setting the metabolism of nemic parasites, predators or the faculative plant parasites that enhance nematode damage, an imbalance may occur which could interfere with expected host-parasite relations.

Although the great variation in specific nematode response to treated plants precludes any statement of general nematicidal activity, it may be safe to say that amino acid antimetabolites should be helpful in developing control techniques for parasitic nematodes. Also there is reason to expect that these chemicals will minimize the problem of pesticide toxicity to humans if applied as nematicides, because of the likelihood that certain of the nematicidal antimetabolites could be readily metabolized by warm-blooded animals.

SUMMARY

An experiment is described wherein eight of seventeen amino acid antimetabolites apparently prevented any multiplication by *T. christiei* when applied to the rootzone of tomato plants growing in nematode-infested soil. Only one of the antimetabolites controlled *H. nannus*, while seven reduced galling due to *M. incognita acrita.*

Plant response to the antimetabolites in terms of increases in height are reported for autoclaved and non-autoclaved soil. Reductions in growth due to certain of the amino acid antimetabolites were greater in the autoclaved soil, evidently because of microbial transformations in the non-autoclaved soil.

Implications are discussed for the potential applications of antimetabolite nematode control chemicals.

LITERATURE CITED

1. Bird, A. F. 1958. The adult female cuticle and egg sac of the genus **Meloidogyne** Goeldi, 1887. Nematologica 3:205-212.
2. Chain, E. B. 1958. Chemistry and biochemistry of antibiotics. Ann. Rev. of Biochem. 27:167-222.
3. Christie, J. R. and V. G. Perry. 1951. Removing nematodes from soil. Proc. Helm. Soc. Wash. 18:106-108.
4. Dougherty, E. C. et al. 1959. Axenic cultivation of **Caenorhabditis briggsae** (Nematoda: Rhabditidae) with unsupplemented and supplemented chemically defined media. Ann. N. Y. Acad. Sci. 77:176-217.
5. Mitchell, P. 1958. Membrane penetration and the therapeutic value of chemicals. The Strategy of Chemotherapy. 94-103. Cambridge University Press. New York.
6. Myuge, S. G. 1956. The trophic characteristics of **Meloidogyne incognita.** Zhurnal Obschii Biologii. 17:396-399.
7. ———— 1956. A contribution to the study of the physiology of the nutrition of the gall nematode. Dokladi Akademii Nauk. SSSR. 108:164-165.
8. Peacock, F. C. 1960. Inhibition of rootknot development on tomato by systemic compounds. Nematologica 5:219-227.
9. Woltz, S. S. 1963. Growth-modifying and antimetabolite effects of amino acids on chrysanthemum. Plant Physiol. 38 (in press).
10. Woltz, S. S. and C. R. Jackson. 1961. Production of yellow strapleaf of chrysanthemum and similar disorders by amino acid treatment. Plant Physiol. 36:197-201.
11. Wooley, D. W. 1952. A study of antimetabolites. John Wiley and Sons, Inc. New York.

COMPARISON OF COVERED TO NON-COVERED SIDE DRESSING OF UREA, AMMONIUM NITRATE, URAN, FERAN AND CALCIUM NITRATE ON SWEET CORN

G. M. VOLK

Florida Agricultural Experiment Station

Gainesville

The possibility of gaseous loss of nitrogen from surface applied nitrogenous materials has been of concern to soils specialists for many years, but only recently has a major effort been made to determine the nature of this loss and its economic significance under different environments. It is well known that loss of nitrogen as ammonia gas takes place when ammoniacal nitrogen or urea is left unincorporated on calcareous soils, and that an appreciable portion of fertilizer nitrogen could not be accounted for in the crop, soil and drainage water.

