks after petal fall were found to be effective (Buchanan *et al*., 1969) [5]. It was found that pureed and sliced peaches could be held up to 24 hours without darkening.

Cherry

Gibberellin treatment can also decrease cherry pitting (Looney and Lidster, 1980) [37]. Although it enhances fruit firmness and decreases bruising, it appears that the effect on pitting is not a direct result of the increased firmness. In contrast, the PGR which are the gibberellins inhibitors, when used in high concentrations, can increase storage disorders in stone fruits.

10. Prevention of frost injury of temperate fruits by application of gibberellins

Pear

An increase in set of frost damaged ‘Conference’ pear was obtained by workers at the East Malling Research Station in England (Modlibowska, 1963) [20] by applying GA_3 at a concentration of 50ppm at different stages of development, from just before bloom (green cluster stage) to fruit set.

The results of the present study showed that fruit set can be largely increased in pear after frost damage by application of gibberellin, GA_3 or GA_{4+7}. Promote growth of shoots reduce the incidence of Pseudomonas syringae and produce a reasonable harvest. This study showed, by repeated application, that a lower temperature (even frost) does not limit the expected rescue. Other issues to be researched on in future are mechanism of gibberellin-driven freeze damage rescue, cultivar differences and timing of applications related to freeze events and rates.

11. Increasing plant size and/or yield

Effect of gibberellins on cherry trees

Gibberellins applications can hasten the growth of certain young trees. Trees of ‘Montmorency’ cherry that had produced terminal buds initiated a second flush as a result of application of gibberellins at concentration of 100 to 1000ppm (Hull and Lewis, 1959) [15]. All treatments produced an increase in trunk diameter. Flesh and dry weights of the aerial portion of the trees increased proportionately with concentration of gibberellins applied.

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