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Regulation of Sodium Arsenite as an Injurious Material

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Effective January 1, 1962, sodium arsenite was placed under regulation as an injurious material. Since then, persons intending to use it in California have been required to obtain a permit from the county agricultural commissioner. In addition, it is illegal to sell or deliver it to persons who do not have the required permit.

The regulation was adopted after public hearing and consideration of the history of accidental deaths over the years as well as injury to property.

Section 1080 of the Agricultural Code provides that "after investigation and hearing the Director shall adopt rules and regulations governing the application, in pest control or other agricultural operations, of any material he finds and determines to be injurious to persons, animals, or crops other than the pest or vegetation it is intended to destroy."

Section 1080.1 of the Code provides that "it is unlawful to use any form of 2,4-Dichlorophenoxy acetic acid (2,4-D) or other herbicide which the Director' finds and determines, after hearing, to be injurious to crops, except as provided in this Section and the rules and regulations of the Director."

Based on this authority two sets of regulations have been adopted by the Department, one pertaining to injurious materials and the other pertaining to injurious herbicides.

Since sodium arsenite is used not only for herbicidal purposes but for control of many other pests it was placed in the injurious materials regulations.

There have been some questions asked in connection with interpretation of the regulation that you may be interested in.

One question that occasionally arises is whether a permit is required for all uses of sodium arsenite or if some uses are exempt.

As just mentioned, Section 1080 of the Agricultural Code provides the Director authority, after investigation and hearing, to adopt rules and regulations governing the application, in pest control or other agricultural operations, of any material which he finds and determines to be injurious to persons, animals, or crops, other than the

pest or vegetation which it is intended to destroy. Thus an injurious material sold for weed control or control of a plant disease or of a micro-organism is subject to the requirement of a permit. On the other hand, if sodium arsenite is sold for a non-agricultural and non-pesticidal use, for example, in metallurgy, or in drilling to facilitate the operation mechanically, the use would not be subject to the requirement of a permit.

All sizes of sodium arsenite pesticide containers are subject to the requirement of a permit; however, there is an exemption in that no permit is required to use products sold as dilute ready-to-use syrups or dry baits, registered and labeled for use as poison baits for the control of insects and other arthropods, snails and slugs, or rodents.

Sometimes the question arises whether use of the organic arsenic compounds sold for control of crabgrass require a permit. The regulations apply to sodium arsenite only, including any preparation of arsenic trioxide or arsenous acid with sodium hydroxide or sodium carbonate, which contain as an active ingredient arsenic, all in water soluble form. The organic compounds include such materials as disodium methylarsonate, octyl ammonium methylarsonate and dodecyl ammonium methylarsonate. Since these materials are not prepared from arsenic trioxide and sodium hydroxide or sodium carbonate they are exempt from the requirements of the regulations.

Where persons intend to use sodium arsenite for a purpose that is not directly related to agriculture they sometimes are uncertain about the need for a permit. For example, sodium arsenite is recommended by the University of California Agricultural Extension Service for control of submerged aquatic weeds and such a use requires a permit.

Occasionally persons ask if sodium arsenite intended for application to roadbeds or areas to be blacktopped requires a permit. They are probably doubtful because this seems to be a non-agricultural operation. Since the use of blacktop is for control of weeds, a pesticide use, a permit is required, even though it may not involve agriculture. In this connection the Department has distributed an announcement to architects and contractors pointing out the dangers of sodium arsenite, that it can be used

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only under permit, and that there are alternative materials available for soil sterilization.

After the regulations were adopted manufacturers of sodium arsenite realized the market would be considerably reduced and they commenced recommending other herbicide formulations. One of the materials that has received increased attention is the herbicide erbon and its formulations with other materials. Erbon is 2-(2,4,5-Trichlorophenoxy) ethyl 2,2-dichloropropionate and is a compound of the alcohol 2,4,5-Trichlorophenoxy ethanol and dichloropropionic acid. Its uses does not seem to present the hazard that 2,4-D and 2,4,5-T offer, it has not been placed under a regulation as an injurious herbicide, and of course its use does not require a permit.

