Effects of plant growth regulators applications on induction of lateral branching in Oregon Spur apple nursery trees

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ABSTRACT

The study presents the influence of 6-benzyladenine alone and in combination with gibberellic acid on growth and lateral branching of one-year-old ‘Oregon Spur’ apple nursery trees grafted on MM-106 rootstock. Different concentrations of BA and BA+GA_3 (200, 300, 400, 500, 600 and 700 ppm) were applied three times at one week interval during second vegetative growth. Investigation reveal that Oregon Spur have strong apical dominance and plant applied with growth regulators resulted in a significant increase in number of feathers (0.58 to 6.18 per tree) compared to untreated control (0.18 per tree). However, BA alone has more significant effect on number of feathers (1.45 to 6.18 per tree) than BA+GA_3 (0.58 to 4.35 per tree). Maximum number of feathers (6.18 per tree) has been obtained with 500 ppm BA treatment. This treatment also resulted in more uniform feather length (2.58 short and 2.55 medium length lateral branches per tree) and correct distribution of feathers along the trunk (20.63 cm branching zone) with appropriate average feathers crotch angle (54.74° from vertical). Furthermore, this treatment resulted in 100 per cent feathered trees compared to none in control and 2.88 trunk and mean feather diameter ratio compared to 1.54 in control. Some treatments with BA had a negative influence on the tree height. Whereas, most treatments increased trunk diameter and crotch angle compared to control.

Key words: Malus domestica, plant growth regulators, 6-benzyladenine, gibberellic acid.
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expensive method to induce laterals branching (Sazo and Robinson, 11). Among the many PGRs tested
6-BA and BA+GAs are the most commonly used
PGRs, but the recommendations are contradictory
and vary from region to region (Cowgill et al., 1; Doric et al., 2; Radivojevic et al., 7; Robinson and Sazo, 8)
which might be due to available growing period and
interaction of application of PGRs with environmental
variable; furthermore studies are limited to few
regions and on few cultivars and many researchers
found that feathering response with the application
of PGRs vary with cultivar to cultivar (Doric et al., 2;
Radivojevic et al., 7; Robinson and Sazo, 8). Oregon
Spur is one of the most important apple cultivar in
India and is highly suitable for intensive production.
Therefore, the aim of this study was assessment
of effectiveness of different concentration of 6-BA
and BA plus GA₃ in promoting lateral branching
(feathering) in one year old Oregon Spur apple
nursery trees grafted on MM-106 rootstock.

MATERIALS AND METHODS

Present research work on one-year-old ‘Oregon
Spur’ apple grafted on MM-106 was conducted in
2016 and 2017 at ICAR-CITH, Srinagar (33.58’
N, 74°48’ E and 1644 m a.s.l.). The treatments
include the application of 6-benzyladenine and
6-benzyladenine plus gibberellic acid (1:1) @ 200,
300, 400, 500, 600 and 700 ppm respectively. The
soil of experimental block was clay loam in texture
with pH 6.86, EC 0.38 dSm⁻¹. Treatments were applied
thrice at weekly intervals to one year old grafted
nursery trees planted at 90 × 60 cm spacing in the
second year of the nursery cycle, when the central
leader shoot tip was growing. The apical section of
the central shoot was with a hand held sprayer until run-
off. Control trees were unsprayed. The experimental
procedure followed a randomized block design with
four replications distributed down a row with each
experimental unit being a section of five trees (20
trees per treatment). All the other management
practices were done as required uniformly In the fall,
trees were measured in the nursery for tree height,
trunk diameter (10 cm above bud union), total number
of lateral (any lateral shoot longer than 5 cm), total
number of feathers (any lateral shoot longer than 10
cm and above 70 cm from ground level), distance
from the ground level to each of the induced feathers,
length, diameter and crotch angle of each feather,
branching zone (distance between the highest and
lowest feathers) and per cent feathered tree (tree with
at least three feathers higher than 70 cm above the
ground was considered as feathered tree and their
number was expressed as a per cent of total number
of trees per plot). Weather data during both study
years were obtained from airbase meteorological
station, Srinagar and presented in Fig. 1-4. The
mean annual temperature during 2016 and 2017 was
respectively 0.51°C and 0.26°C higher than the mean
for the years 2005 to 2015. The total precipitation
during 2016 and 2017 was respectively 174.33 and
49.85 mm less than average of 2005 to 2015. Daily
M, Mm and A temperature on treatment application
day during 2016 and 2017 are presented in Fig.1 and
Fig. 2 respectively. Whereas, during 2016 and 2017
M, Mm and A temperature of one week before first
application, during applications week and one week
after last application are shown in Fig. 3 and Fig. 4
respectively. The data were analysed by one-way
analysis of variance (ANOVA) using software SAS
9.3. Significant differences between means were
evaluated using Duncan’s multiple range test at the
level of p=0.05.

