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REVIEW

Application of sesquiterpene (GA_3) to spermology: a contradictory report

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ABSTRACT

Sunflower (*Helianthus annus* L.) is one of the fastest growing oil seed crops of India. It is highly desirable as a premium oil to supplement our oil seeds production, contributes about 24% of the domestic edible oil production and may substitute imports substantially, reduces the level of blood cholesterol and ultimately coronary heart diseases. The commercial cultivation of sunflower began in early seventies with a meagre area of 14 thousand hectares. It has gone up to 2.77 million hectares of the area with a production of 1.35 million tonnes in the year 2010. Gibberellic acid (GA_3), a sesquiterpenoid chemical compound, is the first widely available active form of commercial gibberellins. GA_3 improves growth physiology, cell elongation and cell differentiation thus augmenting plant height. Therefore, it is proposed to apply GA_3 to chickpea to increase the stem height for better harvesting of solar energy for maximum utilization of its potential for seed production. However, this favourable effect on growth and development could be offset, at times, by substantial loss in yield due to lodging and poor rate of biological nitrogen (N_2) fixation. To counter this, it is proposed to strengthen the fast growing stem and maximum production of nodules on root system by some means. Interestingly, the synthetic growth regulators bring about the more or less same plant responses when applied exogenously at very low concentrations.

Key Words: Gibberellic acid, harvesting, potential, productivity, Sunflower and yield.
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INTRODUCTION

Oilseeds occupy an important position in Indian agriculture being next to food grains as a farm commodity. The important oilseeds produced in the country include castor seed, groundnut, linseed, niger seed, rapeseed-mustard (Mamgain *et al.*, 2013), safflower seed, sesame seed (Malaghan *et al.*, 2013), soyabean and sunflower seed. Out of these, castor seed and linseed are the source of non-edible oils basically for industrial use. Edible oils are used as such or after hydrogenation mainly for cooking purposes. Sunflower (*Helianthus annuus* L.) is one of the fastest growing oilseed crops of India. It was introduced as an oilseed crop in 1969. This crop has gained importance due to its short duration of maturity, containing of excellent quality of oil, photo-insensitivity, wide adaptability into different kinds of cropping pattern, high energy hull and drought tolerance. The commercial cultivation of sunflower began in early seventies with a meagre area of 15 thousand hectares. It has gone up to 2.07 million hectares of the area with a production of 1.25 million tonnes in the year 2004. As for its place among oilseed crops, it occupies the fourth place in terms of acreage and production (Ali *et al*., 2005). Sunflower is the major non-conventional oilseed corp. It has been described as "drenched with sun-vitality" because the head follows the sun, ending up facing the west "to absorb the few last rays for the dying sun" (Nagaraj, 1995). Moreover, sunflower has the potential to produce the highest oil yield per hectare and is also a good source of honey (Munir, 2006). Therefore, it is highly desirable to supplement our oilseeds production through the cultivation of sunflower, as it contributes 23.68% of the domestic edible oil production and may substitute imports substantially (Anonymous, 2008).

Sunflower seeds contain 48-53% oil. The oil is generally considered as a premium oil because of its light colour, higher level of unsaturated fatty acids d high smoke points. The oil contains 90% unsaturated fatty acids as oleic aid linoleic acids with the remainder consisting of palmitic, stearic and saturated fatty acids. Its consumption reduces the level of blood cholesterol, a factor which is responsible for the incidence of coronary heart disease (Munir, 2006; Kalaiyarasan and Vaiyapuri, 2007). The oil is also rich in vitamin A, D, E and K, essential for health (Pandey, 2000). Moreover, the occurrence of alfatoxins in the seeds is rare. The oil cake left after the extraction of the oil is rich in high quality protein (40-44%) and is used as cattle and poultry feed. However, the average production of seeds in our country is low (603 kg/ha) compared with the world average of 1225 kg/ha aid also non-availability of quality seeds for further seed production (Uppar and Kulkami, 1989; Khan *et al.*, 2003). The situation necessitates to find out the ways to increase productivity on sustained basis. It may be added that efforts have been made to boost up the productivity not only by adopting the scientific agro-practices but also by overcoming the incomplete development of seeds, among other shortcomings.

