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Research Article

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Effect of Plant Growth Regulators in African Marigold: A Review

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Abstract:

African marigold, being tall enough and producing large flowers suitable for preparing garlands, is the most cultivated cultivar of marigold in Nepal. Besides, pinching and other improved cultural techniques, a number of chemicals, hormones and phyto-hormones are being tested and found to impart a varying response in African marigold. This review has its importance for standardizing the type and concentration of plant growth regulators in African marigold. Online journals, scientific papers, proceedings, books, thesis and lecture notes are the key reference site for this review. Gibberellins or gibberellic acids (GA_3), ethrel, paclobutrazol, salicylic acid, Indole 3 Acetic Acid, Naphthalene Acetic Acid (NAA), Chlormequat Chloride and sea weed extract are the most widely used and proven biochemical with pronounced effect on growth, development and differentiation in marigold. Among these, 300 ppm, 350 ppm and 450 ppm of GA_3 results higher plant height, minimum days for flower initiation and higher basal diameter respectively. Similarly, 450 ppm for higher number of branches and leaves per plant and 400 ppm of GA_3 or 600 ppm of CCC has been found to impart higher number and weight of flowers per plants. Besides, 1000 ppm of CCC has been found more effective to impart higher productivity (yield/ha) in African marigold. Hence, plant growth regulators have been a valuable agent for optimizing yield and yield potential in African marigold.

Keywords: garlands, phyto-hormone, plant growth regulators, *Tagetes*, yield

Introduction:

Marigold, a promising flower species for Nepal (Khanal, 2014; Acharya et al., 2021; Pandey et al., 2021), native to North America (Jadhav, 2018; Narute et al., 2020) belongs to class Magnoliopsidae and family Asteraceae / compositae (Shafiullah et al., 2018; Singh et al., 2018) and has ornamental, pharmaceutical, ceremonial and antimicrobial properties (Gómez-Rodríguez et al., 2003) besides its use in landscape gardening (Shivaprakash et al., 2011). In addition, marigold in Nepal has cultural, religious (Dhakal & Bhattarai, 2017) and social importance.

Based on production, basically two species (African marigold: *Tagetes erecta* and French marigold: *Tagetes petula*) are common (Poudel et al., 2017; Pandey et al., 2021). African marigold being tall, producing large flowers are being used for aesthetic purpose and for preparing garlands. The flower, yellow to orange in color, consists of number of ray florets at periphery with disc florets at the center. The mature seed is small with delight jet black color and is termed as achene (Zhang et al., 2005). Propagation of marigold through seeds or by softwood cutting are more common these days (Acharya et al., 2021).

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The sales of a garland made up of marigold stand at around one million 300 thousand units (The Rising Nepal, 2015). Loose flowers like marigold and makhamali (globe amaranth) and its garland is imported to Nepal from India (30% demand being fulfilled through import from India, (FAN, 2018) particularly during Tihar, a festival of flowers and light (Pandey et al., 2021). Kathmandu, Bhaktapur, Dhading, Nuwakot (Poudel et al., 2017), Lalitpur, Makawanpur, Chitwan, Kavre, etc. are major marigold demanding districts of Nepal.

Due to easier cultivation, wider adaptability (Kumar et al., 2014; Das et al., 2020), shorter life span and good keeping quality along with wider variability in color(Pandey et al., 2021), shape, size (Arora, 1988; Kumar et al., 2010; Mohanaty et al., 2018) fragrance, ease of transportation, lucrative returns (Acharya et al., 2021), etc. marigold gets attention among the flower growers in a developing country like Nepal. Besides, farmers were not aware about the use and application of growth regulators and retardants in marigold. One garland costs NRs. 60-70 on average and the sale of marigold garland per day was around 10,000-15,000 in Nepal (FAN, 2020). As a result, import of marigold has been increasing in recent years as production can't meet the local demand.

This paper reviewed the application of various biochemicals to quantify yield and quality of African marigold. Among phytohormones and plant growth regulators Gibberellins or Gibberellic acids (GA_3) (Sunitha, 2007; Pandey & Chandra, 2008; Ramdevputra et al., 2009; Rajhansa et al., 2013; Palei et al., 2016; Acharya et al., 2021; Karki et al., 2021), ethrel (Rajyalakshmi & Rajasekhar, 2014), paclobutrazol (Rathore et al., 2011), salicylic acid (Basit, 2018; Poudel & Subedi, 2020), Naphthalene Acetic Acid (NAA) (Kanwar & Khandelwal, 2013), Chlormequat Chloride (CCC) (Kumar et al., 2012; Rajyalakshmi & Rajasekhar, 2014), etc. are the most widely used and proven biochemical for ornamentals (including African marigold) with pronounced effect on plant growth, development, morphology, phenology and overall differentiation (Singh et al., 2019).