One of the manufacturers that had a considerable business in sodium arsenite for herbicidal use around homes proposed a new formulation containing petroleum oil, prometone, and 1% 2,4-D. A hearing was held on the petition of this firm and the injurious herbicide regulations were amended to exempt formulations containing up to 1.25% of injurious herbicides from the requirement of a permit.

Regulation of sodium arsenite to prevent loss of life and property was considered for many years. The injurious materials regulations were amended to regulate it after a public hearing in Sacramento in May 1961. In support of the need for the regulation there is the history of accidental deaths, particularly of children, by poisoning. The fatalities frequently occurred in a similar manner in that homeowners would buy a small container, often a one-quart size, and take it home to sterilize the soil in driveways or areas near sidewalks. The homeowner would leave it either in the original container or transfer some to an empty soft drink or other beverage or food container readily at hand. Small children playing around the home would gain access to this container, drink some of the material, and almost invariably death would follow. There

have also been reported deaths where large scale commercial use of sodium arsenite was involved where the material was placed in a second container without label or identification and a person would drink from it.

In addition to accidental deaths there have been a great many instances where the material has been used and caused injury to valuable plants through leaching in the soil because the user did not realize how readily the material could migrate.

In addition to requiring the user to obtain a permit from the agricultural commissioner, the regulations prescribe certain conditions to be met by those who possess or use sodium arsenite as follows:

(a) No pesticide containing sodium arsenite shall be applied on exposed vegetation (other than dormant grapevines) unless the vegetation to be treated is enclosed within a good and sufficient fence or otherwise made inaccessible to grazing animals, pets, and children.

(b) No pesticide containing sodium arsenite shall be applied on soil or vegetation (other than dormant grapevines) in any area penetrated by roots of any plant of value, without the written consent of the owner of such plant.

(c) No pesticide containing sodium arsenite shall be kept or placed in drinking cups, pop bottles, or other containers of a type commonly used for food or drink.

(d) No pesticide containing sodium arsenite, whether in concentrated or dilute form, shall be stored, placed, or transported in any container or receptacle which does not bear on the outside a conspicuous poison label which conforms to the label required to be placed on all packages of arsenic compounds and preparations sold or delivered within the State.

These are only procedures that any careful person would observe in the use of a poisonous material like sodium arsenite.

Substitute Herbicides for Sodium Arsenite

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If we look back in history, compounds containing arsenic have been useful to man in a number of ways for centuries. Hippocrates, the father of medicine, in the 5th century B.C., recommended a paste of the sulfide of arsenic for the treatment of ulcers and similar disorders! It was during a later era that the toxic properties of arsenic became fully appreciated, when certain of them were put to extensive use by professional poisoners of the Middle Ages.

Records indicate the first use of arsenic as a pesticide in the 17th century when mixtures of white arsenic and honey were used as an ant bait.² Later with the appear-

ance of smelting processes for lead, copper, zinc, and iron, relatively crude arsenic compounds became available in increased supply. White arsenic and sodium arsenite came into widespread use as herbicides from 1900 to 1910. Sodium arsenite was first used as a selective weed killer on sugar cane in the Hawaiian Islands. Beginning about 1914 the railroads in America were using countless tons of arsenic as a non-selective contact and soil sterilant.³ By 1917 sodium arsenite was recommended for field bindweed control here in California, and in 1922 the California Department of Agriculture reported that, with one exception, all of the commercially available herbi-

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cides contained arsenic. From the 1930's to date we have seen a rapid progression of new herbicides including, interestingly, some new forms of less poisonous arsenic.