Due to the high priority accorded to food grains, not much can be done to bring more land under oilseed cultivation. Moreover, a majority of farmers (75%) has marginal holdings of less than two hectares. Keeping in mind such a limitation on increasing the acreage for cultivation, it is highly desirable to innovate ways which can augment the yields. One such approach could be to facilitate the utilization of the available resources leading to maximum vesting of solar energy. To achieve this, plant growth regulators could be used as they are known to affect many facets of plant life including growth, flowering, fruiting and ion port (Wareing and Phillips, 1981; Khan *et al.*, 2002; Siddiqui and Mohammad, 2003).

Gibberellins are known to control a wide range of physiological actions in plants. For example, application of gibberellic acid (GA_3) improves cell elongation and cell differentiation. Therefore, the present author proposed to apply GA_3 to sunflower seeds to increase plant growth for better vesting of solar energy.

SUNFLOWER: CULTIVATION AND AGRONOMIC PRACTICES

Farmers have been growing crop plants for a long time. However, their production has failed to keep pace with ever increasing demand and thus there is always a need for improvement in their productivity. Farm scientists have been able to demonstrate that the productivity of crop plants could be improved to a great extent through proper selection of cultivars, balanced mineral nutrition, adequate plant protection measures, improved agronomic practices, adequate internal hormonal balance and proper partitioning between source and sink, among others (Lammerts *et al*., 2011). In the following pages, an effort has been made to review the available literature on the general aspects of sunflower, on plant growth regulators and on crop response to exogenous application of GA_3. Sunflower is popularly known as 'surajmukhi' as it follows the sun by day, always turning towards its direct rays. It belongs to the genus *Helianthus* which has been derived from 'Helios' meaning sun and 'anthos' meaning flower. The genus belongs to the family Asteraceae.

It is an annual, erect and herbaceous plant with leaves simple, alternate with stout petioles and lanceolate shape. Leaves are rough on both surfaces. Plaits have a composite inflorescence, referred to as capitulum or head. The campitulum consists of a receptacle with involucres bracts that are modified leaves; ray-flowers on the outer whorl of the receptacle that are sterile and golden yellow, but may be pale yellow, orange yellow or reddish; disk-flowers on the inner whorl of the receptacle that are perfect flowers of yellow or brown colour. The cultivated genotypes are characterized by a single stem terminating in a capitulum. Sunflower is protandrous, in which the male and female elements mature at different times. There appears to be a time-lag of 18-24 hours in the maturity of the male and female elements. So it is essentially a cross pollinated plant, besides showing varying degrees of self-incompatibility. The flowers are pentamerous and epigynous (Friss, 1984). The corolla is of five fused petals. The stamens are syngenesious. The filaments are free but anthers are usually connate into a tube around the style. The anthers are dithecous, introrse and opening by the longitudinal slits. Gynoecium is bicarpellary and syncarpus. The ovary is inferior and unilocular with a single basal anatropous ovule and basal placentation. Fruit is cypsela, a single head produces 350 to 2000 seeds. Seeds are pointed at base and round at end. Colour of the seeds varies from black to white but brown, striped or mottled seeds may also occur (Weiss, 1983; Sharma, 2000; Reddi and Reddy, 2002).

Sunflower is probably originated in southern United States and Mexico from where it was introduced into Europe and later into former USSR. It was taken to Spain before the middle of the sixteenth century. In the nineteenth century, the cultivation of sunflower as an oilseed crop began in the Soviet Union and the majority of the present day varieties grown all over the world trace back their origin to the USSR (Weiss, 1983; Reddi and Reddy, 2002). Sunflower is grown in many countries of the world including Argentina, Bulgaria, Canada, Rumania, Russia, Turkey and South America. In India, it was introduced in 1969 and became quite popular among the farmers. At present, it is grown extensively in Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu (Weiss, 1983; Anonymous, 2002).

This crop requires a cool climate during germination and seedling growth, warm weather from the seedling stage up to flowering and non-cloudy sunny days during flowering to maturity. The crop can thrive well in a variety of soils. It performs well in deep, natural and well-drained light soils as well as I heavy soils. The optimum pH of the soil for this crop is 6.5 to 8.5 (Anonymous, 2002; Reddi and Reddy, 2002).