RESULTS AND DISCUSSION

Untreated trees of Oregon Spur revealed a lack
of branching potential and on the basis of pooled
value of year 2016 and 2017 only 0.85 natural lateral
(more than 5 cm) were found on trees, thus cultivar revealed strong apical dominance. Whereas, the number varied from 2.10 (BA+GA3-200 ppm) to 9.73 (BA-700 ppm) laterals per tree for the treated ones (Table 1). Moreover, control tree developed only 0.05 lateral between 5-10 cm length and at more than 70 cm tree height. Whereas, in trees other than control the number varied from 0.28 (BA+GA3-200) to 2.33 (BA+GA3-600 ppm) (Table 1). Untreated control trees had very few feathers (0.18) whereas, all the plant growth regulator treatments significantly enhanced the feathers in one year old apple nursery tree (p<.0001). However, the lowest concentration of BA and BA+GA3 (200 ppm) caused the low feathering of apple nursery tree, whereas increased concentration of BA and BA+GA3 from 200 to 700 ppm increased the number of feathers more than four-fold and seven-fold, respectively (Table 1). On the basis of pooled value of two year study among all the PGR’s treatments the most feathers were counted for BA-500 ppm (6.18 per tree). However, this treatment remains statistically at par with BA-700 ppm (6.15 per tree). Increasing concentration of BA from 500 to 700 did not positively influence the development of feathers indicating that only 500 ppm is needed for acceptable branching. Apparently, BA alone was more effective than BA+GA3 in feather formation. It is might be due to higher concentration of benzyladenine (200-700 ppm) when applied as alone as compared to lower concentration (100-350 ppm) in combination with GA3. That is in accordance with results of Gastol et al. (3) they concluded that higher doses of BA (780 mg BA+120 mg GA3 per dm3) promoted more branching as compared to lower (330 mg BA+570 mg GA3 per dm3) in ‘Boskoop’ cultivar of apple. These results suggest that higher concentration (more than 400 ppm) would seem to provide major stimulus for feather formation in one year old Oregon Spur apple nursery tree. The application of BA alone or in combination with GA3 significantly affected the formation of feathers might be due to application of BA affects the flow of auxins (Muller and Leyser, 6) and temporarily impedes the main shoot growth (Sazo and Robinson, 11) which helps to overcome apical dominance and create favourable environment of feather formation in one year old Oregon Spur apple nursery trees.

