



Liquid vs. Solid

Fertilizers

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FERTILIZER materials which are in solution, moved and stored in tanks, and transferred through pipes by pumps or gravity are called "liquid fertilizers." Anhydrous ammonia is one example of a liquid fertilizer which is held under pressure. But aqua ammonia, a solution of anhydrous ammonia in water, is a liquid fertilizer which is not held under pressure. Nutrients supplied by liquid fertilizers must be water soluble so they are readily available to plants as long as they remain in solution.

To compare liquid fertilizers with solid forms, first of all, consider the various liquid fertilizers used to supply nitrogen (N), phosphorus (P), and potassium (K).

Ammonia Lost from Liquid

Anhydrous ammonia is ammonia gas kept under extreme pressure so that it is a liquid. This fertilizer, which contains 82% N, must be handled and applied with special high-pressure equipment.

Another widely used liquid nitrogen fertilizer is aqua ammonia; it is simply anhydrous ammonia dissolved in water. This fertilizer contains 15 to 25% N and is not held under pressure, and is much easier and safer to handle and apply than anhydrous ammonia.

Ammonium nitrate, and various ammonium phosphates, are sometimes added to aqua ammonia to obtain a higher ratio of N in liquid mixtures. These materials also are used alone to supply N, or both N and P. Nitrogen often is supplied as urea (a synthetic organic nitrogen

carrier) and also by various natural organic nitrogen carriers such as fish emulsions.

One of the difficulties experienced with anhydrous and aqua ammonia is the loss of ammonia by volatilization. This is detected by the smell of ammonia after the fertilizer is applied. When applied to acid soils, ammonia losses may be as high as 15%. On alkaline soils, volatilization losses can exceed 50%. Thus, to minimize loss, it is necessary to inject these materials below the soil surface. Application of anhydrous and aqua ammonia in irrigation water also greatly reduces volatile losses.

The other liquid forms of nitrogen mentioned usually do not volatilize when applied properly. Some of the inorganic forms of nitrogen can "burn" leaves when applied in high concentrations directly on plants. Organic sources of N, on the other hand, are less likely to burn leaves and are preferred for foliar applications.

Phosphorus Popular In Compound Form

Phosphorus is supplied in liquid form as phosphoric acid (H_3PO_4), and also as various ammonium and potassium phosphates. Phosphoric acid, which contains about 24% P is very corrosive and must be handled in stainless steel or rubber-lined containers.

Where soils are very alkaline, phosphoric acid is applied directly to the soil. In most areas, however, phosphoric acid is neutralized by adding aqua ammonia before application. These mixtures are much less corrosive than phosphoric acid, and or-

dinary steel containers can be used to handle them. Phosphorus found in liquid phosphorus fertilizer is completely water soluble which makes it readily available to plants.

Potassium Chloride: Most Common K Carrier

Muriate of potassium (KCL), or potassium chloride, probably is the most common carrier of potassium used in the liquid form. It is a solution of solid KCL in water. Sulfate of potash and potassium phosphate also are used as liquid carriers. Potassium solutions are very corrosive and proper care of equipment used to handle these solutions must be practiced. However, the addition of aqua ammonia to the KCL solution reduces its corrosive powers considerably.

Various mixtures of N, P, K, and their compounds are used to make liquid fertilizers at different N, P, and K ratios; for example, 15-2-4 and 6-5-10. These mixed fertilizers cannot contain more than about 20% total N, P, and K (by weight), because it is not possible to dissolve more in a given volume of water.

Oxide Statement Confuses

The expression of plant nutrients in the elemental form, P and K, rather than the oxide form, P_2O_5 and K_2O , is being done for greater clarity and simplicity. Although phosphorus and potassium have been expressed as oxides for many years, considerable confusion often occurs in discussing and reporting fertilizer trials, for example. Use of the oxide statement is actually incorrect, since these nutrients

are not in the P_2O_5 and K_2O form in fertilizers. These are some of the reasons national soil and agronomic societies recommend the use of the elemental form to denote plant nutrients. It is very simple to convert from one form to the other by multiplying by appropriate factors shown in Table 1.

Liquid vs. Solid Fertilizer

Now that some of the liquid fertilizers have been discussed, let us see how they compare with solid fertilizers.

