Physiological Response of Tomato Seedlings to Aminotriazole Toxicity

In order to evaluate the reliability of the determination of aminotriazole in soils, biological observations were made on tomato seedlings planted concurrent with chemical analyses. Small clay pots were used and the plants were subirrigated. In practically all instances the amount of aminotriazole found by chemical analyses was proportional to the degree of plant injury. Table V gives comparisons between the amount found and the plant responses for each soil type.

Physiological reactions were concordant with the amounts of aminotriazole found in all soils, although the recoveries of aminotriazole varied.

Thus, the quantity of chemical that was extractable from the soil definitely appeared to correlate with the amount the plant itself was able to absorb. Observations on aminotriazole toxicity to tomato seedlings 8 days after planting indicated that complete albinism in the true leaves to severe necrosis occurred when as much as 25 p.p.m. of chemical was present. At a concentration of 20 p.p.m. severe albinism was noted, while 5 to 7 p.p.m. of aminotriazole caused albinism in various degrees with loss of turgidity in the cotyledons. These leaves generally do not turn white but change to various shades of yellow when affected. When only 2 p.p.m. of aminotriazole was present, albinism occurred in 8 days with little change in the cotyledons.

Further observation showed the degree in which aminotriazole affected tomato seedlings from 2 to 12 days after planting. When as much as 27 p.p.m. of chemical was present, albinism occurred in 2 days, became more widespread in 5 days, then developed severe necrosis, followed by death of the plant in 8 to 12 days. At a concentration of 7 p.p.m. albinism was evident in 2 to 5 days and became severe at 8 days. When only 2 p.p.m. of aminotriazole was present, albinism was noted at 5 days but was more pronounced one week later.

It appears that knowledge of a soil's base exchange capacity can definitely aid in planning pre-emergence work. The unique structural, adsorption, and metal-complexing properties and the effect of 3-amino-1,2,4-triazole on plant processes offer unusual possibilities for basic research in plant physiology.

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FERTILIZER GRANULATION

Effects of Formulation on Granulation of Mixed Fertilizers

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More than 80 of some 1200 fertilizer mixing plants in the United States are producing granular mixed fertilizers and the number of plants going into production is continuously increasing. It was estimated that, at the close of 1955, the capacity for annual production of granular mixtures in this country exceeded 2,000,000 tons, or 12% of the total production of mixtures. This trend toward greater production of granular mixed fertilizers is accompanied by the need for basic information on optimum conditions for agglomeration of a wide range of formulations.

The volume of liquid phase present at the surface of solid particles during the processing of a mixed fertilizer is one of the most important factors governing the degree of agglomeration (*1*, *5*). The liquid phase consists of an aqueous solution of the soluble constituents of the mixture. Its volume is dependent on the types and amounts of salts in the liquid phase of the mixture as well as on the moisture content and temperature (*1–4*). This volume of liquid phase is not readily determined by direct means (*7*), but the agglomeration characteristics of mixed fertilizers can be ascertained by correlating the soluble salt content of the mixture with the moisture requirement for optimum agglomeration at a given temperature. Accordingly, the present paper relates to a study of the moisture requirement for optimum agglomeration of mixed fertilizers formulated with triple and ordinary superphosphates, anhydrous ammonia, and varying proportions of ammonium nitrate, ammonium sulfate, and potassium chloride alone and in combination. The data should serve as a guide in predicting the relative effect of formulation on moisture requirement for optimum agglomeration of mixed fertilizers under fixed conditions of plant operation. This study is part of a broad research program on the preparation of high-analysis fertilizers of improved physical condition being conducted in cooperation with the Tennessee Valley Authority.