Feather length of nursery tree has direct relation with orchard tree productivity (Sadowski et al., 10) and is important in determining the quality of nursery tree. In the present investigation the length of feathers was also affected with different plant growth regulator treatments. In treated tree, short (10-20 cm), medium (21-40) and long (>40 cm) feathers and total length of feathers were significantly greater in higher doses of BA and BA+GA3. Less than 40 cm feather length is ideally suited for high density planting (Sazo and Robinson, 12) as shorter feathers are easier to manage in the close in-row spacing. Examining the length of feathers, it is easy to see that the treatment with the higher BA concentrations (500-700) produced maximum number of short and medium feathers. On the basis of pooled value of two years investigation the highest number of short feathers (2.73) was obtained from BA-600 ppm treatment although, this treatment remained statistically at par with BA-500 (2.58) and BA-700 ppm (2.6). Whereas significantly higher numbers of medium feathers (2.55) were obtained from BA-500 ppm treatment and it remained statistically at par with BA-400 (2.3) and BA-700 ppm (2.23) (Table 1) and length of most of the feathers on the control tree almost exceeded 40 cm. These finding thus also suggest that treatments containing higher concentration of BA are more effective in the formation of feathers of ideal length i.e. 10-40 cm. As far as mean feather length to concern generally trees with higher number of feathers recorded the lower mean length of feathers (Fig. 5). In trees treated with
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higher doses of BA the mean feather length value were low which might be due to higher number of feathers produced by these trees. These results are in accordance with earlier research findings, which confirmed that an increase in the number of feather permits variation in mean feather length (Doric et al., 2; Radivojevic et al., 7). Further, control, 200 ppm BA and BA+GA$_3$ promoted the longest feathers compared to other treated trees because most of feathers in these treatments induced in early spring thus they got more vegetative growth period, further as these treatments have few feathers therefore the water and nutrients were used for the growth of a smaller numbers of feathers. The results are in conformity with the findings of Cowgill et al. (1); Doric et al. (2) and Radivojevic et al. (7); Robinson and Sazo (8). The total length of feather varied from 0.71 m (untreated control and BA+GA$_3$-200 ppm) to 1.75 m (BA- 700 ppm). In general the trees with higher numbers of feathers produced higher total length of feathers. Application of BA alone was more effective than combine application with GA$_3$ in respect of total feathers this might be due to BA treatments inducing more number of feathers compared to BA+GA$_3$ treatments. The results are in agreement with previous reports (Doric et al., 2; Radivojevic et al., 7).

The height of first feather from ground is important determinant of quality of nursery tree. In present investigation only those laterals were considered as a feather, which were longer than 10 cm and above 70 cm from ground. Pooled value of two years investigation revealed that lateral branching below 70 cm was observed in control (0.63) as well as in all treatments (0.78-2.13) (Table 1). However, these laterals were not included in the analysis, as the main emphasis of the investigation was on feathers. According to Sazo and Robinson (12), the bottom feather of nursery tree should not be lower than 75 cm from ground level for high density planting and in all treatments except BA+GA$_3$-200 ppm induced feathers at desirable height i.e. 77.41 to 83.41 (Fig. 6). In both experimental years higher concentration of BA alone and in combination with GA$_3$ resulted in the expansion of the branching zone. Further, on the basis of pooled value of two experimental years branching zone value were higher when BA was applied alone (6.52-20.63 cm) than in combination with GA$_3$ (4.40-17.74 cm) (Table 1). However, average shoot internode length was found higher in trees treated with BA+GA$_3$ even though the branching zone observed was higher in BA treated tree due to higher number of induced feathers and highest branching zone (20.63 cm) was observed in treatment which induced highest number of feathers i.e. BA-500 ppm. The present results are also supported by Doric et al. (2).

The results of two years of investigation revealed that tree treated with plant growth regulators produced feathers with wider crotch angle from vertical compared to untreated control and the effect is found more prominent in trees treated with higher concentrations of PGR’s (Table 1). On the basis of pooled value of two year investigation the widest crotch angle (57.42°) was achieved from BA+GA$_3$-500 ppm treatment followed by 56.77° and 55.10° from BA+GA$_3$-700 and 400 ppm treatments respectively, indicating that combine application of higher concentration of BA+GA$_3$ achieved a wider crotch angle compared to BA alone. Application of
aggressive chemical branching agents like BA in nursery tree can result in more obtuse feather angle (Steiner et al., 14). From these findings we can say that higher concentration of BA acts as aggressive branching agent compared to lower rate of BA with GA3. However, when assessing treatment effects, number of feathers (vary from 1.45 to 6.18 per tree in BA alone treatments compared to 0.58 to 4.35 per tree in BA+GA3 treatments) should be considered as well, as it can have effect on the feather crotch angle, which tends to be wider in the lowest feathers relative to those in the higher tiers. The results are in accordance with Stanisavljevic et al. (13) and in contradiction with Doric et al. (2) and Radivojevic et al. (7). Wider angle produced by all the treatments compared to control would be a significant advantage for apple orchard system like the Tall Spindle since less labour would be required to tie feathers or branches down after planting.