Recent reports by the writer have shown that urea nitrogen is subject to significant volatile loss of nitrogen as ammonia when top-dressed on light sandy soils even in the moderate to strongly acid range. Losses of nitrogen as ammonia during 7 days following surface application of 100 pounds of dry urea-nitrogen were 20 to 30% for four different sods, and 17 to 59% for acid light sandy soils (2). Losses from ammonium nitrate or ammonium sulfate were negligible in these tests, but losses from Uran solution (16.5% urea-N plus 15.5% ammonium nitrate-N) were similar (based on urea content) to those from solid urea for turf, but much less for bare soils.

A second series of tests showed that volatile loss of ammonia following application of 100 pounds of urea-nitrogen per acre averaged 29.0% for unlimed turf and 36.0% for surface-limed turf (3). Respective losses from ammonium sulfate were 0.4% and 19.7%, and from ammon-

Florida Agricultural Experiment Stations Journal Series No. 1554.

ium nitrate, 0.3% and 3.4.% Greenhouse cropping for plant recovery of nitrogen from field-treated bare soil supported the general trend in data obtained by direct measurement of volatile ammonia.

A third series of tests in which ammonium nitrate, ammonium sulfate, urea and calcium nitrate were top-dressed on Pensacola bahiagrass and coastal Bermudagrass with and without previous surface liming showed that there was differential nitrogen recovery from different sources, and that the recovery from ammoniates and urea was decreased by the surface liming (4). Average protein production per acre from four 50-pound applications of nitrogen over a two-year period on unlimed soil was: ammonium nitrate, 1016 pounds; ammonium sulfate, 996 pounds; urea, 961 pounds; and calcium nitrate, 939 pounds. Protein production by the same materials on the surface-limed areas was 10% less than the above for ammonium nitrate, 7% less for ammonium sulfate, 18% less for urea but 2% more for calcium nitrate. The data indicated that the effect of lime was not uniform, but specific for the form of nitrogen involved.

A comparison of pelleted ammonium nitrate with Uran solution involving four 50-pound nitrogen applications surface-applied over a period of two years showed that ammonium nitrate was 17% more efficient than Uran as measured by nitrogen recovery by grasses (5).

The use of 25 to 50 pounds of nitrogen as unincorporated top dressing on oats and millet resulted in crop recovery of 54% of the nitrogen applied as urea and 73% of equivalent amounts of nitrogen applied as ammonium nitrate (6).

Presumably, incorporating those forms of nitrogen subject to volatile loss as ammonia should increase efficiency over non-incorporation. The current study was made to determine the relative response of a tilled row crop to covering side dressing materials, including solutions, as compared to leaving the side dressing uncovered until eventually incorporated by subsequent rainfall or essential tillage.

EXPERIMENTAL

The majority of the data were obtained from plots on Leon fine sand during the second and third years, 1961 and 1962, from the virgin condition following a crop of watermelons. An Ona-Kanapaha fine cand complex, six years under tillage, was used for simple tests comparing different sources as a single side dressing in 1962. All plots consisted of 40 feet of harvest row of approximately 40 plants. Ears were harvested twice at green-corn maturity in 1961, and once in 1962. Yields were not culled but represent the entire gross weight of harvest. Leaf analysis for total nitrogen was of the ear leaf taken at the time of ear harvest. The 1961 plots were completely rerandomized for 1962.

In 1961, 886 pounds of 2-12-12 per acre were used in the drill at planting. In 1962, 900 pounds were used. This was followed by either one or two side dressings of 47 pounds nitrogen each in 1961. One side dressing of 75 pounds nitrogen was used in 1962. Dry materials were in pelleted form and were hand applied in bands near each row. A syphon bottle delivering a continuous single stream was used for the solutions. The material to be covered was applied first, followed by tillage through all plots. This threw soil toward the row for covering as well as tilling both treated and as yet untreated plots. The material to be left uncovered was then applied and left undisturbed for periods ranging from about ten days up to harvest time in some blocks. Each soil area was laid out in from three to four major blocks, and side dressing was progressively delayed by blocks to cover a range of rainfall patterns if they occurred.

