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Slow Release Fertilizer has no Effect on Soil and Plant Nitrogen and Fruit Yield in Bell Pepper (*Capsicum annum* L.)

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: To evaluate the effects of combining slow release fertilizer (SRF) with conventional N fertilizer on the levels of soil nitrogen (N), leaf N, and yield of bell pepper plants.

Study Design: The design was a randomized complete block with a factorial arrangement. There were four treatments [2 N fertilizers x 2 N rates (200 kg/ha N and 280 kg/ha N)] and four replications. The N fertilizers treatments were calcium nitrate + SRF and calcium nitrate (CN) alone as the control. The rate treatments were 200 and 280 kg/ha N.

Place and Duration of Study: Horticulture Farm, Department of Horticulture, Tifton Campus, University of Georgia, spring of 2008.

Methodology: Bell pepper 'Heritage' (Harris Moran, Modesto, Calif., U.S.) transplants were planted on 10 Apr. 2008 in two rows of plants per bed, with a distance between plants of 0.30 m. Soil and leaf nitrogen and other nutrients were monitored during the season.

Results: There were no consistent differences in the concentrations of NH_4^+-N and NO_3^--N at both 0-30 cm and 30-60 cm soil depth between CN + SRF and CN alone. Leaf N concentrations 40 DAT and 68 DAT were higher in plants fertilized with CN + SRF compared to the control, while there were no differences in leaf N concentration 98 DAT. Leaf N concentration was increased at the highest N fertilization rate. Marketable and total fruit yields and individual fruit weight were

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unaffected by fertilizer treatment and N rate.

Conclusion: Utilization of a slow-release fertilizer (combined with calcium nitrate) had no benefit in reducing soil N losses or in increasing leaf N status and bell pepper fruit yields.

Keywords: Fertilization; nitrogen leaching; nutrition; nutrient management; vegetables; irrigation.

1. INTRODUCTION

High fruit yield and quality demands adequate availability of plant mineral nutrients. Many vegetable growers often apply excessive rates of nitrogen (N) fertilizers resulting in N losses to the environment [1]. The N use efficiency of application has been estimated to be 50% or less [2]. Best management practices such as controlled release fertilizers (CRF) may help in reducing the cost of fertilizer inputs and diminish the impact of N and other nutrients to the ecosystems [1,3] The N use efficiency may increase when the SRF has a N release rate that matches the crop requirements [2,4]. The CRFs may prolong the availability of N and other plant nutrients [5] and reduce N leaching, particularly in sandy soils [6,7]. CRFs are often mixed with conventional N fertilizers with the goal of increasing N use efficiency without reducing fruit yields. In bell pepper, SRF at 168 kg/ha N was found to produce similar marketable yield compared to conventional fertilizer at 224 and 336 kg/ha N [8]. The objective was to evaluate the effects of an SRF combined with a conventional N fertilizer and N rate on soil N, leaf N, and fruit yield of bell pepper plants.

2. MATERIALS AND METHODS

The experiment was conducted at the Horticulture Farm, Tifton Campus, University of Georgia, during the spring of 2008. The soil was a Tifton Sandy Loam (a fine loamy, siliceous thermic Plinthic Paleudults) with a pH of about 6.5. Bell pepper 'Heritage' (Harris Moran, Modesto, Calif., U.S.) transplants were planted on 10 Apr. 2008 in two rows of plants per bed, with a distance between plants of 0.30 m. At the time of transplanting, each seedling received about 250 mL of a 10,000 ppm N solution as a starter fertilizer (10-34-00). Plants were grown on raised beds (1.8 m from center to center of each bed), black plastic mulch, and drip irrigation. The experimental plot consisted of a 9.1 m long bed section. There was a 3 m separation between plots in the same bed. The design was a randomized complete block with a factorial arrangement. There were four treatments [2 N fertilizers x 2 N rates) and four replications. The N fertilizer treatments were calcium nitrate alone (CN) and CN combined with SRF. The rate treatments were 200 and 280 kg/ha N. The SRF [Nitamin NFusion (22 N: 0 P_2O_5: 0 K_2O), Georgia-Pacific, Atlanta, GA, U.S.] was a granular formulation consisting of 43% water-soluble N (70% of N as urea and 30% of N as methylene urea polymers).

Nitrogen was applied weekly starting on 18 Apr. either as calcium nitrate $[Ca(NO_3)^2]$ alone [(CN) control fertilizer] or as a mixture of SRF + CN (30% N derived from the SRF and 70% N from CN). Nitrogen and potassium fertilization after planting were made through the drip irrigation system. Calcium nitrate alone was applied 12 times, while the SRF + CN mixtures were applied eight times. Potassium (K) was supplied as potassium thiosufate or KCl for all treatments at 166 kg/ha K. In weeks 8 through 12, K continued to be applied to the SRF plots at the same rate as in the calcium nitrate treatment plots.

