Effect of Soil Applications of Aldicarb on the Growth, Yield, and Chemical Composition of Tobacco Plants

Panos G. Balayannis

Tobacco plants growing under greenhouse conditions on soil containing 2–8 ppm of aldicarb appeared vigorous, and the fresh weight of their roots and of their six uppermost fully developed leaves was higher than that of the controls. The chemical had no significant effect on the dry weight of the plant, whereas it increased the concentration of water-soluble sugars in the leaves and decreased their nicotine and crude protein content. The nitrate reductase activity of leaves, determined on the 30th and 50th day after treatment, was found to be reduced. Leaf and root contents of iron, manganese, and zinc were increased whereas potassium, total ash, and water-soluble and -insoluble ash contents were decreased, compared to those of the controls.

Aldicarb is a very important pesticide for the protection of plants against sucking insects and nematodes. It is used in tobacco fields for the protection of the young seedlings from aphids and other sucking insects, like *Thrips tabaci*, which are the main vectors of virus diseases.

It has been observed that this pesticide not only protects the crop from insects and nematodes but also enhances plant vigor; the leaves obtain a bright green color and the yield, as fresh weight, of the treated crop is increased (Union Carbide Corp., 1971). Similar phenomena have been observed by the author in tobacco crops treated with aldicarb at the rate of 4 ppm (soil).

It is well established that certain pesticides influence the chemical composition and the yield of plants to which they are applied. For example, simazine increases the protein content in corn (Ries and Gast, 1965), rye (Ries et al., 1967), and a number of forage crops (Allinson and Peters, 1970). Vergara et al. (1970) found that the application of simazine could increase the protein content of rice but at the cost of a reduction in total grain and protein yields. Chopra et al. (1974) showed that chick peas (*Cicer arietinum*), treated with carboxin (Vitavax), gave higher grain yields. The reducing sugars and the protein content of the seeds, however, were low, compared with those of the control plants. Jaiswal et al. (1973), in India, found that soil applications of lindane and isobenzan (Telodrin) boosted sugarcane yield to such an extent that it could not be ascribed exclusively to the control of pests. Both pesticides resulted in an increase of the total root weight regardless the absence or presence of sodium nitrate. Zsoldos (1974) studied the effect of Kitazin (I.B.P.), a systemic fungicide against *Piricularia oryzeae*, on the ion uptake by the root, the plant growth rate and the free amino acid content of the whole plant. He found that in the presence of 10^{-3}–5×10^{-4} M Kitazin, the potassium and phosphate ion uptake were effectively inhibited, the free amino acid content remained very low, as compared to that of the control, and the growth of the plants was markedly retarded. Concentrations lower than 10^{-4} M Kitazin were not injurious but showed some favorable effects.

In the present investigation, the effects of soil application of aldicarb on yield (fresh weight), nutrient content (Fe, Mn, Zn, Cu, K, Na), water-soluble and water-insoluble ash, water-soluble sugars, and protein content of tobacco plants are examined and possible mechanisms underlying these effects are discussed.

MATERIALS AND METHODS

Tobacco plants, var. "Argos dwarf", 20 days old were transplanted into 5-L clay plots, three uniform plants per pot. Each pot contained 3.5 kg of air-dry soil of the following characteristics: clay, 23%; silt, 35%; sand, 45%; pH 7.1 (soil:water 1:1); $CaCO_3$, 5% (Bernard); organic matter, 2% (Walkley-Black); C.E.C. = 25 mequiv/100 g of dry soil; exchangeable cations (Hasse, 1971), K^+ = 207 ppm, Fe^{2+} = 56 ppm, Mn^{2+} = 16.5 ppm, Zn^{2+} = 0.6 ppm, and Cu^{2+} = 0.6 ppm.

All plants were grown under greenhouse conditions and received exactly the same treatment throughout the experiment, e.g., watering at regular intervals, hand weeding, etc. The plants were inspected twice per day, morning and evening, for disease and insect infections. No disease problem occurred during the experimental period although, when the plants were young, caterpillars of the Noctuideae family attacked some plants; these larvae were removed by hand. No other protection measure was required until the end of the experiment and consequently no chemical other than aldicarb was used throughout the experiment.