The present research revealed that the majority of the treatments with high doses of BA (400, 500 and 700 ppm) produced significantly shorter tree (156.4-159.48 cm) compared to lower doses (165.08-166.80 cm) and untreated ones (167.1) (Table 1) which might be because high doses of BA treatment temporarily slows the main shoot growth (Sazo and Robinson, 11), which can negatively affect the final tree height in investigated cultivar. In addition, the tree height was possibly reduced in treatments with higher doses of BA, as the more active growing laterals shoot, induced by these treatments, competing for limited nutrients and other growth factors, but still the height of the treated trees met the standard requirements. The results are in accordance with Cowgill et al. (1) where they reported that trees treated with higher doses of BA (1000 ppm) were significantly shorter than lower doses (500 ppm). Furthermore, control trees were significantly taller than trees treated with BA+GA3 (156.95-162.18) which might be due to less number of feathers and apical dominance. That is in accordance with results of Rufato et al. (9), they reported that combine application of BA+GA4+7 reduced tree height compared to BA alone and untreated control in Maxi Gala cultivar of apple grafted on G.202. However, many researchers have expressed contrasting findings, stating that combine application of BA+GA4+7/GA3 significantly increase tree height compared to BA alone and untreated control in Mutsu (Gastol et al., 3); Golden Delicious (Cowgill et al., 1); Gala and Jonagold (Doric et al., 2) apple cultivars.

