Effect of Timing of Fertilizer Application on Yield, Quality and Elemental Leaf Concentration of Transplanted Fresh Market Tomato

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Abstract

Experiments were conducted to determine the effect of timing of NPK fertilizer applications on yield, elemental leaf concentration and fruit quality of tomatoes. NPK at 136-30-113 kg ha^{-1} was applied, all or half at planting and half at 2, 4, or 6 weeks after, in double bands 10 cm on each side of a row and 10 cm deep. Yield of early and total marketable, large and medium fruits declined with all NPK applied at planting and half, 4 or 6 weeks after. Applying half the NPK fertilizer at planting and half 2 weeks later produced the highest early and total marketable yield. 'Floradade' produced greater early, total and marketable fruit yield, but lower vine yield than did 'Floradel'. Except for P, elemental leaf concentrations, fruit pH, titratable acidity, and percent total soluble solids (%TSS) were similar. No benefits were gained by applying NPK greater than two weeks after the first application.

Key words. Lycopersicon esculentum, soluble solids, plant nutrition, titratable acidity

1. Introduction

Tomato (*Lycopersicon esculentum Mill*), ranks second in dollar value among all vegetables produced in the United States (USDA, 2009). In 2009, total production of tomatoes in the U.S. was 15.8 million tons of which 13.9 million tons were used for processing and the remainder was used for fresh market. California is the highest producing state for processing tomatoes with Florida being the highest producer of fresh market fruits, while Alabama produced 22.5 million tons of fresh market tomatoes in 2009. (USDA, 2009). Fertilizer recommendations for vegetable crops are generally provided with cultural practices that include the rate of fertilizer applied. Where fertilizer is applied mechanically, the frequency and timing of application is restricted to the early stages of tomato growth. However, the wide adoption of drip irrigation especially for processing tomatoes has helped to manage both water and fertilizer more efficiently. According to Hartz and Bottoms (2009), potential increases in yield and the ability to apply fertilizer, especially N with no cultural constraints is causing a re-evaluation of fertilizer management practices. Many studies have been done on timing or split application effects of N and K on yield and quality indices of tomatoes. Few studies, however, have evaluated the effect of timing of NPK fertilizer application on fresh market tomatoes. Although a few studies have shown that heavy application of N, P and K may depress tomato yield, most studies suggest that split application of N is more efficient than a single application at planting in producing greater yield and quality.

For example, Wien and Minotti (1988) reported that split application of N fertilizer at planting or by side-dressing was just as effective in increasing fruit yield as applying all N at planting. However, when rate was doubled either at initial application or when side dressed, no further increases in marketable yield was obtained. Locascio and Smajstrla (1989) evaluated the effect of timing of N and K applications on tomato production and reported increased extra-large, large, and total marketable yields and N and K concentration, while yield of medium fruits were lower with N and K applied 40% preplant and 60% through drip irrigation than all applied preplant. They also showed that N and K leaf concentration was higher. Cook and Sanders (1991) showed that the number of tomato fruits was not affected by the by the frequency of N application but fruit sizes were. Kinoshita (2011) found no differences in marketable fruit yield of tomato treated with controlled release (CRF) or liquid fertilizer (LF) while nutrient uptake was lower among plants receiving CRF.

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Huett and Dettmann (1988) reported that percent dry matter and total solids increased with N application. Adams and Winsor (1973) found that the effect of N levels on fruit quality exceeded that of K. They indicated that titratable acidity increased with N levels. The objective of this study was to determine the effect of timing of complete NPK fertilizer applications on yield, elemental leaf concentration and raw product quality of transplanted fresh market tomatoes.

2. Materials and Methods

Field experiments were conducted in randomized complete block design with four fertilizer treatments in a factorial arrangement and 4 replications. Soil type was a Norfolk sandy loam (fine, siliceous, thermic typic Palendult) with a pH of 6.2, q.1% organic matter, cation exchange capacity of 4.94 mm L/Kg and total N of 0.08%. General soil samples from 0 to 25 cm depths were taken randomly from eight cores prior to planting, composited and analyzed by the Plant and Soil Testing laboratory at Auburn University. In addition to the treatments, calcitic lime and gypsum were applied at the rate of 2.5 t ha^{-1} and 567kg ha^{-1}, respectively.