The tests on Leon fine sand were superimposed on four replicates of three lime levels—0, 1900, and 4800 pounds per acre—established in 1959. Their identity was maintained as appropriate major blocks with multireplication of nitrogen tests in each for the current work. The 1962 tests were modified by a uniform application of one ton of dolomitic limestone in the fall of 1961.

Tests conducted on the Ona-Kenapaha area were similar to those on the Leon area in 1962, except that no lime variable existed, and the tests were of materials left on the surface without a specific comparison to immediate incorporation. The design consisted of three major blocks side dressed at different times with each treatment replicated nine times by subblocks within each date block. Further details of sources and treatments accompany the tables to follow.

The 1961 growing season was relatively dry. Rainfall was excessive immediately prior to planting but very deficient thereafter. Supplementary irrigation was not adequate. Moderate but widely spaced rains fell during the 1962 season, but irrigation was adequate to maintain favorable moisture with very little leaching loss.

RESULTS AND DISCUSSION

Data on urea, ammonium nitrate and Uran 32 (16.5% urea-N plus 15.5% ammonium nitrate-N) from the Leon soil area for 1961 appear in Table 1, and on these plus Feran 21 (ammonium nitrate solution) and calcium nitrate (Prill

Table 1. Effect of covering nitrogen where numbers of side dressings, N source and lime were variables. Leon fine sand, 1961.

Treatments	Urea 1[a]	Urea 2	Amm. Nitrate 1	Amm. Nitrate 2	Uran Solution 1	Uran Solution 2	Average 1	Average 2
	Tons Ear Weight per Acre							
No Lime (pH 4.5)								
Uncovered N	3.25	4.86	3.89	4.14	3.57	3.36	3.57	4.12
Covered N	2.82	4.62	3.84	4.92	3.39	5.11	3.35	4.88
Medium Lime (pH 5.2)								
Uncovered	3.94	4.73	3.83	4.72	4.27	5.16	4.01	4.87
Covered N	3.81	5.73	4.22	5.81	4.13	5.85	4.05	5.80
High Lime (pH 5.7)								
Uncovered N	4.23	4.53	4.41	5.36	3.94	5.33	4.19	5.07
Covered N	4.20	5.92	4.08	5.64	4.16	4.64	4.15	5.30
Average								
Uncovered	3.81	4.71	4.04	4.74	3.93	4.62	3.92	4.69
Covered	3.61	5.42	4.05	5.46	3.89	5.20	3.85	5.33[b]
	Percentage Nitrogen in Ear Leaf							
No Lime								
Uncovered	2.46	3.03	2.44	2.93	2.53	2.68	2.48	2.88
Covered	2.74	3.05	2.57	3.09	2.59	2.99	2.63	3.04
Medium Lime								
Uncovered	2.51	2.99	2.41	2.90	2.53	3.02	2.48	2.97
Covered	2.50	2.96	2.33	2.91	2.45	2.99	2.43	2.95
High Lime								
Uncovered	2.38	2.78	2.51	2.99	2.40	2.93	2.43	2.90
Covered	2.44	2.63	2.43	2.99	2.40	2.92	2.42	2.85
Average								
Uncovered	2.45	2.93	2.45	2.94	2.49	2.88	2.46	2.92
Covered	2.56	2.88	2.44	3.00	2.48	2.97	2.49	2.95
	Average Weight per Ear in Pounds							
No Lime								
Uncovered	0.45	0.53	0.46	0.49	0.47	0.45	0.46	0.49
Covered	0.44	0.50	0.47	0.50	0.47	0.50	0.46	0.50
Medium Lime								
Uncovered	0.50	0.50	0.48	0.53	0.49	0.50	0.49	0.51
Covered	0.48	0.53	0.50	0.54	0.50	0.55	0.49	0.54
High Lime								
Uncovered	0.48	0.49	0.49	0.49	0.48	0.52	0.48	0.50
Covered	0.47	0.55	0.49	0.52	0.49	0.52	0.48	0.53
Average								
Uncovered	0.48	0.51	0.48	0.50	0.48	0.49	0.48	0.50
Covered	0.46	0.53	0.49	0.52	0.49	0.52	0.48	0.52
	Total Ear Weight as % of Ear Plus Stover							
Average								
Uncovered	36	40	35	34	37	36	36	35
Covered	33	43	36	40	34	43	34	42

