Control of fruit drop and development in tomato, *Lycopersicum esculentum* Mill, using plant growth regulators

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ABSTRACT
Generally, the exogenous application of different plant hormones increased fruit yield of tomato. The higher fruit set and reduction in fruit drop induced by the applied plant hormones resulted in increase in growth rate of fruits and the concomitant increase in the final fruit size. The exogenous application of giberrellic acid ($GA_{3)}$ increased tomato plant height even after the end of hormone treatment and had a positive effect on petal elongation and inflorescence stalk length. Tomato plants treated with giberrellic acid (GA_3) increased the number of inflorescences per plant by 28% as compared to the Control. Both giberrellic acid (GA_3) and 2,4-dichlorophenoxyacetic acid (2, 4-D) achieved significantly higher levels of fruit set than the Control. The percentage of fruits set increased by 35 % in plants treated with giberellic acid as compared to the Control. The mean increase in tomato fruit mass was about 4.9 g/fruit for GA_3 treated plants and 5.6 g/fruit for plants treated with 2,4-dichlorophenoxyacetic acid (2, 4-D) as compared to the Control. The application of 20 mg/L of either 2,4-D significantly reduced fruit drop by more than 55%, or GA_3 by 52% as compared to the Control, while a combination of 2,4-D and GA3 reduced fruit drop by 75% as compared to the Control. Naphthalene acetic acid (NAA) reduced fruit drop by 57% while Aminotheoxyvinylglycine (AVG), an inhibitor of ethylene biosynthesis, gave a reduced fruit drop of 68% as compared to the Control. Further, 2,4-D and NAA individually outperformed GA_3 in preventing fruit drop or retaining fruits on the treated tomato plants. It was also observed that the tomato plants treated with the plant growth regulators remained more active with regard to photosynthesis as compared to the Control, and generated sufficient nutrient stock for developing flowers and fruits which gave rise to higher fruit yield.

KEYWORDS: Gibberellic acid (GA_3); 2,4-dichlorophenoxyacetic acid (2,4-D); Naphthalene acetic acid (NAA); Fruit set; Fruit development; Fruit drop; Aminotheoxyvinylglycine (AVG); Parthenocarpy; Abscission; etc.

1.0 INTRODUCTION

Fruit set and development are vital processes which must successfully take place in crops. These two processes are preceded by the process of flowering. Pollination and fertilization of the ovules are important for seed production, which is particularly important for plants propagated from seeds. Fruit set occurs with development of a fruit from an ovary. Among the major causes accounting for fruit drop are self-incompatibility, inadequate pollination, nutritional deficiency, water stress, insect-pest and disease infestations and hormonal imbalances (Singh et al., 2008). Flowers require an endogenous hormonal stimulation to set fruit, especially sufficient levels of auxin and gibberellic acid. The ensuing growth of the formed fruit is also controlled by hormones synthesized by the endosperm and embryos present in the seeds. When gibberellic acid or auxin is sprayed before pollination occurs, they can trigger fruit set even without pollination and can induce parthenocarpic fruit development. In this study, the effects of an auxin, 2,4-dichlorophenoxyacetic acid (2,4-D), gibberellin acid (GA_3), naphthalene acetic acid (NAA), amonotheoxyvinylglycine (AVG) - an inhibitor of ethylene biosynthesis, on fruit set and reduction in fruit drop were investigated on tomato plant. Gibberellic acid is known to play a crucial role in the sugar metabolism of plants. Gibberellins actively participate in the hydrolysis of sucrose and starch. They promote the activity of the enzyme, invertase, which catalyzes the hydrolysis of sucrose, thereby yielding glucose and fructose. Gibberellins also induce higher activity of α- and β-amylases which degrade starch and represent best means for the mobilization of carbohydrate reserves in the plant. The plant growth regulators such as GA_3, NAA, and 2, 4-D are known to increase membrane permeability in plant cells which might facilitate accelerated breakdown of organic acids stored in cell vacuoles with consequent increase in total soluble solids (TSS) content.

