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# Influence of Plant Growth Regulators and Signal Molecules on Growth, Fruit Set and Aril Characters of Pomegranate

Lalithya K.A., Raju B., Manjunath G., Kulkarni M. S., Swamy G. S. K.

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**Abstract** Plant growth regulators such as NAA, $GA_3$, 2,4-D, paclobutrazol, ethrel and signal molecules like salicylic acid, nitric oxide, and elicitor like chitosan and Bronopal were taken for present investigation to know their impact on growth, fruit set and aril characters of pomegranate fruits in both 2015 and 2016. Maximum increase in plant height (0.54 m) and plant spread in both N-S (1.50 m) and E-W (0.62) direction by $GA_3$ treatment resulted in enhancing plant canopy (8.72 $m^3$) in both season. In contrast, maximum reduction in plant height and plant spread in both N-S and E-W direction by paclobutrazol treatment followed by ethrel treatment resulted in minimizing plant canopy (3.88 $m^3$ and 3.97 $m^3$). Moreover, foliar application of ethrel at 200 ppm resulted in enhancing maximum fruit set (72.20%) and minimum seed weight (4.62 g 100 $arils^{-1}$) while 2,4-D treatment enhanced aril weight (38.50 g 100 $arils^{-1}$) in pomegranate fruits.

**Keywords** Vegetative growth, Signal molecules, Plant growth regulators, Fruit set, Aril weight.

Lalithya K. A.*, Raju B., Manjunath G.,
Kulkarni M.S., Swamy G.S.K.
University of Horticultural Sciences,
Bagalkot 577103, Karnataka, India
e-mail : Lalalithya0@gmail.com
*Correspondence

## Introduction

Cultivation of pomegranate is one of the profitable venture help in increasing standard of living and became livelihood for most of the growers. India is considered as one of the largest producer of pomegranate in world having annual production of 1789.31 thousand metric tonnes per annum with 180.64 thousand ha cultivable area and productivity of 9.91 tonnes per ha [1]. Rich source of antioxidant property, anti-diabetic, anti-cancer, anti-aging properties besides its attractive fruit color and refreshing arils, and production of pomegranate throughout the year enhanced its export potentially in recent years [2—4]. Lack of knowledge and non adoption of modern cultivation aspects impaired both production and the quality of pomegranate fruits. Maximum flower drop and poor fruit setting are major problems faced by most of the growers moreover, improper management of plant canopy prone to attack of pest and diseases, also leads to poor development of quality fruits [5]. Thus, application of plant growth regulator might become an alternate component in order to enhance produc-

**Table 1.** Time of application of plant growth regulators and signal molecules at different intervals.

| Treatments | Concentration | Application | No. of sprays |
|---|---|---|---|
| NAA | 40 ppm | At 15 days after pruning, 30, 60 and 90 days after complete flowering | 4 |
| $GA_3$ | 50 ppm | At 15 days after pruning, 20 days interval after I$^{st}$ spray | 5 |
| 2,4-D | 30 ppm | At 15 days after pruning, 30, 60 and 90 days after complete flowering | 4 |
| Paclobutrazol | 200 ppm | At 15 days after pruning, 60 and 90 days after complete flowering | 3 |
| Ethrel | 200 ppm | At 15 days after pruning, 60 and 90 days after complete flowering | 3 |
| Salicylic acid | 1 mM | At 15 days after pruning, 20 days interval after I$^{st}$ spray | 6 |
| Chitosan | 75 ppm | At 15 days after pruning, 20 days interval after I$^{st}$ spray | 6 |
| Nitric oxide | 0.1 mM | At 15 days after pruning, 20 days interval after I$^{st}$ spray | 6 |
| Bronopol | 500 ppm | At 15 days after pruning, 20 days interval after I$^{st}$ spray | 6 |
| Untreated | – | – | – |

tion and productivity apart from altering plant vigor in pomegranate plants [6, 7].

Plants growth regulators are small organic compounds which help to modify the growth and developmental process, apart from changing behavior in cropping system [8, 9]. Exogenous application of auxin played vital role in enhancing various physiological responses like embryogenesis, seed germination, apical dominance and flower and fruit development [10], while, pre-harvest application of ethylene triggered various developmental processes by enhancing maximum number of productive shoots, femaleness, fruit set, yield, and quality apart from inducing immune system in horticultural crops [11, 12]. Similarly, application of paclobutrazol, a gibberellin inhibitor induced reproductive growth by blocking the conversion of kaurene to kaureonic acid by suppressing vegetative growth [13] in contrast, application of gibberellic acid enhanced vegetative growth in most of fruit crops [14—16].

