EFFECT OF CHILLING AND GIBBERELLIC ACID ON VEGETATIVE GROWTH AND RUNNER PRODUCTION OF STRAWBERRY UNDER TUNNEL CONDITIONS IN POTHOWAR

Samia Ikram, Khalid Mahmood Qureshi*

ABSTRACT

Strawberry (*Fragaria ananasa*) is a soft fruit of Rosaceae family with some known vernalization requirement. Strawberry is propagated by means of healthy runners; current trial was conducted to investigate the effect of chilling and gibberellic acid on vegetative growth and runner production of strawberry under tunnel conditions at Department of Horticulture Pir Mehar Ali Shah Arid Agriculture University Rawalpindi, Pakistan, during 2011-12. Gibberellic acid with 200ppm, 400ppm and chilling 4°C were applied alone and in combination before flower initiation and it was observed that strawberry plants responded much better with application of GA₃ @400ppm and produced maximum vegetative growth parameters such plant height (25.337 cm), petiole length (22.60 cm), number of trusses (2.9), leaf area (139.86 cm²), number of runners (20.55), runner number of leaves (7.44), runner canopy spread (30cm), leaf area of runner (80.33 cm²) and weight of mother runner (22.90 g) while chilling at 4°C proved better to produce maximum crown diameter (3.63 cm), number of leaves (15.44), fresh weight of leaves (48.17 g) and better canopy size (31.55 cm) under tunnel condition.

KEYWORDS: Strawberry; gibberellic acid; chilling; vegetative growth; runner production.

INTRODUCTION

*Fragaria ananasa* a famous soft fruit commonly known as strawberry is a member of Rosaceae family. There are some factors that can affect yield and quality of strawberry. Growth regulators are considered one of those most important factors (25). Strawberry plants consist of a crown (shortened stem) from which all leaves, roots, flowers and runners grow (6). Various strawberry species grow wild all over the world, but cultivated strawberry is based upon two species *Fragarin chiloensis* and *Fragarin virginiana*. Hybrid between these two species was the ancestor of all the modern strawberry cultivar (17). The climatic condition of Pakistan is very suitable for the cultivation of

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strawberry. Strawberry requires low chilling temperature. It can be grown in many soil types. The harvest of strawberry begins in early summer and generates revenue when few other crops are available. Therefore, strawberry is very demanding enterprise (4). Strawberry is newly introduced crop in Pakistan; therefore its average yield per acre is very low as compared to other countries. Its future is very much bright in our country in general and in Swat valley, NWFP in particular because this fruit fetches maximum economic returns for the farmer (13).

Some factors affecting runner plant yield and quality are plant growth regulators (40), altitude (30) and some cultural applications (1). Strawberry plants pick up vegetative and floral vigour under the chilling effect in autumn and winter. The plants of strawberry recuperate vegetative and floral vim under a chilling effect in autumn and winter (33). Strawberry is responsive to the application of plant growth regulators, GA$_3$ at 90 ppm level produced the best result in terms of vegetative growth, runner production of strawberry reported by Kumar et al (22). In most of the treatments GA$_3$ application increased petiole length and leaf area of the strawberry plants (30).

Many studies have shown that runner quality (Runner height, runner spread, weight of runner, runner leaf number) is a major factor that affects both productivity and fruit quality (10, 32, 8). The fate of axillary buds is also affected by the plant growth regulator gibberellin (GA) and its exogenous application enhances runner formation in short day length (16). Maximum number of runners obtained when plants were treated with GA$_3$, this can be imputable to higher rate of cell division and stimulation of vegetative growth (3). It reduces flowering and as a result vegetative growth including production of runners increases (12).

Runner production greatly depends upon ecological factors, in Pakistan it is only restricted to swat region, from where the runners are supplied all over the country which greatly influence the economy of the grower and runner price. This researchable issue can be solved by studying the effect of gibberellic acid on runner production and it can be exploited to minimize the runner production pressure on swat region. Present trial was carried out with aim to address aforesaid issue.

**MATERIALS AND METHODS**

Chemical and reagents

Gibberellic acid was purchased from Sigma-Aldrich Germany, hydrochloric acid and acetone of Merck (Private) Limited, Pakistan. Milli-Q water was used to prepare all solutions.
Preparation of stalk solutions

The solutions of 200 ppm and 400 ppm gibberellic acid were prepared by dissolving 200 mg/liter and 400 mg/liter respectively in distil water for the subject study.