The early medicinal use of arsenic notwithstanding, the inorganic forms of arsenic - the sodium, calcium, and lead salts of arsenic as well as arsenic trioxide - are very poisonous agents. The annual review of news articles by the press reporting accidental poisoning, usually of children and often pets and livestock, attest to the hazards associated with the indiscriminate use of arsenicals by the lay public. The California Department of Agriculture is to be commended for adding the more poisonous arsenicals to the Injurious Materials list. The act of obtaining a permit will emphasize the need for exercising appropriate caution in applying, handling, and storing these compounds.

To discuss substitute herbicides for sodium arsenite as well as for other inorganic arsenicals, we need to look at the various uses of these materials in weed control.

As mentioned earlier, sodium arsenite has been used for years as a contact herbicide. At a 1% concentration, based on active arsenic trioxide equivalent, sodium arsenite will give complete non-selective top-kill. At reduced rates it is occasionally used as a selective contact in grass turf for the control of crabgrass, annual bluegrass, chickweed, and other weeds. As substitutes, weed oil, dinitro, and pentachlorophenol are widely known and used in general contact sprays. More recently, water soluble herbicides such as endotal, diquat, and paraquat are coming into use for top-kill treatments. In turf weed control, the relatively recent group of organic arsenicals including disodium methyl arsonate, ammonium methyl arsonate, calcium propyl arsonate, are very effective as selective foliar herbicides for the control of established crabgrass - and are much more selective, I might add. Dalapon is very useful at 5#/A or less for grass control in dichondra. Cacodylic acid (dimethyl arsenic acid) is finding use as a non-selective herbicide for turf renovation. One should note that while these organic arsenic compounds are from 2.5 to 5 times less toxic than their inorganic counterparts, label precautions for these and all pesticides should be studied and adhered to.

Sodium arsenite is hard to beat for the control of submerged aquatic weeds in static water. However, for alternative herbicides there is endotal, silvex, granular 2,4-D, acrolein, weighted emulsions of aromatic solvents, and chlorinated benzene. These compounds are not completely interchangeable for all uses and requirements made of reservoirs and farm ponds. Acrolein, aromatic solvents, and chlorinated benzene are toxic to fish, silvex should not be used in irrigation or livestock water, etc.

The phenoxy, 2,4-D, closed the chapter on the acid arsenical sprays as a foliar applied translocatable herbicide in the 1940's. Since then the phenoxy family of foliar herbicides has grown to include MCP, 2,4,5-T, 2,4,5-TP (silvex) in the parent acid form, as well as both water soluble and oil soluble forms and the emulsifiable

esters. In addition we have amitrole, dalapon, and Banvel-D.

It was in the non-selective soil sterilant category that sodium arsenite and arsenic trioxide were most effectively utilized in vegetation control. In lower rainfall areas, sodium arsenite applied at heavy rates may be effective for four successive years.⁴ There are, today, a host of herbicides that are effective substitutes for sodium arsenite and arsenic trioxide. Inorganic herbicides such as borates, chlorates, borate-chlorate mixtures; and the growing organic group, the substituted ureas including monuron and diuron, the triazine family of chemicals including simazine, atrazine, and prometone, the uracils including isocil and bromocil. Then we have the mixtures of these and other herbicides including monuron TCA, erbon, simazine + amitrole, etc. Fumigants such as methyl bromide and CS₂ are effective short-lived sterilants. Again, all these materials are not logically interchangeable for one another for all weed control situations. Their choice should be influenced by economics, weed species to be controlled, crops or ornamentals to be protected, expected precipitation, soil type, etc.

Many of the alternative herbicides I have mentioned are available in the small package line for the home owner. Wisely employed, these weed destroying chemicals can beautify the home while taking the drudgery out of the means to this end. But, for the uninitiated home owner, beware of indiscriminate use. Read the label on the container; discuss your problem with experts. They can often suggest means of gaining the desired end - dead weeds - and point out pitfalls to avoid. These herbicides, as the term implies, are highly proficient in destroying vegetation. Weeds in your brick patio, for example, can be controlled; but the wrong herbicide selection, or the improper use of the right one, can take out your prized shade trees as well. The adage - "If a little bit is good, more is better" - may work with paint bucket and brush on the side of the house, but can be ruinous in both the back 40 and the back yard where herbicides are concerned.

