Yield Response of Watermelon and Muskmelon to L-Tryptophan Applied to Soil

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Abstract. This study was conducted to determine the influence of L-tryptophan (L-TRP) applied to soil on the yield of two watermelon (*Citrullus Lanatus* L.) and one muskmelon (*Cucumis melo* L.) cultivars. Experiments were established in which L-TRP was applied to seedlings as a soil drench in the glasshouse ranging from 6×10^{-5} to 60 mg·kg⁻¹ soil; the seedlings were transplanted into the field 2 weeks later. The application of L-TRP enhanced the cumulative weight of the melons 58% ('Royal Sweet' watermelon), 80% ('Royal Windsor' watermelon), and 42% ('Top Score' muskmelon) over their respective controls: the average weight per fruit was increased up to 43% for watermelon and 36% for muskmelon. No increase in yield was observed when L-TRP was applied to the seedlings directly in the field, but only when added in contained systems 2 weeks before transplanting into the field. The increase in yield was due to a physiological response rather than a nutritional effect because of the low L-TRP concentrations applied.

L-Tryptophan (L-TRP), also known as β -3-indolylalanine, is considered an essential amino acid to man, animals, and some bacteria (*Lactobacillus arabinosus*, *L. casei*, *Streptococcus faecalis*, and *Leuconostoc mesenteroids*) (Meister, 1965). Plants are capable of synthesizing TRP from 3-phosphoshikimic acid and subsequently chorismic acid and anthranilic acid (Lehninger, 1975). Several microorganisms release secondary metabolites upon the use of TRP. The release of auxins has been reported as a result of TRP metabolism in soil (Frankenberger and Brunner, 1983). Thimann (1935) was the first to demonstrate that TRP is a precursor of the plant hormone indole-3-acetic acid (IAA) when working with cultures of *Rhizopus suinus*. We recently demonstrated the conversion of L-TRP to IAA by a fluorescent pseudomonas isolated from a soil-root interface by ion suppression-high performance liquid chromatography (HPLC)-UV spectrometry (Frankenberger and Poth, 1987a). The isolation and detection of IAA as a secondary metabolite of L-TRP was also demonstrated from *Pisolithus tinctorius* (an ectomycorrhizal fungus) by thin-layer chromatography, HPLC, an enzyme-linked immunosorbent (monoclonal antibody) assay, and unequivocally identified by gas chromatography-mass spectrometry (Frankenberger and Poth, 1987b).

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Tracer studies have demonstrated that TRP is metabolized to IAA in higher plants. Exogenously supplied 2-¹⁴C-DL-tryptophan incubated in watermelon tissue was incorporated into IAA (Dannenburg and Liverman, 1957). Dual-labeled experiments with ¹⁴C-labeled indole and ³H-serine added to pea seedlings confirmed that the indole was incorporated into IAA via TRP (Erdmann and Schiewer, 1971). Further work in our laboratory has established that the microbial pathway of IAA production with TRP serving as a precursor involves a transaminase reaction with the formation of indole-3-pyruvic acid as an intermediate (Frankenberger and Poth, 1988). Recently, we have reported that the application of TRP to soil affects the yield of radish, most likely due to TRP-derived auxins (Frankenberger et al., 1990). The objective of this study was to determine the effects of L-TRP applied as a soil additive on the yield of watermelon and muskmelon in the field.

This study was conducted at the Moreno

Valley Field Station, Univ. of California, in Summer 1987 on a Hanford sandy loam (coarse-loamy, mixed thermic Typic Xerorthent). Soil analyses indicated the following chemical and physical properties: pH 5.9; total N, 730 ppm; total P, 530 ppm; composition, sand 55%, silt 29%, and clay 16%.