Liquid fertilizers have several advantages over solid forms, and some are listed below.

1. Convenience in handling; i.e. by pumps and gravity.
2. Easy to obtain uniform mixtures and applications.
3. Easy to place in bands or rows.
4. May be applied with irrigation water.
5. Phosphorus availability increases.

Liquid fertilizers characteristically also have several disadvantages when compared with solids. For example:

1. Liquids corrode metal containers and other equipment.
2. Possibly, nitrogen is lost by volatilization of ammonia in some carriers.
3. Phosphorus is "fixed" in certain soils.
4. Total plant food in solution is limited to about 20%.

5. Larger quantities of liquids must be applied with some carriers to obtain equivalent amounts of plant food supplied by solid forms.

Crop Response Compares Forms

The response of crops to nutrients applied in the two forms is probably the most important comparison. Many experiments have been conducted to compare the yield response from liquid and solid forms of fertilizer. Generally, when properly used, equal response is obtained with anhydrous ammonia and nitrogen solutions as with the same amounts of actual N applied in the solid form.

The sugar industry in Hawaii conducted an extensive series of experiments comparing liquid

aqua ammonia and solid ammonium sulfate. No difference in yields of cane or sugar was found.

These results, as well as the fact that aqua ammonia was

cheaper than ammonium sulfate, encouraged the industry to shift from solid ammonium sulfate to liquid aqua ammonia.

Coastal bermudagrass yield response to liquid fertilizers was

Table 1. Oxide-elemental Conversion Methods.

Percent or Pounds		Multiply by factor		Converted to Percent or Pounds
Conversion from oxide to element				
P_2O_5	×	0.44	=	P
K_2O	×	0.83	=	K
Conversion from element to oxide				
P	×	2.29	=	P_2O_5
K	×	1.20	=	K_2O

Adapted from: Crops and Soils. 1962. 14: (6):5-7.

Table 2. Yield of Wheat Forage as Influenced by Source of P. (Norfolk sand loam, Alabama, 1957.)*

Source**	Form	(lbs./A) Dry Forage
None	—	1321
Concentrated superphosphate	solid	1923
Ammonium metaphosphate	solid	1925
Ammonium metaphosphate	liquid	1965
Diammonium phosphate	solid	1920
Diammonium phosphate	liquid	2047
Ammonium superphosphoric acid	liquid	1837
	LSD (.05)	453

*Adapted from: Lathwell, D. J., Cope, J. T. Jr., Webb, J. R. 1960 Agronomy Journal 52:251-254.

**P applied at 9 lb. (20 lb. P_2O_5)/A banded in the row.

Table 3. Comparison of Liquid and Solid Fertilizers for Coastal Bermudagrass (Cecil sandy loam, Athens, Georgia, 1962.)*

Treatment	Pounds per acre N-P-K	Forage yield /A (Oven-dry) Total of 4 clippings
1. Liquid 14-3-6	100-22-42	2871
2. Solid 16-3-7	100-22-42	3494
3. Liquid 14-3-6	200-44-84	5161
4. Solid 16-3-7	200-44-84	7073
5. Liquid N sep.		
Liquid H_3PO_4 and KCl sep.	200-44-84	6025
6. Liquid N & H_3PO_4 mixed		
KCl sep.	200-44-84	6673

*Adapted from: Morris, H. D. 1964. Georgia Agr. Res. Ga. Agr. Exp. Sta. 5:16. (Fertilizer ratios in the original article were in terms of P_2O_5 and K_2O .)

Table 4. Comparison of Liquid and Solid Forms of N for the Application of 50 lb. N per Acre of Turf.

Form of Fertilizer	Liquid	Solid
Source of N	NH_4NO_3	$(NH_4)_2SO_4$
%N in concentrated material	17	21
Dilution of material for application	1:60	none
%N in applied material	0.4	21
Amount of conc. material for 50 lb. N/A	26 gal.	238 lb.
Amount of diluted material applied /A	1,560 gal.	238 lb.
Weight of material applied /A	12,500 lb.	238 lb.

compared to that from solid fertilizers in Georgia. Some data are presented in Table 3. A comparison of treatments 1 and 2, and treatments 3 and 4, shows that liquid fertilizers gave lower yields than solids; this difference being greater at the higher rate of application. The author of that article states that yield differ-

ence may be due to plant poisoning by the liquid fertilizer, since foliage on plots that received liquid fertilizer, in any form, was injured. Injurious effects disappear about two weeks after application. The liquid nitrogen used was composed of one-half urea and one-half ammonium nitrate. Concentration of the fer-

tilizer solution was not given, but it appears that the concentration was too high because leaves were burned.