[a] 1's received one side dressing of 47 lb. N; 2's received two side dressings of of 47 lb. N each. Yield data are averages of 6 plots and two plots under 1 and 2 side dressings respectively. 886 lb. of 2-12-12 was applied 4/4/61 in the drill to all at planting. 1900 lb. and 4800 lb. of calcic lime was applied in 1959 to provide Medium and High lime respectively.

[b] Two side dressings (94 lb. N) produced 38% (Sig. .01) more yield than one (47 lb. N), and covering the second side dressing produced 14% more yield than leaving it uncovered (Sig. .01).

Cal), for 1962, in Table 2. Data from the Ona-Kanapaha area for all five materials are in Table 3. Identities of data by dates of side dressing on Leon fine sand are not shown in Tables 1 and 2 because there was no important correlation with the rainfall or irrigation pattern during the tests; however, they do represent the average response to a *range* of precipitation patterns and thus are a more reliable measure than if only one date was involved.

Data for the Ona-Kanapaha area are arranged by date of side dressing because some indication of differential response with date of side dressing exists.

Data in Tables 1 and 2 show certain unexpected responses. Pooling data for one side dressing of urea and Uran solution on low and medium lime areas indicated that covering these materials reduced the overall average yield by 7%. The soil covering was relatively thin, about one to two inches in depth, and may have served only to supply a more favorable condition for rapid hydrolysis of urea and possible volatile loss of ammonia (1). On the other hand, when the ammonia producing materials were left on the surface, the dry environment may have retarded availability to the plant to a more favored later date. The latter appears to be the less probable, because covering non-urea materials under identical conditions produced little differential effect. The freshly tilled soil usually presented a dry surface by the time non-incorporated side dressings were applied. A second side dressing in 1961 produced an average yield increase of 29% for all three materials. Covering this second side dressing produced 14% more yield than leaving it uncovered. Either moisture relationships varied from those at the time of the first side dressing, or critical requirement of the crop for nitrogen, supplied more immediately by covering, was responsible.

Pooling data for two years showed an average yield increase of 7½% for ammonium nitrate over urea and 6½% for Uran solution over urea. In the 1962 tests, in which Feran solution and calcium nitrate were added to the tests, there was only a 3% increase for the non-urea materials due to covering. There was a consistent positive yield response to medium or high lime over low lime with all materials both years.

Examination of the data on percentage nitrogen in the leaf, average ear weight, and ratio of ear weight to that of the total above-ground plant leads to certain conclusions. The second side dressing (1961) produced slightly larger ears, but apparently its major effect was to bring late ears into the harvest. Ratio of ear weight to stover shows that there was more effect on ear development than on the growth of the plant in general.

Apparently liming did not increase the percentage nitrogen in the ear leaf at harvest, but it did increase average ear weight. The differential effect of ammonium nitrate as compared to urea and Uran on yield was not reflected in nitrogen percentage in the leaf or in average ear weight.

As previously stated, comparison of covered to uncovered side dressings was not made on the Ona-Kanapaha area. All materials were left uncovered until incorporated by rainfall, irrigation or essential tillage. Responses to the various materials were quite uniform, with yields for urea and Uran treatments averaging only two to three percent below the non-urea materials. The urea treatment on the April 25 date and the Uran treatment on the May 2 date are the only ones exhibiting statistically significant differences from other materials. The fact that on these dates the companion urea-bearing material did not follow the same trend makes any conclusion questionable without further evidence. The major difference between nitrogenous materials on the average was only 4.4%, and experimental error was small (LSD 4.5%).