Signalling molecules are new class of phytohormones which play beneficial role in inducing physiological response in plants apart from their defense responses. Salicylic acid, a phenolic acid compound generates a wide range of metabolic and physiological responses in plants in addition to their defense responses in plant system [17]. Nitric oxide, an important signalling molecule played a diverse physiological role in most of the plants by promoting seed germination, leaf extension, root growth, stomatal closure, delaying leaf senescence and fruit maturation [18]. Moreover, chitosan application enhanced various physiological and biochemical process in various horticultural crops [19—21].

As limited information is available about the influence of plant growth regulators on enhancing vegetative growth and reproductive growth of pomegranate and no reports are available on signalling molecules on enhancing its growth, yield and quality, this would be new approach to study influence of plant growth regulators and signal molecules on growth, fruit set and aril characters of pomegranate fruits.

## Materials and Methods

Selection of experimental site

Uniformly grown three year old pomegranate plants

**Table 2.** Effect of growth regulators and signal molecules on plant height, plant spread and plant canopy in pomegranate (pooled data).

| Treatments | Plant height (m) | | | Plant spread (m) N-S direction | | | Plant spread (m) E-W direction | | | Plant canopy ($m^3$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before first spray | After last spray | Total height increased | Before first spray | After last spray | Total height increased | Before first spray | After last spray | Total height increased | Before first spray | After last spray | Total height increased |
| $T_1$- NAA at 40 ppm | 1.69 | 2.02 | 0.33 | 1.44 | 2.71 | 1.26 | 1.33 | 2.75 | 1.42 | 1.70 | 8.02 | 6.31 |
| $T_2$- $GA_3$ at 50 ppm | 1.69 | 2.24 | 0.54 | 1.37 | 2.88 | 1.50 | 1.43 | 3.05 | 1.62 | 1.77 | 10.49 | 8.72 |
| $T_3$- 2,4-D at 30 ppm | 1.67 | 2.12 | 0.45 | 1.34 | 2.69 | 1.34 | 1.39 | 2.68 | 1.28 | 1.64 | 8.18 | 6.54 |
| $T_4$- Paclobutrazol at 200 ppm | 1.73 | 1.88 | 0.15 | 1.40 | 2.36 | 0.96 | 1.43 | 2.46 | 1.02 | 1.80 | 5.68 | 3.88 |
| $T_5$- Ethrel at 200 ppm | 1.69 | 1.87 | 0.18 | 1.37 | 2.37 | 0.99 | 1.34 | 2.42 | 1.07 | 1.61 | 5.58 | 3.97 |
| $T_6$- Salicylic acid at 1 mM | 1.78 | 2.08 | 0.30 | 1.43 | 2.58 | 1.14 | 1.40 | 2.65 | 1.24 | 1.87 | 7.51 | 5.63 |
| $T_7$- Chitosan at 75 ppm | 1.76 | 2.18 | 0.41 | 1.44 | 2.62 | 1.18 | 1.41 | 2.64 | 1.23 | 1.87 | 7.98 | 6.11 |
| $T_8$- Nitric oxide at 0.1 mM | 1.80 | 2.14 | 0.34 | 1.40 | 2.64 | 1.24 | 1.38 | 2.70 | 1.31 | 1.81 | 8.06 | 6.25 |
| $T_9$- Bronopol at 500 ppm | 1.66 | 2.06 | 0.39 | 1.42 | 2.66 | `1.23 | 1.39 | 2.59 | 1.20 | 1.73 | 7.44 | 5.71 |
| $T_{10}$- Control | 1.72 | 1.92 | 0.19 | 1.46 | 2.50 | 1.03 | 1.42 | 2.57 | 1.14 | 1.87 | 6.42 | 4.55 |
| SEm ± | 0.02 | 0.04 | 0.01 | 0.04 | 0.05 | 0.05 | 0.03 | 0.07 | 0.05 | 0.10 | 0.39 | 0.37 |
| CD at 5% | 0.07 | 0.13 | 0.04 | – | 0.16 | 0.16 | – | 0.22 | 0.17 | – | 1.18 | 1.11 |

with spacing of 4 m × 2 m were selected for present investigation at Division of Fruit Science, UHS, Bagalkot for two consecutive seasons of 2015 and 2016. Ten treatments were replicated thrice with randomized complete block design. Three plants were selected per treatment in each replication.

