Sinergism among auxins, gibberellins and cytokinins in tomato cv. Micro-Tom

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ABSTRACT

The aim of this study was to evaluate the effect of isolated and combined applications of gibberelic acid (gibberelin), indolbutyric acid (auxin) and kinetin (cytokinin) on vegetative and reproductive development of tomato test plants (Solanum lycopersicum cv. Micro-Tom), to better elucidate the interactions among these hormonal classes. The following treatments were accomplished through foliar application: GA3 (5 mg L-1); IBA (5 mg L-1); KIN (9 mg L-1); GA3 + IBA (5 mg L-1 + 5 mg L-1); GA3 + KIN (5 mg L-1 + 9 mg L-1); IBA + KIN (5 mg L-1 + 9 mg L-1); GA3 + IBA + KIN (5 mg L-1 + 5 mg L-1 + 9 mg L-1) and Stimulate® (100 mL L-1). Plants from the control were sprayed with water. Stimulate®, a commercial liquid formulation containing KIN (90 mg L-1), GA3 (50 mg L-1) and IBA (50 mg L-1). We analyzed the shoot dry matter (g), root dry matter (g); fruit fresh matter (g); fruit dry matter (g) and fruit size (cm). The experimental design was completely randomized with nine treatments and fifteen replications. The treatment means were compared by Tukey’s test. Some combined applications of GA3, IBA and KIN or Stimulate® promoted significant increases in the dry matter accumulation of roots and fresh and dry matter of fruit compared to the control. Besides the perspective to extend such results for commercial tomato production, the relevance of known hormonal interactions for the results obtained is discussed.

Keywords: Solanum lycopersicum, hormonal balance, plant regulators, hormonal interactions.

RESUMO

Sinergismo entre auxínias, giberelinas e citocininas em tomate cv. Micro-Tom

Neste trabalho objetivou-se avaliar o efeito da aplicação isolada e combinada do ácido giberelício (gibberelina), ácido indolbutírico (auxina) e cinetina (citocinina) sobre o desenvolvimento vegetativo e reprodutivo de plantas teste de tomateiro (Solanum lycopersicum cv. Micro-Tom), para elucidar as interações entre essas classes hormonais. Através de pulverização foliar, os seguintes tratamentos foram realizados: ácido giberelício (5 mg L-1); ácido indolbutírico (5 mg L-1); cinetina (9 mg L-1); ácido giberelício + ácido indolbutírico (5 mg L-1 + 9 mg L-1); ácido giberelício + cinetina (5 mg L-1 + 9 mg L-1) e ácido indolbutírico + cinetina (5 mg L-1 + 9 mg L-1); ácido indolbutírico + cinetina (5 mg L-1 + 9 mg L-1) e Stimulate® (100 mL L-1). As plantas do controle foram pulverizadas com água. Stimulate® é uma formulação comercial líquida contendo uma combinação de cinetina (90 mg L-1), ácido giberelício (50 mg L-1) e ácido indolbutírico (50 mg L-1). Foram analisadas as variáveis: massa seca da parte aérea (g) e das raízes (g), massa fresca (g) e massa seca (g) dos frutos e o tamanho dos frutos (cm). O delineamento experimental foi inteiramente casualizado com nove tratamentos e quinze repetições. As médias dos tratamentos foram comparadas pelo teste Tukey. A aplicação conjunta de ácido giberelício, ácido indolbutírico e cinetina ou de Stimulate® promoveu incrementos significativos sobre o acúmulo de matéria seca nas raízes e nas massas de matéria fresca e seca dos frutos com relação ao controle. Com a perspectiva de estender tais resultados para a produção comercial de tomate, a relevância do conhecimento das interações hormonais apresentadas pelos resultados obtidos é discutida.

Palavras-chave: Solanum lycopersicum, balanço hormonal, reguladores vegetais, interações hormonais.

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Bioregulator is an organic non-nutrient compound that promotes, inhibits or modifies morphological and physiological processes of the plant when applied at low concentrations (Castro et al., 2009).

These substances can be applied directly on plants (leaves, fruits, seeds) causing changes in structural and functional processes, in order to increase production, improve quality and facilitate harvesting. The PGR’s regulated some processes in plants, such as germination, rooting, flowering, fruiting and senescence (Castillo et al., 2005).

Although plant growth regulators have extensively been used with the aim to increase crop productivity, a large variation in results still persists, probably due to specific environmental conditions and farming practices employed. Moreover, it is known that plant hormones rarely act alone. Thus, even when a response in the plant is attributed to the action of a plant regulator alone, the tissue receiving the application contains endogenous hormones that contribute to the outcome (Castillo et al., 2005; Castro et al., 2009).