When the plants had six uppermost leaves fully expanded, 100 pots with the most uniform plants were selected and divided into four groups (treatments). The first group was taken as the control. The soils of the second, third, and fourth group were treated with aldicarb in a granular formulation (Temik-10 G) so that the final concentrations in the soil were 2, 4, and 8 ppm, respectively. The pots were arranged in a randomized complete block design, with 25 pots per treatment. Twenty-eight days after the aldicarb application, the first sample of five pots (replicates) was randomly taken from each treatment. The sampling was repeated on the 42th, 56th, and 70th day after treatment. Each of the five replications was analyzed separately. A minimum of three determinations were made on each replicate. An analysis of variance was performed and the means were compared at the 5% confidence level, according to Duncan's multiple range test.

The whole plants were removed from the pots and the roots were kept intact by carefully washing away the soil with tap water. The root volume was then determined by the Inman-Bamber and Tainton technique (1972). The soil-free plants were washed with tap water and rinsed in 0.1 N HCl and finally with demineralized water. The plants were dried with blotting paper and divided into roots, stalks, and leaves. The roots and the six uppermost fully expanded leaves were kept for analysis.

The fresh weights of roots and leaves were determined, and then the samples were placed in paper bags, dried in a forced-draft oven for 72 h at 70 °C, and then weighed.

The dried tissues of roots and leaves were ground separately in a Wiley mill, equipped with a 20-mesh stainless steel sieve and cutting blades, redried, and stored over calcium chloride in desiccators until analyzed. For the

Agricultural Chemistry Laboratory, Athens Faculty of Agriculture, Votanikos, Athens (301), Greece.

0021-8561/83/1431-1351$01.50/0

Table I. Effect of Aldicarb on the Volume, Fresh Weight, and Dry Matter Content of Tobacco Roots[a]

ppm of aldicarb in soil	volume, cm^3				fresh weight, g				dry weight, %[b]			
	28 days[c]	42 days[c]	56 days[c]	70 days[c]	28 days[c]	42 days[c]	56 days[c]	70 days[c]	28 days[c]	42 days[c]	56 days[c]	70 days[c]
0	4.83^{A}	7.73^{A}	14.93^{A}	23.95^{AB}	3.83^{A}	5.60^{A}	13.50^{A}	22.50^{A}	7.88^{A}	10.80^{B}	7.53^{B}	10.56^{A}
2	5.09^{A}	7.40^{A}	16.13^{A}	21.65^{A}	4.00^{B}	6.50^{B}	14.50^{B}	22.30^{A}	6.50^{A}	9.06^{B}	6.89^{AB}	9.09^{A}
4	4.87^{A}	9.02^{B}	16.13^{A}	26.40^{B}	3.90^{B}	6.20^{B}	14.50^{B}	22.08^{A}	6.40^{A}	7.90^{AB}	7.84^{B}	9.95^{A}
8	5.28^{A}	7.95^{A}	16.80^{A}	23.47^{AB}	4.50^{C}	6.70^{C}	17.70^{C}	24.80^{B}	6.78^{A}	7.61^{A}	6.73^{A}	8.32^{A}

[a] Each value is the mean of five replicates. Means followed by the same letter in each column are not significantly different at the 5% level as determined by Duncan's multiple range test. [b] Data are expressed on a fresh weight basis. [c] Days elapsed after soil application of aldicarb.

Table II. Effect of Aldicarb on the Fresh Weight, Dry Weight, and Total Ash Content of Tobacco Leaves[a]

ppm of aldicarb in soil	fresh weight, g				dry weight, %				total ash, %[b]			
	28 days[c]	42 days[c]	56 days[c]	70 days[c]	28 days[c]	42 days[c]	56 days[c]	70 days[c]	28 days[c]	42 days[c]	56 days[c]	70 days[c]
0	7.53^{A}	10.08^{A}	14.42^{A}	18.10^{A}	12.75^{A}	14.66^{A}	14.31^{B}	15.46^{B}	15.84^{C}	14.55^{B}	12.95^{D}	14.25^{D}
2	8.84^{AB}	10.09^{A}	16.60^{AB}	19.09^{AB}	12.43^{A}	13.55^{AB}	13.10^{AB}	14.17^{B}	12.27^{B}	14.99^{B}	13.01^{B}	12.59^{C}
4	9.53^{B}	10.58^{A}	16.24^{B}	21.07^{B}	12.12^{A}	14.07^{AB}	11.59^{A}	14.54^{B}	11.01^{A}	14.57^{B}	10.58^{A}	10.34^{B}
8	12.06^{C}	14.18^{B}	15.85^{B}	21.50^{B}	11.46^{A}	11.31^{A}	11.15^{A}	11.53^{A}	10.47^{A}	12.79^{A}	10.55^{A}	9.71^{A}