Soil samples were collected 47 (27 May), 69 (18 June), and 99 (18 July) days after transplanting (DAT) at 12 and 24 inches deep. Leaves were sampled on 40 DAT (20 May), 68 DAT (17 June), and 98 DAT (17 July). Soil and leaf samples were analyzed at the Univ. of Georgia Soil, Plant & Water Analysis Lab (Athens, Ga). Soils were analyzed for pH and K, Mg, Ca, Mn, NH_4^+-N, NO_3^--N, P and Zn. Leaves were analyzed for N P, K, Mg, Ca, Mn and Zn. The leaf N level was estimated by determining the chlorophyll content (SPAD-502, Minolta) 26, 33 and 53 days after transplanting. Leaf samples were collected 40 days after transplanting (DAT), 68 DAT, and 99 DAT to determine the mineral nutrient concentration in the leaves.

Plants were irrigated based on cumulative evapotranspiration and appropriate crop coefficients depending on the stage of crop development. Pesticides were applied as necessary, following the recommendations of the

Univ. of Georgia Extension Service. Harvest was conducted six times from 6 June (57 DAT) to 28 July (109 DAT). Bell pepper fruit were graded as marketable or cull, according to the USDA grading standards [9], and fruit numbers and weights were determined.

Data were analyzed using the General Linear Model Procedure of SAS (v. 9.3, SAS Institute, Cary, NC), using the LSD test ($P < 0.05$) to separate the treatment means.

3. RESULTS AND DISCUSSION

3.1 Weather

Over the growing season, the cumulative rainfall was 198 mm and the average maximum, minimal, and mean air temperatures were 29.7ºC, 18.3ºC, and 24.0ºC, respectively.

3.2 Soil Mineral Nutrients

Soil analyses showed that early in the season (47 DAT), NH_4^+-N and NO_3^--N concentrations were higher and pH lower in soils fertilized with CN + SRF than in those fertilized with CN (Table 1). This may be explained by a reduction in soil NO_3^--N leaching in the SRF treatments. Slow-release fertilizers have been found to decrease N leaching [4]. Differences in soil total N between CN + SRF and CN, however, became smaller as the season progressed and, by 99 DAT, no differences in soil N concentrations existed despite no N fertilizer had been applied in the CN + SRF plots for 42 days. The reduced levels of soil N levels in mid- and late season may be due to N being leached or taken by plants. Thus, there was no consistent effect of SRF on soil N. Ideally, SRF should release nutrients gradually to make them available to crops as the plants need them. The N released from the SRF is enhanced with increasing temperature because N release is a temperature-dependent microbial process [10,11]. The higher soil NO_3^--N concentration with 280 kg/ha N compared to 200 kg/ha was expected because of the differences in N amounts applied. Concentrations of NH_4^+-N and NO_3^--N in the soil at 0-30 cm were higher than those at 30-60 cm during the growing season. Concentrations of NH_4^+-N and NO_3^--N in the soil decreased as the season progressed. The use of SRF was associated with a small reduction in soil pH. The pH decreases probably had no significant impact on the crop because pH remained within an acceptable range for bell pepper [12].

The NO_3^--N is very mobile in the soil, particularly in low texture soils [13]. Soils in the Georgia Coastal Plain are typically low in cation exchange capacity and therefore do not retain cations well [14]. Because of their negative charges, anions (such as NO_3^--N) are retained weakly to the soil particles and thus leach more rapidly than cations. Soil pH, and Mg and Ca concentrations were lower with 280 kg/ha N compared to 200 kg/ha N. Soil pH, Ca, Mn, P, and Zn were higher, and Mg was lower at 0-30 cm depth compared to 30-60 cm depth (Table 2).

3.3 Leaf Nutrients

Early in the season (40 DAT), leaf N concentration was higher in plants fertilized with CN + SRF compared to CN, while there were no consistent treatment differences in leaf N later in the season (Table 3). The increased leaf N in the CR + SRF treatment is consistent with the occurrence of high soil N levels in the CR + SRF treatment (Table 1). Leaf N was reduced late in the season in all treatments, although CN + SRF at 280 kg/ha N had the highest leaf N. In all the sampling dates, the other leaf mineral nutrients were in general least affected by the fertilizer treatment or N rate (Table 4). Chlorophyll indices have been employed to estimate leaf chlorophyll and N [15]. In the present study, chlorophyll indices were less sensitive to detect differences in leaf N status between treatments compared to laboratory determinations of leaf N. Leaf chlorophyll indices were unaffected by fertilizer treatment in mid-season (48 DAT) and late season (98 DAT) (Table 5). Chlorophyll indices were increased at augmented N rate (280 kg/ha N) 48 DAT and (not significantly) at 98 DAT. The greater chlorophyll indices at the higher N rates were consistent with the increased leaf N values.