In the realm of selective soil sterilization we should consider substitutes for lead and calcium arsenate in crabgrass control in turf. Within the past five years several excellent preemergent crabgrass herbicides have been made available by industry. Zytron and Dacthal are examples. Betasan is a more recent comer that looks promising in both grass turf and dichondra. Both monuron and neburon can be used selectively in dichondra. Bandane and trifluralin may be available in the near future for grass turf.

Certain uses of inorganic arsenic herbicides have, by natural course of events, already been displaced in some areas of weed control. Inorganic arsenicals remain available and, in terms of weed control performance, are reliable herbicides. These are available to both the large and small consumer. The important objection to them down through the years has been the great poison hazard. Where this is a prime consideration in your selection of an

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herbicide, there are substitutes available to you for non-selective contact sprays, for selective sprays in turf, in aquatic weed control, in foliar translocatable herbicides, and in both selective and non-selective soil sterilization.

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The Effects of Traffic on Turfgrasses

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The ability to withstand harmful effects of traffic is a requisite of most turf. The damage inflicted on turf may be of several types. Simple weight or pressure on the turf will crush leaves, stems and crowns of the grass plant. Most pedestrian and machine traffic, however, also exerts a scuffing or tearing action, greatly increasing the damage to the plant parts.

Football fields, golf tees and golf fairways are subjected to the most severe damage of all, entire pieces of the turf frequently being torn or chopped loose. Unusual, recuperative ability is demanded of the turf here in addition to wear resistance.

One effect of traffic is less visible than those mentioned above, but no less important. This is the compaction of the soil which in turn restricts the growth of grass roots and tops.

Any traffic which may damage leaf stem or root tissue may predispose the turf to disease by providing entryways for the disease organisms.

Until recently little information was available about the comparative wear resistance of turfgrasses and the factors affecting this resistance.

Ferguson¹ reported results of studies at Texas A & M during 1958 and 1959. These studies compared the turf damage on bentgrass greens resulting from shoes of three types, ripple sole, conventional spike and modified spike. The modified spike shoe had the spike receptacle and supporting disk between the inner and outer soles of the shoe. Thus only the actual spike was exposed.

The wear treatments, simulating actual putting green use, were ten minutes of traffic daily for five weeks. Of the three types of shoes, one pair of each was used on different three-foot square plots.

After the five weeks of traffic, the plots were badly worn where the conventional and modified spikes were used, but only moderate damage was observed on plots where ripple sole shoes were used.

The plots were evaluated for recovery following a six-weeks traffic-free period. Full recovery was noted on the ripple sole and modified spike treatment plots. Conventional spike treatment plots had recovered only partially and weeds had invaded.

Ferguson attributed these results to increased soil compaction resulting from the exposed shoulder around the conventional spike.

Turfgrass wear resistance studies were conducted at UCLA during a three-year period (3, 4). A power-driven device designed to produce measurable amounts of specific types of wear was used in most of these studies (2).

From these studies it was possible to determine com-

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parative wear resistance values for many of the common turfgrasses. Zoysiagrasses, bermudagrasses and tall fescue were found to be highly wear resistant and Kentucky bluegrass, perennial ryegrass and red fescue moderately resistant. All bentgrass varieties and dichondra were low.

The presence of crabgrass, *Poa annua* and broad-leaved weeds lowered the wear resistance of all types of turf.

Stoloniferous grasses (*Zoysia* and bermuda) were the only ones able to completely recover and crowd out weeds. Tall fescue and perennial ryegrass turfs became open and bunched. Soil compaction was great and undoubtedly was an important cause of the poor recovery.