The greater production of granular mixed fertilizers requires basic information on optimum conditions for agglomeration of formulations. A laboratory study showed that at approximately 194° F. ammonium nitrate was most effective in decreasing the moisture required for optimum agglomeration, followed by ammonium sulfate and potassium chloride. An apparent direct relationship was observed between salt solubility and the rate of decrease in moisture requirement with increase in soluble salt content of the mixed fertilizer. Replacement of ammonium sulfate with ammonium nitrate equivalent to 7 units of nitrogen in ammoniated mixed fertilizers, prepared with ordinary or triple superphosphate and potassium chloride, reduced the moisture requirement for optimum agglomeration from approximately 14 to 2% for 1:1:1 ratios and from 16 to 6% for 1:2:1 ratios.

Materials

Particle size and nutrient contents of the commercial materials used are given in Table I. The superphosphates were commercial materials made from Florida pebble phosphate rock and virgin acid. The ammonium nitrate as received was a clay-coated granular product and was ground before use. Ammoniation was with anhydrous ammonia.

Table I. Particle Size and Chemical Analyses of Initial Materials

Material	*Nutrient Content, %*	*Particle Size[a], % of Material in Tyler-Mesh Range of*				
		10–20	*20–35*	*35–65*	*65–150*	*150*
Ordinary superphosphate	20.2 P_2O_5[b]	12	25	22	22	19
Triple superphosphate	46.1 P_2O_5[c]	15	21	27	20	17
Anhydrous ammonia	82.3 N	..	..	..	..	..
Ammonium nitrate	33.5 N	..	11	30	39	20
Ammonium sulfate	19.3 N	2	6	42	41	9
Potassium chloride	60.7 K_2O	2	4	43	35	16

[a] Materials presized to pass 10-mesh screen before use.

[b] Citrate-insol. 0.03, water-sol. 17.91, free H_3PO_4 5.77%.

[c] Citrate-insol. none, water-sol. 42.7, free H_3PO_4 0.24%.

Equipment and Procedure

Laboratory investigations were carried out with the equipment shown in Figure 1. The ammoniator-granulator consisted of a stainless steel drum, 7 inches wide and 14 inches in diameter. It rotated at 30 r.p.m., and was equipped with an internal scraper to prevent build-up of fertilizer on the walls. Anhydrous ammonia, stored in a 2-gallon stainless steel tank, was drawn into a calibrated steel pipe equipped with a sight glass, from which a measured amount was delivered to the batch through a tube extending through the left trunnion of the drum. Temperature of the material in the drum was measured with a fixed iron-constantan thermocouple connected through the other trunnion to a temperature recorder. Two gas flames directed on the sides of the drum supplied external heat as required.

A batch consisting of 1000 grams of material was wetted to the desired moisture content, thoroughly mixed, and immediately placed in the preheated drum. It was then ammoniated at a maximum temperature of 190° to 200° F. during rotation of the drum for a 7-minute period, the first 2 or 3 minutes of which were required for the ammonia injection.

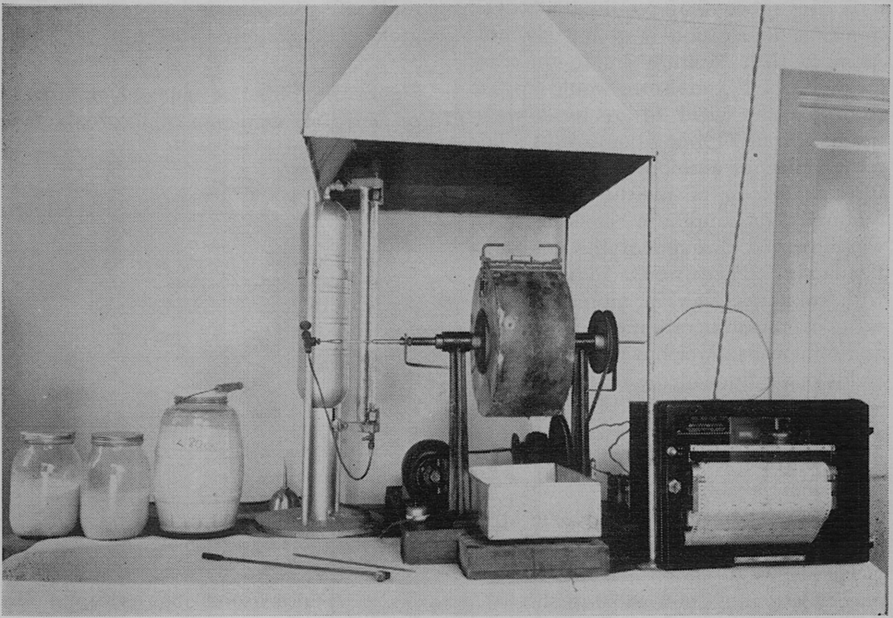
A representative sample of the treated material was taken immediately on opening the drum. This sample, after cooling, was subjected to moisture analysis by the vacuum desiccation method and the remainder of the material was dried, cooled, and subjected to particle-size analysis.

