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Pepper Fertilization Practices in the Lower Rio Grande Valley of Texas

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ABSTRACT

Fertilization programs used commercially for bell peppers (*Capsicum annuum*) in the subtropical Lower Rio Grande Valley of Texas may vary substantially from recommendations based on research. Therefore, a commercial fertilization program used on a significant fraction of the pepper production in this area was evaluated at 2 different locations. Preplant soil tests showed NO_3-N levels were very low at one location and very high at the other. Nitrogen application where preplant soil NO_3-N was low resulted in a six-fold yield increase (from 197 to 1203 kg ha-^{1}), and improvements in fruit weight, fruit volume, fruit density, wall thickness, wall strength, and carotenoid and chlorophyll a and b contents. No other nutrient application at either location, nor N application at the site where preplant soil NO_3-N levels were high significantly affected yield by size class, fruit quality characteristics, storage properties, or mineral and organic components. Nitrogen application had the greatest effect on dry weight accumulation and N uptake during fruit set and maturation when N demand was high. Where N responses were observed, N application increased total dry weight in both plant and fruit by 150% and total N uptake by 186%, yet this increase amounted to a N fertilizer uptake efficiency of only 12%. Thus, N should be used judiciously to prevent pollution of drainage and ground waters.

RESUMEN

Los programas de fertilización usados comercialmente para el chile pimiento morrón (*Capsicum annuum*) en la subtropical parte baja del Valle del Rio Grande de Texas pueden variar considerablemente de las recomendaciones basadas en investigación. Por lo tanto, un programa de fertilización comercial que es usado sobre una fracción significativa de la producción de chile en esta área fue evaluado en dos diferentes localidades. Los análisis de suelo realizados previamente a la plantación mostraron que los niveles de NO_3-N fueron muy bajos en una localidad y muy altos en la otra. La aplicación de nitrógeno en el sitio con bajo nivel de NO_3-N incrementó seis veces el rendimiento (de 197 a 1203 kg ha^{-1}), y mejoró el peso, el volumen y la densidad del fruto, así como el grosor y la resistencia de la pared y los contenidos de carotenoide y de las clorofilas a y b. Ninguna otra aplicación de nutrientes en cualquiera de las localidades o ninguna aplicación de nitrógeno en el lugar donde los niveles presiembra de NO_3-N fueron altos, afectaron significativamente el rendimiento en lo referente al rango de tamaños, las características de la calidad del fruto, las propiedades de almacenaje o los componentes orgánicos o minerales. La aplicación de nitrógeno tuvo el mayor efecto sobre la acumulación del peso seco y la asimilación de nitrógeno durante el establecimiento y la maduración del fruto, cuando la demanda de nitrógeno fue alta. En los casos donde se observaron respuestas al nitrógeno, la aplicación de nitrógeno incrementó el peso seco total tanto en la planta como en la fruta en un 150% y la asimilación de nitrógeno total por un 186%, sin embargo, este incremento totalizó una eficiencia de asimilación de fertilizante nitrogenado de solamente un 12%. Por lo tanto, el N debe ser usado juiciosamente para prevenir la contaminación del agua del drenaje y del suelo.

The first fertilization studies on peppers (*Capsicum annuum*) in the Lower Rio Grande Valley (LRGV) were conducted about 50 years ago (Pickett, 1946). Nitrogen fertilizer application rates which give the highest yields have generally been around 112-134 kg N ha^{-1} (Thomas and Heilman, 1964; Wiendenfeld, 1979; Wiedenfeld, 1986). Higher N application rates have given erratic results, sometimes increasing yields (Thomas, 1968), somtimes decreasing yields (Thomas and Heilman, 1964). High N application rates have also been found to increase susceptibility of bell pepper fruit to infection by bacterial soft rot (Thomas, 1968). Phosphorus application has been evaluated in only one study (Thomas and Heilman, 1964) and did not affect yields. Other plant nutrient applications have not been studied on peppers in south Texas.

Recommendations for fertilization of bell peppers vary. Longbrake et al. (1976) recommended multiple applications that totaled as much as 280 kg N, 168 kg P_2O_5 and 56 kg K ha^{-1} by the bloom and early fruit set stage of plant development. Foliar applications and the inclusion of micronutrients are also recommended by these authors. No evidence exists to support such recommendations in the LRGV of Texas. Pennington and Thompson (1982) concluded that for the LRGV, based on the available research, fertilizer levels of 112 kg N and 45 kg P_2O_5 ha^{-1} would be adequate. Villalón (1992) recommended 67 kg P_2O_5 ha^{-1} at planting directly below the seed, 34-56 kg N ha^{-1} sidedress at thinning, and 45-56 kg N ha^{-1} sidedress at 1st bloom.