A convincing feature of the comparisons in general is the fact that small differences often were statistically significant. This does not mean that such differences are of practical importance. It does show that the data could be trusted to show any important differences in materials if they did exist, rather than having them obscured by a high degree of experimental error, as is often the case.

Summary and Conclusions

Urea, ammonium nitrate, Uran solution, Feran solution and calcium nitrate were used as side dressings on Iona sweet corn. A comparison of immediate covering to non-incorporation until the advent of rainfall, irrigation or essential tillage was made in two-year tests on Leon fine sand. In single side dressing tests urea produced 6% to 8% less yield of ears than did the other materials. Shallow covering of single side dressings of urea and Uran by tillage reduced yield by 7% on low and medium lime but not on high lime plots, while there was a general small (3%) benefit from covering non-urea materials. This suggests that shallow covering of the urea may

Table 2. Effect of covering nitrogen side dressing where nitrogen source and lime were variables.[a] Leon fine sand, 1962.

Treatments	Urea[d]	Amm. Nitrate	Uran Sol.	Feran Sol.	Calcium Nitrate[b]	Average
		Tons Ear Weight per Acre				
Low Lime (pH 5.2)						
Uncovered N	4.47	4.81	5.06	4.82	4.53	4.74
Covered N	4.33	4.75	4.42	4.96	4.91	4.67
Medium Lime (pH 5.9)						
Uncovered N	5.32	5.42	5.59	5.56	5.59	5.50
Covered N	5.00	5.65	5.19	5.74	5.72	5.46
High Lime (pH 6.2)						
Uncovered N	4.89	5.24	5.49	5.36	5.40	5.28
Covered N	5.34	5.31	5.67	5.42	5.60	5.47
Average						
Uncovered	4.89	5.16	5.38	5.25	5.17	5.17
Covered	4.89	5.24[c]	5.09	5.37[c]	5.41[c]	5.20
		Percentage Nitrogen in Ear Leaf				
Low Lime						
Uncovered	2.72	2.95	2.90	2.96	2.88	2.88
Covered	2.62	2.94	2.89	2.97	2.84	2.85
Medium Lime						
Uncovered	2.88	2.84	2.90	2.84	2.91	2.87
Covered	2.73	2.85	2.80	2.88	2.82	2.82
High Lime						
Uncovered	2.87	2.92	2.92	2.92	2.92	2.91
Covered	2.58	2.98	2.87	2.89	2.86	2.84
Average						
Uncovered	2.82	2.90	2.91	2.91	2.90	2.89
Covered	2.64	2.92	2.85	2.91	2.84	2.84
		Average Weight per Ear in Pounds				
Low Lime						
Uncovered	0.51	0.55	0.55	0.54	0.55	0.54
Covered	0.51	0.54	0.53	0.57	0.55	0.54
Medium Lime						
Uncovered	0.58	0.57	0.60	0.58	0.59	0.58
Covered	0.57	0.60	0.56	0.57	0.60	0.58
High Lime						
Uncovered	0.57	0.57	0.59	0.60	0.60	0.59
Covered	0.60	0.58	0.59	0.58	0.60	0.59
Average						
Uncovered	0.55	0.56	0.58	0.57	0.58	0.57
Covered	0.56	0.57	0.56	0.57	0.58	0.57

[a]One ton of dolomite was applied uniformly after the 1961 harvest. 900 lb. of 2-12-12 uniform at planting, 3/19/62; plus one 75 lb. N side dressing. Data are average of 9 plots.

[b]Prill-Cal (N is 11/12 nitrate and 1/12 ammoniacal).

[c]There was a 3% increase from covered ammonium nitrate, Feran, and calcium nitrate as compared to uncovered (Sig. .01).