2.0 MATERIALS AND METHOD

A total of three hundred and sixty (360) young tomato plants were used for this investigation. Each treatment was allotted 60 experimental tomato plants (i.e. twenty plants with three replications). There were six (6) treatments including the Control. The application of 2,4-dichlorophenoxyacetic acid (2,4-D) = T1 or gibberellic acid ($GA_{3)}$ = T2, was made once the tomato plant showed 50% of flowers in anthesis. The flowers and leaves on the plants were sprayed with either 100ml 20mg/L of 2,4-D or gibberellic acid (GA_3) or naphthalene acetic acid (NAA) = T3 or amonotheoxyvinylglycine (AVG) = T4, inhibitor of ethylene biosynthesis, or a combination of 2,4-dichlorophenoxyacetic acid (2,4-D) and gibberellic acid (GA_3) = T5. The control plants (i.e. the experimental Control) = T6, were not subjected to exogenous application of any plant hormone. Plant growth regulators were applied twice during blooming of flowers using a hand water-sprinkler. The floral buds at the initial stage and at full bloom were counted. The percentages of fruit set by 50 days after flowering were calculated. The percentage of fruit set was determined by comparing the initial number of flowers present on each treated branch of the tomato plant with the total number of tomato fruits on the branches 50 days post anthesis. The number of fruits on each branch was counted using a manual counter. The fruit drop was calculated by counting the number of fruits dropped from each tomato plant and expressed in percentage. The fruit yield was recorded at the time of harvest and expressed in terms of Kg/plant.