On 29 Apr. 1987, seeds of two watermelon cultivars, Royal Sweet and Royal Windsor, and a muskmelon, 'Top Score', were planted in flats of washed silica sand in a glasshouse to obtain uniform size. Temperatures ranged from 28°C during the day to $\approx$ 19°C at night. Ten days later, the seedlings were transplanted into cells containing the field soil (50 g each). The seedlings were treated with Hoagland's mineral nutrient solution (one-half strength). On 19 May 1987, L-TRP (Sigma, St. Louis) (15 ml solution) was added as a soil drench at concentrations ranging from 10^{-9} to 10^{-3} M (6×10^{-5} to 60 mg·kg⁻¹ soil). A control was treated with deionized water. On 2 June 1987 the seedlings were transplanted into the field.

The experimental layout was a completely randomized design with 6 × 6 m spacing for the watermelon and 3 × 3 m for the muskmelon with 15 replicates per treatment. Irrigation water was applied as furrow irrigation. The field was broadcast with ammonium nitrate (100 kg·ha⁻¹) before planting. The yield was expressed in number of melons per plant and the cumulative weight of fruit per plant. The harvest schedule for the watermelon was as follows: 28 Sept., 26 Oct., and 20 Nov. (harvests 1, 2, and 3, respectively). Muskmelons were picked weekly starting from 14 Sept. throughout 28 Oct. with the data pooled into three harvests. Ripe watermelons were picked based on the dried curly tendril on the leaf near the stem. The muskmelon was considered mature when the fruit changed from green to yellow (tan) and an abscission layer formed between the stem and fruit. The data in each harvest were subjected to an analysis of variance and means of L-TRP treatments were compared with the control according to Dunnett's test. Regression analyses were performed on the treatments excluding the control (Steel and Torrie, 1980). Fruit size (kg/fruit) was determined by dividing the mean fruit yield per plant by the mean number of fruit per plant for each

Table 1. Cumulative yield of 'Royal Windsor' watermelon in response to L-tryptophan during three harvests.

L-Tryptophan (mg·kg ⁻¹ soil)	Fruit						Size (kg/fruit) ^z
	No./plant			Total fresh wt/plant (kg)			
				Harvest			
	1	2	3	1	2	3	
Control	0.6	2.6	3.8	1.7	15.1	20.5	5.39
60	1.3	3.3	4.5	3.6	22.1	28.2	6.27 (16%)
6.0	0.8	2.8	4.1	1.9	24.1	31.2	7.61 (41%)
6.0 × 10 ⁻¹	1.1	3.0	4.4	5.2	23.3	30.2	6.86 (27%)
6.0 × 10 ⁻²	1.9*	4.1	5.3	4.4	28.4	33.7	6.36 (18%)
6.0 × 10 ⁻³	0.8	3.5	5.0	3.3	24.6	31.5	6.30 (17%)
6.0 × 10 ⁻⁴	1.4	3.7	5.1	5.7	27.1	34.5*	6.76 (25%)
6.0 × 10 ⁻⁵	1.2	3.6	5.2	2.4	29.2*	36.9*	7.10 (32%)

*Figures in parenthesis indicate percent increase over the control.

*Means significantly different from control at $P = 0.05$, according to Dunnett's test.

Table 2. Cumulative yield of 'Royal Sweet' watermelon in response to L-tryptophan during three harvests.

L-Tryptophan (mg·kg ⁻¹ soil)	Fruit						
	No./plant			Total fresh wt/plant (kg)			Size (kg/fruit) ^z
	Harvest						
	1	2	3	1	2	3	
Control	1.1	2.7	3.7	5.3	18.6	26.9	7.27
60	2.8*	4.3	5.1	18.9*	34.0*	37.0	7.25 (0%)
6.0	1.1	3.3	4.5	6.6	30.2	34.8	7.73 (6%)
6.0 × 10 ⁻¹	1.4	4.3	4.8	11.4	32.1	36.2	7.54 (4%)
6.0 × 10 ⁻²	1.4	3.3	3.9	8.9	29.9	34.2	8.77 (21%)
6.0 × 10 ⁻³	1.4	3.3	4.4	10.6	33.0*	40.6	9.23 (27%)
6.0 × 10 ⁻⁴	1.7	4.0	5.4	11.3	32.8*	39.6	7.33 (1%)
6.0 × 10 ⁻⁵	2.5*	4.7*	5.5*	14.2	38.5*	42.6*	7.75 (7%)

^zFigures in parenthesis indicate percent increase over control.