Growth conditions and plant materials

The trial was conducted in climatic conditions of Rawalpindi in the tunnels operated in research field area, during 2011-12. The trial was designed to investigate the effect of chilling and gibberellic acid on the vegetative and runner quality parameters of strawberry plants in tunnel conditions, the study further enlightened the importance of chilling for strawberry plant. Rawalpindi region comprises humid to sub-tropical climate and fall under semi-arid region with annual precipitation of about 1044 mm, which falls mostly during monsoon (July – September). Runners of Strawberry cv. “Chandler” were imported from Swat (Mangora). These were kept in cold chamber 4°C in cold chamber of Mack Pharma tech Private Limited per treatment for about fifteen days to complete the chilling needs of strawberry plants. The runners were planted in well drained sandy loam soil, 22-25°C with humidity 65-75%. Plantation was done on ridges by keeping plant to plant distance of 8 cm and row to row distance of 1 feet. Irrigation was done soon after planting and then applied on weekly basis and as per plant requirement November 2011 under field conditions in tunnels at Department of Horticulture by following RCBD.

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Temperature</th>
<th>Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy loam</td>
<td>22-25°C</td>
<td>65-75%</td>
</tr>
</tbody>
</table>

A foliar spray of gibberellic acid (GA₃) was done before flowering (27) and the concentration of gibberellic acid (GA₃) in combination with chilling temperature of 4°C used are as

\[
\begin{align*}
T₁ &= \text{Control/ untreated} \\
T₂ &= \text{Gibberellic acid @ 200 ppm} \\
T₃ &= \text{Gibberellic acid@ 400 ppm} \\
T₄ &= \text{Chilling @ 4°C} \\
T₅ &= \text{Chilling @ 4°C + GA₃ (Gibberellic acid@200 ppm} \\
T₆ &= \text{chilling @ 4°C + GA₃ (Gibberellic acid@ 400 ppm.}
\end{align*}
\]
Traits studied

Following vegetative, reproductive and quality parameters were studied plant height (cm), crown diameter (cm), petiole length (cm), number of leaves, number of trusses, number of runners, leaf area (cm$^2$), fresh weight of leaves (g), dry weight of leaves (g), canopy size, chlorophyll content, runner height, runner canopy, number of runner leaves, leaf area of runners (cm$^2$), weight of mother runners (g) with standard procedures (2).

Statistical analysis

The experiment was laid down by using linear model RCBD. The collected observations were analyzed using Statistica. The means were compared by using least significant difference (LSD) at 5% probability level (37).

RESULTS AND DISCUSSION

Plant height (cm)

Data (Table 1) showed that treatment (T3) containing (GA3) 400 ppm was most effective and contributed to the plant height maximum of 25.337 cm followed by T4 (chilling temperature @ 4°C) that produced height of 24.887 cm and it is statistically at par with T3, GA3 @ 400ppm. The other treatments increased height as 23.667cm (T1, Control), 21.333cm (T5, Chilling @ 4°C + GA3 @ 200 ppm), 20.110cm (T2, GA3 @ 200 ppm) and 18.777cm (T6, Chilling @ 4°C + GA3 @ 400 ppm) respectively. It is concluded that gibberellic acid @ 400 ppm and the chilling @ 4°C are most effective treatments to promote maximum plant height. Similar results were also reported by Guttridge (14) who noted maximum plant height when the temperature was increased. Chughtai (7), reported that GA3 when sprayed during winter favors production during spring (36). Findings of this research are in line with the previous findings of Ouzoundou et al (27) and Kasim et al. (20) those observed rise in plant height in capsicum and artichoke by the treatment of GA3. The effect of chilling was similar with that of GA3 application because chilling also stimulates gibberellic acid production in plants.

Crown diameter (cm)

T4, chilling @ 4°C produced the maximum crown diameter of 3.63 cm while all the other treatments showed non-significant effect on the crown diameter of strawberry plant (Table 1a). The results related crown diameter showed that GA3 application @ 400 ppm induced maximum crown diameter while all the
other treatments of GA₃ and chilling alone and in combinations increased the crown diameter of strawberry plant in similar pattern. The findings are in line with the work of Hytonen et al. (16) who suggested that GA₃ significantly increased the vegetative parameters especially canopy spread, number of leaves, runners and number of lateral branches. Another study by Ragab (31) reported that GA₃ improved significantly total carbohydrates content in roots and crowns of strawberry transplants.