3.4 Fruit Yield

Marketable and total fruit yields and individual fruit weight were unaffected by fertilizer treatment and N rate (Table 6). Results indicate that, regardless of the use of slow release fertilizer, N rates above 200 kg/ha are unnecessary. As in the present study, other reports have failed to find fruit yield increases with use of slow release fertilizers [7].

Table 1. Concentration (kg/ha) of NH_4^+ and NO_3^- in the soil at 30 and 60 cm of soil depth during the growing season as affected by nitrogen rate and calcium nitrate alone (CN) or combined with a slow release fertilizer (CN + SRF)

		27 May (47 DAT)				18 Jun (69 DAT)				18 Jul (99 DAT)			
		0-30 cm		30-60 cm		0-30 cm		30-60 cm		0-30 cm		30-60 cm	
N Rate	**Fertilizer**												
kg/ha		**NO_3^-**	**NH_4^+**	**NO_3^-**	**NH_4^+**	**NO_3^-**	**NH_4^+**	**NO_3^-**	**NH_4^-**	**NO_3^-**	**NH_4^+**	**NO_3^-**	**NH_4^+**
200	CN + SRF	49 b^z	5.8 b	24 ab	4.8 ab	4 b	15	12 bc	17	0.7	16	2	20
	CN	17 d	2.2 b	13 b	2.4 c	7 b	14	9 c	13	0.6	16	4	24
280	CN + SRF	62 a	11.0 a	31 a	5.8 a	5 b	15	14 b	17	0.9	18	2	20
	CN	35 c	1.7 b	14 b	3.4 bc	13 a	15	23 a	13	1.1	20	6	13

^{z} *Within a column, values followed by the same letter are not significantly different at P = 0.05*

Table 2. Soil pH and mineral nutrient concentration as affected by nitrogen fertilizer, N rate of application, and soil depth

	(kg/ha)						
	pH	**K**	**Mg**	**Ca**	**Mn**	**P**	**Zn**
47 DAT							
N Fertilizer							
CN + SRF[y]	6.76 b[z]	176	75	1271	28	194	10
CN	6.94 a	164	87	1230	26	172	9
P	0.017	0.274	0.100	0.341	0.095	0.194	0.104
N Rate							
200 kg/ha	6.93 a	176	84	1273	26	187	9
280 kg/ha	6.78 b	165	80	1228	27	179	9
P	0.035	0.328	0.506	0.305	0.396	0.616	0.893
Depth							
30 cm	6.95 a	176	64 b	1331 a	28 a	211 a	10 a
60 cm	6.75 b	165	99 a	1170 b	25 b	156 b	8 b
P	0.008	0.345	<0.001	0.001	0.002	0.002	0.003
69 DAT							
N Fertilizer							
CN + SRF	6.75 b	207	81 b	1290	34	200	11 a
CN	6.89 a	179	94 a	1335	30	185	9 b
P	0.027	0.087	0.044	0.389	0.095	0.405	0.044
N Rate							
200 kg/ha	6.87	186	95 a	1355	32	197	10
280 kg/ha	6.77	200	80 b	1269	31	188	11
P	0.787	0.361	0.018	0.100	0.441	0.633	0.594
Depth							
30 cm	6.91 a	181	60 b	1343	32	221 a	11
60 cm	6.74 b	205	114 a	1282	31	165 b	10
P	0.006	0.141	0.0001	0.242	0.470	0.007	0.269
99 DAT							
N Fertilizer							
CN + SRF	6.88	85 a	37 a	426	9	69	4
CN	6.95	67 b	31 b	435	10	69	4
P	0.457	0.013	0.043	0.860	0.546	0.562	0.162
N Rate							
200 kg/ha	7.03 a	70	40 a	453 a	9	68	4
280 kg/ha	6.81 b	79	28 b	412 b	10	70	4
P	0.027	0.164	0.0003	0.002	0.218	0.690	0.820
Depth							
30 cm	7.05 a	72	24 b	432	9.8	76 a	4.1 a
60 cm	6.78 b	79	43 a	430	9.5	62 b	3.4 b
P	0.005	0.282	0.0001	0.910	0.702	0.034	0.014

[z] Means separated within columns and within dates (by main factor) by Fisher's protected LSD test ($P \leq 0.05$).
[y] CN: calcium nitrate; SRF: slow release fertilizer