A comparison of treatment 5 with 6 shows a 648-lb. difference in yield in favor of treatment 6. The only difference between these two treatments is that liquid nitrogen in treatment 6 was applied separately, followed by H_3PO_4 . The liquid in treatment 8 was mixed with the H_3PO_4 before application, and they were applied together. The author suggests this increased yield is due either to a reduction in loss of nitrogen from urea in the nitrogen solution, a decrease in the phytotoxicity of the materials from mixing, or a combination of these factors. These data emphasize the fact that application of liquid fertilizers in too high concentration can seriously damage grass.

Equal crop response, therefore, has been obtained from the proper application of either liquid or solid forms when the same amount of actual N, P, and K has been applied.

Should You Use Liquid or Solid?

Since liquid and solid fertilizers give the same yield response, which form should be used? In order to answer this question, one must evaluate several factors concerning these two forms of fertilizer. Two of the most important factors are relative cost per unit of plant nutrient and application costs of the two materials. Also considered must be the relative concentrations of nutrients in the final volume of applied material.

Data in Table 4 illustrate some calculations which should be made during the evaluation of the two forms. A liquid nitrogen fertilizer containing 17% N, such as ammonium nitrate (NH_4NO_3), is compared with a solid nitrogen fertilizer containing 21% N, ammonium sulfate ($(NH_4)_2SO_4$). The liquid material weighs about 11.5 lbs. per gallon and is supplied in 30-gal. drums, while the solid material comes in 80- or 100-lb. bags. Manufacturers recommend

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.....Book Review.....

Management of Artificial Lakes and Ponds

by George W. Bennett, Reinhold Publishing Corp., 430 Park Ave., N. Y., N. Y. 10022, 1962, 283 pp. \$8.00.

Management of Artificial Lakes and Ponds deals with a complex subject. But the author displays an intimate knowledge of limnology, ecology, botany, zoology, ichthyology, conservation, and control, which enables him to sift practical information from a voluminous bibliography of technical material. He includes in his text adequate theory and a maximum of useful advice for those interested in water management.

Contents vary from the history of fish culture, through a discussion of kinds of excavated water bodies as possible habitats for game fish, to a consideration of fish as a productive crop, their reproduction and mortality.

The most important chapter for readers of this magazine is called "Theories and Techniques of Management." Included in this section are subjects of rough fish control and aquatic weed control. Both are dealt with from a management standpoint.

Information on weed and water relationships is invaluable to controllers who seek to make the best possible use of water without nuisance weeds. *Management* is not a handbook for removal of aquatic weeds from standing water, even though it contains a chart of recommended materials and rates to control various weeds. It is designed for the lake manager, whose duty ranges widely, but it is equally

useful to the aquatic weed controller seeking new markets for his service. If aquatic weed controllers expect to cultivate business from commercial, municipal, or state recreational establishments, they will have to be familiar with the ideas, and needs of lake, pond, or aquatic game managers. This book helps to supply that familiarity.

Management is easy to read. Author Bennett's style reflects many years of association with people who knew less about limnology and ecology than he, and who wanted to learn. His book conveys concepts in an understandable way: "Prospective homeowners who contemplate purchase of lots for permanent homes on small lakes should insist on a sewage (septic) system which will carry all effluents away from the lake. Effluents from tile fields enter the lake, and because they carry phosphates and nitrates, they act as fertilizers which stimulate aquatic vegetation and create nuisances."

Bennett is a writer with humor: "One type of *Spirogyra* (algae) is notoriously slippery, and once I saw a bather slip and sit down at the top of a steep spirogyra-covered lake spillway and slide entirely to the bottom before he could stop . . . Needless to say, he repeated the act until the algae as well as the seat of his bathing suit was practically gone."

Judging from the scant number of books on this subject, *Management of Artificial Lakes and Ponds* is welcome, and just in time, if not a decade overdue.

cessful but there is need for a better method of making this material stick to annual grasses through the entire fire season, because light rain or heavy winds can dissipate this material.