Commercial fertilization programs utilized in the LRGV presume that the risk of plant nutrient deficiencies can not be tolerated on a high value crop, and that over application

Table 1. Fertilizer treatments

Study	Tmt #	N	P_2O_5	K_2O	S	Ca	
						Soil	Foliar
		kg ha⁻¹					
Spring	1	336	152	67	476	261	-
	2	-	152	67	476	261	-
	3	336	152	67	-	261	-
	4	336	152	67	476	-	-
	5	-	152	67	-	261	-
	6	-	152	67	476	-	-
	7	336	152	67	-	-	-
	8	-	152	67	-	-	-
	9	-	-	-	-	-	-
	10	336	152	67	476	261	112
	11	336	152	67	476	-	112
Fall	1	224	152	67	476	261	-
	2	224	-	67	476	261	-
	3	224	152	-	476	261	-
	4	224	152	67	-	261	-
	5	224	152	67	476	-	-
	6	112	152	67	476	261	-
	7	112	-	67	476	261	-
	8	112	152	-	476	261	-
	9	112	152	67	-	261	-
	10	112	152	67	476	261	-
	11	-	152	67	476	261	-
	12	-	-	-	-	-	-
	13	224	76	67	476	261	-
	14	112	76	67	476	261	-
	15	224	152	34	476	261	-
	16	112	152	34	476	261	-
	17	224	76	34	476	261	-

Nitrogen (46-0-0), P_2O_5 (0-46-0) and k_2O (0-0-60) fertilizers were banded in the soil in split applications. Sulfur (elemental) and soil Ca (gypsum) fertilizers were preplant broadcast and were incorporated. Foliar Ca ($CaCl_2$) was applied at the rate of 1.1 kg Ca ha^{-1} wk^{-1} for 10 weeks beginning at bloom stage of plant development.

insures that none occur. Except for N, few nutritional deficiencies have ever been identified on peppers, yet a wide array of products are utilized to prevent or correct such deficiencies. Such insurance may or may not be a sound business practice, but concern is starting to grow about the fate of the unused nutrients in the environment.

This study was conducted to evaluate the effectiveness of various components (N, P_2O_5, K_2O, S and Ca) of a "typical" commercial fertilizer program used on bell peppers in the LRGV of Texas on fruit yield, quality and storage characteristics.

MATERIALS AND METHODS

Two field studies were conducted during 1994 in commercial fields; a spring study west of Mission, and a fall study north of Donna. The soil type at both locations was a McAllen sandy clay loam. Seed were planted double row with 25 cm (10 in.) between rows on beds spaced 1 m (40 in.) apart. The spring study was planted to the variety 'Jupiter' in January, and in the fall study to the variety 'Capistrano' in July, both widely used varieties in the LRGV. Plots in both studies were irrigated, thinned to a 20 cm (8 in.) spacing, and treated for weeds and pests in the same manner as tht surrounding pepper fields.

Experimental design: The fertilizer treatment used in the spring study consisted of single rates of soil applied N, P_2O_5, K_2O, S and both soil and foliar applied Ca, with eleven different treatments consisting of various combination of the presense or absence of the different elements (Table 1). The treatments in the fall study utilized soil applications of high and low rates of N, P_2O_5 and K_2O along with single rates of S and Ca which were either present or absent, with a total of 17 treatment combinations used (Table 1). Treatments were applied in randomized block designs with 5 replications. Plots in the spring study were 27.5 m long by 4.1 m wide (4/40 in. rows), except for foliar Ca treatment subplots which were 9.2 m long with the corresponding main plots being reduced to 16.8 m long to accommodate the subplots. Plots in the fall study were 21.4 m long by 4.1 wide (4-40 in. rows) with no subplots. Spring fertilizer applications were made as follows: N split into 3 equal applications made preplant, at thinning and at first bloom; P_2O_5 split into 112 kg ha^{-1} preplant and 40 kg ha^{-1} at thinning; K_2O split equally between applicaitons made preplant and at thinning; and S and soil Ca all applied preplant. Foliar Ca in the spring study was applied at the rate of 1.1 kg ha^{-1} wk^{-1} for 10 weeks beginning at the bloom stage as a solution containing 0.5% $CaCl_2$ and 0.25% sticker-speader. Fall fertilizer applications were made as follows: N split equally between applications made preplant and at thinning; low rates of P_2O_5 and K_2O were all applied preplant while high rates were split for P_2O_5 into 112 kg ha^{-1} preplant and 40 kg ha^{-1} at thinning, and for K_2O into 45 kg ha^{-1} preplant and 22 kg ha^{-1} at thinning; and S and soil Ca all preplant. All N (46-0-0), P_2O_5 (0-46-0) and K_2O (0-0-60) were applied banded below and to the side of the seed row, while S (elemental) and soil Ca (gypsum) were applied broadcast and were incorporated into the soil.