**Petiole length (cm)**

The observations in (Table 1) identified that T₃, GA₃ @ 400 ppm increased the petiole length to the maximum value of 22.60 cm followed by the treatment of T₅, chilling @ 4°C + GA₃ @ 200 ppm that contributed to petiole length of 20.66 cm, the other treatments produced petiole length of 18.4 cm (T₄, chilling @ 4°C), 16.40 cm (T₆, chilling @ 4°C + GA₃ (400 ppm), 15.78 cm (T₂, GA₃ @ 200 ppm) and the lowest values 14.39 cm by T₁, control. The petiole length is regarded as a measure of evaluating the chilling requirement of strawberry plant and according to the present results it is revealed that GA₃ application either alone or in combination helped to increase the petiole length of strawberry plant. Petiole length increased as a result of increase in cell division at higher leaf positions in vegetative growth period (26). GA₃ also increased cell division which is the possible reason for its contribution in elevated petiole length. Our findings are in agreement with the result of (29, 5, 11).

**Number of leaves**

The maximum 15.44 leaves (Table 1) were counted for the treatment T₄, chilling @ 4°C followed by control by producing average of 12.55 leaves while all the other treatments affected leaf production non significantly and contributed 7.44 leaves (T₂, Gibberellic acid @200 ppm), 9.77 leaves (T₃, GA₃ @ 400 ppm), 8.88 leaves (T₅, chilling @ 4°C + GA₃ @ 200 ppm) and 9.33 leaves (T₆, chilling @ 4°C + GA₃ @ 400 ppm). The study revealed that chilling not only increased number of leaves during vegetative growth but also maintained it throughout its life span while it was observed that in case of gibberellic acid spray either alone or in combination with chilling during the course of collection of data that the number of leaves were more at vegetative growth period but as the reproductive stage and runner production started, the number of leaves started reducing this may be due to shifting of energy reserves to runners.
Number of trusses

The maximum of 2.9 trusses (Table 1) were produced by $T_3$, gibberellic acid application at a concentration of 400 ppm followed by the treatment of $T_5$ (chilling @ 4°C + GA$_3$@ 200 ppm) by producing 2.57 trusses per plant while the other treatments produced 1.96 ($T_4$, chilling @ 4°C), 1.92 ($T_2$, GA$_3$ @ 200 ppm), 1.11 ($T_6$, chilling @ 4°C + GA$_3$ @ 400 ppm) and 1.03 trusses by ($T_1$) (control) respectively. As previous literature about gibberellic acid state that it stimulates flower production in all horticultural plants including strawberry similarly it increases the number of trusses per plant and the possible reason for this is that growth GA$_3$ stimulates florogen production. Our findings are in agreement with the results of Guttridge and Thompson (14) who stated that GA$_3$ increased number of truss in strawberry.

Number of runners

Maximum number of runners (Table 1) were produced by GA$_3$ either alone or in combination with chilling. $T_3$, GA$_3$ @ 400 ppm contributed to average of 20.55 runners per plant followed by $T_5$, chilling @ 4°C + GA$_3$ 200 ppm by producing 16 runners while the rest treatments produced 13.22 ($T_6$, chilling @ 4°C + GA$_3$ @ 400 ppm), 10.22 ($T_2$, GA$_3$ @ 200 ppm),4.11 ($T_4$, chilling @ 4°C) and least number of 3.33 runners were contributed by $T_1$, control. Growth regulators are the factors that affect runner plant yield and also its quality suggested by Wang (40). Other factors are cultural practices (1) and altitude of area of production. Gibberellic acid has a role in auxiliary bud differentiation which is the possible reason for its runner producing effect. It has been reported that short day plants were when sprayed with gibberellic acid before flowering they started producing runner in long days (16). Our result findings are in agreement with (16, 22, 25, 28).