For sunflower, the season of planting, the photoperiod and within limits altitude are not the limiting factors. Hence it is possible to cultivate this crop throughout the year. At the time of sowing, the soil should be friable and free from weeds. Three to four ploughings and diskings are sufficient for preparing the land. Soil should be moist at least the depth of about 10 cm before sowing and this condition necessitates good soaking rains or irrigation before sowing. Well-filled plump seeds at 8 to 10 kg are required to cover one hectare. For controlling seed-borne fungal diseases, seed treatment with either 'brassical' or 'capton' at the rate of 3 g/kg of seed is recommended. The seeds are drilled at a depth of 5 cm by adopting a spacing of 45 cm between rows and 30 cm between plants in the row. The population densities recommended are 60,000 - 80,000 plants per hectare under irrigated conditions. A basal dose of 40 kg nitrogen (N), 26 kg phosphorus (P) and 17 kg potassium (K) per hectare is recommended under irrigated conditions. Generally, two hoeing are sufficient for the successful cultivation of this crop (Weiss, 1983; Anonymous, 2002; Reddi and Reddy, 2002).

The sunflower crop matures in 90-100 days. The crop has to be harvested when the lower side of the head turns green to lemon yellow colour and some of the bracts dry up. At physiological maturity, the seeds attain maximum weight and oil concentration and harvesting at this stage results in highest seed and oil yield. Ten per cent of heads should turn brown and florets attached to the tip of the seeds drop off naturally. During harvesting, proper care should be taken to avoid quantitative and qualitative losses. The harvesting of the crop is done by means of hand operated sickles. The crop is made into bundles and stacked in the sun for a couple of days. Then it is threshed by beating the seed bearing parts of the plants taken in convenient sized bundles, by means of a wooden mallet to separate the seeds. The cleaned and threshed seeds may then be dried in the sun for another couple of days and then stored in seed bins or gunny bags. The storage room should be completely free from humidity (Weiss, 1983; Reddi and Reddy, 2002).

In India, sunflower was used mainly as ornamental crop but in recent past it became an important source of edible and nutritious oil. It is a major source of vegetable oil in the world. Its seeds contain about 48-53% edible oil. It possesses good flavour and high smoking point. The oil is easily digestible. The oil is rich source (64%) of linoleic acid which is good for heart patients. Linoleic acid helps in washing out cholesterol deposition in the coronary arteries of the heart. The oil is free from heart disease causing linolenic acid, erucic acids and cholesterol. The oil is also used for manufacturing hydrogenated oil. Sunflower oil contains protein, vitamins A, D and E. Being of semidrying and stable type, sunflower oil is used in making paint, varnish and soap. It is also used in the preparation of cosmetics and pharmaceuticals. Oilcake is the byproduct of the sunflower oil extraction and is a source of protein for animal feed blends. Sunflower oilcake, however, is

considered to be of relatively poor quality due to high crude fibre content. Sunflower seeds make a nutritious food for cattle, poultry, hogs and cage birds (Nagaraj, 1995; Pandey, 2000; Anonymous, 2002; Reddi and Reddy, 2002).

PHYTOHORMONES OR PLANT GROWTH REGULATORS (PGRS)

There are numerous substances natural and synthetic that has profound influence on growth and differentiation of plant cells and organs. Their role in development has been studied for nearly a century, yet the concept of hormones in plants is steeped in controversy. In 1905, the British physician E. H. Starling introduced the term 'hormone' to describe these chemical messengers (Hopkins, 1999). The term phytohormone was coined by Thimann in 1948 who defined it "an organic compound produced naturally in higher plants controlling growth or other physiological functions at a site remote from its place of production and active in minute amounts" (Sinha, 2004). The exact location of synthesis of phytohormones is uncertain but actively growing tissues, leaves, developing seeds thought to be active sites of synthesis of phytohormones. However, it appears that all tissues have the potential to produce only of the phytohormones, which are transported via xylem or phloem (Weiler and Ziegher, 1981). The prevailing direction of transport depends on the type of phytohormone and development stage of plant. Phytohormones act at genetic level (Bajguz, 2000; Marschner, 2002; Taiz and Zeiger, 2006). The commonly recognized classes of plant hormones are auxins, gibberellins, cytokinins, abscisic acid, ethylene and are now supplemented with brassinosteroids and jasmonic acid (Dewitt and Ockelen, 2001).

GIBBERELLINS: A MOST STRATEGIC GROUP OF PLANT HORMONES

Gibberellins are chemically closely related to diterpens, which are themselves members of vast group of naturally occurring compounds in plants called terpenoids. The discovery of gibberellins dates from 1898, when Korishi, for the first time described "bakanae disease" (foolish seedling) of rice with characteristics symptoms of tall spindy plants (Arteca, 1996).