Measurements: Soil samples were taken prior to fertilizer application and planting on 17 Dec 1993 for the spring study and on 1 July 1994 for the fall study. Ten random spots were sampled within each half-block to a depth of 15 cm and composited, giving a total of 10 samples from each location. Soil samples were air dried, ground, and analyzed by the Texas A&M Extension Soil Testing Laboratory for fertility status.

Yields were determined by picking the peppers from the middle 2 rows of each plot excluding 1.5 of row on each end, and harvested fruit were divided into size and quality classes. Picking and grading was done either by staff of the commercial producer or by TAES staff after training by the commercial producer. Grading was accomplished in a manner similar to that done for commercial producer. The number of fruit and weight for each grade class of pepper fruit was recorded for each plot. Fruit was harvested on 20 May, 7 June and 22 June for the spring study, and on 28 October and 17 November for the fall study.

Five pepper fruit were selected from each plot for each of the first two harvests for determination of pepper fruit quality and composition. These peppers were evaluated for the following quality parameters: fruit weight, fruit volume, fruit diameter, fruit density, wall thickness, wall penetration force and fruit dry weight. The fruit were then subsampled, freeze-dried, ground through a 40-mesh screen, and subsequently analyzed for chlorophyll and carotenoid pigments (Welburn and Lichtenthaler, 1984) and mineral composition (Plank, 1992).

Post harvest pepper shelf life was determined by selecting a subsample of up to 20 fruit from each plot in the first three replications for the first and second harvests of the spring and fall studies. These samples were stored in shipping boxes in the cooling facilities at the packing shed of the commercial shipper at the temperature and humidity used for storage of regular commercial shipments. Samples were rated after two weeks according to standards used for commmercial shipments for the following defects: sunburned, cracked, sunscald, windscar, wilted, pitted walls, decayed walls, bruised shoulder, and misshapen fruit.

All data were analyzed statistically using analysis of variance, and comparisons of means were made for various treatment groupings (none vs applied for each nutrient, soil vs foliar applied Ca, application rate) with orthogonal contrasts using the SAS GLM procedure (SAS Institute Inc., 1988)

RESULTS AND DISCUSSION

Analyses of soil samples taken preplant to determine fertility status showed values for most nutrients typical for soils in the LRGV (Table 2). Organic matter content at both locations was slightly higher than normally encountered, but this parameter depends on the previous cropping history. One clear difference between the 2 locations was that soil NO_3-N was very low at the spring study location and very high at the

Table 2. Analysis of preplant soil samples taken from each study location. Values are means of analysis run on 10 samples at each location. All parameters except pH and organic matter content are in units of ppm.

Soil parameter	Mission location 17 Dec 93		Donna location 1 July 94	
NO_3-N	8	very low	44	very high
P	259	very high	182	very high
K	527	very high	535	very high
Ca	23,500	very high	17,400	very high
Mg	666	high	637	high
S	301	high	297	high
Na	210	low	283	low
salinity	475	none	826	slight
pH	8.2	moderately alkaline	8.2	moderately alkaline
organic matter	1.2%		1.1%	

Samples were analyzed by the Extension Soil Testing Laboratory, Texas A&M University, College Station, TX.

Table 3. Pepper yields by size class and total for treatment receiveing N vs no N in the Spring, and unfertilized in the Fall, for each harvest date and total for all pickings.