The amount of water required to give maximum yield of granules in the particle-size range of 6- to 20-mesh according to the Tyler standard screen scale (optimum agglomeration) was determined on each mixture by treating successive batches with increasing increments of water and subjecting the batch to the ammoniating and granulating procedure. Batches containing less water than that required to give optimum agglomeration yielded an excessive amount of fines and those containing more water yielded an excessive amount of oversize. When the optimum agglomeration point was established for a given mixture, it was verified by two or three additional runs under the same conditions.

Experimental

Figure 2 shows the variation in yield of 6- to 20-mesh product with change in moisture content of two mixed fertilizers having 1:2:1 ratios. Both mixtures

Figure 1. Small scale rotary ammoniator and granulator



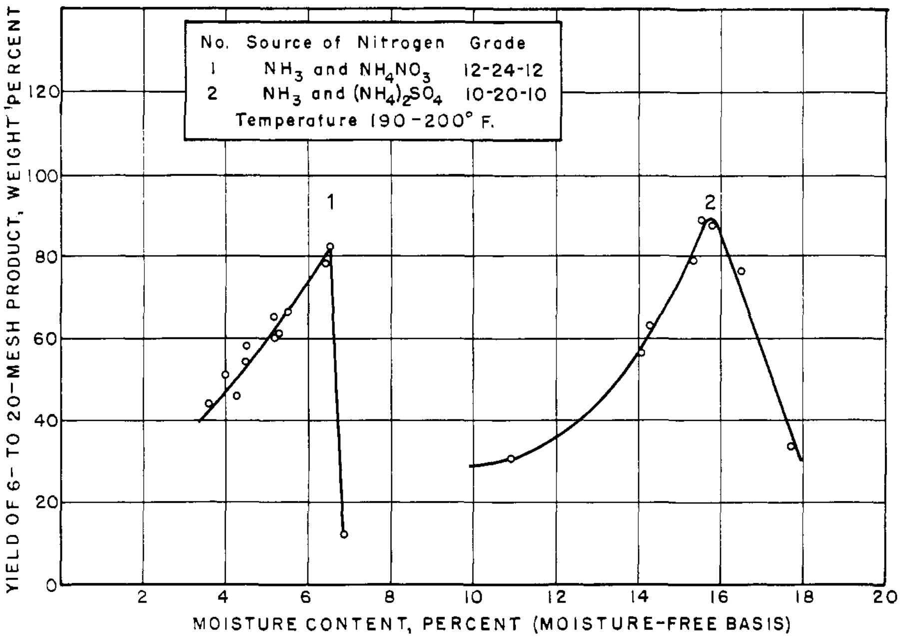


Figure 2. Variation in agglomeration with moisture content of 1:2:1 ratio fertilizers

