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Effect of IN-M1 Concentric® on Plant Growth and Fruit Yield of Tomato In South Florida

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The effect of a biostimulant, IN-M1 Concentric®, in promoting plant growth and yield of tomato was evaluated under field conditions in Homestead, FL, over two growing seasons. 'Sanibel' tomato was used both seasons. All treatments were arranged in a randomized complete block (RCB) design with six replications for each treatment. In the 2017–18 season, IN-M1 was first applied at 1% by soil drench at transplanting and then as a foliar spray at flowering. Four fertilization levels, 25%, 50%, 75%, and 100% of the recommended rate were applied through irrigation drip lines. No significant increases in fruit yield were detected in any treatments compared to the untreated control. However, a beneficial effect on fruit yield was found with 75% fertilization level, where total yield from the first two harvests increased by 5.1%. In the 2018–19 season, IN-M1 was applied through irrigation drip immediately after transplanting and at flowering. Three rates of IN-M1 [0.25, 0.5, and 1.0 gallons/acre (gal/A)] were tested on tomato plants grown at 90% of the recommended fertilization rate. IN-M1 at 0.5 gal/A significantly ($P < 0.1$) increased plant height compared to the untreated control. Though the effect of IN-M1 on fruit yield was not significant at ($P = 0.1$) compared to the untreated control, beneficial effects on fruit yield were observed. IN-M1 at 0.25, 0.5, and 1.0 gal/A increased yield of extra-large and large sized fruit by 12.7%, 18.3%, and 9.3%, respectively, compared to the untreated control. The biostimulant IN-M1 could be applied to promote plant growth, increase fruit yield, and reduce fertilizer use in tomatoes in south Florida.

Florida ranks first in the production of winter fresh market tomato in the United States (Tomato101). Florida provides more than 50% of fresh tomatoes in the country on 31,500 acres. The total value of tomato exceeds $600 million, which accounts about one third of the total value of all fresh vegetable crops in Florida.

Tomato plants in open field conditions often face various stresses in Florida at different developmental stages, including transplanting shock, heat, chilling, etc. One approach to coping with such environmental stresses is to apply biostimulants (Bulgari et al., 2019; Colla and Rouphae, 2015). Plant biostimulants are products prepared from different organic or inorganic substances and/or microorganisms, that have beneficial effects on improving plant growth, productivity, and alleviating negative effects of abiotic stresses (Bulgari et al., 2019).

IN-M1 Concentric® is a plant biostimulant and registered as 'Garden Solution' in the US. It is a mixture of beneficial microorganisms and their metabolites <http://www.concentricag.com/>. IN-M1 has been applied in high value vegetable crops, such as lettuce, strawberry and fresh market tomato to promote plant growth and fruit yield. IN-M1 contains seven beneficial bacterial species and three fungal species. It also has been reported that IN-M1 can be used to reduce fertilizer rates, particularly nitrogen, in vegetable crops. In this study, we conducted two field trials to evaluate the beneficial effects of IN-M1 on tomato production in south Florida: 1) effect of IN-M1 on tomato fruit yield and reducing fertilizer use during 2017–18 and 2) effect of IN-M1 rate on tomato plant growth and fruit yield during 2018–19.

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Materials and Methods

Field preparation and crop management. The field trials were conducted over two tomato growing seasons (2017–18 and 2018–19) at the University of Florida's Tropical Research and Education Center, Homestead, FL. Tomato (cv. Sanibel) seedlings were transplanted in beds covered with black plastic mulch in both growing seasons. Irrigation and fertigation were provided by two drip irrigation tapes passing on both sides of each plant, following guidelines from the Vegetable Production Handbook of Florida, 2017–18 (Ditmar et al, 2017). Standard spray programs developed in the lab were followed to control common diseases and pests on tomato.

Effect of IN-M1 on tomato fruit yield and reducing fertilizer usage. A field trial was conducted in the 2017-2018 growing season to evaluate the effect of IN-M1 on tomato fruit yield and reducing fertilizer usage. Each plot consisted of a 22-ft section on a single bed with a 2-ft buffer zone between adjacent plots. Within each plot, 11 plants were planted 2-ft apart. Each bed received one of four levels of fertilization, 100%, 75%, 50%, and 25% of the recommended rate from the Vegetable Production Handbook of Florida 2017–18 (Ditmar, et al., 2017). After transplanting, liquid fertilizer 3–0–10, was applied to each bed twice a week throughout the growing season at the specified rate. Plots treated with IN-M1 and untreated plots were arranged randomly on each bed, with six replicates per treatment.

Tomato seedlings were transplanted into beds on 7 Dec. 2017. After transplanting, seedlings were drenched with Danitol (fenpropathin) at 3.0 mL/gallon to protect seedlings from damage by cutworms. IN-M1 was applied at 1% (v:v) as a soil drench at the base using about 120 mL /plant right after transplanting. A boost

Table 1. Effect of IN-M1 on tomato yield at four fertilizer levels (2017–18).