In the present study minor differences in the trunk diameter were noted among treatments in both experimental years (Table 1). However, on the basis of pooled value of both years application of BA alone (12.77-13.61 mm) and in combination with GA3 (12.35-13.44 mm) significantly increase trunk diameter compared to untreated control (12.06 mm) whereas maximum value (13.61 mm) was recorded for BA-700 ppm treatment. The positive influence of plant growth regulator treatments observed in this study could be explained by the presence of greater number of feathers than control, which can have a considerable beneficial effect on trunk diameter (Jacyna, 4) of investigated trees. The results of present investigation are in agreement with previous research findings which confirm that trunk diameter with the application of BA and BA+GA4+7.
Table 1. Effect of various plant growth regulators treatments on different studied parameter of Oregon Spur apple nursery tree.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Lateral (&gt;5 cm)</th>
<th>Lateral (&lt;70 cm ht)</th>
<th>Lateral (5-10 cm and &gt;70 cm ht)</th>
<th>Feathers Short feathers (10-20 cm)</th>
<th>Feathers Medium feathers (21-40 cm)</th>
<th>Feathers Long feathers (&gt;40 cm)</th>
<th>Total feather length (m)</th>
<th>Branching zone (cm)</th>
<th>Average feather crotch angle (°)</th>
<th>Tree height (cm)</th>
<th>Trunk diameter (mm)</th>
<th>Trunk and mean feather diameter ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated control</td>
<td>0.85f</td>
<td>0.63d</td>
<td>0.05f</td>
<td>0.18</td>
<td>0.00f</td>
<td>0.15f</td>
<td>0.71f</td>
<td>4.58f</td>
<td>48.75f</td>
<td>167.10a</td>
<td>12.06c</td>
<td>1.54g</td>
</tr>
<tr>
<td>BA-200 ppm</td>
<td>2.58e</td>
<td>0.78cd</td>
<td>0.35f</td>
<td>1.45g</td>
<td>0.10e</td>
<td>0.33e</td>
<td>1.03abc</td>
<td>1.02a</td>
<td>6.52f</td>
<td>51.96d</td>
<td>166.80a</td>
<td>12.77bcd</td>
</tr>
<tr>
<td>BA-300 ppm</td>
<td>5.78c</td>
<td>1.10bcd</td>
<td>1.78bcd</td>
<td>2.90e</td>
<td>0.75c</td>
<td>1.45c</td>
<td>0.75d</td>
<td>0.98e</td>
<td>10.43d</td>
<td>53.29bcd</td>
<td>159.48bcd</td>
<td>13.13bc</td>
</tr>
<tr>
<td>BA-400 ppm</td>
<td>9.38a</td>
<td>2.13a</td>
<td>2.13abc</td>
<td>5.13c</td>
<td>1.93c</td>
<td>2.30c</td>
<td>0.90bcd</td>
<td>1.46b</td>
<td>16.62c</td>
<td>53.41bcd</td>
<td>159.48bcd</td>
<td>13.13bc</td>
</tr>
<tr>
<td>BA-500 ppm</td>
<td>9.45c</td>
<td>2.00b</td>
<td>1.50cd</td>
<td>6.18a</td>
<td>2.58a</td>
<td>2.55a</td>
<td>1.03abc</td>
<td>1.69a</td>
<td>20.63a</td>
<td>54.74bcd</td>
<td>156.40c</td>
<td>13.43c</td>
</tr>
<tr>
<td>BA-600 ppm</td>
<td>8.23b</td>
<td>1.38b</td>
<td>1.18de</td>
<td>5.68b</td>
<td>2.73b</td>
<td>1.73b</td>
<td>1.25a</td>
<td>1.66a</td>
<td>19.10b</td>
<td>54.57bcd</td>
<td>159.58bc</td>
<td>13.08ab</td>
</tr>
<tr>
<td>BA-700 ppm</td>
<td>9.73a</td>
<td>1.95a</td>
<td>1.63bcd</td>
<td>6.15a</td>
<td>2.60a</td>
<td>2.23a</td>
<td>1.30a</td>
<td>1.75a</td>
<td>18.45b</td>
<td>54.82bcd</td>
<td>157.55a</td>
<td>13.61a</td>
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<tr>
<td>BA+GA3-200 ppm</td>
<td>2.10a</td>
<td>1.20b</td>
<td>0.28f</td>
<td>0.58h</td>
<td>0.03e</td>
<td>0.10e</td>
<td>0.45df</td>
<td>0.71f</td>
<td>4.40f</td>
<td>50.09d</td>
<td>162.18bc</td>
<td>12.49cd</td>
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<tr>
<td>BA+GA3-300 ppm</td>
<td>2.23a</td>
<td>1.08c</td>
<td>0.33f</td>
<td>0.80h</td>
<td>0.10a</td>
<td>0.28a</td>
<td>0.43f</td>
<td>0.75f</td>
<td>10.06d</td>
<td>49.46d</td>
<td>160.66bc</td>
<td>12.56cd</td>
</tr>
<tr>
<td>BA+GA3-400 ppm</td>
<td>4.18b</td>
<td>1.10c</td>
<td>0.68ef</td>
<td>2.50f</td>
<td>0.85f</td>
<td>1.13e</td>
<td>0.53f</td>
<td>0.80f</td>
<td>9.61f</td>
<td>55.10abc</td>
<td>156.95c</td>
<td>12.77abcd</td>
</tr>
<tr>
<td>BA+GA3-500 ppm</td>
<td>4.28c</td>
<td>1.03c</td>
<td>0.58ef</td>
<td>2.75ef</td>
<td>0.65f</td>
<td>1.00d</td>
<td>1.13df</td>
<td>1.10cd</td>
<td>10.20c</td>
<td>57.42d</td>
<td>159.10c</td>
<td>12.35cd</td>
</tr>
<tr>
<td>BA+GA3-600 ppm</td>
<td>7.63d</td>
<td>1.13cd</td>
<td>2.33a</td>
<td>4.18d</td>
<td>1.63d</td>
<td>1.38cd</td>
<td>1.18e</td>
<td>1.36e</td>
<td>16.60d</td>
<td>54.86bcd</td>
<td>159.78bc</td>
<td>13.15cd</td>
</tr>
<tr>
<td>BA+GA3-700 ppm</td>
<td>7.80d</td>
<td>1.18d</td>
<td>2.28ab</td>
<td>4.35d</td>
<td>2.03d</td>
<td>1.63d</td>
<td>0.70ef</td>
<td>1.28bc</td>
<td>17.74bc</td>
<td>56.77bc</td>
<td>157.30c</td>
<td>13.44bc</td>
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<td>Pr &gt; F</td>
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<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>0.0015</td>
<td>0.0084</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

