per acre increased the soil acidity very significantly for at least the duration of the experiment, which was 3 months.

Before the addition of straw, soils containing the nitrates of calcium and magnesium were slightly more acid than those containing the carbonates of calcium and magnesium. After the addition of straw, the acidity in the soil treated with the nitrates increased very significantly over the soil treated with carbonates, even though nitrogen levels in all treatments were equivalent.

Sodium nitrate in the calcium and magnesium nitrate treatments exerted a significant effect in counteracting acidity between 2 and 3 months after straw addition. However, where calcium and magnesium were not present, sodium nitrate and straw resulted in more soil acidity than straw alone.

Literature Cited

(1) Harston, C. B., and Albrecht, W. A., *Soil Sci. Soc. Am., Proc.* 7, 247–57 (1942).
(2) Mooers, C. A., *et al.*, *Soil Sci.*, **66,** 399–400 (1948).
(3) Pierre, W. H., *J. Am. Soc. Agron.*, **20,** 254–69 (1928).
(4) Salonen, M., *Maataloustieteellinen Aikakauskirja*, **18,** 182–93 (1946).
(5) Waksman, S. A., and Heukelekian, O., *Soil Sci.*, **17,** 275–91 (1924).
(6) White, J. W., *et al.*, *Ibid.*, **68,** 229–35 (1949).

Received for review February 2, 1953. Accepted April 10, 1953. Published with the approval of the director of the Idaho Agricultural Experiment Station as Research Paper 357.

PLANT NUTRIENTS

Foliar Applications to Vegetable Crops

R. L. ISAACS, Jr., and J. B. HESTER
Department of Agricultural Research, Campbell Soup Co., Riverton, N. J.

Urea spray with a suitable wetting agent applied to the foliage in the regular spray program for control of insects and disease has proved very effective in supplying nitrogen to certain vegetable crops. Urea and ammonium nitrate in equal mixture can be used for certain vegetable crops at a greater concentration than either material alone.

THE UTILIZATION OF NUTRIENTS through the leaves of plants has been investigated by a number of workers (*2, 3, 5, 6, 8*). For several years it has been known (*1, 4, 7*) that such deficiencies as iron and manganese can be corrected through foliage application of these elements. Compounds like urea and ammonium nitrate are rather effective in supplying a readily available source of nitrogen for the plants, particularly where plants are often sprayed or have a low nitrogen-consumption capacity. The object of this presentation is to explain the experiences of the authors with foliar sprays.

Variability of Tolerance of Plants

Tomatoes will tolerate only between 4 and 5 pounds of urea per 100 gallons of water when used as a spray material at the rate of 150 gallons per acre. The recommended pest-control spray program for tomatoes consists of five to seven sprays of insecticides and fungicides per crop, applied at the rate of 150 gallons per acre. It, therefore, becomes obvious that a moderate amount of nitrogen can be applied as urea spray as part of the regular spray program. It has been the experience of the authors that urea is compatible with the fungicides and insecticides ordinarily applied.

Ten sprays of urea at weekly intervals plus 1500 pounds of an 0–10–10 (N–P_2O_5–K_2O) fertilizer mixture as compared to 1500 pounds of a 5–10–10 alone produced nearly comparable yields. This work was continued for a 2-year period and then the better program seemed to be to apply part of the nitrogen in a 3–10–10 (or 3–12–12) fertilizer mixture and the balance as a spray. Table I shows comparable results with the urea spray as the source of nitrogen.

In carrot production, however, the situation is different. Up to 30 pounds of urea per 100 gallons of water can be used effectively, but the suggested rate is 20 pounds per 100 gallons. If this procedure is combined with the three or four sprays normally applied to control diseases and insects, a considerable portion of the nitrogen used by carrots can be supplied.

The original experiments with carrots were designed to supply all of the nitrogen from urea spray, in which case a ton of 0–10–10 fertilizer was applied broadcast previous to planting. Later experiments indicated that it was desirable to apply part of the nitrogen as commercial fertilizer, using a 3–10–10 or a similar grade and supplementing with the urea spray (Table II).

So far no chemical reaction of the urea spray with the insecticides and fungicides normally used with tomatoes and carrots has been observed.

Urea and Ammonium Nitrate Mixture

Experimentation was started with the use of urea and ammonium nitrate combination sprays. It was found that more nitrogen could be applied without injury using this combination than using urea or ammonium nitrate alone. In fact, the application of nitrogen in the form of spray could be doubled in almost all cases. However, ammonium nitrate could not be used with arsenicals unless lime was included in the mixture.

It is the practice of a number of growers, particularly in southern New Jersey, to use calcium arsenate at the recommended rates of 4 to 6 pounds per 100 gallons of water without lime. Under these circumstances ammonium nitrate appeared to increase the solubility of the arsenate to such an extent as to cause toxicity. Therefore, it is undesirable to use ammonium nitrate without lime in the spray mixture. On the

Table I. Influence of Urea Spray upon Yield of Tomatoes

Year	Treatment[a]	Tons per Acre	
		Rutgers	Garden State
1949	0-10-10	7.41	9.80
	0-10-10 + N spray	7.64	11.84
	5-10-10	7.72	11.73
1950	0-10-10	7.17	10.46
	0-10-10 + N spray	9.21	10.90
	5-10-10	11.45	12.25
1951	0-10-10	5.5	7.0
	3-10-10 + N spray	9.5	9.1
	5-10-10	12.9	10.2
1952	0-10-10	4.05	7.27
	3-10-10 + N spray	5.65	9.43
	5-10-10	6.16	10.26

[a] Nitrogen added as spray to equal 5-10-10.