It is often discussed whether plant hormones act independently, however the interrelationships in plant development result from the combination of many signals, of second messengers and of the combined action of many of these substances. Studies on intact plants or isolated plant tissues have evidenced the existence of synergistic, antagonistic and additive interactions between two or more plant hormones (Castro et al., 2009).

Auxins and cytokinins act synergistically to regulate cell division and antagonistically to control buds formation and lateral roots, suggesting multiple mechanisms of interaction (Coenen & Lomax, 1997). The auxin and gibberellin control separate processes that, when combined, contribute to stem elongation and fruit set (including ovary growth), suggesting an additive effect, in which the auxin stimulates growth by cell expansion and cell division while gibberellin acts in the expansion as well as in the number of cells (Yang et al., 1996).

Valio & Schwabe (1978) observed a negative interaction between gibberelin and cytokinin on elongation of the bean stem. Leite et al. (2003) also noted that these two plant regulators, when applied separately, promoted stem elongation of soybean plants; however, when applied together, cytokinin inhibited the effects of gibberellin, reducing the size of the plants, which showed a decrease in the number of nodes, stem diameter, leaf area and dry matter production, with no effect on the number of leaves, shoots and root dry matter.

The Micro-Tom cultivar was proposed by Meissner et al. (1997) as a genetic model because of its small size (8 cm) and short life cycle (70 to 90 days). The tomato ‘Micro-Tom’, as well as mutants in this genetic background, showing changes in metabolism and sensitivity to different classes of plant growth regulators, is an advantageous model to study the different classes of plant growth regulators and their interactions.

Sirtoli et al. (2008) and Choudhury et al. (2013) proved that the isolated or combined PGR’s show different responses in biometrical and productive parameters in Solanum lycopersicum. But there is no scientific evidence in literature about the use of Stimulate® on development of tomato plants.

The aim of this study was to evaluate the effect of isolated and combined application of GA₃ (gibberellin), IBA (auxin) and KIN (cytokinin) on the vegetative and reproductive development of tomato plants (Solanum lycopersicum, cv. Micro-Tom) to better understand the interaction between these hormonal classes.

RESULTS AND DISCUSSION

Longer internodes and delayed flowering were observed in plants treated with GA₃ alone (Figure 1). Taiz & Zeiger (2009) reported that by promoting cell growth and division, the gibberellin stimulates elongation of internodes. The plants treated with IBA alone showed no auxillary buds (apical dominance). This phenomenon which is contrary to that observed in plants treated with kinetin (see below), is commonly associated with auxin.

The plants treated with kinetin alone presented reduced internodes and excessive stimulus to the development of lateral buds (Figure 1).

The results in Table 1 show that when the indolbutyric acid was present,
Table 1. Shoot and root dry matter, dry and fresh matter of fruit and fruit size of tomato cv. Micro-Tom treated with different plant growth regulators (massa seca da parte aérea e radicular, massa seca e fresca dos frutos e tamanho do tomate cv. Micro-Tom tratados com diferentes reguladores vegetais). Piracicaba, ESALQ, 2009.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Shoot dry matter (g)</th>
<th>Root dry matter (g)</th>
<th>Fruits fresh matter (g)</th>
<th>Fruits dry matter (g)</th>
<th>Fruit size (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>9.65 a</td>
<td>0.11 c</td>
<td>39.27 cde</td>
<td>4.65 d</td>
<td>1.76 abc</td>
</tr>
<tr>
<td>GA&lt;sub&gt;3&lt;/sub&gt;</td>
<td>7.00 abc</td>
<td>0.17 bc</td>
<td>47.10 ab</td>
<td>13.55 ab</td>
<td>1.70 bc</td>
</tr>
<tr>
<td>IBA</td>
<td>5.67 bc</td>
<td>0.18 abc</td>
<td>46.35 abc</td>
<td>8.14 cd</td>
<td>1.89 abc</td>
</tr>
<tr>
<td>KIN</td>
<td>9.06 ab</td>
<td>0.11 c</td>
<td>42.45 bcd</td>
<td>8.25 cd</td>
<td>1.85 abc</td>
</tr>
<tr>
<td>GA&lt;sub&gt;3&lt;/sub&gt; + IBA</td>
<td>4.90 c</td>
<td>0.22 abc</td>
<td>38.37 de</td>
<td>9.71 bc</td>
<td>1.83 abc</td>
</tr>
<tr>
<td>GA&lt;sub&gt;3&lt;/sub&gt; + KIN</td>
<td>6.36 abc</td>
<td>0.18 bc</td>
<td>34.62 e</td>
<td>13.65 ab</td>
<td>1.66 e</td>
</tr>
<tr>
<td>IBA + KIN</td>
<td>6.27 c</td>
<td>0.16 bc</td>
<td>43.75 bcd</td>
<td>13.34 ab</td>
<td>2.13 ab</td>
</tr>
<tr>
<td>GA&lt;sub&gt;3&lt;/sub&gt; + IBA + KIN</td>
<td>3.11 c</td>
<td>0.35 a</td>
<td>51.45 a</td>
<td>15.75 a</td>
<td>2.16 a</td>
</tr>
<tr>
<td>Stimulate®</td>
<td>3.54 c</td>
<td>0.35 a</td>
<td>51.70 a</td>
<td>15.00 a</td>
<td>2.17 a</td>
</tr>
<tr>
<td><strong>F (treat)</strong></td>
<td>6.86 **</td>
<td>5.50 **</td>
<td>13.23 **</td>
<td>17.17 **</td>
<td>4.56 **</td>
</tr>
<tr>
<td><strong>CV (%)</strong></td>
<td>30.64</td>
<td>40.55</td>
<td>8.98</td>
<td>19.70</td>
<td>11.89</td>
</tr>
</tbody>
</table>