Leaf area (cm$^2$)

The greatest leaf area (139.86 cm$^2$) was produced by $T_3$, GA$_3$ @ 400 ppm (Table 1) followed by $T_2$, GA$_3$ @ 200 ppm with contribution of leaf area of 130.39, $T_6$, (chilling @ 4°C + GA$_3$ @ 400 ppm) produced 97.82 cm$^2$ leaf area, 91.95 cm$^2$ is contributed by $T_4$, (chilling @ 4°C), $T_5$, (chilling @ 4°C+ GA$_3$ @ 200 ppm) produced 80.83 and the lowest leaf area of 75.12 cm$^2$ was produced by control. Gibberellic acid alone or in combination produced the highest values of leaf area in our study and the previous findings of Dwivedi et al. (11), Parousssi et al. (29) and Sharma and Singh (36) also stated the positively significant effect of GA$_3$ growth regulator in increasing leaf area.
Effect of chilling and GA on strawberry

Fresh weight of leaves (g)

The most significant statistical data of strawberry plant is observed for fresh weight of leaves (Table 1), the heaviest fresh leaves (48.17 g) were produced by T₄ (chilling @ 4°C) followed by T₅ (combination of chilling and gibberellic acid @ 200 ppm) by contributing to leave weight of 38.41 g then the leave weight of 37.70 g is contributed by T₃ (Gibberellic acid @ 400 ppm) 28.57 g, 25.25 g and 15.25 g were the weights contributed by T₆ (chilling @ 4°C + Gibberellic acid 400 ppm) T₂ (gibberellic acid 200 ppm) and T₁ (control) correspondingly. The results related fresh weight of strawberry revealed that the heaviest leave weight is the contribution of chilling which are in agreement with the work of Risser & Robert (33) who stated that as a result of chilling effect in autumn and winter the strawberry plant gain up its vegetative and floral vigor. Gibberellic acid also contributed to produce heavy leaves than control either alone or in combination with chilling because GA₃ also improves health of strawberry plant as reported by previous scientist (13,19,36,27) both of these (GA₃, Chilling) increased biosynthetic production in strawberry and add up to the weight.

Dry weight of leaves (g)

T₁, control played its part to produce highest readings of 18.44 g (Table 1) followed by chilling treatment by contributing to weight of 18.30 g while 9.04 g, 14.35 g, 17.53 g and 13.73 g were recorded for the treatments with T₂ (GA₃ 200 ppm) T₃ (GA₃ 400 ppm) T₅ (Chilling @ 4°C + GA₃ 200 ppm) and T₆ (Chilling @ 4°C + GA₃ 400 ppm) respectively. The results of our findings are in contradiction with the findings of Kasim et al., (20); Sharma & Singh, (34); Ouzounidou et al., (27) stated that gibberellic acid significantly improved dry weight of shoots in strawberry. Our results can be justified by the statement that due to runner production by the treatments with gibberellic acid and chilling all the biosynthesis produced were transferred to the daughter runners for their healthy production and mother plant itself became weak and showed less biosynthesis in terms of leave weight.

Canopy size

The widest plant spread (Table 1) was produced by T₄ chilling treatment that is 31.55 cm while all the other treatments produced non-significant data as they are statistically at par with each other. The rest of the treatments contributed to the spread of 29.16 cm (T₂, GA₃ @ 200 ppm), 23.78 cm (T₃, GA₃ @ 400 ppm), 26.22 (T₁, Control), 20.83 (T₅, chilling @ 4°C + GA₃ @ 200 ppm) and minimum spread of 14.22 cm by T₆ (chilling @ 4°C + GA₃ @ 400 ppm).
Our results described that chilling had a positive increasing effect on plant canopy these findings are in accordance with the work of Larson & Shaw (23) who suggested that low night temperature and short days boost plant vigor and productivity and Strand (38) stated that strawberry need adequate chilling to optimize number of branches for quality fruit production.

**Chlorophyll content (mg/ml)**

The data related chlorophyll contents of strawberry leaves as effected by different treatments of gibberellic acid and chilling (Table 1) showed that three treatments are statistically at par by effecting chlorophyll content in similar manner and producing chlorophyll content of 40.93 mg/ml, T2, (Gibberellic acid 200 ppm), 39.96 (T5, chilling @ 4°C + @ 200 ppm) and (38.56 mg/ml) T6, (chilling @ 4°C + Gibberellic acid 400 ppm) the other treatments contributed to chlorophyll content of 33.40 T3, (Gibberellic acid) 400 ppm, 32.28 (T1, control) and least contents of 25.80mg/ml by T4, (chilling @ 4°C). The present result are in agreement with the work of Kalir & Mayber (18) and Khan et al (21) who reported increase in chlorophyll content by gibberellic acid, as we all know that gibberellic acid is a multipurpose growth regulator that also improves plant coloration (19).