	Recommended fertilizer[y]							
	25%		50%		75%		100%	
Yield per acre (lb)[z]	CK	IN-M1	CK	IN-M1	CK	IN-M1	CK	IN-M1
1st harvest	9503 a	8385 a	10062 a	9743 a	11660 a	12059 a	8146 a	9503 a
2nd harvest	12618 a	14055 a	19326 a	18528 a	19885 a	21083 a	20524 a	20205 a
3rd harvest	6229 a	6469 a	10062 a	9264 a	14614 a	13177 a	14295 a	10861 a
Extra large	12698 a	12698 a	20045 a	18767 a	22360 a	22680 a	20923 a	19087 a
Large	13416 a	14135 a	16052 a	16052 a	19326 a	19246 a	17809 a	17409 a
Medium	2236 a	2076 a	3354 a	2556 a	4472 a	4392 a	4153 a	4073 a
Total yield	28350 a	28909 a	39451 a	37451 a	46159 a	46318 a	42885 a	40569 a

[z]Plants population was estimated at 3660/acre with 2 ft between plants to estimate the fruit yield/acre.
[y]Means followed by the same letters in each row with each item for comparison at each fertilizer level indicate no significant difference at $P = 0.05$.

foliar application was applied at 1% on 10 Jan. 2018 when plants started flowering. Fruit were harvested from all plants in each plot on 26 Feb., 13 Mar., and 27 Mar. 2018. Fruit were graded into three categories: extra-large, large, and medium based on the USDA standard. Fruit yield of each category was recorded for each plot at each harvest. Student t-test was performed using the SAS statistical software Version 9.4 (SAS Institute Inc., Cary, NC). Means of fruit yield for each category were separated between the treatments and the untreated control at each fertilization level using Fisher's protected LSD ($P = 0.05$).

Effect of IN-M1 rate on tomato plant growth and fruit yield. A field trial was conducted in the 2018–19 growing season to evaluate the effect of IN-M1 rate on tomato plant growth and fruit yield. Each plot consisted of a 35-ft section on a single bed with a 2-ft buffer zone between adjacent plots. Within each plot, 17 plants were planted 2-ft apart. Treatments included IN-M1 at 1.0, 0.5, 0.25 gallons/acre and an untreated control. IN-M1 was applied through drip irrigation lines. The experimental design was a randomized complete block (RCB) design with six replications. Fertilizer (3–0–10) was applied twice a week after transplanting at 90% of the recommended rates according to the Vegetable Production Handbook of Florida 2018-2019 (Ditmar et al., 2018).

Tomato (cv. Sanibel) seedlings were transplanted on 30 Oct. 2018. After transplanting, seedlings were drenched with Danitol (fenpropathin) at 3.0 mL/gallon to protect them from damage by cutworms and other insects. IN-M1 was first applied right after transplanting on 30 Oct. and again on 26 Nov. 2018 when plants started flowering. Plant height was measured on 20 Nov. 2018. Fruit of the six best plants in each plot were marked and fruit were harvested from the selected plants on 30 Jan., 11 Feb., and 19 Feb. 2019. Fruit were graded into three categories by size: extra-large, large, and medium based on the USDAs grade standards. Fruit yield of each category was recorded for each plot at each harvest. Analysis of variance (ANOVA) was performed using the SAS statistical software Version 9.4 (SAS Institute Inc., Cary, NC). Means of plant height and fruit yield per plant for each category were separated among the treatments using Fisher's protected LSD ($P = 0.1$).

Results

Effect of IN-M1 on tomato fruit yield and reducing fertilizer usage. In this trial, treatments with IN-M1 did not have significant effect on tomato yield at any of the four fertilizer levels (Table 1), due to the large variation among replications. However, beneficial effects were observed with IN-M1 on increasing early

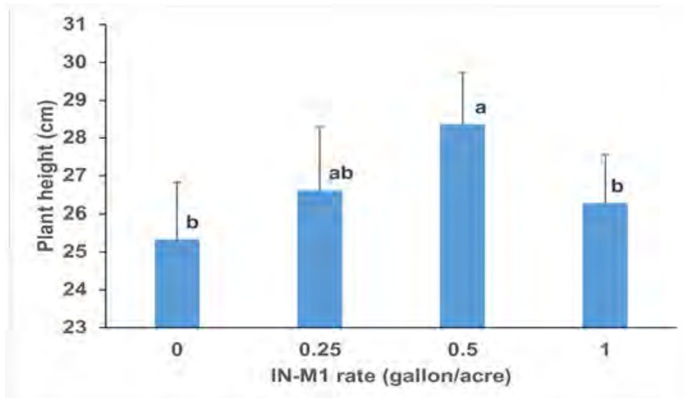

Fig. 1. Effect of IN-M1 at three rates on tomato plant growth in the 2018–19 growing season. Bars (with standard errors on the top) labeled with same letters were not significantly different at $P = 0.1$.

fruit yield and total yield at 25% and 75% of recommended fertilizer levels, particularly yield of extra-large and large fruit, which increased by 719 lb/acre and 240 lb/acre, respectively (Table 1).