[a] Each value is the mean of five replicates. Means followed by the same letter in each column are not significantly different at the 5% level as determined by Duncan's multiple range test. [b] Data are expressed on a dry weight basis. [c] Days elapsed after the soil application of aldicarb.

determination of Fe, Mn, Zn, Cu, K, and Na, both in leaves and in roots, 1 g of the corresponding dried sample was digested with 20 mL of concentrated nitric acid and 4 mL of 72% perchloric acid and then diluted to a known volume with deionized water (Singh et al., 1972). Determinations of Fe, Mn, Zn, and Cu were made with a Varian Model 1001 atomic absorption spectrometer. Potassium and sodium were determined with an E.E.L. flame photometer. In the dried matter of the leaves the following constituents were also determined by using the methods described by Gaines (1971): (1) total ash; (2) water-soluble and water-insoluble ash; (3) alkalinity of water-soluble ash; (4) alkalinity of water-insoluble ash; (5) total protein. The nicotine content of the mature leaves was determined according to the official CORESTA method (ISO, 1972).

For nitrate reductase activity determination, samples consisting of the uppermost fully expanded leaves were collected from control plants and from plants grown in soil with 2 ppm of aldicarb, on the 30th, 50th, and 70th day after application. From each sample, disks of leaf tissue were cut (10 mm in diameter) and placed (200 mg) into wide-neck conical flasks (200 mL).

Similar samples, from the control plants only, were taken at various time intervals during the experiment, and each sample was divided into two subsamples and cut into disks, similar to the ones described above. Tissues (disks) from each subsample (200 mg) were placed into 200-mL conical flasks; the first was impregnated with a 1-ppm aqueous solution of aldicarb by using the infiltration technique of Finke et al. (1977), whereas the second was treated as the control. Nitrate reductase activity in all samples was determined by using the assay method of Stewart et al. (1973).

The method of Gaines (1971) was used to prepare the extracts of the leaf material for reducing sugar and sucrose determination. The conversion of sucrose to reducing sugars was accomplished by mild acid hydrolysis (Gaines, 1971). Reducing sugars were estimated by the arsenomolybdate reagent of Nelson (1944).

RESULTS AND DISCUSSION

The experimental data indicate that aldicarb in soil, in concentrations of 2–8 ppm, increases significantly the fresh weight of roots and leaves of tobacco plants growing on it; i.e., the productivity of the plant increases (Tables I and II).

Table III. Effect of Aldicarb on the Concentration of Reducing and Total Water-Soluble Sugars in Tobacco[a]

ppm of aldicarb in soil	reducing sugars as invert sugar, %			total water-soluble sugar, %		
	42 days[b]	56 days[b]	70 days[b]	42 days[b]	56 days[b]	70 days[b]
0	3.3^{A}	4.0^{A}	10.0^{A}	7.0^{A}	8.0^{A}	15.0^{A}
2	4.5^{B}	4.0^{A}	11.0^{A}	10.0^{B}	8.4^{B}	16.0^{B}
4	4.8^{B}	4.3^{A}	12.0^{B}	9.0^{B}	9.2^{B}	17.0^{B}
8	5.5^{C}	4.8^{B}	14.4^{C}	11.0^{B}	12.0^{C}	23.0^{C}

[a] Each value is the mean of three replicates. Means followed by the same letter in each column are not significantly different at the 5% level as determined by Duncan's multiple range test. Data are expressed on a dry weight basis. [b] Days elapsed after aldicarb application.

The increased productivity of the plants, expressed in terms of fresh weight, may be attributed to an increase in either the dry matter of the plant or its water content or both.

The results of the present work showed no significant increase in dry matter, either of the root system or of the six fully expanded top leaves, in the plants grown in soil containing aldicarb. Therefore, the increase of their fresh weight was probably due to an increase in the water content of their tissue.

Table III shows that the leaves of plants grown on soil treated with aldicarb had a higher concentration of water-soluble sugars and the increase tended to be proportional to the concentration of aldicarb in the soil.