Date	Treatment	Size Class Extra Large	Large	Medium	Chopper	Total
		boxes ha⁻¹				
20 May	no N	3	21	21	6	51
	N	72	141	73	20	306
	significance[1]	***	***	***	***	***
7 June	no N	1	19	73	78	171
	N	33	202	227	77	539
	significance	***	***	***	n.s.	***
22 June	no N	0	1	10	33	44
	N	13	68	298	398	777
	significance	*	***	***	***	***
Spring total	no N	4	41	104	117	266
	N	118	411	598	495	1622
	significance	***	***	***	***	***
28 Oct	check	369	668	224	25	1286
	fertilized	381	752	272	43	1448
	significance	n.s.	n.s.	n.s.	n.s.	n.s.
17 Nov	check	80	437	361	26	904
	fertilized	58	244	292	24	618
	significance	n.s.	***	n.s.	n.s.	**
Fall total	check	449	1105	585	51	2190
	fertilized	439	996	564	67	2066
	significance	n.s.	n.s.	n.s.	n.s.	n.s.

[1]Differences between treatment means for each size class and harvest date are not significant (n.s.) or significant at the 5% (*), 1% (**) or 0.1%(***) level.

[2]The standard unit of measure for peppers in the industry is the shipping box which contains 41.8 L (1.48 ft.3) of volume and holds approximately 11.8 kg (26 lbs) of bell peppers.

Table 4. Bell pepper fruit quality parameters for the 1st and 2nd pickings of the spring crop for no N and N fertilizer application, and averaged across all treatments for the 1st picking of the fall crop.

Picking Date -	20 May		7 June		28 Oct
Treatment -	no N	N	no N	N	-
Quality Parameter					
fruit weight (g)	147	179	121	163	175
fruit volume (cm^3)	274	338	221	301	-
fruit diameter(mm)	78.2	83.1	76.5	86.3	84.1
density ($g\ cm^{-3}$)	.531	.538	.554	.543	-
wall thickness (mm)	5.58	6.00	4.69	5.37	5.93
wall strength (N)	3.83	4.16	3.21	3.57	4.08

Differences between no N and N treatments for all parameters shown on the 20 May and 7 June picking dates are significant at the 5% confidence level using orthogonal contrasts. No significant differences due to treatments were found on the 28 Oct. picking date.

fall site. However, soil N can be quite variable due to the dynamic nature of the N cycle in a subtropical environment.

Bell pepper yields were very strongly affected by N application in the spring crop at the N-deficient site (Table 3). Where N was applied yields increased more than 600% compared with where no N was applied, and the relative increase due to N application was greatest for the largest size class and somewhat smaller for the lower size classes. No other nutrient applied in the spring had a significant effect on bell pepper yields. In the fall study, by contrast, there were only very minor fertilizer effects on bell pepper yields. Fertilizer application actually resulted in lower yields compared with the unfertilized check for the large class and total yields for the second picking in the fall study.

Nitrogen application increased average fruit weight, fruit volume, fruit diameter, wall thickness and wall strength in both the first and second pickings in the spring study (Table 4). These same parameters in the fall study were generally higher than in the spring study, and were unaffected by any fertilizer application.

Table 5. Bell pepper fruit constituents in the second picking on 7 June in the spring crop for no N and N fertilizer application, and averaged across all treatments in the second picking on 28 Oct. in the fall crop.

Fruit constituent	7 June		28 Oct
	no N	N	
Protein N (%)	1.33	1.78	-
P (%)	.304	.287	-
K (%)	2.24	2.39	-
Ca (%)	.068	.143	-
S (%)	.160	.189	-
Na (ppm)	175	225	-
Mn (ppm)	5.51	7.19	-
chlorophyll a (mg g^{-1})	.455	.526	.559
chlorophyll b (mg g^{-1})	.184	.213	.227
total chlorophyll (a+b)	.639	.739	.786
carotenoids (mg g^{-1})	.284	.274	.270
chlorophyll:carotenoid ratio	2.27	2.70	2.92

Differences between no N and N treatments for all parameters shown on the 7 June picking date are significant at the 5% confidence level using orthogonal contrasts. No significant differences due to treatments were found on the fall picking date.

Table 6. Bell pepper fruit quality evaluations after 2 weeks in storage following the first 2 spring pickings and both fall pickings, averaged across all fertilizer treatments. Damage ratings are reported as percent of the sample.