**Height of runner (cm)**

The Statistical analysis of the experiment reveals that maximum runner height of 14.22 (Table 2) is contributed by T5, chilling @ 4°C + @ 200 ppm followed by T2, (GA3 Gibberellic acid 200 ppm) by producing runner height of 13.08 cm the other treatments contributed to the runner height of 12.77 cm T3, (Gibberellic acid 400 ppm) 11.66 cm T6 (chilling @ 4°C + Gibberellic acid 400 ppm) 9.05 cm (T4 chilling @ 4°C) and lowest height of 6.33 cm is recorded for (T1, control). It is evident from the present results that GA3 increase cell division and affects the growth parameters like plant and runner height, spread, number of leaves, leaf area as stated by the work of Nishizawa (26).

**Runner canopy spread (cm)**

The maximum runner plant spread of 30 cm (Table 2) is produced by T3, (Gibberellic acid 400 ppm) followed by T2, (Gibberellic acid 200 ppm) by contributing to runner plant spread of 22 cm, the rest of the treatments produced runner plant spread of 21.66 cm (T4, chilling @ 4°C), 20.66 cm (T5, chilling @ 4 °C + @ 200 ppm) 20.66 (T6, chilling @ 4°C + Gibberellic acid) 400 ppm) and minimum of 17.33 cm by (T1, control). As gibberellic acid is a
Table 1. Effect of chilling and gibberellic acid on the vegetative parameters of strawberry.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Height of plant (cm)</th>
<th>Crown diameter/length (cm)</th>
<th>Petiole length (cm)</th>
<th>Number of leaves</th>
<th>Number of trusses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (T1)</td>
<td>23.66 ± 1.71 ab</td>
<td>2.26 ± 0.28 b</td>
<td>14.39 ± 0.30 e</td>
<td>12.65 ± 3.89 ab</td>
<td>1.03 ± 0.005 d</td>
</tr>
<tr>
<td>GA3 200 ppm (T2)</td>
<td>20.11 ± 0.039 b</td>
<td>1.79 ± 0.26 a</td>
<td>15.78 ± 0.67 de</td>
<td>7.44 ± 0.39 b</td>
<td>1.92 ± 0.05 c</td>
</tr>
<tr>
<td>GA3 400 ppm (T3)</td>
<td>25.3 ± 0.89 a</td>
<td>2.65 ± 0.15a</td>
<td>22.80 ± 0.31 a</td>
<td>6.77 ± 0.80 b</td>
<td>2.83 ± 0.03 a</td>
</tr>
<tr>
<td>Chilling @ 40C (T4)</td>
<td>24.88 ± 0.44 a</td>
<td>2.59 ± 0.20 ab</td>
<td>18.46 ± 0.35 c</td>
<td>15.44 ± 0.72 a</td>
<td>1.96 ± 0.09 c</td>
</tr>
<tr>
<td>Chilling @ 40C + GA3 200 ppm (T5)</td>
<td>21.33 ± 2.14 abc</td>
<td>2.84 ± 0.56ab</td>
<td>20.66 ± 0.71 b</td>
<td>8.88 ± 1.28 b</td>
<td>2.57 ± 0.05 b</td>
</tr>
<tr>
<td>Chilling @ 40C + GA3 400 ppm (T6)</td>
<td>18.77 ± 1.74 c</td>
<td>1.96 ± 0.10 b</td>
<td>16.40 ± 0.017 d</td>
<td>9.33 ± 0.89 b</td>
<td>1.11 ± 0.10 d</td>
</tr>
</tbody>
</table>