On the other hand, aldicarb had an opposite effect on the concentration of crude protein in the leaves and on their nicotine content (Table IV). The reduction in protein concentration tended to be consistent with increasing amounts of aldicarb in the soil. The nicotine content of the leaves in all treatments, 70 days after application, was about 25% lower than in the controls. No significant differences were observed among the treatments. These finding are in agreement with the well-established evidence that the water content of plant tissue is positively correlated with the tissue content of water-soluble substances and negatively correlated with the crude

Table IV. Effect of Aldicarb on the Nicotine and Crude Protein Content of Tobacco Leaves (Percent on Dry Weight Basis)[a]

ppm of aldicarb in soil	nicotine				crude proteins			
	28 days[b]	42 days[b]	56 days[b]	70 days[b]	28 days[b]	42 days[b]	56 days[b]	70 days[b]
0			0.463^{B}	0.580^{B}	13.92^{B}	13.23^{C}	11.59^{C}	13.42^{C}
2			0.437^{A}	0.426^{A}	7.69^{A}	11.09^{B}	9.77^{B}	11.72^{B}
4			0.392^{A}		8.57^{A}	9.07^{A}	9.07^{B}	8.51^{A}
8			0.349^{A}	0.433^{A}	9.14^{A}	9.07^{A}	7.56^{A}	8.95^{A}

[a] Each value is the mean of three replicates. Means followed by the same letter in each column are not significantly different at the 5% level as determined by Duncan's multiple range test. [b] Days elapsed after the soil application of aldicarb.

Table V. Effect of Aldicarb on the Nitrate Reductase Activity in Tobacco Leaves [nmol of NO_2 (g Fresh Weight)$^{-1}$ h^{-1}][a]

treatment	time elapsed after application of aldicarb: in the soil, days			to leaf tissues, h		
	30	50	70	0	6	24
control	3.72^{B}	5.00^{B}	2.92^{A}	4.60^{A}	5.38^{A}	4.46^{A}
aldicarb[b]	2.66^{A}	3.58^{A}	2.46^{A}	4.76^{A}	5.36^{A}	3.76^{A}

[a] Each value is the mean of 10 replicates. Means followed by the same letter in each column are not significantly different at the 5% level as determined by Duncan's multiple range test. [b] Plants in soil with 2 ppm of aldicarb or leaf tissue impregnated with a solution (1 ppm) of aldicarb.

protein content (Meyer et al., 1960).

Furthermore, it was found that aldicarb in soil had a negative effect on the nitrate reductase activity of leaves (Table V). The activity of this enzyme appeared to be reduced to about 30% in the samples collected on the 30th and 50th day after treatment. No significant differences were observed 70 days after pesticide application. When the compound was introduced directly into the leaf tissues (see Materials and Methods) and the enzyme activity was determined 6 and 24 h after treatment, no significant differences between treatments and the controls could be observed (Table V). This suggests that the inhibition of leaf reductase activity is due to aldicarb metabolites rather than to the intact pesticide molecule.

In the present work, it was not elucidated whether the observed significant reduction in crude protein and nicotine content of the treated leaves could be attributed entirely to the inhibition of the nitrate reductase by aldicarb. It has been shown, however, that nitrate reductase activity is closely related to the protein production of the plant. Croy (1967), for instance, found that nitrate reductase activity was linearly correlated with the total grain protein production in wheat. Hageman and Flesher (1960) also found a positive correlation between nitrate reductase activity and the protein content in two strains of corn. Much evidence, also, suggests a negative correlation between nitrate reductase activity and water-soluble sugars in plants. Vanadium, for instance, a known nitrate reductase inhibitor, when applied to the foliage of sugar beet plants as vanadyl sulfate, significantly increases the sucrose content of the roots. Similar results have been obtained by using maleic hydrazide, which is also a nitrate reductase inhibitor (Singh and Wort, 1969; Wort and Singh, 1970). The above investigators attributed the increased sucrose content of plants to an inhibition of protein synthesis, with a concomitant increase in sugar content. Allinson and Peters (1970) also found a negative correlation between protein synthesis and carbohydrate content of plant tissue. On the other hand, chemicals that increase the nitrate reductase activity also increase their protein content. Ries et al. (1967) found that certain *s*-triazines increase the nitrate reductase activity; these triazines, when applied in the soil, increase the protein content of the plants grown on those soils (Singh et al., 1972). It could therefore be suggested that the effects of aldicarb on soluble sugars and protein content of leaves may be attributed, to some extent at least, to the influence of the chemical on leaf nitrate reductase activity.