were formulated with triple superphosphate, potassium chloride, anhydrous ammonia (4 pounds per 20 pounds of phosphorus pentoxide), and the remainder of the nitrogen from either ammonium nitrate (Mixture 1) or ammonium sulfate (Mixture 2). The substitution of ammonium sulfate for ammonium nitrate in the formula decreased the grade from 12–24–12 to 10–20–10. The optimum yields of 6- to 20-mesh products in Mixtures 1 and 2, respectively, were 82% at 6.5% moisture and 89% at 15.8% moisture. Increasing the moisture content of Mixture 1 as little as 0.4% above that required for optimum agglomeration (6.5 to 6.9%) yielded a preponderance of oversize granules and decreased the yield of 6- to 20-mesh product from 82% to 12%. This tendency toward overagglomeration with slight excess of moisture above that required for optimum agglomeration was not as pronounced with Mixture 2. In this case an excess of 1% moisture would appear to lower the yield of 6- to 20-mesh product from 89% to about 60%. The sensitiveness of ammonium nitrate mixtures to excess of moisture over that required for optimum agglomeration was observed throughout the course of this study. These results indicate that, with mixtures high in ammonium nitrate, overagglomeration can be avoided and somewhat lower but more consistent yields of product in the desired particle size range can be obtained by agglomerating at a lower moisture content than that required for optimum agglomeration. For example, the results for Mixture 1 indicate that agglomeration with 5 to 5.5% moisture gives consistent yields of 60 to 65% product in the particle-size range of 6- to 20-mesh.

The effect of progressive increase in ammonium nitrate content on the moisture required for optimum agglomeration of complete mixed fertilizers is shown in Figure 3. The data represented by curve 1 were obtained on a series of 5 mixtures of 1:1:1 ratio formulated with ordinary superphosphate, anhydrous ammonia (6 pounds per unit of phosphorus pentoxide), potassium chloride, and varying proportions of ammonium nitrate and ammonium sulfate which supplied the remainder of the nitrogen. No filler was used in the preparation of the mixtures, so that grades ranged from approximately 9–9–9 to 11–11–11. Curve 2 represents data obtained with a series of mixtures formulated similarly, except that the phosphatic constituent was triple superphosphate and the degree of ammoniation was 4 pounds of anhydrous ammonia per unit of phosphorus pentoxide. The grade of the mixture varied from approximately 12–12–12 to 15–15–15. Curve 3 represents data on 1:2:1 ratio mixtures of the same type, with the grade varying from approximately 10–20–10 to 12–24–12. These data show the effect of increasing ammonium nitrate content on the moisture requirement for optimum agglomeration. The general pattern of this set of curves would probably hold for any nutrient ratio of high-analysis mixed fertilizer.

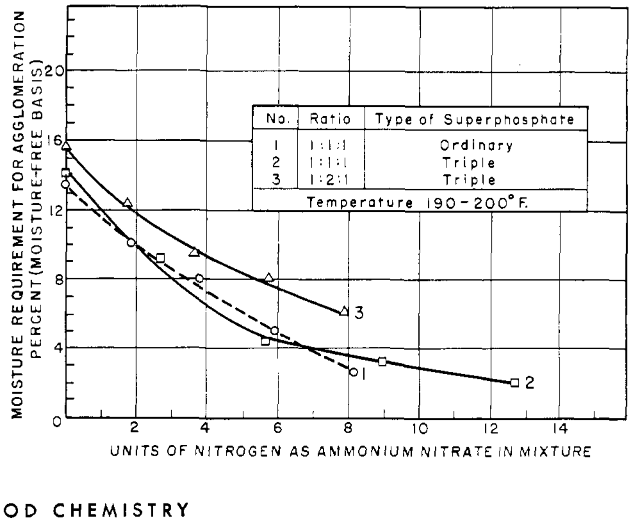
The nonlinear form of the curves in Figure 3 is the resultant of the interaction of the salts present on the moisture requirement. Accordingly, the effects of potassium chloride, ammonium sulfate, and ammonium nitrate on agglomeration were compared individually.

