Research Updates

Fertilizing Drip-irrigated Bell Peppers Grown on Loamy Sand soil

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Summary. The effects of fertilizer rates and application frequency on drip-irrigated bell peppers (*Capsicum annuum* L.) were evaluated at two sites in 1992 and one site in 1993 in southern New Jersey. Yield and fruit quality were greatest with 158N–69P–131K lb/acre at the site with a sandy loam soil. Yield and fruit quality responded to additional fertilizer at sites with loamy sand soils. Average marketable fruit weight increased with increasing fertilization rate at one of the two loamy sand sites. The incidence of sun scald decreased with increasing fertilization rate. Increasing the frequency of drip-applied fertilizer from 11 to 22 days did not affect yield or fruit quality in either year when the same amount of fertilizer was applied. These results show that maximizing the yield of bell peppers grown on loamy sand soils in New Jersey may require higher fertilization rates than previously recommended.

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Bell peppers are produced on about 5,300 acres in New Jersey, with > 85% of the production in the southern vegetable-growing region (Brown, 1993). This region is in the coastal plain of New Jersey and is characterized by coarse-textured soils (Tedrow, 1986). Most soils in this region are classified as sandy loam and loamy sand soils. These soils are well drained and warm early in the spring, making them suitable for early vegetable production.

Drip irrigation has become increasingly popular in the southern vegetable production region of New Jersey and has become part of an intensive production system that also incorporates raised beds and polyethylene mulch. This production system has allowed vegetable growers to produce high yields of high-quality bell peppers while reducing irrigation and fertilizer inputs. Research conducted in various regions of the United States has shown that using drip irrigation and polyethylene mulch results in higher yield and quality of vegetables than bare-ground, sprinkler-irrigated culture (Bhella, 1988, 1985; Bhella and Kwolek, 1984; VanDerwerken and Wilcox, 1988). Polyethylene mulch has been attributed with retaining soil moisture and heat, reducing weed competition, and reducing nutrient leaching. Drip irrigation has improved irrigation and fertilization efficiency.

Much disparity exists in N rates required for optimum bell pepper production in the United States. Reported rates range from 62 to 225 lb/acre (Fletcher et al., 1993; Hartz et al., 1993; Knavel, 1977; Locasio and Fiskell, 1977; Locasio et al., 1981; Paterson, 199 1). These differences might be expected given the variations in cultural practices and environments in which bell peppers are grown. Fertility practices for drip-irrigated bell peppers grown on raised beds with polyethylene mulch have been investigated in New Jersey (Paterson, 1987, 1990, 1991), but were studied at only one location. Soil at this location was sandy loam in texture with an organic matter content of 1.5% and a measured cation-exchange capacity of 3 to 5 me/100 g. A rate of 158N-69P-131K lb/acre maximized yield at this location. These experiments showed that bell pepper yield was maximized when one-third of the fertilizer was applied preplant followed by periodic, equally spaced and equal rate applications through the drip irrigation system. These studies also showed that the frequency of fertilizer application through the drip-irrigation system, with up to 3 weeks between applications, did not affect yield. The results of these experiments have been published as recommendations in an extension bulletin available to vegetable growers (Reiners and Garrison, 1994).

Field experiments comparing drip-fertilization treatments on different soils have been limited. Cook and Sanders (1991) reported that drip-irrigated tomatoes grown on a poorly buffered, loamy sand soil with an organic matter content of 0.4% had significantly higher yield and larger fruit when N was applied daily vs. monthly. Tomatoes grown on a loamy fine sand soil with an organic matter content of 1.2% did not require such frequent fertilization through the drip-irrigation system to maximize yield and fruit size.

In New Jersey, observations by vegetable growers and others have suggested that fertilization rates higher than university-recommended rates might be required to optimize yield and quality of bell peppers on soils with organic matter contents of < 1%

and cation-exchange capacities of < 1 to 2 me/100 g. Rutgers Univ. fertilization recommendations were developed on a sandy loam soil with an organic matter content of 1.5% and a cation-exchange capacity ranging of 3 to 5 me/100g. The objective of these experiments was to determine if higher-than-university-recommended fertilization rates resulted in increased yields of bell peppers grown on loamy sand soils.