Plant Growth Regulators:

Germination:

15 ml/l of alkaline seaweed extract of *Ascophyllum nodosum* Acadian Seaplants™ has found to increase the germination by two-fold in African marigold (Tavares et al., 2020). This may be is due to the presence of cytokinin, auxin, gibberellins, betaines and alginates in nodosum (MacKinnon, 2010) that supports germination (Santos, 2019). GA_3 @ 200 ppm induces germination (90%) which is followed by NAA @ 60 ppm (88%) as compared to ethrel @ 750 ppm (80%). GA_3 @ 200 ppmhas found to induce maximum field emergence (77 %) than ethrel and CCC @ 750 or 1000 ppm (Sunitha, 2007). Also, increase in concentration of colchicines reduces the germination in marigold (Rathod et al., 2018).

Plant Height:

GA_3 at 50 ppm, 100 ppm and 200 ppm significantly increases the plant height (Kumar et al., 2010, Rajhansa et al., 2013; Kumar et al., 2020) in African marigold cv. Pusa Narangi Gainda. The result was similar with finding of Sunitha, 2007; Palei et al., 2016 in Tagetes erecta Linn. On further increasing on concentration of GA_3 upto 300 ppm, [or 350 ppm (Kumar et al., 2012)] plant height also gets increased (Swaroop et al., 2007; Ramdevputra et al., 2009; Patil et al., 2016). Similarly, in case of French marigold, increasing concentration up to 450 ppm significantly increased plant height (Pandey & Chandra, 2008). According to (Kumar et al., 2010) higher the concentration of GA_3 higher will be its effectiveness in cells multiplication as well as their elongation. GA_3 accelarates the conversion of tryptophan to Indole Acetic Acid which in turn causes cell division and elongation (Kuraishi & Muir, 1964).

Also, GA_3 (100 ppm) was found more effective than naphthalene acetic acid and ethrel of same or lower concentration in respect of plant height (Palei et al., 2016). However, the plant height was found greater with GA_3 @ 100 ppm than 200 ppm (Singh, 2004); 150 ppm than 200 ppm (Kanwar & Khandelwal, 2013); 300 ppm than 400 ppm (Patil et al., 2016) and 100 ppm than 200 ppm (Narute et al., 2020). Similar result was obtained by treatment combination of GA_3 @ 200 ppm, azospirillium @ 5kg/ha and Phosphate solubalizing bacteris @ 5 kg/ha (Shivaprakash, 2011). On the other hand, ethrel, a gaseous hormone had a dwarfing effect on plants. The effectiveness increases on increasing the concentration in marigold (Kumar et al., 2010) and in chrysanthemum (Gautam et al., 2006).

Salicylic acid @ 120 ppm imparts maximum plant height (50.63 cm) than its lower concentration in African marigold (Basit, 2018) and plant height

increases on increasing concentration upto 500 ppm (Poudel & Subedi, 2020). Increased cell division both in stems and roots (Martin-Mex et al., 2005); rubisco chemical action and photosynthetic rate (Basit, 2018) due to salicylic acid may support the statement. Similar result was also obtained by Kamkari et al. (2016), Choudhary et al. (2016) (marigold) and Gutiérrez-Coronado et al. (1998) (Soybean). This might be due to salicylic acid on increasing cell divisions in both stems and root (Kamkari et al., 2016). Higher the concentration of colchicines during seed treatment (upto 2.5%), lower will be the plant height (Rathod et al., 2018). Triacontanol (TRIA), CCC and NAA @ 20, 4000 and 10 ppm were found effective than 30, 5000 and 20 ppm respectively in increasing plant height in African marigold variety Calcutta Marigold. Seed treated with 15 ml/L of commercial seaweed extract Acadian Seaplants™ (70 ml) induce seedling height to be increased by 84% (Tavares et al., 2020).

Stem Diameter:

Concentration of GA_3 is positively correlated with plant basal diameter; upto a limit of 200 ppm (Kumar et al., 2010; Rajhansa et al., 2013); 300 ppm (Kumar et al., 2010; Palei et al., 2016); 450 ppm (Pandey & Chandra, 2008), but reverse is the effect by ethrel and the effect of ethrel is greater than control (Kumar et al., 2010). GA_3 applied result the reflection of the stimulation from cambium and their immediate cell progeny that increases stem girth (Scurfield and Moor, 1958). Similar effect of GA_3 and ethrel was also obtained by Gautam et al., 2006 in chrysanthemum. Similarly, increasing concentration of Salicylic acid up to120 ppm was found to induce more stem diameter in marigold (Basit, 2018).