Studies comparing several varieties of bermudagrass showed that Sunturf and U-3 were most wear resistant, followed by Ormond, Texturf 1-f (T-35A) and Uganda in that order. Tifgreen and Tifway were not available for testing at that time. However, recent observations indicate that they are perhaps comparable to Sunturf.

Sunturf recovered most rapidly and Uganda the slowest. There was no significant difference in recovery rate between the other three varieties.

It was observed in these studies that high clipping increased the wear resistance of all varieties. This was in part the result of greater amounts of leaf and stem tissue, a thicker thatch or cushion.

Soil moisture was an important factor also. An excessively wet or dry soil significantly lowered wear resistance of all turfs.

Other studies compared the effects of high (2 inches) and low (1/2 inch) clipping over a three-year period on wear resistance of several cool season grass mixtures.

All plots were maintained at 1 1/2 inches for 4 weeks prior to the wear tests. Thus, the tests evaluated the effects of the previous mowing practices and not of the

amount of grass material at the time of testing.

It was found that the previous close clipping significantly lowered the wear resistance of all mixtures (Bluegrasses, fescues, ryegrass, and colonial bentgrass in various combinations) compared to the high clipping. As all plots were at the same height when tested, this difference reflected the deleterious effect of the earlier close clipping on turf vigor.

Some cultural recommendations may now be made to improve quality and wear resistance of turfs subject to heavy traffic.

1. Select wear resistant grass varieties.
2. Mow as high as permitted by other requirements of the turf.
3. Distribute the traffic as evenly as possible over the turf to avoid concentration of wear.
4. Try to maintain a moist but not excessively wet soil during the traffic period.
5. To speed recovery, alleviate soil compaction as quickly and thoroughly as possible.
6. Follow good weed control practices.
7. Follow a program of fungicide treatments to prevent disease. Always apply a broad spectrum fungicide after a period of extra heavy traffic.

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The Chemical Control of Puncture Vine

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A major breakthrough on puncture vine, one of the State's worst weeds, was recorded by California Department of Agriculture weed control specialists with the completion of three years of field plot trials in 1962.

The trials, designed to control roadside infestations, were requested by County Agricultural Commissioners seeking more economical and positive control methods.

Analysis of the problem showed that a preventative and maintenance program should be developed.

The first step was to find a soil sterilant that would be: (1) highly toxic; (2) comparatively insoluble; and (3) would persist in the upper soil surface. Price-wise the material should be economical.

Initial trials were conducted in Butte County. To explore wider environmental conditions, the trials were repeated in Siskiyou, Madera, Merced, and San Bernardino

Counties.

The soil sterilant list included fenac, 2,3,6-trichlorobenzoic acid, atrazine, simazine, prometone and amitrole. The sodium salt and amide forms of fenac were tried at the rates of 2,4 and 6 pounds of acid equivalent per acre. Trichlorobenzoic acid was tried at the same rates. Atrazine, simazine, and prometone were tried at higher rates.

Concerning relative toxicity, statewide soil sterilant trials showed that (1) fenac was highly toxic to puncture vine; (2) trichlorobenzoic acid closely followed fenac; and (3) puncture vine tolerated amitrole and the triazine compounds.

At Chico, plots were established January 13 and March 9, 1960. These plots in the first season received 14.8 and 4.22 inches of rainfall, respectively. In other

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areas of the state, fall, mid-winter and spring applications were made. Plot trials and field operations over a period of three years indicate that good results with fenac can be expected when four inches of rain on heavy fertile soils and about two inches on infertile and sandy soils follow application.

The optimum lethal rate of fenac, as the sodium salt, was found to be four pounds of acid equivalent in a hundred gallons of water per acre. The sodium salt of fenac was registered as Fenac Industrial by Amchem Products, Inc., with the California Department of Agriculture on November 18, 1960. It contains 1 1/2 pounds of fenac (2,3,6-trichlorophenylacetic acid) per gallon of product. The more insoluble imide form of fenac compared very favorably to the sodium salt, but it has not been registered.