Means followed by the same letter within a column do not differ in the Tukey test at 5% probability (médias seguidas por mesma letra na coluna não diferem significativamente entre si pelo teste Tukey a 5% de probabilidade); **significant at 1% probability by F test (**significativo a 1% de probabilidade pelo teste F). GA<sub>3</sub>= gibberellic acid (ácido giberélico); IBA= indolbutyric acid (ácido indolbutírico); KIN= kinetin (cinetina).

Only the synergistic effect of three growth regulators GA<sub>3</sub>, IBA and KIN or Stimulate® was able to promote increases in the root system from that of the control (Table 1). In the application of IBA to cuttings of several plants, most of the auxin remained at the basis of the cuttings. The higher rooting promotion of IBA was also related to the fact that its level remain elevated longer than that of indole-3-acetic acid, even though the auxin is metabolized in the tissue (Epstein & Ludwig-Müller, 1993).

The fruit dry matter was higher in treatment with the three growth regulators (GA<sub>3</sub>, IBA and KIN or Stimulate®), and for this parameter, treatments with GA<sub>3</sub>; GA<sub>3</sub> + KIN; IBA + KIN; GA<sub>3</sub> + IBA also differed from the control (Table 1). Both auxin and cytokinin interact in a complex manner to control many aspects of growth and differentiation. The two plant hormones act synergistically to regulate cell division, and antagonistically to control lateral bud or root outgrowth. The manipulation of cytokinin levels in plants by exogenous application results in more auxin. Removal of endogenous auxin source, leads to a large increase in the cytokinin content of xylem exudates. This effect of auxin on cytokinin concentrations in the xylem suggests that auxin can influence apical dominance via inhibition of cytokinin synthesis or export from the roots (Coenen & Lomax, 1997). It is suggested that in intact pea plants, auxin from the apical bud moves into the elongating internodes where it maintains GA biosynthesis (Ross et al., 2000).

The use of three plant growth regulators (GA<sub>3</sub>, IBA and KIN) increased the development when compared to control (Figure 1). The application of Stimulate® and IBA + KIN increased fruit size as compared to the application of GA<sub>3</sub> + KIN treatment (Table 1).

The Figure 1 clearly shows the effects caused by the application of growth regulators: i) GA<sub>3</sub> stimulates elongation of internodes; ii) IBA applied alone, showed no lateral buds (apical dominance); iii) KIN applied alone, did not present significant differences related to the control; iv) the combined growth regulators promoted a blend of the effects mentioned above.

When applied in pairs, GA<sub>3</sub> + IBA; GA<sub>3</sub> + KIN; and IBA + KIN or the three altogether (GA<sub>3</sub> + IBA + KIN or Stimulate®), it appears that there is a combination of the effects of each of plant growth regulators to promote a more balanced shoot development (Figure 1); similar results were reported.
Figure 1. Development and flowering of tomato ‘Micro-Tom’ submitted to different treatments with plant growth regulators and compared to the control (desenvolvimento e florescimento de tomate ‘Micro-Tom’ submetidos a diferentes tratamentos com reguladores vegetais e comparados ao controle). Piracicaba, ESALQ, 2009.
by Choudhury et al. (2013), in tomato plants subjected to gibberellic acid and 4-chloro phenoxy acetic acid, when applied alone or associated, which resulted in increases in crop production.

This work points to the possibility of future studies to assess morphological changes in plant tissues treated with plant growth regulators, as well as on changes in the shoot and root structures.

The conclusions are that the combined application of GA$_3$, IBA and KIN or Stimulate® promote significant increases in the dry matter accumulation in roots and fresh and dry matter of fruits of tomato ‘Micro-Tom’ in relation to control.

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