History of Discovery

In 1954, British chemists Brian and others identified and chemically characterized a pure compound from culture filtrates of *Gibberella fujikuroi*. They called this new substance "gibberellic acid" (Fig. 1). The ICI team gave the name "gibberellic acid" while the USDA team, "gibberellin X". The former name has been universally accepted and gibberellic acid is now also known as GA_3 (Moore, 1989). At present, the number of gibberellins known from all sources, ling plants is 125. They differ from one another by the presence or of the location configuration (internal ester) in the ring A and the substituents, mainly hydroxyl groups about the whole ring structure. Due to presence of an additional ethylenic double bond in ring A, GA_3 is more unsaturated and, thereby, more active than other gibberellins (Salisbury and Ross, 1992; Kumar and Purohit, 2003; Sinha, 2004).

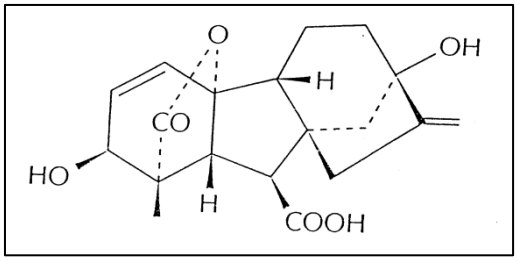

Fig. 1. Chemical structure of gibberellic acid

Exogenous application of GA_3 has been shown to relieve certain type of dormancy including physiological dormancy, photodormancy and thermodormancy (Hartmann *et at.*, 1990) and to promote flowering in a variety of plant species under non-inductive conditions (Zeevaart, 1983; Harkness and Lyons, 1994). The influence of gibberellins includes parthenocarpic fruit development, senescence, promote cell growth, increase cell wall plasticity, an elongation and growth of whole plant, among others (Salisbury and Ross, 1992; Taiz and Zeiger, 2006).

In nature, phytohormone required for growth and development are synthesized in plants themselves (Berg, 2009). However, they could be added exogenously to exploit the full genetic potential of plants. Generally, the hormones are supplied to plants via pre-sowing seed treatment or through foliar application as dilute solutions at crucial stages (Ahmad *et al.*, 2001; Hayat *et al.*, 2001; Afroz, 2006). Plant growth and development are controlled by various intrinsic and extrinsic factors. Phytohormones belong to the former. They get involved through the modification of transcription, translation and/or differential sensitivity of the tissue. GA_3 is one of the growth promoting phytohormones. It has been shown to regulate many facets of plant life, including seed germination, vegetative growth and differentiation (Khan *et al*., 1996, 2006; Siddiqui and Mohammad, 2003; Afroz *et al*., 2005; Khan, 2008; Siddiqui *et al*., 2008).

Responses of Oil Yielding Crops against Application of Gibberellic Acid

A lot of work has been done on the effect of phytohormones on the performance of oilseeds of the family Asteraceae. In the following pages, an effort has been made to review the available literature on the sunflower and safflower for the last three decades. De-La- Guardia and Benlioch (1980) performing an experiment on sunflower noted that application of GA_3 solution on each cotyledons of 6 day (d) old seedlings resulted in a tenfold increase in the length of the first internode. They also noted an increase in the content of reducing sugars. Umoessicn and Forward (1982) studied the effect of GA_3 on the distribution of product of photosynthesis in sunflower. GA_3 was applied to the same leaf or to the terminal bud or the roots, and the distribution of assimilated MC was determined at intervals of 1-96 h. GA_3 had no significant effect on initial distribution of ^{14}C during the period of rapid export from the leaf, but enhanced re-export from the root after translocation from the leaf had virtually ceased. Most of the ^{14}C exported from the roots accumulated in the shoot tip. The site of application of the hormone was of relatively minor importance. Wherever it was applied the major

effect was enhancement of movement from the roots to the shoot tip. Application to the terminal bud was most effective in this respect. There was no evidence that GA_3 directly affected the transport system, but the data support the hypothesis that it increases the strength of the sink in the shoot tip.