Materials and methods

'Bell Captain', 'Gator Belle', and 'Camelot' bell peppers were grown at Mullica Hill, Bridgeton, and Woodstown, N. J., respectively. Seed was sown into flats with growing cells 1.5 × 1.5 × 2.0 inches deep with peat–vermiculite growing media for all experiments. Seed was sown on 11, 17, and 1 Mar. for the Mullica Hill, Bridgeton, and Woodstown sites, respectively. Plots were established and maintained using raised beds, black polyethylene mulch, and drip irrigation.

Experimental sites were selected based on their soil physical properties. Soil at the Mullica Hill site was a Freehold loamy sand (fine-loamy, mixed, mesic Typic Hapludults) and at the Woodstown site soil was a Sassafras loamy sand (fine-loamy, siliceous, mesic Typic Hapludults). These soils were coarse-textured and had relatively low organic matter content and cation-exchange capacity. Soil at the Bridgeton site was a Sassafras sandy loam (fine-loamy, siliceous, mesic Typic Hapludults). This soil was finer-textured than the soil at the Mullica Hill and Woodstown sites and had a higher organic matter content and cation-exchange capacity (Table 1). The Bridgeton site was the site where the previously published fertilization recommendations were developed.

Nine-week-old transplants were set in the field on 13 May 1992 in Mullica Hill, 20 May 1992 in Bridgeton, and 30 Apr. 1993 in Woodstown. Transplants were planted with a water-wheel transplanter at all sites. Plants were arranged in double, staggered rows on the beds at plant populations of 11,616; 11,616; and 9957/acre in Mullica Hill, Bridgeton, and Woodstown, respectively. Bed spacing was 5 ft at all sites. In-row plant spacings were 18, 18, and 21 inches at Mullica Hill, Bridgeton, and Woodstown, respectively. The pair of rows on each bed was spaced 12 inches apart.

A dry blend (10N4.4P-8.3K) fertilizer was applied at all sites and incorporated before beds were formed to supply 50N–22P-42K lb/acre. A 20N–8.7P–17K soluble fertilizer (urea, H_3PO_4, and KOH) was used for the drip-irrigation system fertilizer applications in 1992. Pre-dissolved 10N–4.4P-8.3K fertilizer [urea, $NH_4H_2PO_4$, $(NH4)_2HPO_4$, and KNO_3] was used in 1993. Fertilization treatments were derived from university recommended rates for drip-irrigated bell pepper production (Reiners and Garrison, 1994). These recommendations state that 50N–22P42K lb/acre be applied preplant and incorporated and that 18N-7.9P-15K lb/acre be injected through the drip irrigation system within 1 week of transplanting and repeated every 3 weeks until six applications have been made with the drip system. This results in a total application through the drip system of 108N-47P–90K lb/acre and a total overall fertilization rate of 158N–69P–131Klb/acre. Fertilization treatments in our studies resulted from using the same amount of preplant fertilizer as the university recommendations and reducing or increasing the amount of fertilizer injected through the drip-irrigation system by multiples of one-third of the recommended rate (Table 2). The first fertilizer application through the drip-irrigation system was made within 1 week of transplanting at all locations. The final application was made about 128 days after transplanting. Crops were at mid-harvest at this date. Fertilizer was applied every 11 days for treatments with 12 applications during the season and every 22 days for treatments with 6 applications during the season. Boron was applied to all treatments at all sites in six equal applications through the drip irrigation system every 22 days. A total of 1.5 lb/acre of B was applied at each site.

Irrigation was managed using tensiometers placed in each replication directly below the drip irrigation tape at 6- and 12-inch depths. Irrigation was initiate-d when tensiometers indicated that 50% of the available water was depleted at the 6-inch depth, and was initiated at 20 to 25 centibars (cb) at the Mullica Hill and Woodstown sites and at 30 to 35 cb at the Bridgeton site. These soil tension setpoints were based on published soil-moisture release data (Alderfer, 1966). The duration of each irrigation was 2 h at the Mullica Hill and Woodstown sites and 3 hat the Bridgeton site, and occurred every 1 to 3 days during periods without rain. Reference evapotranspiration (grass) rates on sunny summer days in this region range from 0.2 to 0.3 inch/day. Irrigation duration was based on soil water-holding capacity, an assumed available water depletion of 50% at irrigation initiation, a target irrigation depth of 12 inches, and an assumed hemispherical-shaped water distribution pattern in the plant bed. Soil tension levels at the 12-inch depth were not influenced by irrigation events, indicating that fertilizer was not leaching due to irrigation. T-tape (T-Systems International, San Diego) drip tape with emitters spaced 12 inches apart was operated at 10 psi. The drip