Fenac is selective for members of the grass family. Hence, where heavy grass populations are encountered, this type of plant competition can be encouraged with the selective use of fenac.

Concerning other aspects of its use, we are not sure about its fate in the soil, its ability to stay put, and what affect it might have on trees where the roots underlay the treated area. Minimum lethal amounts apparently do not persist in the soil; hence, the remaining soil residue probably will not be lethal in the following year. As puncture vine is a highly prolific annual, any practical control program should be aimed at obtaining complete destruction of seedlings. Therefore, it is our recommendation that at least four pounds of fenac per acre be applied to the previously treated areas in succeeding control operations until puncture vine in the area is no longer a problem, or until such time that a few surviving plants can be economically controlled with foliar sprays alone.

As fenac is a hormone-type material, spray drift to susceptible broad-leaved crops should be avoided. Tests have shown that very small amounts of the material can injure most vegetable crops. The manufacturer's label statement advises that fenac should not be stored near fertilizers and fungicides. It is our recommendation that the label instructions and precautionary measures should be carefully followed.

In our attempt to find effective foliar sprays for spot treating for maintenance control, we tried the following: Dicryl², Karsil³, TD-47 (endothol)⁴, Endothol Harvest Aids, amitrole, amitrole-T, atrazine⁵, atratone⁷, and prometone⁸.

The systemic herbicides amitrole-T and amitrole showed promise. Both formulations were explored at the rates of 2, 4, and 8 pounds of active material per acre. Amitrole-T had very little advantage over straight amitrole. Although amitrole was a fairly satisfactory herbicide, it was slow in killing treated plants and, in some cases, plants survived. Our next step was to find something that could be combined with amitrole to increase its effect. Of several materials, atrazine proved the most effective. its effect is apparently contact in action. The best com-

ination was found to be three pounds of actual amitrole plus one pound of actual atrazine per acre. The herbicide was applied at the volume rate of 100 gallons to which was added eight ounces of X-77.

In repeated trials we found for spot treating that 300 gallons of solution per acre was required to wet puncture vine thoroughly. On this basis we found that one pound of actual amitrole and 1/3 pound of actual atrazine gave effective control. To completely destroy puncture vine plants, it is necessary to spray the entire plant. The proper time to spray puncture vine is when it is young and actively growing and before seed pods develop. Actually, the best practice is to spray the plants before they have produced blossoms. All recurrent seedling growth must be sprayed if control is to be effective.

Puncture vine sprayed with the amitrole-atrazine combination declines slowly and three or four weeks may elapse before the plant dies. In the case where nearly mature vines are treated, some of these may eventually recover. To increase toxicity of the combination, we conducted surfactant trials during the summer of 1962

Plots, employing a constant rate of three pounds of actual amitrole and one pound of actual atrazine per acre with variable rates of surfactants, were established. To fully test the relative capacity of the surfactants, near mature puncture vine was factants included two proprietary products, kerosene and the U.S.P. grade of propylene glycol. The trials were begun on June 26 and final readings were taken on Sept. 20. A long time was required to obtain the final readings because nearly mature plants had been purposefully selected for the trials. We would not ordinarily spray plants that had nearly matured.

Of the several surfactants tried, propylene glycol emerged as the most feasible additive. Compared to several of the other surfactants, the initial results with propylene glycol appeared disappointing. However, in the latter stages of plant decline, propylene glycol emerged as an extremely effective surfactant. We found that propylene glycol at one and two quarts per hundred gallons of spray solution greatly enhanced the toxicity of the amitrole-atrazine combination. We believe that for young immature plants one quart of propylene glycol per hundred gallons of solution is sufficient. The U.S.P. grade of the product in fifty gallon drum lots sells for \$1.70 a gallon and in five gallon lots it sells for a little under \$3.00 a gallon.