3.0 RESULTS AND DISCUSSION

Generally, the exogenous application of different plant hormones increased fruit yield of tomato. The higher fruit set and reduction in fruit drop induced by the applied plant hormones resulted in increase in growth rate of fruits and the concomitant increase in the final fruit size. The exogenous application of GA_3 increased tomato plant height even after the end of hormone treatment and had a positive effect on petal elongation and inflorescence stalk length. Tomato plants treated with giberrellic acid (GA_3) increased the number of inflorescences per plant by 28% as compared to the Control. Both giberrellic acid (GA_3) and 2,4-dichlorophenoxyacetic acid (2, 4-D) achieved significantly higher levels of fruit set than the Control. The percentage of fruits set increased by 35 % in plants treated with giberellic acid as compared to the Control. The mean increase in tomato fruit mass was about 4.9 g/fruit for GA_3 treated plants and 5.6g/fruit for plants treated with 2,4-dichlorophenoxyacetic acid (2, 4-D) as compared to the Control. The application of 20 mg/L of either 2,4-D significantly reduced fruit drop by more than 55%, or GA_3 by 52% as compared to the Control, while a combination of 2,4-D and GA_3 reduced fruit drop by 75% as compared to the Control. Naphthalene acetic acid (NAA) reduced fruit drop by 57% while Aminotheoxyvinylglycine (AVG), an inhibitor of ethylene biosynthesis, gave a reduced fruit drop of 68% as compared to the Control. Further, 2,4-D and NAA individually outperformed GA_3 in preventing fruit drop or retaining fruits on the treated tomato plants. It was also observed that the tomato plants treated with the plant growth regulators remained more active with regard to photosynthesis as compared to the Control, and generated sufficient nutrient stock for developing flowers and fruits which gave rise to higher fruit yield. In this study, the exogenous application of 2,4-D applications, NAA and GA3 increased fruit size. The report by Singh and Singh, (2015) is also in support of the result of this study that NAA, GA_3 and 2,4-D notably reduced fruit drop. Also, Ahmed et al., (2012) reported that the application of NAA, GA_3 and 2,4-D significantly enhanced fruit retention in mango and use of thiourea increased the formation fruitful buds in grape, and mango (Tongumpai et al., 1997). Fruit drop, an abscission phenomenon, often occurs due to auxin deficiency in growing fruits and could be prevented by the exogenous application of synthetic auxins such as NAA and 2,4-D. This result is similar to the one reported by Krishnamoorthy, (1993). The author reported that increase in fruit weight and volume in NAA, 2,4-D and GA_3 treated trees seems again due to their role in cell enlargement and division, increase in intercellular spaces in the mesocarpic cells and higher translocation of photosynthates and mineral nutrients from vegetative parts towards the developing fruits that are extremely active metabolic sink. The work of Coggins and Lovatt, (2004) on citrus supports the result of this study that auxins prevent the dropping of fruit as they reported that auxins do that by maintaining the cells at zone of abscission, preventing the synthesis of hydrolytic enzymes such as cellulase, which decompose the cell wall. The compound 2,4dichlorophenoxyacetic acid (2,4-D) is regarded as one of the most effective ones in preventing fruit drop. Fruit drop could be caused by auxin deficiency in growing fruits and could be prevented by the exogenous application of synthetic auxins like 2,4-D or NAA. The results of this study that auxin, reduce fruit drop is in consonance with the work of Ram (1983) which reported that deficiency of auxins, $GA_{3,}$ cytokinins coupled with a high level of growth inhibitors (i.e. ABA and ethylene) cause fruit drop. According to Murti and Upreti (1995), an increase in the level of auxin corresponds with a period of rapid growth while a high level of inhibitor of auxin corresponds with high rate of fruit drop. The exogenous application of GA_3 increased tomato plant height even after the end of hormone treatment and had a positive effect on petal elongation and inflorescence stalk length. Tomato plants treated with giberrellic acid (GA_3) increased the number of inflorescences per plant by 28% as compared to the Control. In this study, both giberrellic acid (GA_3) and 2,4-dichlorophenoxyacetic acid (2, 4-D) achieved significantly higher levels of fruit set than the Control. The results of this study are supported by Nitsch. (1952) and Schwabe (1981) as they reported that natural and artificial auxins supplied exogenously to unpollinated flowers induced fruit growth in tomato and in other horticultural plants, suggesting that these hormones can replace the signals provided by pollination and fertilization. Further, Kinet and Peet (1997) averred that reproductive developments in tomato including stamen and pollen differentiation and fruit set are important to fruit yield, quality, and are dependent on the relative amounts of endogenous growth regulators. They reported that fruit set in tomato was a critical stage, and that this stage was highly affected by environmental factors and plant growth regulators. Comparing the effects of 2,4-D and GA_3 on fruit development with the Control plants, fruits from untreated tomato plants developed normally with filled locular tissue and seed formation while the cavities of fruit treated with 2,4-D and GA_3 were not filled. Similarly, Serrani et al. (2008) and Ozga et al., (1999) reported a synergistic effect of auxin and gibberellin on fruit growth in pea and tomato suggesting that the two phytohormones interact in regulating fruit development. Auxin and gibberellin may act in parallel or in a sequential way on fruit set. Gimici et al. (2006) reported that the application of 2,4-D resulted in increased tomato fruit size, fresh and dry weight when used at recommended concentration. The percentage of fruits set increased by 35 % in plants treated with giberellic acid as compared to the Control. Fruit set is defined as the transition of a quiescent ovary to a rapidly growing young fruit, which is an important process in the sexual reproduction of flowering plants (De Long, Mariani, and Vriezen, 2009). Transition from a flower to a developing fruit is termed fruit set and is accompanied by the wilting or abscission of petals and stamens (Martens, et al. 1994). Fruit set depends on the successful completion of pollination and fertilization (Gillaspy, et al., 1993). In this study, the mean increase in tomato fruit mass was about 4.9 g/fruit for GA_3 treated plants and 5.6 g/fruit for plants treated with 2,4-dichlorophenoxyacetic acid (2, 4-D) as compared to the Control. The 2,4-D applications increased fruit size. Further, the application of the growth regulators triggered fruit set even without pollination and induced parthenocarpic fruit development. The effect of gibberellins in fruit set was also supported by the analysis of the parthenocarpic tomato mutants *pat, pat2 and pat3/4.* These mutants showed increased level of GAs and an enhanced expression of GA biosynthetic genes (Fos, et al., 2000; Olimpieri et al. 2007). The application of gibberellic acid (GA_3) outwardly eliminated the deficiency of endogenous gibberellic acid (GA_3) and enabled the tomato berry to be as large as the fruits in the control plants which had seeds. The result indicated that tomato plant treated with 2,4-D had increased stem thickness, decreased leaf size, induced epinastie and flower bud abscission. The 2,4-D applications produced a reduction in the fruit number with an increase in the average weight without affecting the yield. The application of 2,4-D increased the fruit growth rate. The diameter differences between fruit treated and untreated with 2,4-D were evident from fruit early development. These differences increased progressively with the developmental stage. During the fruit early development the fresh weight increased. The auxin, 2,4-D, application produced increase in fruit weight and delayed abscission. The exogenous application of 2,4-D induced the development of seedless parthenocarpic fruit. At higher GA_3 concentrations, it induced more proportion of smaller fruits per plant.

4.0 CONCLUSION

Fruit drop can be controlled by the exogenous application of plant growth regulators such as auxins and gibberillins. These plant growth regulators tend to delay the senescence and reduce unwanted fruit abscision (i.e. fruit drop). The application of 2,4-dichlorophenoxyacetic acid (2, 4-D) or gibberellic acid (GA_3) or amonotheoxyvinylglycine (AVG) increase the flowering, fruit set, fruit size and control the fruit drop.

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