[d]Pooling two years' data on one side dressing (Tables 1 and 2) shows that ammonium nitrate produced 7½% and Uran 6½% more yield than urea (Sig. .01); and a 7% yield increase resulted on the average from not covering urea and Uran where 3900 lb. or less total lime had been applied (Sig. .01).

Table 3. Comparative efficiency of various nitrogenous materials side-dressed and left uncovered. Ona-Kanapaha fine sand, pH 5.7.

	Urea	Amm. Nitrate	Uran Sol.	Feran Sol.	Calcium Nitrate	Average
		Tons Ear Weight per Acre[b]				
75 lb. N						
Side-dressing on:						
April 25	5.15	5.54	5.69	5.72	5.72	5.56
May 2	6.01	5.95	5.51	5.88	5.95	5.86
May 9	5.73	5.64	5.83	6.20	5.66	5.81
Average	5.63	5.71	5.68	5.93	5.78	5.75
		Average Weight per Ear in Pounds				
April 25	0.62	0.62	0.61	0.61	0.62	0.62
May 2	0.60	0.62	0.57	0.59	0.60	0.60
May 9	0.59	0.60	0.60	0.60	0.60	0.60
Average	0.61	0.61	0.59	0.60	0.61	0.60

Data are average of 9 plots. 900 lb. 2-12-12 at planting on 3/20/62.
Rain or Irrig.: 4/26, 0.12"; 5/8, 0.50"; 5/17, 1.30".

LSD: April 25 planting 0.41 T. (0.5).
May 2 planting 0.32 T. (0.5).
Precision approximates 4.5% of average yield.

even enhance volatile loss of ammoniacal nitrogen under some conditions. There was an average 29% increase for two side dressings over one (94 lb N vs. 47 lb. N) for all materials and placements, and a relative 14% increase in yield by covering the second side dressing as compared to leaving it uncovered. This indicated that placing the materials in a manner that hastened availability was of critical importance for a late side dressing. There was a marked positive yield response to lime, as would be expected. In general, yield increases were due primarily to increase in numbers of ears, with increased ear size making a minor contribution. Apparently this was the result of bringing more late developing ears into the harvest.

Tests of the above five materials on an Ona-Kanapaha fine sand complex were of side dressing left on the surface until incorporated by rainfall, irrigation or necessary tillage, and did not include a comparison to immediate covering. Urea and Uran averaged only 3% less yield than the non-urea materials, but this was the result of averaging in yields that were 7 to 8% low on certain dates of side dressing only. These may have been associated with differential effects of various precipitation patterns on the materials.

It is concluded that the occasional benefit derived from covering side dressings was primarily the result of improved timing of availability of the applied nitrogen rather than the source of nitrogen per se. Any advantage of water-soluble inorganic nitrogen over urea as sidedressings to tilled crops was not of the order observed for top dressings on oats and millet (6) but was relatively small, ranging from 3 to 11% under the various conditions of the tests.

LITERATURE CITED

1. Earnst, J. W. and H. F. Massey. The effects of several factors on volatilization of ammonia formed from urea in the soil. Soil Sci. Soc. Am. Proc. 24: 87-90. 1960.

2. Volk, Gaylord M. Volatile loss of ammonia following surface application of urea to turf or bare soils. Agron. J. 51: 746-749. 1959.

3. ——————. Gaseous loss of ammonia from surface-applied nitrogenous fertilizers. Agric. and Food Chem. 9:280-283. 1961.

4. ——————. Top liming pastures may temporarily reduce efficiency of nitrogen fertilizers. Fla. Agric. Exp. Sta. Res. Rep. V. 7, No. 4. 1962.

5. ——————. A comparison of urea-ammonium nitrate solution to prilled ammonium nitrate for top-dressing pasture grasses. Ass. South. Agric. Workers Proc. 59: 85. 1962.

6. ——————, W. H. Kelly and W. G. Blue. Recovery of nitrogen from several sources by oats and millet. Soil and Crop Sci. Soc. Fla. Proc. 19: 379-385.