The micronutrients (Table VI), Fe, Mn, Zn, and Cu, were found in a higher concentration in the root system of the plants treated with aldicarb although the differences among the treatments were not significant. A similar pattern was also observed in the leaves, with the exception of copper. In general, the copper content of the leaves did not show any significant differences between treated and untreated plants.

The above data on the mineral composition of treated

Table VI. Effect of Aldicarb on the Concentration of Micronutrients Fe, Mn, Zn, and Cu in the Root and Leaves of Tobacco Plants (ppm on Dry Weight Basis)[a]

ppm of aldicarb in soil	root				leaves				analyzed mineral
	28 days[b]	42 days[b]	56 days[b]	70 days[b]	28 days[b]	42 days[b]	56 days[b]	70 days[b]	
0	1027^{A}	1546^{A}	1460^{A}	2120^{A}	149.00^{A}	157.00^{A}	242.00^{A}	176.00^{A}	Fe
2	1080^{A}	1580^{A}	1594^{B}	2240^{B}	169.40^{A}	168.00^{A}	265.30^{A}	206.40^{B}	
4	1387^{B}	1944^{B}	2050^{C}	2600^{C}	201.00^{B}	213.00^{B}	402.70^{C}	280.00^{C}	
8	1530^{C}	2040^{B}	2030^{C}	2720^{D}	205.00^{B}	242.00^{C}	307.50^{B}	216.60^{B}	
0	34.50^{A}	55.00^{A}	38.40^{A}	32.80^{A}	30.10^{A}	32.30^{A}	25.60^{A}	30.90^{A}	Mn
2	38.20^{B}	59.00^{AB}	42.20^{A}	38.40^{B}	31.62^{AB}	35.50^{A}	31.00^{B}	29.60^{A}	
4	39.20^{B}	73.00^{C}	48.20^{B}	42.60^{C}	36.60^{C}	44.50^{B}	30.70^{B}	39.00^{B}	
8	45.60^{C}	63.00^{B}	49.00^{B}	42.00^{C}	33.60^{B}	45.30^{B}	46.00^{C}	46.00^{C}	
0	96.00^{A}	79.60^{A}	62.00^{A}	54.80^{A}	36.50^{A}	54.40^{A}	37.20^{A}	36.80^{A}	Zn
2	141.20^{C}	122.60^{C}	114.00^{B}	73.60^{D}	54.00^{C}	67.10^{C}	46.60^{B}	45.50^{B}	
4	103.00^{A}	93.50^{B}	66.20^{A}	62.40^{C}	43.20^{B}	59.00^{B}	46.70^{B}	49.70^{C}	
8	102.46^{A}	82.80^{A}	61.20^{A}	58.60^{B}	39.10^{A}	55.50^{AB}	40.22^{A}	43.10^{B}	
0	20.20^{A}	22.60^{A}	24.00^{A}	23.00^{A}	10.37^{A}	12.60^{A}	13.50^{B}	13.50^{B}	Cu
2	30.60^{C}	28.80^{C}	30.20^{B}	36.80^{C}	14.60^{C}	16.60^{C}	12.90^{AB}	11.80^{AB}	
4	22.80^{B}	25.60^{B}	24.80^{A}	27.00^{B}	10.80^{A}	14.20^{AB}	13.40^{A}	10.40^{A}	
8	24.00^{B}	24.00^{AB}	24.40^{A}	28.60^{B}	9.70^{A}	14.60^{B}	9.90^{A}	11.70^{AB}	

[a] Each value is the mean of three replicates. Means followed by the same letter in each column are not significantly different at the 5% level as determined by Duncan's multiple range test. [b] Days elapsed after soil application of aldicarb.