Number of branches per plant:

Number of branches per plants increases on increasing concentration of GA_3 @ 100 (Palei et al., 2016); @ 200 ppm (Kumar et al., 2010; Rajhansa et al., 2013); @ 450 ppm (Pandey & Chandra, 2008). Similar positive relation was also found by Kumar et al. (2012). However, Ramdevputraet al., (2009) found that 200 ppm of GA_3 impart more branches than 300 ppm. Patil et al., 2016 also found NAA @ 400 ppm induces formation of more branches per plants than GA_3 @ 400 ppm or lower. Cycocel @ 2400 ppm gave highest number of branches per plants than its lower concentration of 1200, 1600 and 2000 ppm (Kumar et al., 2012). On the contrary, Ethrel @ 100 ppm results more branches than 200, 300 and 400 ppm. Also, action of Ethrel was found superior to that of Paclabutrazol (Rathore et al., 2011).

Number of leaves and chlorophyll per plant:

Number of leaves per plants increases on increasing concentration of GA_3 upto 100 ppm (Palei et al., 2016); upto 200 ppm (Gautam et al., 2006); upto 450 ppm (Pandey & Chandra, 2008). Likewise, is the action of Cycocel @ 2400 ppm (Kumar et al., 2012) and Salicylic acid @ 1 Mm (Pacheco, 2013).Also, Kinetin @ 50 ppm was found superior to GA_3 and IAA @ 100 ppm and 200 ppm for number of leaf and leaf area index (Singh, 2004). However increased concentration of ethrel had found to decreases number of leaves. Similarly, size of leaf is found to have a positive correlation with concentration of GA_3 and is negatively correlated with ethrel (Kumar et al., 2010). This result follows the line of Sebanek et al. (1976) in tulip.

NAA @ 150 ppm imparts more chlorophyll content (2.89 mg/g) in leaves (Kanwar & Khandelwal, 2013). A positive association between chlorophyll-a, chlorophyll-b, overall chlorophyll content and carotenoid content and concentration of Salicylic acid has also been found (Basit et al., 2018). Salicylic Acid enhances cell division in leaf surface (Rivas-San Vicente & Plasencia, 2011) and effect photosynthetic pigments and their derivatives (Hayat et al., 2010) which directly affect cell division and leaf pigment contents (Uzunova & Popova 2000). But, Khan et al. (2003) and Pacheco et al. (2013) do not observe a significant association or may differ based on species and cultivar (Arfan et al., 2007).

Flower bud Initiation:

Days of early flowering decreases on increasing concentration of GA_3@ 100 ppm (Palei et al., 2016); @ 200 ppm (Kumar et al., 2010; Rajhansa et al., 2013); @ 300 ppm (Kumar et al., 2012; Kumar et al., 2014;Patil et al., 2016); @ 350 ppm (Kumar et al., 2012). But, flowering can be delayed by ethrel @ 100, 200, 300 and 400 ppm (Kumar et al., 2010). Earliness in flowering due to GA_3 may be is due to its effect in reducing juvenility and delayedness in flowering due to ethrel may be is due to its action on suppressing biosynthesis of gibberellins (Kumar et al., 2010).

Flavonoid content of marigold inflorescence was positively correlated with concentration of salicylic acid (Pacheco et al., 2013). Similar effect was obtained by Kim et al. (2009) in *Taraxacum officinale* suggesting its effect on biosynthesis of secondary metabolites.

Number of flowers per plants:

Number of flowers per plant increases on increasing concentration of GA_3@ 100 (Palei et al., 2016); @ 200 ppm (Sunitha, 2007; Kumar et al., 2010); @ 300 ppm (Swaroop et al., 2007; Kumar et al., 2014); @ 350 ppm (Kumar et al., 2012); @ 400 ppm (Tripathi et al., 2003); @ 450 ppm (Pandey & Chandra, 2008). According to Tripathi et al. (2003) effect of GA_3 @ 400 ppm is similar with that of CCC @ 600 ppm. But, Rajyalakshmi & Rajasekhar (2014) found the number of flowers per plant to be greater with CCC @ 500 ppm than GA_3 @ 300 ppm. Also, the action of GA_3 was found more pronounced with corresponding concentration of NAA (Swaroop et al., 2007). Singh (2004) also found that GA_3 @ 200ppm increased number of flowers than 100 ppm of GA_3 and Kinetin. However Kanwar & Khandelwal (2013) and Ramdevputra et al. (2009) had suggested to use 150 ppm than 200 ppm and 100 ppm than 200 ppm and 300 ppm of GA_3 to produce more flowers per plants. Also, Paclobutrazol @ 100 ppm has been found to increase the number of flowers in African marigold (Rathore et al., 2011). However, the lower concentration of ethrel (100 ppm) results higher number flowers (53.23) (Kumar et al., 2010). The result was consistent with the finding of Tripathi et al. (2003) in French marigold and Talukdar & Paswan (1994) in chrysanthemum.