### Imposition of treatments

Growth regulators like naphthalene acetic acid (NAA), gibberellic acid ($GA_3$) and 2,4-Dichlorophenoxy acetic acid (2,4-D) were completely dissolved by using 1 N NaOH and final volume was made up to 1,000 mL with distil water and stored at 4°C until use. Known quantity of salicylic acid was dissolved in hot water (70 °C) by constant stirring. Chitosan was dissolved by using 1 to 2 mL of 1% glacial acetic acid by constant stirring until it get complete dissolved and pH was adjusted to 5.6 by using 1 N NaOH or by 1% acetic acid.

Required concentrations are directly drawn from stock solution and applied for treatment plants at different time intervals (Table 1) with the help of knapsack sprayer at morning hours till it runoffs from leaf surface. Other intercultural operations were carried out as per the guidelines given in package of practice, UHS, Bagalkot.

### Recording observations

Following observations on growth, fruit set and aril characters were recorded in each treatment. Growth parameters like plant height and plant spread was measured twice during cropping season. Initially, soon after pruning and before imposition of treatment and final observation were taken after imposition of last treatment. Plant canopy were calculated by using formula

$$\text{Plant canopy} = 4/6\pi hr^2$$

Where, r = Sum of (East-West) and (North-South) direction (m)/4, h = Height of plant (m)

Per cent fruit set was calculated by the ratio of number of fruits after complete flowering to total number of flowers produced per plant.

**Table 3.** Effect of growth regulators and signal molecules on fruit setting and aril characters in pomegranate (pooled data).

| Treatments | Fruit setting percentage | 100 aril weight (g) | Seed weight (g) |
|---|---|---|---|
| $T_1$- NAA at 40 ppm | 64.24 | 32.50 | 4.96 |
| $T_2$- $GA_3$ at 50 ppm | 61.78 | 35.00 | 4.68 |
| $T_3$- 2,4-D at 30 ppm | 64.01 | 38.50 | 5.15 |
| $T_4$- Paclobutrazol at 200 ppm | 68.19 | 32.00 | 5.19 |
| $T_5$- Ethrel at 200 ppm | 72.20 | 33.00 | 4.62 |
| $T_6$- Salicylic acid at 1 mM | 61.66 | 32.50 | 5.06 |
| $T_7$- Chitosan at 75 ppm | 57.75 | 33.66 | 5.31 |
| $T_8$- Nitric oxide at 0.1 mM | 61.52 | 32.83 | 5.18 |
| $T_9$- Bronopol at 500 ppm | 54.31 | 32.83 | 5.21 |
| $T_{10}$- Control | 50.40 | 24.83 | 5.80 |
| SEm ± | 3.22 | 0.67 | 0.09 |
| CD at 5% | 9.57 | 2.01 | 0.29 |

### Statistical analysis

Statistical analysis of the data was done by following the Fisher's analysis of variance (ANOVA) technique as given by Panse and Sukathame [22]. The level of significance used in $F$ test was $p$=0.05.

## Results and Discussion

### Effect of plant growth regulators and signal molecules on growth parameters

It is evident from present investigation that, foliar application of $GA_3$ at lower concentration enhanced vegetative growth in both first and second year by recording 0.43 m and 0.65 m increase in plant height during first and second year compared to rest of the treatments (Table 2). Increase in plasticity of the cell wall followed by the hydrolysis of starch into sugars reduces the cell water potential, resulting in the entry of water into the cell causing cell division and its elongation in plant system [23, 24]. This statement is in accordance with the present findings where foliar application of $GA_3$ at 50 ppm resulted in extending maximum plant height (2.24 m) and plant spread in both North-South and East-West direction by 2.88 m and 3.05 m respectively. Accordingly, maximum increase in plant height and plant spread resulted in obtaining maximum plant canopy (10.49 $m^3$) in both 2015 and 2016 (Table 2). Obtained results are in line with findings of Kumar et al. [25] and Uddin et al. [14] where foliar application of $GA_3$ at 75 ppm showed increase in plant height and maximum plant spread in strawberry plants.