Individual Salt Effects on Agglomeration

The relative effects of ammonium nitrate, ammonium sulfate, and potassium chloride on the moisture required for optimum agglomeration of ammoniated triple superphosphate and of ammoniated ordinary superphosphate are shown in Figure 4. The degree of ammoniation was 4 pounds of anhydrous ammonia per unit of phosphorus pentoxide present in triple superphosphate and 6 pounds per unit of phosphorus pentoxide in ordinary superphosphate. The moisture required for optimum agglomeration of the ammoniated triple superphosphate alone was 21.8% and, of the ammoniated ordinary superphosphate, 14.9%. In general, an increasing proportion of soluble salt decreases the moisture requirement rapidly for the first increments of salt present, and less rapidly beyond about 10% salt content of the mixture. Ammonium nitrate was most effective in decreasing the moisture required for optimum agglomeration, followed by ammonium sulfate, and potassium chloride in that order. The decrease in moisture requirement with increase in the proportion of soluble salt may be attributed to the increase in volume of liquid phase, owing to its content of dissolved salt, and to the increased number of dense, nonporous, crystalline salt particles having a saturated solution at their surfaces, thus forming granule nuclei requiring less moisture to promote agglomeration than do the more porous superphosphate particles.

Maximum effect of ammonium nitrate in decreasing the moisture requirement at the agglomeration temperature (190° to 200° F.) appears to be reached

Figure 3. Effect of ammonium nitrate content on moisture required for agglomeration of mixed fertilizers



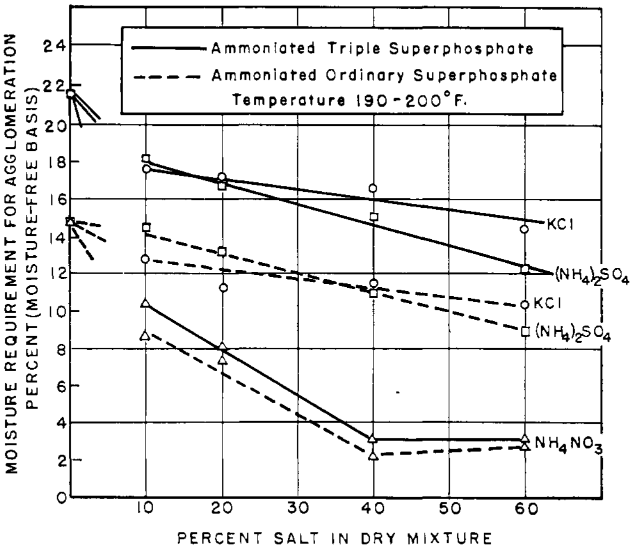


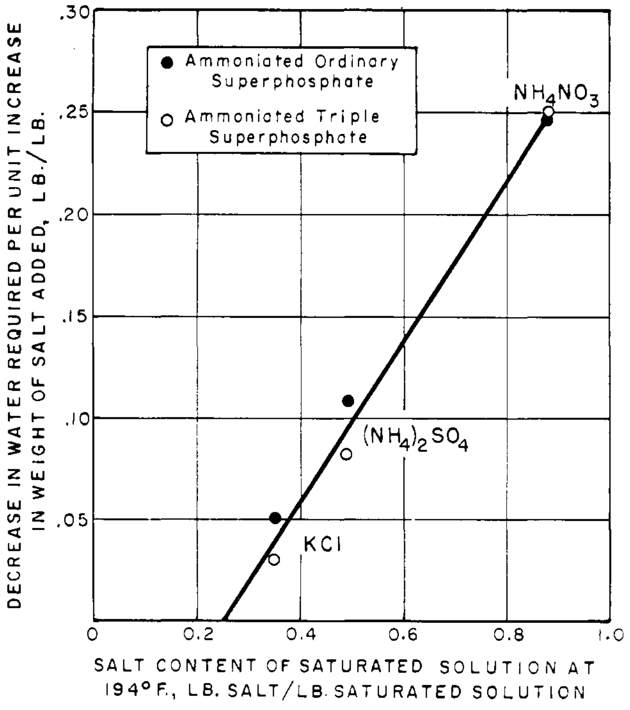
Figure 4. Effect of salts on moisture required for agglomeration of triple superphosphate and ordinary superphosphate mixtures