*Means significantly different from control at $P = 0.05$, according to Dunnett's test.

Table 3. Cumulative yield of 'Top Score' muskmelon in response to L-tryptophan during three harvests.

L-Tryptophan (mg·kg ⁻¹ soil)	Fruit							Size (kg/fruit) ^z
	No./plant			Total fresh wt/plant (kg)				
	Harvest							
	1	2	3	1	2	3		
Control	3.2	8.8	11.9	2.3	7.1	11.8	0.99	
60	3.7	9.9	14.9	3.2	9.3	15.1	1.01 (2%)	
6.0	3.1	8.3	12.1	2.5	8.4	14.2	1.17 (18%)	
6.0 × 10 ⁻¹	3.6	9.2	13.7	3.3*	9.2	15.0	1.09 (10%)	
6.0 × 10 ⁻²	3.9	10.7	13.6	3.4*	10.0*	16.6*	1.22 (23%)	
6.0 × 10 ⁻³	3.4	10.4	13.4	3.0	9.7*	16.7*	1.25 (26%)	
6.0 × 10 ⁻⁴	3.1	9.9	12.2	2.5	9.7*	16.5*	1.35 (36%)	
6.0 × 10 ⁻⁵	3.1	9.7	13.9	2.9	9.5	16.6*	1.19 (20%)	

^zFigures in parenthesis indicate percent-increase over control.

*Means significantly different from control at $P = 0.05$, according to Dunnett's test.

treatment upon the cumulative third harvest.

'Royal Windsor' watermelon. During the first harvest, 6×10^5 mg L-TRP/kg soil was the only treatment that yielded more fruit than the control (217% increase) (Table 1). However, there were no significant difference; in the number of fruit during the second and third harvests, although the same L-TRP treatment (6×10^5 mg·kg⁻¹ soil) increased the number of fruit by 58% and 39%, respectively, over the controls. Regression analysis excluding the control revealed a significant negative linear correlation ($r = 0.763^*$) between log[L-TRP] and the cumulative number of fruit at the third harvest.

There were considerable differences in the cumulative weight of the harvested melons upon treatment with L-TRP, particularly at 6×10^5 mg·kg⁻¹ soil (Table 1). The yield increase in the total fresh weight was enhanced as much as 235% (first harvest), 93% (second harvest), and 80% (third harvest) upon various concentrations of L-TRP applied. During the third harvest, the lowest L-TRP concentration (6×10^5 mg·kg⁻¹ soil) significantly promoted the cumulative weight of the melons compared to the control. There was a significant negative linear correlation ($r = 0.893^{**}$) between log[L-TRP] (excluding the control) and cumulative fruit weight. On average, the weight of each fruit per plant was greatest with 6.0 mg L-TRP/kg soil, being 43% greater than the control (Table 1). All L-TRP applications enhanced the average weight of the melons by 16% to 41%.

'Royal Sweet' watermelon. L-Tryptophan

added to soil enhanced the number of fruit per plant with this cultivar from 3% to 64% (Table 2). The greatest significant and consistent response was observed with the application of 6×10^5 L-TRP/kg soil. With each successive harvest, there was 127%, 74%, and 49% more fruit upon treatment with 6×10^5 L-TRP/kg soil than for the control for the first, second, and third harvests, respectively. However, regression analysis showed no relationship between the L-TRP concentration applied and the number of fruit per plant.

The enhancement in cumulative weight of melons upon treatment with 6×10^5 mg L-TRP/kg soil was 168% (first harvest), 107% (second harvest), and 58% (third harvest) greater than the control. The cumulative weight of the fruit was significantly enhanced during the second harvest at the application rates of 6×10^5 to 6×10^3 mg L-TRP/kg soil. During the third harvest, the lowest concentration (6×10^5 mg L-TRP/kg soil) had a significant positive effect compared with the control. There was a significant negative linear relationship ($r = 0.756^*$) between log[L-TRP] (excluding the control) and the cumulative fruit yield. The average weight of each 'Royal Sweet' melon was increased up to 27% with the optimum concentration of L-TRP being 6×10^3 mg/kg soil (Table 2).