Paclobutrazol which act as anti-gibberellin agent, showed minimum canopy spread (5.68 $m^3$) by minimizing plant height (1.88 M), plant spread in both North-South (2.36 m) and East-West direction (2.46 m) in pomegranate plants when compared to other treatments. These results are in conformity with findings of both Golla [26] and Yeshitela et al. [27], where foliar application of paclobutrazol helped in minimizing vegetative growth of mango tree. Paclobutrazol act as growth retardant by inhibiting the biosynthesis of gibberellin by oxidation of ent-kaurene to ent-kauronic acid in endoplasmic reticulum through disabling cytochrome P-450 dependent oxygenase, changing its distribution pattern by hindering vegetative growth phase, diverting most of the nutrients towards reproductive growth [28].

### Effect of phytohormones on fruit setting percentage in pomegranate fruits

As per the data present in Table 3, foliar application of ethrel at 200 ppm resulted in obtaining 72.20% fruit set in both season. Maximum production of hermaphrodite flowers followed by lesser flower dropping in treatment plants resulted in obtaining higher fruit setting percentage in pomegranate (Unpublished data). These statements are in line with earlier reports given by Lakshmipathi et al. [11] where maximum production of hermaphrodite flowers by ethrel treatment resulted in obtaining maximum fruit setting percentage in cashew. Similarly, foliar application ethrel at lower concentration enhanced maximum fruit set in bael fruits [29].

Foliar application of paclobutrazol also showed favorable results in obtaining maximum fruit setting (68.19%) in pomegranate. These results are in accordance with findings of Samani [30] where foliar application of paclobutrazol resulted in inducing maximum fruit set in peach crop. Accordingly, plants which received foliar spray of NAA and 2,4-D treatments noticed higher fruit setting percentage in pomegranate (Table 6). Similar observations were made by Ghosh et al. [31] where, foliar application of NAA at 25 ppm resulted in obtaining maximum fruit setting percentage in pomegranate. Maximum translocation of metabolites towards sink due to hormonal application resulted in preventing development of abscission layer at the site of fruit development which favors strong attachment at its production site [32]. This statement is in line with findings of Uniyal and Misra [29] where foliar application of NAA noticed maximum fruit setting in bael.

## Influence of plant growth regulators and signal molecules aril characters of pomegranate

Application of phytohormones significantly enhanced quality of aril by reducing seed weight compared to control. Data presented in Table 3 revealed that, foliar application of 2,4-D at 30 ppm significantly enhanced aril weight by recording 38.50 g aril weight per 100 arils followed by $GA_3$ treatment (35.00 g 100 $arils^{-1}$) in both consecutive seasons of 2015 and 2016 compared to control (24.83 g 100 $arils^{-1}$). Obtained results are in accordance with the findings of Adi reddy and Prasad [33] and Rahemi and Atahossaeini [34] where foliar application of 2,4-D resulted in attaining maximum aril weight in pomegranate fruits.

Foliar application of ethrel at 200 ppm resulted in decreasing seed weight (4.62 g 100 $aril^{-1}$) followed by $GA_3$ (4.68 g 100 $aril^{-1}$) compared to control (5.80 g 100 $aril^{-1}$) (Table 3). Present finding are in line with statement given by Uniyal and Misra [29] where foliar application of ethrel resulted in minimizing seed weight in bael fruit. Similar results were obtained by Anawal et al. [35] where foliar application of NAA followed by $GA_3$ treatment significantly minimized seed weight in pomegranate.

From this study it was concluded that, foliar application of $GA_3$ played vital role in enhancing vegetative parameters while application of growth retardants like ethrel and paclobutrazol significantly enhanced fruit yield by increasing maximum fruit setting in pomegranate plants. Both 2,4-D and $Ga_3$ treatment found beneficial in enhancing aril weight and ethrel treatment significantly minimized seed weight in arils of pomegranate fruits. Thus it is evident to say that, beneficial effects of phytohormones can be judiciously utilized to enhance growth, yield and quality of pomegranate fruit to ensure sustainability in crop production.

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