Shukia *et al.* (1987) studied the effect of GA_3 on seed setting and seed filling in sunflower. 200 ppm GA_3 was applied to the buds of sunflower cvs. EC 68413 and EC 68414 at the opening stage, 45 days after sowing (DAS). Control plants were treated with distilled water. At maturity, heads were divided into 4 equal parts across the centre and seeds were collected from peripheral, middle and central portions of each part. Hollow seeds were separated from filled seeds. Total number of seeds/100 cm^2 was greatest in the central portion in both cultivars. The GA_3 treated plants had higher number of seeds in all 3 portions of both cultivars than the control plants.

Czapla *et al.* (1988) conducted trials to investigate the effect of applying GA_3, indole acetic acid (IAA), kinetin (Kn) and phenylacetic acid (PAA) on growth and development of sunflower. Sunflowers were given foliar rays of 3 mg GA_3 or Kn or 2 mg IAA/dm^2 or a mixture of all three, or GA_3, Kn or PAA applied directly to the soil or as an oil emulsion covering urea granules. Growth regulator application method did not significantly affect fresh weight or height, although foliar GA_3 applications tended to be most effective. Applying growth regulators with urea was most effective in increasing inflorescence number. AI-Gharbi and Yousif (1989) conducting an experiment on sunflower, noted that applied GA_3 increased seed protein content whereas of chlormequat increased seed oil content.

Kene *et al.* (1991) conducting an experiment on sunflower cv. G.V. EC 68414, studied the effect of foliar application of growth regulators on growth, yield and oil content. Data revealed that, the seed yield was significantly increased with GA_3 at 15 and 30 ppm and indole butaric acid (IBA) at 30 ppm sprayed at flowering stages. Similar trend was also noticed in respect of plant height, leaf area index (LAT), head diameter and oil content. Pearce *et al.* (1991) performing an experiment on sunflower cv. Delgren 131, noted that the treatment with GA_3 or GA_1 applied to the cotyledonary petioles of 6 d old seedlings results in faster elongation of hypocotyls. Also, Beltrano *et al.* (1994) conducting an experiment on sunflower cv. SPS 894 and ACA 882, studied that the application of foliar spray of GA_3 (150 mg/l) at 20, 40 or 60 days after emergence (DAE) did not affect yield components. However, foliar spray of benzyl adenine (BA) at 150 or 250 mg/l with or without GA_3 particularly at 40 or 60 DAE reduced the percentage of empty echenes and increased achene weight, 1000-achene weight and achene number and seed yield. Kene *et al.* (1995) performing an experiment on sunflower cv. EC 68414, noted that the spray of 50 or 30 ppm GA_3 or 30 ppm IBA increased plant height, LAT, head diameter, seed yield and oil content. Also, Almeida and Pereira (1996) studied the involvement of GA_3 in the control of flowering of sunflower cv. 33 in an experiment by direct application of GA_3 to the apex of the plants, analysis of the endogenous levels of gibberellin like substances at different plant ages, and indirectly by the application of paclobutrazole, an inhibitor of gibberellin synthesis. Aqueous solution of GA_3 (10^{-3} M) was applied as a 30 µl droplet to the apices of the plants with the help of a graduated microsyringe, with GA_3 applying every two from 10^{th} to 20^{th} d. GA_3 speeded up flower initiation and floral apex development. The time of GA_3 application was more critical than the amount of GA_3 applied. The application of paclobutrazole markly delayed floral initiation this effect was also dependent on plant age. Both GA_3 and paclobutrazole had their greatest effects between 10 and 20 DAS suggesting that an increase in GA_3 in that time period plays a role in floral initiation.

Moreover, Almeida and Pereira (1997) conducted an experiment to investigate the effect of GA_3 and paclobutrazole on vegetative development of sunflower cv. 33. They applied 5-30 µ1 of 10^{-3} M GA_3 to the apices of 10 d old seedlings or 30 µl ID the apices of 10 to 20 d old seedlings or immersed some seeds in GA_3 for 9 h before sowing. In a second set of experiments, 10^{-3} M paclobutrazole was died in 20 µl drops to apices of 10-20 d old seedlings or to the soil of 10-14 d seedlings. The stimulatory effect of GA_3 on plant height was dependent on age of seedlings, the younger plants being most sensitive (Silverstone *et al*., 1997). Paclobutrazole when applied to the soil caused dwarfing and retarded leaf expansion, the younger seedlings being more sensitive.