Table VII. Effect of Aldicarb on the Concentration of Potassium and Sodium in the Root and Leaves of Tobacco Plants (mg/g on Dry Weight Basis)[a]

ppm of aldicarb in soil	root				leaves			
	28 days[b]	42 days[b]	56 days[b]	70 days[b]	28 days[b]	42 days[b]	56 days[b]	70 days[b]
				Potassium				
0	5.64^{A}	4.72^{A}	5.10^{A}	5.80^{AB}	7.32^{B}	7.88^{BC}	7.39^{B}	6.90^{C}
2	6.41^{A}	5.05^{AB}	5.42^{AB}	5.25^{A}	7.10^{AB}	8.04^{C}	6.02^{A}	5.54^{B}
4	5.29^{A}	5.36^{B}	5.74^{B}	6.12^{B}	6.81^{A}	7.60^{B}	6.17^{A}	4.23^{A}
8	5.27^{A}	5.42^{B}	5.66^{B}	5.82^{AB}	6.78^{A}	6.79^{A}	6.19^{A}	4.07^{A}
				Sodium				
0	1.88^{B}	1.55^{C}	1.76^{C}	2.17^{B}	0.37^{D}	0.41^{D}	0.30^{B}	0.35^{B}
2	2.47^{BC}	1.35^{B}	1.50^{B}	2.70^{C}	0.34^{C}	0.38^{C}	0.28^{B}	0.29^{A}
4	2.53^{C}	2.18^{D}	1.99^{D}	2.23^{B}	0.27^{B}	0.36^{B}	0.21^{A}	0.28^{A}
8	1.60^{A}	1.25^{A}	1.40^{A}	1.87^{A}	0.23^{A}	0.32^{A}	0.22^{A}	0.27^{A}

[a] Each value is the mean of three replicates. Means followed by the same letter in each column are not significantly different at the 5% level as determined by Duncan's multiple range test. [b] Days elapsed after the soil application of aldicarb.

Table VIII. Effect of Aldicarb on the Amount of Water-Soluble and Water-Insoluble Ash Content and on the Alcalinity of Tobacco Plants[a]

ppm of aldicarb in the soil	28 days[b]		42 days[b]		56 days[b]		70 days[b]	
	I	II	I	II	I	II	I	II
				Ash Content[c]				
0	10.64^{B}	5.20^{B}	9.77^{A}	4.79^{B}	6.88^{B}	5.23^{A}	8.99^{B}	5.19^{C}
2	7.57^{A}	4.71^{B}	11.40^{B}	3.59^{B}	7.83^{C}	6.08^{B}	7.41^{C}	5.25^{C}
4	8.06^{A}	2.95^{A}	11.10^{B}	3.30^{A}	5.79^{A}	4.83^{A}	6.02^{B}	4.32^{B}
8	7.46^{A}	3.01^{A}	9.49^{A}	3.48^{A}	5.72^{A}	4.83^{A}	5.57^{A}	4.14^{A}
				Alcalinity[d]				
0	3.93^{B}	7.25^{A}	5.65^{B}	10.60^{C}	3.00^{B}	7.50^{D}	4.50^{B}	7.50^{B}
2	3.20^{A}	11.40^{C}	5.65^{B}	9.33^{BC}	3.00^{B}	8.28^{C}	2.50^{A}	8.68^{B}
4	3.25^{A}	13.68^{B}	4.20^{A}	12.40^{A}	2.00^{A}	10.35^{A}	1.90^{A}	10.50^{A}
8	3.25^{A}	15.85^{B}	4.80^{A}	15.10^{AB}	2.00^{A}	11.88^{B}	2.50^{A}	11.05^{A}

[a] Each value is the mean of three replicates. Means followed by the same letter in each column are not significantly different at the 5% level as determined by Duncan's multiple range test. [b] Days elapsed after the soil application of aldicarb. [c] (I) Water-soluble ash expressed as percent of dry weight. (II) Water-insoluble ash expressed as percent of dry weight. [d] (I) Alcalinity of water-soluble ash expressed in milliliters of 0.1 N acid per 100 g dry weight of tobacco leaves. (II) Alcalinity of water-insoluble ash expressed in milliliters of 1.0 N hydrochloric acid required to neutralize the water-insoluble ash of 1.0 g dry weight of tobacco leaves (Gaines, 1971).

plants indicate that aldicarb significantly increased the uptake by the roots and the translocation to the leaves of the micronutrients Fe, Mn, and Zn. The uptake of Cu is also improved but not its translocation to the leaves.

There is sufficient evidence suggesting that the higher concentration of Fe, Zn, and Mn in the leaves is positively correlated with their chlorophyll content (Jacobson, 1945; Tso, 1972a; Deschreider and Van Collie, 1952). In the present investigation, the chlorophyll content of tobacco leaves was not determined but the visual appearance of the treated plants suggested such an increase. Zn is also directly involved in the synthesis of tryptophan (Tsui, 1948), a precursor of auxin synthesis. Tsui (1948) and Kalekenov (1962) showed that Mn, when it was in higher concentration in the nutrient solution, intensified photosynthetic processes and increased the content of cellulose and water-soluble sugars of tobacco plant leaves.