*Significance: * * * * * * * * * * * * * * * *

Values within a column followed by the same letter are not significantly different at P>0.05, as established by the Duncan’s Multiple Range Test. *, significant at P>0.05
significantly increased in Jonagold (Doric et al., 2) whereas, slightly increased in Cadel (Radivojevic et al., 7) apple cultivars. Though the contradictory results are obtained too in apple cultivar Golden Delicious (Steiner et al., 14) Gala (Doric et al., 2) and Jonagold (Radivojevic et al., 7). As far as mean diameter of feathers to concern treatment, which obtained highest number of feathers (6.18 per tree for BA-500 ppm, Table 1) recorded the lowest mean diameter of feathers (4.68 mm, Fig. 7). Whereas, untreated control, 200 ppm BA+GA, and BA resulted in significantly higher diameter (7.57, 7.16 and 7.14 mm respectively, Fig. 7) compared to other treatments however, all these treatment remain statistically at par with each other. Generally, the mean feather diameter decreasing with increasing number of feathers on treated trees might be due to the inter-shoot competition. Trunk and mean feather diameter ratio plays a critical role in canopy management in early years of high density orchard and accordingly, to preserve a hierarchy of branch the leader should be 3 times the diameter of any of the lateral branches in the upper part of the tree. However, in this investigation the trunk diameter was taken in to consideration instead of central leader which certainly have higher diameter value than leader in upper part of trees in spite of this, in present investigation we had achieved 2.88 value in best performing treatment i.e. BA-500 (Table 1) indicating that almost all the feathers produced by these treatments will remain suitable after planting.

Both, BA alone and BA+GA treatments results in substantial increase in numbers of per cent feathered plants. In both years of investigation, 100 per cent feathered trees were observed for BA-500, BA-700 and BA+GA-700 ppm, additionally during 2017 application of BA-600 ppm also observed 100 per cent feathered trees. However, it is worth mentioning that without exogenous plant growth regulators or even lower concentration of BA+GA (200 ppm) no trees were feathered (Fig. 8). The findings also indicate a higher effectiveness of application of BA

![Fig. 7. Effect of various plant growth regulators treatments on average feather diameter (pooled value). The bars represent ± S.E.](image)

![Fig. 8. Feathered trees (%) obtained in different plant growth regulators treatments during 2016 and 2017. The bars represent ± S.E.](image)
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alone compared to combine application with GA₃ for feathering in one year old Oregon Spur apple nursery trees. The results are in agreement with Gastol et al. (3).

In conclusion, application of BA alone had a greater positive effect compared to combine application with GA₃. Its beneficial effects were mainly reflected in the increase in total number of feathers, number of short and medium feathers, branching zone, trunk and mean feather ratio and per cent feathered trees. Results based on all the studied parameters proved that application of BA-500 performed better than rest of the treatments for feathering in one year old Oregon Spur apple nursery trees.

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Received : July, 2018; Revised : February, 2020; Accepted : February, 2020