Table 3. Foliar nitrogen concentration in bell pepper at three different days after transplanting (DAT) as affected by calcium nitrate (CN) alone or mixed with slow-release fertilizer (CN + SRF) and nitrogen rate

Treatment	Leaf N (%)		
	40 DAT	**68 DAT**	**98 DAT**
CN + SRF A 200 kg/ha N	5.1 ab[z]	5.0 a	3.5 b
CN + SRF @ 280 kg/ha N	5.5 a	4.9 a	3.5 b
CN @ 200 kg/ha N	4.8 b	4.0 b	3.6 b
CN @ 280 kg/ha N	4.8 b	4.8 a	4.2 a
Significance	0.099	0.003	0.023

[z] Means separated within columns by Fisher's protected LSD test ($P \leq 0.05$)

Table 4. Leaf mineral nutrients as affected by calcium nitrate (CN) alone or mixed with slow-release fertilizer (CN + SRF) and nitrogen rate. Leaves were sampled 46, 67, and 98 days after transplanting

	(%)				mg/kg	
	P	**K**	**Mg**	**Ca**	**Mn**	**Zn**
47 DAT						
Fertilizer						
CN + SRF	0.34 b [z]	4.5	0.31	1.47	41	36
CN	0.39 a	4.5	0.33	1.54	41	37
P	0.041	.985	0.140	0.105	0.625	0.938
Rate						
200 kg/ha	0.36	4.4	0.32	1.48	39 b	36
280 kg/ha	0.37	4.7	0.32	1.54	43 a	38
P	0.757	0.155	0.492	0.164	0.025	0.423
69 DAT						
N Fertilizer						
CN + SRF	0.26	4.0	0.30	1.56	39	26
CN	0.27	3.9	0.31	1.44	34	23
P	0.372	0.494	0.733	0.398	0.063	0.078
Rate						
200 kg/ha	0.27	3.8	0.29	1.40	34	24
280 kg/ha	0.25	4.1	0.31	1.60	38	24
P	0.179	0.233	0.553	0.140	0.143	0.653
99 DAT						
N Fertilizer						
CN + SRF	0.37	3.8	0.18	0.57	27 a	38
CN	0.36	3.6	0.17	0.52	21 b	33
P	0.519	0.161	0.363	0.353	0.032	0.085
Rate						
200 kg/ha	0.36	3.8	0.17	0.54	26	35
280 kg/ha	0.37	3.6	0.18	0.55	24	36
P	0.665	0.127	0.203	0.812	0.643	0.864

[z] *Means separated within columns and within dates (by main factor) by Fisher's protected LSD test ($P \leq 0.05$).*

Table 5. Leaf chlorophyll indices of bell pepper plants as affected by calcium nitrate (CN) alone or mixed with slow-release fertilizer (CN + SRF) and by nitrogen rate

Treatment	**Chlorophyll indices**	
	28 May (48 DAT)	**17 July (98 DAT)**
Fertilizer		
CN + SRF	66.0 [z]	50.5
CN	63.6	53.6
Rate		
200 kg/ha	62.8 b	49.7
280 kg/ha	66.5 a	54.4
Significance		
Fertilizer (F)	0.216	0.400
Rate (R)	0.037	0.206
F*R	0.250	0.543

[z] *Means separated within columns (by main factor) by Fisher's protected LSD test ($P \leq 0.05$).*

Table 6. Fruit yield of bell pepper as affected by calcium nitrate (CN) alone or mixed with slow-release fertilizer (CN + SRF) and N rate

Treatment	Yield (t/ha)			Fruit weight (g/fruit)
	Marketable	Cull	Total	
CN + SRF @ 200 Kg/ha N	47.9 a [z]	10.6 b	58.6 a	301
CN + SRF @ 280 Kg/ha N	33.9 b	15.8 a	49.6 b	270
CN @ 200 Kg/ha N	39.9 ab	15.9 a	55.8 ab	272
CN @ 280 Kg/ha N	48.0 a	11.9 ab	60.0 a	283
P	0.023	0.108	0.035	0.328

[z] Means separated within columns (by main factor and by treatment) by Duncan test ($P \leq 0.05$)

4. CONCLUSION

Utilization of a slow-release fertilizer (combined with calcium nitrate) showed no benefit in reducing soil nitrogen losses or in improving leaf nitrogen status and fruit yields in bell pepper. This report is based only on a single-season trial. Thus, additional research may be necessary to further understand the effects of combining slow-release fertilizer with conventional nitrogen fertilizers on plant nitrogen and bell pepper fruit yield and quality.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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