Means not sharing a letter differ significantly at P < 0.05, ± = standard error

Table 2. Effect of chilling and gibberellic acid on runner development of strawberry.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Height of runner (cm)</th>
<th>Runner canopy spread (cm)</th>
<th>Runner no of leaves</th>
<th>Leaf area of runner(cm²)</th>
<th>Weight of mother runner (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (T1)</td>
<td>6.33 ± 0.57 c</td>
<td>17.33 ± 1.52 b</td>
<td>3.83 ± 0.78 b</td>
<td>47.66 ± 2.51 d</td>
<td>3.24 ± 0.23 c</td>
</tr>
<tr>
<td>GA3 200 ppm (T2)</td>
<td>13.08 ± 1.24 a</td>
<td>22.00 ± 2.06 b</td>
<td>5.55 ± 0.84ab</td>
<td>38.66 ± 3.51 e</td>
<td>11.27 ± 5.26 b</td>
</tr>
<tr>
<td>GA3 400 ppm (T3)</td>
<td>12.77 ± 1.34 a</td>
<td>30.00 ± 2.0a</td>
<td>7.44 ± 1.54 a</td>
<td>80.33 ± 5.50a</td>
<td>22.90 ± 7.99 a</td>
</tr>
<tr>
<td>Chilling @ 4°C (T4)</td>
<td>9.05 ± 1.20bc</td>
<td>21.66 ± 6.85b</td>
<td>3.88 ± 0.19b</td>
<td>66.66 ± 4.93bc</td>
<td>16.76 ± 0.72ab</td>
</tr>
<tr>
<td>Chilling @ 4°C + GA3 200 ppm (T5)</td>
<td>14.22 ± 2.52a</td>
<td>20.33 ± 1.52b</td>
<td>5.99 ± 2.60ab</td>
<td>80.00 ± 5.6c</td>
<td>10.62 ± 1.19b</td>
</tr>
<tr>
<td>Chilling @ 4°C + GA3 400 ppm (T6)</td>
<td>11.66 ± 0.99ab</td>
<td>20.86 ± 4.50b</td>
<td>6.44 ± 2.16ab</td>
<td>70.66 ± 2.80b</td>
<td>11.93 ± 1.91b</td>
</tr>
</tbody>
</table>

Means not sharing a letter differ significantly at P < 0.05, ± = standard error
growth stimulator it positively affects plant and runner growth parameters like crown diameter and plant and runner height etc. the results are in line with the work of Duarte & Hermosa (9) who reported that GA sprays in addition with flower bud removal significantly increased crown shoots, runners and runner plantlets per plant.

**Runner number of leaves**

Most leaves (Table 2) were counted for T₃, (Gibberellic acid 400 ppm (7.44), followed by T₆, (chilling @ 4°C + Gibberellic acid 400 ppm) (6.44) number of leaves the rest of the treatments contributed 5.99 (T₅, chilling @ 4°C + @ 200 ppm), 5.55 (T₂, (Gibberellic acid 200 ppm), 3.88 (T₄, chilling @ 4°C) and 3.83 number of leaves were counted for (T₁, control). Our findings reveal that Gibberellic acid increased number of runner leaves by shifting all the energy reserves of mother plant to the mother and daughter runner.

**Leaf area of runner (cm²)**

Maximum leaf area of runners (Table 2) is produced by T₃, (Gibberellic acid) 400 (80.33 cm²) followed by T₆, (chilling @ 4°C + Gibberellic acid 400 ppm) (70.66 cm²), the other treatments contributed to runner leaf area of 66.66 cm² (T₄, chilling @ 4°C), 60.00 cm²(T₅, chilling @ 4°C + @ 200 ppm), 47.66 (T₁, control) and lowest of 38.66 cm² by T₂, (Gibberellic acid 200 ppm). The results of our experiment reveal that application of gibberellic acid alone or in combination with chilling significantly increases leaf area of mother runner and daughter runners, the findings are in line with the work of Sharma et al., (34) who states that the maximum leaf area per mother plant and leaf area per plant were contributed by application of GA₃.

**Weight of mother runner (g)**

The weight of mother runner (Table 2) as produced by the effect of chilling and gibberellic acid reveals that the maximum mother runner weight of 22.90 g is produced by T₃, (Gibberellic acid 400) followed by 11.93 g T₆, (chilling @ 4 °C + Gibberellic acid 400 ppm), the rest of the treatments contributed to runner weight of 11.27 g (T₂, Gibberellic acid 200 ppm), 10.62 g (T₅, chilling @ 4°C + @ 200 ppm) and minimum of 3.24 g by T₁, (control). It is observed from the present findings that gibberellic acid either alone or in combination helps to produce healthier mother runners, chilling and exogenous application of GA₃ increases biosynthetic production that aids to produce runners with better health as reported by Kasim et al., and Sharma & Singh (20,35).
CONCLUSION

It is concluded from the trial that strawberry plants responded much better with application of gibberellic acid @ 400 ppm for their growth and runner production. Gibberellic acid application alone and in combination with chilling proved to induce early and number of runners. The trial significantly contributed to the production of runner in agro meteorological conditions of Rawalpindi and Islamabad and resolved the difficulty of importing runners for propagative purpose from mangora (Swat) and may be fruitful in future.

LITERATURE CITED


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