Hernandez (1997) studied the effect of exogenous application of plant regulators on morphogenesis of sunflower cv. Dekalb G100. The plants it given 45 pg naphthalene acetic acid (NAA) or BA/plant/d for 10 days or pg GA_3/plant/d for 5 days from the commencement of capitulum Growth regulators were injected into unfolded leaves of the bud. NAA had no significant effect on development compared with untreated controls. GA_3 increased the length of stem internodes and accelerated the onset of floral development by 25%. The most effective growth regulator w BA, which increased leaf area by 38%, stem dry weight by 93% and significantly changed capitulum morphology with an increase in the number of floret primordia of 17% as a result of increased expansion of the receptacle before onset of floret differentiation.

Moreover, Baydar (2000) studied the effect of GA_3 application on male sterility seed yield, oil content and fatty acid synthesis of safflower (*Carthamus tinctorius* L.) cv. GA_3 was applied at 0, 50, 100, 200 or 300 ppm at 40, 55 and 70 DAS. GA_3 induced male sterility at rates of up to 93%, and decreased seed yield per plant. Although GA3 did not affect fatty acid synthesis, oil synthesis increased with increasing GA_3 concentration from 33.8% in controls to 38.8% with the application of 300 ppm at the budding stage.

Furthermore, Shankar *et al*. (2000) studied the effect of pre-harvest spray application of $CaCl_2$ (0.1, 0.5 and 1.0%). BA (10, 20 and 30 ppm) and GA_3 (50, 100 and 150 ppm) along with water as the control at 60, 70 or 80 DAS on the seed quality of sunflower cv. Morden. Sprays of plant growth regulators were given on capitulum. Application of 100 ppm GA_3, especially at 60 DAS and storage of achenes, particularly in poly pack, were more effective in maintaining seed quality in the terms of seedling vigour index. Dholekar *et al.* (2001) studied the effect foliar sprays of four growth regulators, viz. GA_3, succinic acid (SA), 2, 3, 5-triiodo benzoic acid (TIBA) and Kn on yield and yield attributes of safflower cv. Bhima. Control comprised without any spray of growth regulator. GA_3 was applied at 50 ppm, SA at 1%, TIBA at 500 ppm and Kn at 10 ppm at 20 or 30 DAS. Application of Kn at 20 DAS was found significantly superior for seed yield and other characters (number of branches per plant, number of capitula per plant and number of seeds per capitula). Seed oil content was significant highest with Kn applied at 30 DAS stage. TIBA applied at both stages although inhibited stem elongation showed significant increase in yield and yield contributing characters. The ray of GA_3 and SA applied at 30 DAS stage occupied second and third position in respect of seed yield.

On other hand, Shankar *et al.* (2001) studied the effect of sprays of $CaC1_2$ (0.1, 0.5 and 1.0%), BA (10, 20 and 30 ppm) and GA_3 (50, 100 and 150 ppm) at 60, 70 or 80 DAS on growth and yield characteristics of sunflower cv. Morden. They noted that foliar application of GA_3 followed by $CaC1_2$ and BA particularly at 60 DAS significantly increased the total dry matter production. They further noted that sprays of BA (30 ppm) and $CaCl_2$ (0.5%) increased the capitulum diameter, test weight, yield and oil content. Baydar (2002) studied the effect of foliar spray of GA_3 on the performance of safflower cv. Dincer 5-118. He applied four concentration of GA_3 (100, 200, 3000 and 400 ppm GA_3) on buds at 75 DAS. Exogenously applied GA_3 decreased the levels of IAA and ABA. The lowered endogenous GA_3/ABA and Zeatin/IAA ratios in the seeds significantly decreased the germination percentage and hypocotyls elongation, respectively. The seeds from GA3 treated plants had more full percentage and less oil content than seeds from the non GA_3 treated plants. As a consequence, it was indicated that poor germination and emergence vigour might be a major problem in hybrid safflower seeds produced from plants treated with GA_3.

Cecconi *et al.* (2002) studied the effect of spray of GA_3 on the stem elongation of a dwarf mutant *dwl* of sunflower. They applied 20 ml of GA_3 at 0, 0.01, 0.1, 1, 10 and 100 ppm weekly till flowering or till 2, 4, 6 and 8 weeks. They reported that periodic treatment with GA_3 was effective to revert to the wild type phenotype and internode elongation was directly related to the GA_3 concentration.