Similarly, number of flowerswas found significant at 1 mM of salicylic acid in African marigold (Pacheco et al., 2013). Similar effect was postulated by Basit et al. (2018) in marigold and Bayat et al. (2012) in Calendula officinalis.Thepositive effect of salicylic acid may be is due to its action in synthesizing or/and signaling the pathways of other phytohormones like jasmonic acid, ethylene and auxin (Vlot et al., 2009) and GA_3 (Mukherjee and Kumar, 2007; Kim et al., 2009). Also, salicylic acid is believed to accelerate thermogenesis in staminate region of flower up to 14°C, which may induce flowering in plant (Raksin et al., 1987; Raksin, 1992). Increased transcription and translation rate (Singh et al., 2002) and isoenzyme content (Bayat et al., 2012) due to salicylic acid may be the cause.

Weight of flowers per plant:

Flowers weight per plant increases on increasing concentration of GA_3 (upto 400 ppm) (Tripathi et al., 2003; Kumar et al., 2010; Rajhansa et al., 2013; Kumar et al., 2014; Palei et al., 2016). Tripathi et al. (2003) also found that GA_3 @ 400 ppm has a similar effect with 600 ppm of CCC. However, Ramdevputra et al. (2009) found GA_3 @ 100 ppm to be superior to 200 ppm and 300 ppm with weight of flowers per plant as an indicator. Varma (2004) found that the effect of GA_3 @ 150 ppm was at par with 200 ppm. But flowers yield per plant through CCC @ 500 ppm was found higher than that of GA_3 @ 300 ppm (Rajyalakshmi & Rajasekhar, 2013).However, Kanwar & Khandelwal (2013) found decrease in yield per plant on increasing concentration of GA_3 from 150 to 200 ppm. Also, Paclobutrazol @100 ppm results higher weight of flowers per plants than its higher concentration (Rathore et al., 2011). Unlike GA_3, ethrel has a negative effect on weight of marigold (Kumar et al., 2010) and also in chrysanthemum (Deotale et al. 1994).

Increasing salicylic acid concentration increases weight (fresh and dry) of a marigold inflorescence (flower) (Pacheco et al., 2013; Basit et al., 2018). Anwar et al. (2014) had found a similar finding on tuberose. Salicylic acid in association with auxin has been found to alter biophysical characters of cell wall, promoting assimilate translocation up to flowers (Choudhary et al., 2016) and increasing fresh weight. Furthermore, salicylic acid being defense hormone may reduce the stress on flowers increasing dry weight (Champa et al., 2015).

Yield per area:

Productivity of marigold is found positively correlated with concentration of GA_3, up to 450 ppm (Varma, 2004; Sunitha, 2007; Pandey & Chandra, 2008; Ramdevputra et al., 2009; Kumar et al., 2010; Rajhansa et al., 2013). Similar effect was obtained by Tripathi et al. (2003) in French marigold. As GA_3 has a positive effect on earliness on inducing laterals, which then had a sufficient period for carbohydrate accumulation for flower bud differentiation (Kumar et al., 2010). However, GA_3 @ 300 ppm showed more yield than at 400 ppm (Patil et al., 2016). However, the action of CCC @ 500 ppm was found greater than GA_3 @300 ppm in respect of yield per hectare (Rajyalakshmi & Rajasekhar, 2013). Yield per unit area was found maximum (37.07 t/ha) treated with 1000 ppm of cycocel followed by its lower concentration (500 ppm). Paclabutrazol and Ethrel each @ 100 ppm independently increasethe productivity than their higher concentration of 200, 300 and 400 ppm (Rathore et al., 2011). Also, higher concentration of ethrel (300 ppm and 400 ppm) was found to have a negative effect on yield than control (Kumar et al., 2010).

Conclusion:

A number of plant growth regulators have been tested to quantify yield and yield attributes in African marigold. Among mostly tested plant growth regulators (GA_3, Ethrel, Paclobutrazol, Salicylic acid, IAA, NAA, CCC and sea weed extract), GA_3 was believed to impart a positive vegetative, reproductive and yield effect in African marigold. Higher plant height, steam diameter and minimum days for flower bud initiation havebeen found at 300 ppm, 450 ppmand 350 ppm of GA_3 respectively. Similarly, higher number of branches and leaves per plant was found effective at 450 ppm of GA_3. One among, 400 ppm of GA_3 or 600 ppm of CCC can be used to impart higher number and weight of flowers per plants. Likewise, 1000 ppm of CCC has been found to impart higher productivity (yield/ha) in African marigold. Hence, plant growth regulators, being specific mostly on concentration, may be adopted to impart a varied response for vegetative and yield performance of African marigold.

Conflict of Interest:

There are no known concepting publication of this manuscript.

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