'Top Score' muskmelon. Although there were no significant differences in the number of muskmelon upon the application of L-TRP, compared to the control, 6×10^2 mg L-

TRP/kg soil enhanced the number of fruit per plant during the first (22%) and second (22%) harvest (Table 3). The numbers continued to increase during the third harvest with 60 mg L-TRP/kg soil giving the overall greatest yield (25% increase relative to the control).

The cumulative fresh weight was significantly increased upon a L-TRP treatment of 6×10^2 and 6×10^1 mg·kg⁻¹ soil during the first harvest. The effect of L-TRP on muskmelon yield was even more pronounced during the second and third harvest. Application rates of 6×10^5 to 6×10^2 mg L-TRP/kg soil significantly increased the yield in weight as much as 42%. A significant negative linear correlation ($r = 0.762^*$) was found between the cumulative fruit yield at the third harvest and log[L-TRP] (excluding the control). The average weight of each 'Top Score' fruit was enhanced by all L-TRP applications (Table 3). The fruit weight was increased 36% upon the addition of 6×10^4 mg L-TRP/kg soil.

The increase in yield of melons may be attributed to the fact that TRP is a precursor of auxins. The plant response appears to be hormonal since the lower concentrations of TRP (6×10^5 to 6×10^3 mg L-TRP/kg soil) had the most pronounced effect on the number and weight of melons produced. Tryptophan serves as precursor of auxin biosynthesis both in plants and microorganisms. Frankenberger and Brunner (1983) have demonstrated the synthesis of TRP-dependent auxins (indole-3-acetamide and IAA) in soil as a result of microbial action. The effect of TRP on melons could be attributed to substrate-dependent auxin production either endogenously synthesized within the plant after direct uptake of TRP and/or derived as a microbial metabolize and exogenously supplied to the plant. The possibility that plant growth regulators released as microbial metabolizes in the soil can affect plant growth has recently been reviewed by Arshad and Frankenberger (1990b). Previous studies have demonstrated that the application of precursors of various plant growth regulators such as TRP (an auxin precursor), adenine + isopentyl alcohol (cytokinin precursors), and L-methionine and L-ethionine (ethylene precursors) to soil or sand can affect the growth of Douglas fir, radish, corn, and tomato, respectively (Arshad and Frankenberger, 1990a; Frankenberger and Poth, 1987b; Nieto and Frankenberger, 1990).

L-Tryptophan was applied as a soil drench at the seedling stage. There was no vegetative growth response evident before transplanting into the field. The plant response was noted only in fruit yield. The resulting product of L-TRP metabolism via soil microflora or the plant itself may have involved the conversion of auxins into a storage form such as a conjugate and activated upon the reproductive stage. Several studies have revealed that auxin conjugates are synthesized in plants when auxins are applied to plant roots (Iversen et al., 1971; Kendall et al., 1971; Morris et al., 1969).

In the previous summer (1986), attempts were made to add a solution of L-TRP to the

melon seedlings of the same cultivars established in the field. There was no significant difference between the control and L-TRP-treated plants with this type of application. This lack of response might be due to leaching of the TRP and/or adsorption to a large volume of soil, leading to little or no uptake of TRP and/or its metabolizes by the seedling roots. Yield was significantly increased only when L-TRP was contained within the soil matrix and the seedlings were temporarily limited in space for root proliferation, forcing the uptake of L-TRP and/or metabolizes (e.g., auxins) before transplanting to the field.

The application of L-TRP as an agrochemical to seedling transplants could provide substantial economic returns to the melon industry. Fruit size was increased up to 43% for watermelons and 36% for muskmelons upon treatment with L-TRP to soil over their respective controls. However, further research is needed to investigate the effect of TRP treatment on the nutritional quality of the watermelons and muskmelons.

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