Table II. Influence of Urea Spray upon Yield of Carrots

Year	Soil Type	Treatment	Tons per Acre		
			Acceptable	Culls	Total
1950	Sassafras loam	0-10-10	...	...	11.02
		0-10-10 + 1 spray	...	...	11.62
		0-10-10 + 2 spray	...	...	12.68
		0-10-10 + 3 spray	...	...	14.03
		5-10-10	...	...	11.54
1951	Evesboro loamy fine sand	No spray + 0-10-10	8.35	2.12	10.47
		0-10-10 + 2 spray (60 lb. N)	8.75	2.61	11.36
		0-10-10 + 3 spray (90 lb. N)	9.59	2.48	12.07
		0-10-10 + 4 spray (120 lb. N)	10.39	2.59	12.98
		0-10-10 + 5 spray (150 lb. N)	12.00	2.95	14.95
		5-10-10 (2000 lb.)	7.61	3.59	11.20
	Woodstown sandy loam	No spray + 0-10-10	17.26	3.44	20.70
		0-10-10 + 2 spray	19.17	3.43	22.60
		0-10-10 + 3 spray	19.58	3.53	23.11
		0-10-10 + 4 spray	20.09	3.38	23.47
		0-10-10 + 5 spray	20.16	3.58	23.74
		5-10-10 (2000 lb.)	18.96	3.95	22.91
1952	Evesboro loamy fine sand	No spray + 3-10-10	5.15	1.27	6.42
		3-10-10 + 2 spray	6.78	1.77	8.55
		3-10-10 + 3 spray	10.68	1.70	12.38
		3-10-10 + 4 spray	11.15	1.60	12.75
		5-10-10 (2000 lb.)	10.09	1.80	11.89

other hand, where nitrogen is being applied without an insecticide or fungicide, it is desirable to use the mixture of urea and ammonium nitrate, in order to apply the maximum amount of nitrogen without injury.

Tomato Plant Production

In tomato plant production where nitrogen was the only limiting factor, the spray program was beneficial in growing the plants to a shipping size. Where potash or phosphorus was a limiting factor, the use of nitrogen spray actually accentuated the other deficiencies or did no good at all.

Complete N-P-K Sprays

It has been reported in the literature that plant nutrients (nitrogen, phosphorus, potassium, and particularly magnesium) are absorbed through the leaves and stems of the plants. This is unquestionably true. The authors have observed that nitrogen and potassium also leach from the leaves of the tomato plant during excessive rainfall; it is not a one-way phenomenon.

Investigations were initiated to ascertain if tomato plants grown on soils poorly supplied with nutrients and showing both phosphorus and nitrogen deficiencies could absorb plant nutrients through the leaves. Using a Tifton sandy loam with an acid soil reaction and a depleted phosphorus and potash condition, tomato plants grown without fertilizer in the row were sprayed with complete mixtures (specially prepared 7–7–14, 10–52–17, and 13–26–13) as well as urea alone. The plants absorbed the plant nutrients but sacrificed it to the soil. It is obvious that there is a competition between the soil and the plants for certain plant nutrients, particularly phosphates. The phosphates did not increase the growth or phosphate content of the sprayed plants.

The soil must be supplied with phosphatic materials, if the plant is to be able to utilize the nitrogen and potash in the form of spray material. Perhaps much of the literature on the subject of the ready absorption of the nutrients, particularly phosphate, is based on sand culture work, where there is no competition between the plant and soil.

Literature Cited

(1) Boynton, D., Krochmal, A., and Konecny, J., *Proc. Am. Soc. Hort. Sci.*, **57**, 1–8 (1951).

(2) Fisher, E., Boynton, D., and Skodvin, K., *Ibid.*, **51**, 23–32 (1948).

(3) Fisher, E. G., and Cook, J. A., *Ibid.*, **55**, 35–40 (1950).

(4) Guest, P. L., and Chapman, H. D., *Ibid.*, **54**, 11–21 (1949).

(5) Hamilton, J. M., Palmiter, D. H., and Anderson, L. C., *Ibid.*, **42**, 123–6 (1943).

(6) McCall, W., and Davis, J. F., *Mich. State Coll. Agr., Quart. Bull.*, **35**, 373–83 (1953).

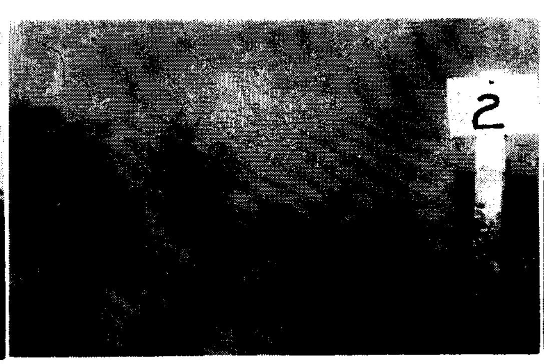
(7) Reuther, W., and Dickey, R. D. Fla. Agr. Expt. Sta., *Bull.* **318** (1937).

(8) Weinberger, J. H., *Proc. Am. Soc. Hort. Sci.*, **53**, 26–8 (1949).

Received for review September 2, 1952. Accepted April 20, 1953. Presented before the Division of Fertilizer and Soil Chemistry at the 122nd Meeting of the AMERICAN CHEMICAL SOCIETY, *Atlantic City, N. J.*

2000 lb. 5-10-10 fertilizer

3-10-10 fertilizer and no spray



3-10-10 fertilizer and 4 sprays