The four treatments consisting of recommended NPK applied at the rate of 136-30-113 kg ha^{-1}, respectively, were all at planting, half at planting and half at 2, 4, or 6 weeks after planting. The fertilizer was applied in double bands approximately 10 cm on each side and 10 cm deep.

Tomato seeds of two 'Floradade' and 'Floradel' were sown in moist commercial Jiffy Mix (Batavia, IL) medium in TLC Pro-Trays transplant flats (TLC Polyform, Inc., Plymouth, MN) in a greenhouse and covered with approximately 0.6 cm of the medium. Trays were watered as necessary and seedlings fertilized with a soluble 20-20-20 NPK fertilizer. Prior to transplanting trays were moved to a cold frame for "hardening off" in which fertilizing and watering were reduced for two weeks. Plants were transplanted into mulched two-row plots each 1.2 m wide and 6.1 m long with a 0.6 m within row spacing and guard plants were used at each end o the rows.

Leaf samples were collected 8 weeks after transplanting from each plot 8 weeks after transplanting. Each sample consisted of the most recently matured leaf from 3 plants when the first fruit clusters were forming. Samples were dried at 70ºC for 48 h ground using a motar and pestle and analyzed by the Plant and Soil Testing Laboratory at Auburn University for N, P, K Mg, Ca, Mn, Fe, B, Zn, Mo and Cu. Plants were harvested four times beginning 63 days after transplanting. In the first three harvests ripe and pink fruits were picked and graded by diameter into 4: extra large (>7.3), large (6.4-7.2 cm), medium (5.7-6.3 cm) and small (<5.6 cm). The number and weights were recorded and at the last harvest, vine weight, the number and weight of mature, immature green and rotted fruits were obtained. After harvest, fruits were evaluated for morphological quality and marketability. Marketable yield consisted of extra-large, large and medium fruits.

For titratable acidity, pH, and total soluble solids, four fruits of each size were selected at random. The middle portions were removed, cut into pieces and homogenized in a blender after which 10 g were combined with 100 ml deionized water and dispersed into solution and the pH was determined. Titratable acidity was determined by titrating the solution with 0.1 N NaOH and percent total soluble solids by using a hand-held refractometer adjusted to a refractive index of 1.3330 using deionized water (A.O.A.C., 1986). All data were combined by treatments and analyzed by the General Linear Models procedure (SAS Institute, 2009). Linear and quadratic effects were partitioned from the main effect of fertilizer treatments and cultivar.

3. Results and Discussion

The main effect of timing of fertilizer applications significantly impacted early and total marketable fruit yield while the main effect of cultivar affected both early and total fruit yield (Table 1). Both early and total marketable fruit yield was significantly lowered when all the fertilizer was applied at planting and half at 4 or 6 weeks after planting. This decline in fruit yield was defined by linear and quadratic relationships. Applying half the NPK fertilizer at planting and the remaining half 2 weeks later produced the highest early and total marketable fruit yield. Thus timing of fertilizer application produced no meaningful effects on early and total fruit or vine yield or mean fruit weight (data not shown), and whatever differences detected were strongly related to the cultivars used. Plants receiving half the fertilizer at 4 or 6 weeks after planting responded by producing lower marketable fruit yield. Cultivars significantly influenced early and total and marketable fruit yield as well as vine production (Table 2). 'Fluoridate' produced greater early, total and marketable fruit yield, but lower vine yield than did 'Floradel'. Graded fruit sizes were influenced by both main effects of timing of fertilizer application and the cultivars (Table 3).

The timing of fertilizer applications had no meaningful effect on the production of extra-large or small fruits but significantly affected large and medium fruit production. Yield of large and medium fruits decreased when half the NPK fertilizer was applied at planting and the remainder 4 or 6 weeks later Plants receiving half the NPK fertilizer at planting and half 2 weeks later produced a greater yield of large and medium fruits. Locascio et al. (1989) also found that yield of extra-large, large and medium fruits were significantly greater when N and K were split-applied in a 60:40 ratio than when all was applied pre-plant. 'Floradade' produced greater yields of extra-large, large and medium fruits than did 'Floradel' (Table 4). However, no significant yield differences between the two cultivars were observed for small fruits even though 'Floradade' produced a marginally greater yield than did 'Floradel'. Generally, fruit sizes tended to decline the longer the interval between split applications of the fertilizer.