Aldicarb at 4 ppm significantly increased the sodium concentration of the roots, while at 2 ppm erratic results were observed. The sodium concentration in the roots of plants treated with 8 ppm of aldicarb, however, was always significantly lower when compared with that in the controls and the other two treatments (Table VII). There appeared to be a progressive, though not always statistically significant, trend toward a decrease in the concentration of sodium in the leaves with increasing aldicarb content in the soil (Table VII).

The presence of aldicarb in the soil had no effect on the potassium content of the tobacco roots in the samples collected on the first and the last sampling dates, while it appeared higher in those taken on the second and third sampling dates after treatment (Table VII). The increase became significant, compared with that of the controls, in those plants that were grown on soil treated with 4 and 8 ppm of aldicarb. In the leaves of treated plants, potassium was lower than in the controls. The decrease became statistically significant in the samples from the 56th and 70th day after treatment.

The total (Table II) and water-soluble ash contents of the leaves (Table VIII) followed a similar pattern. This supports the previous findings concerning potassium, because it is well established that the main constituents of total and water-soluble ash consist of potassium salts (Tso, 1972b). There is evidence that potassium deficiency increases carbohydrate concentration in plants (Coil and Slattery, 1948; Eaton, 1952). All the above considerations therefore support the findings that aldicarb increases the carbohydrate content of plant tissue (Union Carbide Corp., 1971).

CONCLUSIONS

The data of this investigation very clearly indicate that aldicarb in soil: (1) apparently increases the concentration of water-soluble sugars in the leaves, (2) decreases nicotine and crude protein content in the leaves, (3) reduces the nitrate reductase activity of the leaves, and (4) affects the concentration of the nutrients Fe, Mn, Zn, and K in the roots and the leaves.

These findings support the hypothesis that the principal cause for the observed vigor and higher yield in fresh weight of the tobacco plants that were treated with aldicarb is its effect on the carbohydrate (increase) and protein (decrease) content of the plant. Other things being equal, the higher concentration of water-soluble sugars in the treated plants may have developed a higher osmotic pressure that increases the absorption and/or retention of water in the plant tissue. This is reflected in the whole plant as an apparently higher yield and enhanced plant vigor.

In a biological system, such as the tobacco plant, the presence of a bioactive compound like aldicarb in its tissue could result in complex phenomena of interactions. Investigations regarding such interactions are very complicated and the interpretation is difficult. Further research would be necessary to elucidate the mechanisms involved in such complex phenomena.

Registry No. Aldicarb, 116-06-3; nicotine, 54-11-5; nitrate reductase, 9013-03-0; Fe, 7439-89-6; Mn, 7439-96-5; Zn, 7440-66-6; K, 7440-09-7; Cu, 7440-50-8; Na, 7440-23-5.