Effect of IN-M1 rate on tomato plant growth and fruit yield. Application of IN-M1 enhanced early plant growth when 90% of the recommended fertilizer was applied. IN-M1 at 0.5 gallon/acre significantly ($P < 0.1$) increased plant height compared to the untreated control at one month after transplanting (Fig. 1). In addition, plant growth looked more uniform when tomato plants were treated with IN-M1 at 0.5 and 1.0 gallon/acre. Though not significant at ($P = 0.1$) compared to the untreated control, IN-M1 at all three rates increased fruit yield (Table 2): of extra-large and large fruit by 9.3% to 18.3% and total yield by 11.0% to 16.9% (Table 3). Among the three rates tested, 0.5 gallons/acre was the best one for increasing plant growth and fruit yield.

Discussion and Conclusions

In our field trials conducted during two growing seasons, tomato plants which received IN-M1 treatment had better early growth and produced higher yields of extra-large and large fruit at early harvest. In addition, our results indicated that less fertilizer could be used to achieve a similar yield when plants were treated with IN-M1. Our results agreed with others from elsewhere with IN-M1 on vegetable crops including tomato.

It has been reported that application of biostimulants can help plants combat abiotic stresses including transplant shock, thus

Table 2. Effect of IN-M1 on tomato plant growth and yield (2018–19).

Treatment	Fruit yield /plant (kg)[z]				
	Extra-large	Large	Extra-large +large	Medium	Total
Untreated control	3.26 a	2.43 a	5.69 a	0.69 a	6.39 a
IN-M1 @ 0.25 gallon/acre	3.57 a	2.84 a	6.41 a	0.80 a	7.21 a
IN-M1 @ 0.5 gallon/acre	3.92 a	2.81 a	6.73 a	0.74 a	7.47 a
IN-M1 @ 1.0 gallon/acre	3.65 a	2.57 a	6.22 a	0.87 a	7.09 a
LSD (P = 0.1)	0.70	0.49	1.03	0.24	1.12

[z]Means followed by same letters in each row indicate no significant difference at P = 0.1.

Table 3. Effect of IN-M1 on tomato yield increase.

Treatments	% Yield increase	
	Extra-large + Large	Total
Untreated control	–	–
IN-M1 @ 1 gallon/acre	9.3	11.0
IN-M1 @ 0.5 gallon/acre	18.3	16.9
IN-M1 @ 0.25 gallon/acre	12.7	12.8

enhancing plant growth (Bulgari et al., 2019). In one of our field trials, tomato plants treated with IN-M1 at 0.5 gallon/acre were significantly taller than the untreated control (Fig. 1). Because IN-M1 is a mixture of beneficial microorganisms and their metabolites, it is difficult to define the exact mechanism(s) leading to such an effect on plant growth promotion. It has been suggested that the application of biostimulants can benefit nutrient uptake and efficiency (Bulgari et al., 2019; Colla and Rouphae, 2015), which may help achieve similar fruit yields with reduced fertilizer usage. This will not only help reduce the input for growers, but also reduce the potential pollution of the soil and ground water with leached fertilizers. Similarly, a synergistic action between beneficial microorganisms and their metabolites including trace plant hormones could improve soil conditions for plant development and directly affect the physiology of the plant, which could lead to increased branch and flowering, and eventually increasing fruit yield (Bulgari et al., 2019). Applications of IN-M1 may help tomato growers increasing fruit yield with reduced fertilizer usage following the ban of the fumigant methyl bromide which has led to a yield decline in Florida tomatoes (Guan et al., 2017).

Biostimulants may also help alleviate the damaging effect of salinity stress on plant growth (Bulgari et al., 2019). In a small-scale greenhouse trial with squash, weekly applications of IN-M1 significantly increased shoot fresh weight compared to the untreated control when squash plants were irrigated with salty water (Liu and Zhang, unpublished data). With increasing concerns over sea level rise and sea water intrusion, salinity stress may become a threat to vegetable production in south Florida including tomato. Application of IN-M1 could be a potential tool in mitigating salinity damage to vegetable crops in Florida.

In conclusion, our field trials suggested that the application of IN-M1 can stimulate plant growth and increase fruit yield of tomato in south Florida, particularly for extra-large and large sized fruit at early harvests. Further tests are needed to optimize its application in tomato and to investigate potential effects on mitigating salinity stress.

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