Table 1. *Summary of preplant soil test results.*

Site	Texture[w]	pH[v]	CEC[z] (me/100 g)	OM[y] (%)	Soil test values[x] (lb/acre) P_2O_5	K_2O	Ca	Mg	B
Mullica Hill	LS	6.7	1.5	0.6	422	230	772	189	0.7
Bridgeton	SL	6.7	4.0	1.5	328	114	901	203	0.9
Woodstown	LS	6.7	2.0	0.9	902	206	500	116	1.0

[z]*Cation-exchange* capacity *(1 N NH_4OAc, pH 7.0).*
[y]*Organic matter (Walkley-Black).*
[x]*Mehlich-1(0.05 N HCl + 0.025 N H_2SO_4) soil test values*
[w]*Textural class: LS =* loamy *sand, SL = sandy loam.*
[v]*pH measured using 1 soil: 1 water* (v/v) *ratio.*

Table 2. *Summary of fertilization treatments*

Site	Total rate (lb/acre)[z]	Via drip irrigation: Rate (lb/acre)	No. applications	Each applied (lb/acre)
Mullica Hill	122N–53P–101K	72N–31P–60K	12	6N–2.6P–5K
	158N–69P–131K	108N–47P–90K	12	9N–3.9P–7.5K
	194N–85P–161K	144N–63P–120K	12	12N–5.2P–10K
	158N–69P–131K	108N–47P–90K	6	18N–7.9P–15K
Bridgeton	122N–53P–101K	72N–31P–60K	12	6N–2.6P–5K
	158N–69P–131K	108N–47P–90K	12	9N–3.9P–7.5K
	194N–85P–161K	144N–63P–120K	12	12N–5.2P–10K
	158N–69P–131K	108N–47P–90K	6	18N–7.9P–15K
Woodstown	122N–53P–101K	72N–31P–60K	12	6N–2.6P–5K
	158N–69P–131K	108N–47P–90K	12	9N–3.9P–7.5K
	194N–85P–161K	144N–63P–120K	12	12N–5.2P–10K
	230N–100P–191K	180N–79P–149K	12	15N–6.5P–12.5K
	266N–116P–221K	216N–94P–180K	12	18N–7.9P–15K
	158N–69P–131K	108N–47P–90K	6	18N–7.9P–15K

[z]*50N–22P–42K lb/acre was applied preplant to soil for all treatments and incorporated.*

tape delivered irrigation water at 0.45 gal/rein per 100 ft of row.

Peppers were harvested seven times at both sites in 1992 and six times in 1993. Fruit were graded into categories that simulated the method used by commercial vegetable growers in New Jersey. Marketable peppers included well-shaped fruit and were separated into three weight categories: large (0.5 lb/fruit or greater), medium (0.33 to 0.5 lb/fruit), and small (0.25 to 0.33 lb/fruit). Slightly misshapen fruit were graded into a lesser-quality marketable category if fruit weight was > 0.25 lb. Moderately to severely misshapen fruit weighing <0.25 lb and fruit with blossom-end rot or sun scald were considered culls. Fruit in all categories were counted and weighed. Data obtained at the Bridgeton site were limited to marketable fruit only.

A randomized complete-block experimental design was used at all sites. Treatments were replicated four times at each site in 1992 and five times in 1993. Data were analyzed using standard analysis of variance and orthogonal polynomials.

Results and discussion

The highest marketable yield at the Bridgeton site resulted from the 194N–85P–161Klb/acre rate, but was only 1.2% greater than the yield with the 158N–69P–131K lb/acre rate (Table 3). Yield response was quadratic, indicating that yield was responding to higher fertilization rates but at a diminishing rate. These results confirm those of previous experiments at this site (Paterson, 1987). The highest marketable yield obtained at the Mullica Hill site resulted from the 194N–85P–161K lb/acre rate. Yield responded in a linear fashion to rate, indicating that the additional fertilizer above 158N–69P–1 31 K lb/acre significantly increased yield. The highest marketable yield obtained at the Woodstown site resulted from the 266N–116P–221K lb/acre rate. Yield response was linear in nature and similar to the Mullica Hill site, where there was a significant yield response to the additional fertilizer. Responses at the loamy sand sites were similar to those of Locasio and Fiskell (1977), who reported that yield peaked at about