at about 40% salt content of the mixture. At this point the moisture requirement is about 3% or less. This is not enough water to dissolve entirely the solid ammonium nitrate present and the liquid phase of the mixture is probably saturated with respect to this salt. Under such conditions the moisture requirement for optimum agglomeration apparently remains nearly constant on further addition of solid ammonium nitrate.

Solubility The proportion of ammonium nitrate, ammonium sulfate, or potassium chloride in most high-analysis mixed fertilizers falls in the range of 10 to 40% (200 to 800 pounds per ton of mixture). Inspection of Figure 4 reveals that, for salt contents in this range, the moisture requirement for optimum agglomeration decreases linearly with increasing proportions of salt at about the same rate for both ordinary and triple superphosphate mixtures. This suggests a possible direct relationship between the solubility of the salt and its tendency to decrease the moisture requirement for optimum agglomeration. The rates of decrease in moisture requirement are indicated by the slopes of the curves in Figure 4—i.e., the change in the pounds of water required per pound of added salt over the range of 10 to 40% salt content. In Figure 5 the slopes of the curves in Figure 4 are plotted against the pounds of salt per pound of saturated solutions of ammonium nitrate (*8*), ammonium sulfate (*6*), and potassium chloride (*6*), respectively, at 194° F.

The linear form of this graph indicates that the tendency of the individual salt to lower the moisture requirement for optimum agglomeration is proportional to its solubility at the agglomeration temperature. This apparent effect of salt solubility on agglomeration is to be studied further with a greater number of salts.

Figure 5. Relationship between salt solubility and rate of decrease in moisture requirement for agglomeration



Mutual Effects of Salts The effects of individual salts on the moisture requirement are illustrated by the results in Figure 6, which show the effect on the moisture requirement obtained by varying the ratio of ammonium sulfate to potassium chloride in a series of mixtures containing 30% of one or both of these salts, 50% ammoniated superphosphate, and 20% ammonium nitrate. Curves 1 and 2 are for ammoniated mixtures prepared with triple and ordinary superphosphates, respectively. In both types of mixtures the moisture requirement for optimum agglomeration varied with the ratio of potassium chloride to ammonium sulfate and the minimum moisture requirement occurred at a ratio of about 2 to 1. As would be expected from the results shown in Figures 4 and 5, the results in Figure 6 continue to show that the individual effect of ammonium sulfate in reducing the moisture requirement is greater than that of potassium chloride.

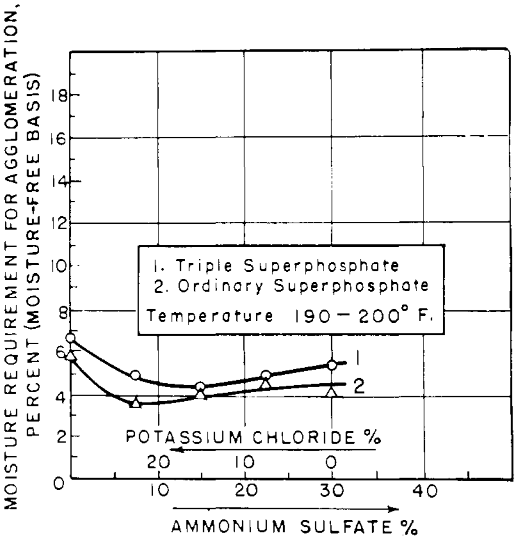


Figure 6. Effect of potassium chloride–ammonium sulfate ratio at 20% ammonium nitrate content on moisture requirement for agglomeration of mixtures

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