LITERATURE CITED

Allinson, D. W.; Peters, R. A. *Agron. J.* **1970**, *62*, 246.
Chopra, S. L.; Sethi, R. K.; Sikka, V. K. *Indian J. Agric. Chem.* **1974**, *7*, 7.
Coil, B. J.; Slattery, M. C. *Plant Physiol.* **1948**, *23*, 424.
Croy, L. I. Ph.D. Thesis, University of Illinois, Urbana, IL, 1967.
Deschreider, A. R.; Van Collie, L. "The trace metals in fresh vegetables"; Ministere Affaires Economy: Bruxelles, Belgium, 1952; Lab. Central Publ. 135, p 12.
Eaton, S. V. *Bot. Gaz. (Chicago)* **1952**, *114*, 165.
Finke, R. L.; Warner, R. L.; Muzik, T. J. *Weed Sci.* **1977**, *25*, 18.
Gaines, T. P. *Ga., Agric. Exp. Stn., Res. Rep.* **1971**, *No. 97*.
Hageman, R. H.; Flesher, D. *Plant Physiol.* **1960**, *35*, 700.
Hesse, R. P. "A textbook of soil chemical analysis"; John Murray: London, 1971.
Inman-Bamber, N. G.; Tainton, N. M. *Proc.—Grassl. Soc. South Afr.* **1972**, *7*, 130.
ISO (International Standard Organization) "Tobacco and tobacco products"; ISO: Germany, 1972; Tech. Bull. ISO/DIS 2881.
Jacobson, L. *Plant Physiol.* **1945**, *20*, 233.
Jaiswal, P. S.; Saini, N. K.; Sharma, S. K. *Plant Soil* **1973**, *38*, 33.
Kalekenov, D. K. "Microelementy i estestvennaja Radioactivnost"; Pochvenij Rostovskogo Gosudarstvennogo Universiteta: Materialy Tretiego Mezhdunarodnogo Soveshchanija, 1961; pp 152–155.
Meyer, B. S.; Anderson, D. B.; Böhning, R. H. "Introduction to Plant Physiology"; Van Nostrand: London, 1960; pp 67, 246.
Nelson, M. *J. Biol. Chem.* **1944**, *153*, 375.
Ries, S. K.; Chmiel, H.; Dilley, D. R.; Filner, P. *Proc. Natl. Acad. Sci. U.S.A.* **1967**, *58*, 526.
Ries, S. K.; Gast, A. *Weeds* **1965**, *13*, 272.
Singh, B.; Vadhwa, O. P.; Wu, M. T.; Salunkhe, D. K. *J. Agric. Food Chem.* **1972**, *20*, 1256.
Singh, B.; Wort, D. J. *Plant Physiol.* **1969**, *44*, 1321.
Stewart, G. R.; Lee, J. A.; Orebamjo, T. O. *New Phytol.* **1973**, *72*, 539.
Tso, T. C. "Physiology and Biochemistry of tobacco plants"; Dowden, Hutchinson, and Ross: Stroudsburg, PA, 1972a; p 36.
Tso, T. C. "Physiology and Biochemistry of tobacco plants"; Dowden, Hutchinson, and Ross: Stroudsburg, PA, 1972b; p 42.
Tsui, Cheng *Am. J. Bot.* **1948**, *35*, 172.
Union Carbide Corp. "Technical information on Temik-10 G Aldicarb pesticide"; Union Carbide Corp.: New York, 1971.
Vergara, B. S.; Miller, M.; Avelino, E. *Agron. J.* **1970**, *62*, 269.
Wort, D. J.; Singh, B. *Agron. J.* **1970**, *62*, 57.
Zsoldos, F. *Plant Soil* **1974**, *41*, 41.

Received for review March 19, 1982. Revised manuscript received April 15, 1983. Accepted August 10, 1983.

Chemical Composition of Seeds of Two Okra Cultivars

Hussain Al-Wandawi

Chemical compositions of the whole mature seeds of two okra varieties were investigated. The results of amino acid analyses indicated okra seed as a potential high-protein source which due to its high lysine level may serve as a supplement to cereal-based diets in which lysine is generally the first limiting amino acid. The most limiting amino acids in the Emerald variety were found to be valine (chemical score, 54.05), isoleucine (54.31), and threonine (60.0), while in the Ibtaira variety, tryptophan, isoleucine, and valine were the most limiting amino acids with chemical scores of 56.67, 57.41, and 67.03, respectively. The results of fatty acid analyses indicaed okra seed oil is akin to other high oleic acid oils and thus is of low essential fatty acid content. The most predominant elements in okra seed were found to be K, Na, Mg, and Ca. The elements Fe, Zn, Mn, and Ni were also present in abundant amounts. Gossypol was found only as traces, while Halphen-positive cyclopropenoid compounds were detected in an amount equal to 2.5 times less than that present in crude cotton oil.

In response to the present deficit and the predicted world shortage of foods, considerable research is being directed toward expanding present supplies and exploring new sources. Okra [*Abelmoschus esculentus* (L) Moench], appears to have potential as a high-protein crop when grown for its seed. Chemical and nutritional studies by Karakoltsidis and Constantinides (1975) on whole mature seeds of okra, Variety Emerald, have shown that the amino acid composition of okra was similar to that of soybeans and that the protein efficiency ratio (PER) was higher for okra. Martin et al. (1979) reported that a high-protein, high vegetable oil product can be prepared from okra seeds at the household level by using simple techniques. Savello et al. (1980) also reported on the nutritional composition of a seed meal prepared from an okra variety grown in

Food Science & Food Technology Division, Department of Agriculture & Biology, Nuclear Research Center, Baghdad, Iraq.

0021-8561/83/1431-1355$01.50/0