Table 3. *The effect offertilization rate on bell pepper production,*

Site	Total N–P–K (lb/acre)	Yield (28 lb bu/acre): Total	Marketable	Culls	Average marketable fruit wt (lb)[z]
Mullica Hill	122N–53P–101K	2,140	2,038	103	0.37
	158N–69P–131K	2,447	2,342	106	0.38
	194N–85P–161K	2,688	2,571	116	0.38
		L**[y]	L*	NS	NS
Bridgeton	122N–53P–101K	---	2,033	---	---
	158N–69P–131K	---	2,504	---	---
	194N–85P–161K	---	2,534	---	---
			L**Q*		
Woodstown	122N–53P–101K	1,883	1,512	371	0.38
	158N–69P–131K	2,029	1,629	400	0.39
	194N–85P–161K	2,232	1,945	287	0.39
	230N–100P–191K	2,227	1,995	233	0.39
	266N–116P–221K	2,346	2,124	222	0.40
		L**	L**	L**C*	L*

[z]*Average fruit weight for well-shaped marketable fruit.*
[y]*Responses were not significant (NS), linear (L), quadratic (Q), or cubic* **(C)** *at* P = *0.05 (*) or* 0.01 *(* *).*

Table 4. *The effect of the number and frequency of fertilizer applications through the drip-irrigation system on bell pepper production.*

Site	No. applications[z]	Frequency (days)	Yield (28 lb bu/acre) Total	Marketable
Mullica Hill	6	22	2427	2280
	12	11	2447	2342
		NS	NS	
Bridgeton	6	22	---	2533
	12	11	---	2504
			NS	
Woodstown	6	22	2101	1759
	12	11	2029	1629
		NS	NS	

[z]**Total** *fertilization rate was 158N–69P–131K lb/acre.*
[NS]Nonsignificant.

200 lb/acre of N.

Cull yield was not affected by fertilization rate at the Mullica Hill site but decreased with increasing fertilization rate at the Woodstown site (Table 3). Avery high proportion of yield was marketable at the Mullica Hill site. Sun scald was the primary culling factor at the Woodstown site but decreased with increasing fertilization rate. Based on visual observations, foliage cover was inadequate at the two lowest fertilization rates at the Mullica Hill and Woodstown sites. Fertilization treatments with inadequate foliage cover had many fruit that were noticeably lighter green. Many of these fruit were marketable, but were of lower overall quality. Plants with higher fertilization were taller and darker green and had larger leaves and more branches. Plants with the highest fertilization at the Woodstown site were extremely vigorous. Branches on these plants were easily broken during mid- and late-season harvests.

Fertilization rate did not significantly affect the size distribution of peppers within the marketable category at the Mullica Hill or Woodstown site (data not shown). Average fruit weight for the well-shaped marketable fruit was not affected by fertilization rate at the Mullica Hill site but increased with increasing fertilization rate at the Woodstown site (Table 3).

The frequency of fertilizer application through the drip-irrigation system did not significantly affect pepper production in either year (Table 4). Irrigation was carefully managed in both years and heavy rains did not occur.' Leaching losses were presumed to be minimal to nonexistent. These results differ from those of Cook and Sanders (1991) in which more frequent fertilizer application increased tomato yield and fruit size on a coarse-textured sandy soil. It would be useful to conduct similar experiments in a year with substantially more rainfall or with heavy individual rainfalls that might potentially leach fertilizer components from the bed. Grower observations have indicated that polyethylene mulch protects against leaching that might be expected from heavy rainfall (P.E. Neary, unpublished data). Growers using drip-irrigation systems in New Jersey have also observed that irrigations > 4h on coarse-textured loamy sand soils have resulted in plant symptoms indicating that N leaching had occurred.

The results of these experiments suggest that bell peppers grown on loamy sand soils with cation-exchange capacities of <2.0 me/100 g and organic matter contents of < 1% require higher fertilization rates than previously recommended to maximize yields. These results also show that increasing the frequency of drip-applied fertilizer from 11 to 22 days does not influence the marketable yield of peppers if drip irrigation is managed to prevent leaching.

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