Nevertheless, Vasudevan *et al.* (2002) studied the effect of growth regulators on seed yield, yield parameters and oil content of sunflower genotypes. They applied sway of (i) TIBA at 240 ppm, (ii) TIBA at 240 ppm + NAA at 50 ppm (iii) 50 ml mixture of IAA (1 ppm) + GA_3 (5 ppm) + cytokinin (0.1 ppm) in 200 ml water, (iv) 100 ml of the mixture (iii above), (v) 100 ml tricontanol in 200 ml water and (vi) 200 ml tricontanol in 200 ml water on three cultivars of sunflower, viz. Morden, HA-234B and KBSH-1. Spray of water constituted control. Spraying of TIBA combined with NAA had highest head diameter, sunflower of filled seeds, seed filling percentage, seed yield, test weight, seed density and volume weight. Cultivar KBSH-1 produced maximum yield and yield components. Yield parameters, like test weight and seed density, differed significantly due to interaction of both growth regulators and cultivars. Baydar and Gokmen (2003) performing an experiment on hybrid seed production in safflower, found that the spray of 100 ppm GA_3 on buds of less than 0.5 cm diameter of non-spiny variety (Dineer '5-118') and spiny variety ('5-154') at three successive growth stages (75, 82 and 89 DAS) did not affect viability of achenes.

In addition, Khan *et al.* (2003) applied five pre-sowing treatment to seeds of four cultivars of sunflower (7-lA, 7-1B, RHA-271 and APSH-11). The seed treatments included (i) hydration for 24 h followed by the drying back to the original moisture level, (ii) cold hydration for 72 h at 10°C followed by the drying, (iii) hydration with 100 ppm GA_3 for 24 h followed by the drying, (iv) hydration for 24 h and the drying followed by dry dressing with thiram at the rate of 0.25% and (v) the untreated seed. They concluded that the hydration of seeds for 24 h followed by the drying proved best particularly for 7-lA and 7-lB. Shivankar *et al.* (2003) studied the effect of pre-sowing seed treatment with potassium chloride, potassium dihdyrogen orthophosphate, manganese sulphate, potassium nitrate, thiourea, GA_3, Kn, hydration, hydration + thiram, thiram or *Trichoderma harzianum* on the performance of sunflower cv. Morden. They noted that the treatment with 50 ppm GA_3 increased seed yield significantly.

Besides this, Siddiqui and Mohammad (2003) conducting an experiment on sunflower cv. Morden, studied the effect of pre-sowing seed treatment with four levels (10^{-6}, 10^{-5}, 10^{-4} and 10^{-3} M) of four plant growth regulators, viz. GA_3, IAA, IBA and Kn, keeping water as the control, on nitrate reductase activity (NRA) and dry matter yield at 30, 60 and 90 DAS and on seeds per head, 1000-seed weight, seed yield per plant, oil content and oil yield per plant at harvest. The four plant growth regulators and their concentrations alone had a significant effect on NRA at 60 and 90 DAS, dry matter yield at 90 DAS and seeds per head, seed yield per plant and oil yield per plant at harvest. Among plant growth regulators, GA_3 proved to be the best at 10^{-5} M. Pramanik and Basu (2004) studied the effect foliar spray of GA_3 and NAA on germination percentage, vigour index, root and shoot length and fresh and dry weight of four cultivars of safflower, namely A_1, A_{200}, A_{300} and Bhima. They applied GA_3 and NAA each at 50, 100 and 200 ppm. The mean germination percentage, vigour index and root and shoot length were higher with the application of NAA, whereas fresh and dry weight were higher with the application of GA_3. Cultivar A_{300} recorded the highest mean germination percentage, vigour index, root and shoot length, whereas cultivar A_1 gave the highest fresh and dry weight.

CONCLUSION

The above review of literature broadly establishes that plant growth hormones in general and GA_3 in particular have stimulative effect on growth and development of plants. Out of the two methods of hormonal applications, pre-sowing seed treatment seems to be promising due to many factors, including the small amount of the hormone required and low operation cost involved. The review of literature also reveals that the duration for soaking treatments is a constant as various researches gave soaking treatments for different duration. The literature further imparts that comparatively less work has been done on sunflower. It is, therefore, highly desirable to extent the work by sinking the seeds of sunflower in aqueous solution of GA_3 of varying concentration for different duration.

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