Except for P, timing of fertilizer application had no significant effect on elemental leaf concentrations (data not shown). These results are consistent with those of Locasio and Smajstrala (1989) who reported that leaf N and K were not affected by the time of N and K application. Generally leaf P concentration was higher when NPK was split-applied and was at the high end of the low range (0.20 to 0.24%) for field grown tomatoes receiving all NPK at planting (Jones et al., 1991), no deficiency symptoms were observed on these plants. Leaf P (0.26% to 0.28%) among the other treatments as well as N and K concentrations was within the sufficiency range for field grown tomatoes (Jones et al., 1991).

Neither fruit pH, titratable acidity, nor total soluble solids (TSS) were influenced by timing of fertilizer application (data not shown). The values for pH and total soluble solids were within the range desirable for both fresh-market and processing applications (Ogbugwo, 1979). The percent total soluble solids was significantly influenced by cultivar (data not shown), with 'Floradel' having a greater %TSS. Generally, the timing of fertilizer did not enhance or adversely affect fruit quality but was marginally influenced by the cultivars used. The differences observed in this study were strongly related to the cultivars used. In general, differences in fruit yields among fertilizer treatments were not statistically significant, though total fruit yields were 15.1%, 13.6% and 25.6% greater for plants receiving half the recommended NPK fertilizer at planting and half two weeks later, respectively, compared to all fertilizer applied at planting, or half at planting plus half 4 or 6 weeks later. In addition, split application of NPK applied 4 or more weeks after planting resulted in a decline in marketable yield. Therefore, it appears that no benefit to was gained by applying NPK fertilizer more than two weeks after the first application.

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Table 1. Main effect of timing of fertilizer application on fruit and vine yield of transplanted tomatoes.

	Early yield		Yield		
	Total	Marketable	Total	Marketable	Vine
Treatments	(t ha-1)				
All NPK[x]	9.40	2.16	22.70	10.03	6.74
2 weeks[w]	9.77	2.40	26.74	11.39	6.90
4 weeks[y]	9.05	1.99	23.09	9.40	6.07
6 weeks[z]	6.96	1.88	19.90	7.69	4.42
Fertilizer	NS	*	NS	***	NS
Cultivar	**	*	*	***	**
Linear	NS	*	NS	NS	NS
Quadratic	NS	*	NS	NS	NS

[x]All recommended NPK at planting
[w]Half of recommended NPK at planting and half 2 weeks later
[y]Half of recommended NPK at planting and half 4 weeks later
[z]Half of recommended NPK at planting and half 6 weeks later
NS, *, **, *** non significant at 0.05, 0.01or 0.001 level of probability.

Table 2. Main effect of cultivar on fruit and vine yield of transplanted tomatoes.

	Early yield		Yield		
	Total	Marketable	Total	Marketable	Vine
Cultivar	(t ha-1)				
Floradade	10.19	2.47	25.64	11.70	5.11
Floradel	7.40	1.70	20.58	7.56	6.96
Significance	**	**	**	**	**

NS, **, *** non significant at 0.01or 0.001 level of probability.

Table 3. Main effect of timing of fertilizer application on vine yield of graded fruit sizes of transplanted tomatoes.

	Extra-large	Large	Medium	Small
Treatments	(t ha-1)			
All NPK[x]	0.26	2.51	2.24	4.24
2 weeks[w]	0.22	2.71	2.76	4.67
4 weeks[y]	0.18	2.33	2.19	4.44
6 weeks[z]	0.22	1.72	1.90	3.25
Fertilizer	NS	**	**	NS
Cultivar	**	***	**	**
Linear	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS

[x]All recommended NPK at planting
[w]Half of recommended NPK at planting and half 2 weeks later
[y]Half of recommended NPK at planting and half 4 weeks later
[z]Half of recommended NPK at planting and half 6 weeks later
NS, **, non significant at 0.01 level of probability.

Table 4. Main effect of cultivar on yield of graded fruit sizes of transplanted tomatoes.

	Extra-large	Large	Medium	Small
Cultivar	(t ha-1)			
Floradade	0.60	6.00	5.08	8.66
Floradel	0.27	3.28	4.01	7.94
Significance	**	***	**	NS

NS, **, *** non significant at 0.01or 0.001 level of probability.