Testing Growth Inhibitors

Growth inhibitors are being tried under varying climatic conditions. As yet no material or method has been found to control annual fire hazardous vegetation at a height that would make it unnecessary to mow. Some satisfactory results have been obtained on inhibiting the growth of shrubs that formerly were pruned often, such as those around headlight screens in narrow median divider strips, or shrubs in planter boxes on freeway islands that must be kept low for sight distance. These plants can be sprayed rather quickly in comparison to the time it takes to prune and haul the brush, to say nothing of the hazard caused to the traveling public and the men doing the work.

We believe that one of the greatest needs is for effective growth inhibitors, or better methods to apply these growth regulators that can be used at different times of year and will not cause noticeable damage to the plant.

The past year has seen increased use of contact sprays on freeway ground cover plantings. These materials are being used to edge ice plant and ivy, doing away with a very expensive method of cutting with mechanical edgers and the problems of hauling and disposal after cutting.

Built Versatile Spray Rig

A number of different types of spray rigs are used by the spray crews in different areas of California. Several years ago the Division of Highways Equipment Department took a commercially available hydraulic boom and adapted it for use on the front of the spray truck so the equipment operator could work from the cab and both he and the driver could see the spray operation. This boom has three 8 ft. sections that can be operated in-

dependently of each other to follow the contour of the ground or be moved out of the way of obstructions. Nozzles in each section may be independently or collectively operated. During the past year a further improvement in spray equipment has been made by the Equipment Department. A 2000 gal. tank was mounted on a truck frame with two 60 gal. stainless steel tanks mounted behind the large tank. Two separate chemicals may be mixed in a heavily concentrated form in each of these tanks; a proportioner pump will measure and mix the material from either or both 60 gal. tanks at any rate per acre that is desired.

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that 1 quart of the concentrated liquid fertilizer be diluted to 15 gals. with water (1:60 dilution) and applied to 500 sq. ft. of turf, approximately 0.01 acres. Nitrogen concentration in this diluted solution is about 0.4%, and when applied at the recommended rate it will supply about 50 lbs. of N per acre.

It will require about 26 gals. of the concentrated liquid to supply 50 lbs. of N per acre of turf. When this is diluted 60 times, volume will be 1,560 gals. which weigh nearly 12,500 lbs. In contrast, ammonium sulfate, which does not require dilution, will supply 50 lbs. of N in 238 lbs. of material.

When liquid fertilizers are applied by broadcast methods to turf or foliage, considerable dilution must be made to prevent plant injury. This dilution results in a marked decrease in the amount of nutrient contained in a unit of the diluted solution and makes large-volume application necessary.

An alternative procedure would be to inject it in a more concentrated form below the ground surface to minimize burning. However, this can be an undesirable practice for turf. Another solution to the problem is to apply concentrated liquid forms into the irrigation water

The 2000 gal. tank needs to carry only water, so the unit may be taken off vegetation spraying and be used for watering planted trees and shrubs without the need of cleaning out tanks or the danger of some chemical being left in the unit after cleaning which might damage plantings.

Different areas of the state of California, variable climatic conditions and diversified land use adjoining the highways and freeways, call for different methods of vegetation control. We feel we have been progressive in trying new chemicals and developing new equipment for this program.

when sprinkling and avoid hauling the large quantity of water. Various metering devices can be obtained for this purpose.

The fact that a large quantity of diluted material is necessary when using liquid fertilizers on turf does not mean that liquid forms are more costly than solids. Ease of handling liquids by pumps or gravity, and their application in irrigation water, may keep cost of using liquid fertilizers relatively low. However, each operator must decide this on the basis of what handling and application costs are for his set of conditions and with his facilities. The cost of the *entire* operation must be considered when the decision is made.

Liquid and solid fertilizers, when properly applied, have been equally effective in producing crop response when compared on a per-pound-of-plant-food basis. In the use of each form, there are certain advantages and disadvantages, and these must be considered. Under certain conditions, the increased ease of handling liquids by pumps or gravity and application in irrigation water or by other means may make liquid fertilizers most economical. Hence, cost to handle and apply the two forms must be considered as well as the cost per unit of plant food in the two forms of fertilizer.