Type of Damage	Spring crop		Fall crop	
	20 May	7 June	28 Oct	17 Nov
		%		
cracked	0	36	20	61
wilted	16	6	6	1
pitted	26	15	8	0
bruised shoulder	0	0	29	6
decayed wall	21	9	3	1
TOTAL	76	72	69	77

No significant differences due to fertilizer treatments were found in any of the parameters measured.

Nitrogen application in the spring study increased the fruit components protein-N, K, Ca, S, Na, Mn, and chlorophylls a and b (Table 5). Nitrogen applicaiton lowered the concentrations of P and carotenoids in the fruit. The concentration of NO_3-N, Cu, Mg, Fe, Zn and Al in the fruit of the spring crop were not affected by N fertilizer application. Applications of P, K, S and both soil and foliar Ca had no effect on the content of these same nutrients in pepper fruit. In the fall crop, the chlorophyll levels averaged higher than in the spring crop even though N application rates were higher for the spring crop (Table 5). On the other hand, carotenoids were lower on average in the fall than in the spring where N had been applied.

As shown in Table 6, across the 2 spring and 2 fall pickings, 74% of the peppers had damage that would affect their marketability after 2 weeks in storage. The primary type of damage was different for each of the 4 pickings. A few storage characteristics were found to be significantly different due to fertility treatment in certain pickings (data not shown) but these were probably only anomalies in a large, diverse data set. These included decreases in pitted and decayed walls with N application; decreases in the percent wilted with P and K application; and a decrease in the percent with shoulder bruise with both K application and fertilized compared with the unfertilized check. However, none of these specific kinds of damage decreases significantly reduces the total percent of the sample damaged.

In the spring crop, plant dry weight was very low early in the crop then increased dramatically in the final 80 days (Table7). Between 13 May and 22 June samplings plant dry weight more than doubled, from 803 to 1748 kg ha^{-1}, in treatments that received N. Where no N was applied the increase in plant dry weight from 13 May to 33 June was 76% while the increase in the amount of N in the plant during this interval was only 10%. Nitrogen application also has a much greater effect on increasing fruit dry weight (511%) than increasing plant weight (79%). Finally, while N application increased fruit yields six-fold, the amount of fertilizer N taken up by the crop, compared with where no N was applied, was 40 kg ha^{-1}, giving a fertilizer use efficiency of only 12%.

Table 7. Dry weight, N content and N uptake by the plants on 4 dates, the fruit, and total (fruit + plants) for the treatments of the spring study that received N versus those that did not.

		Plant				Fruit	
	Treatment	29 Mar	22 Apr	13 May	22 Jun	All Pickings	Total
Dry wt (kg/ha)	no N	14	137	556	978	197	1175
	N	19	187	803	1748	1203	2951
N content (%)	no N	3.07	3.29	3.03	1.95	1.33	
	N	2.85	3.56	3.63	2.26	1.78	
N uptake (kg/ha)	no N	0.5	4.5	17.2	18.9	2.6	21.5
	N	0.6	6.7	29.0	40.1	21.4	61.5

Differences between no N and N treatments for each parameter are significant at the 5% confidence level using orthogonal contrasts.

CONCLUSIONS

The primary nutrient that needed to be applied for bell pepper production in this study was N. An N deficiency only occurred in the spring study. The very high preplant soil NO_3-N levels found at the site of the fall study are a clear indication that, unless unusual circumstances occurred, N was not going to be required at that site. However, the low preplant soil NO_3-N at the spring site did not necessarily indicate that such dramatic responses to N would occur. Few other fertility studies on peppers have ever shown responses to N as large as those found in the spring study. Recommendations based on the available literature and the grower's own judgement based on his experience with his fields are all useful in making a decision about the fertilization program.

The application of other nutrients including both soil and foliar Ca were of little benefit to the pepper crop in either the spring or the fall study. This was demonstrated by a wide variety of parameters measured that included yield by size class multiple pickings, quality characteristics, mineral and organic components of the fruit, and storage properties.

Where N was deficient, fertilizer N application substantially improved yields, yet still only a small percentage of the N applied was actually taken up by the crop. About 88% of the N applied in the spring remained in the soil after the crop. Since no yield increases resulted from any other fertilizers applied in the spring or fall, or any of the N in the fall, all of those nutrients remain in the soil. Of the nutrients applied, only N is a potential contaminant of ground and drainage waters. Hence it should be used only in the amounts needed to support economic yields.

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