During the late winter of 1961-1962, the Butte County Department of Agriculture, following our recommendations, treated 74.5 acre miles of roadsides with fenac as a
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- 2-3. Products of Niagra Chemical Division, Food Machinery Chemical Corp.
- 4-5. Products of the Pennsalt Company.
- 6-7-8. Generic terms for products of the Geigy Agricultural Chemical Company.

puncture vine sterilitant. In the summer, 3,000 acre miles of roadsides were sprayed with the amitrole-atrazine combination as a foliar spray. Butte County Agricultural Commissioner Donald J. Black states that a new program, compared to previous ones, is more effective, economical, and is hastening control. He is well satisfied with the new methods and procedures and will continue their use.

Black reported that fenac was used on roadsides in farm areas, but not in orchard districts. He said that there had been no case of crop injury from either fenac or from the amitrole-atrazine combination.

Puncture vine that survives fenac treatment or the amitrole-atrazine combination can produce viable seed. Our germination trials are too limited to draw any conclusions on what effect these materials may have on seed.

Concerning costs, we find that fenac is economical to use. Based on current prices, the chemical cost of fenac at four pounds per acre is \$22.00.

In many cases the use of the amitrole-atrazine foliar spray can be as economical as weed oil, and it has the advantage of being clean to use. However, it does have several limitations. Drift to susceptible crops can result in damage. And the materials in the combination have not been registered for indiscriminate use in crops. We recommend this combination for roadside or non-agricul-

tural use. We further advise that drift to susceptible crops be avoided. If there is any question of trouble, we advise that weed oil be used instead; and that it be applied so as to avoid drift. The combination of three pounds of amitrole (actual) and one pound of atrazine (actual) plus one quart of propylene glycol as a finished spray costs about \$14.00 an acre. From the job use standpoint, the combination spray may be more economical than weed oil as a general roadside spray. In the case of yellow star thistle, Siskiyou County Deputy Agricultural Commissioner Clifford S. Giebner declares that there has been appreciable residual control in the year following treatment in his county. The situation involves medium to heavy soils and moderate annual rainfall.

We may conclude that chemical control of puncture vine often may be achieved through a preventative and maintenance program.

Fenac may be used in the preventative phase, a combination of amitrole and atrazine in the maintenance phase.

Propylene glycol has been found to be an effective surfactant for amitrole-atrazine puncture vine foliar sprays.

The control methods that have been described, except for weed oil, apply to non-agricultural areas.

Turf Fertilization Program

by

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The growing of turfgrass has several peculiarities which must be recognized before any attempt is made to determine fertilizer requirements and establish fertilization programs.

First, with turf we are not interested in the "crop", that is the top growth removed, but in the sod remaining after cutting. Ideally, this sod must be a dense, smooth, uniform, deep green carpet throughout the year. Furthermore, we want this green carpet to be quite permanent, lasting many years without replanting.

To make the problem even more difficult, we subject the grass to regular frequent defoliation and more or less constant traffic which damages the plant tissue and compacts the soil. Large amounts of water are applied by sprinkler irrigation. Because of these conditions that we impose upon turf, we find that our fertilizer requirements

differ considerably from that of most crops. Nitrogen is the element we emphasize, applying four or more times as much nitrogen annually as phosphorus and potash. Therefore, if a complete fertilizer is used, it should be in the order of a 4:1:1 ratio. In practice the phosphorus and potash needs can be met most easily by a spring and fall application of a complete fertilizer. Then, during the remainder of the year a simple nitrogen material may be used. To be on the safe side, the equivalent of 6 to 8 lbs. of single super-phosphate and 2 to 4 lbs. of potassium sulfate per 1000 sq. ft. of area should be applied annually.

The remainder of my discussion will deal principally with nitrogen. I believe that good quality turf can be obtained from any of our common nitrogen sources if the user knows the characteristics of the materials and uses

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them accordingly. It is up to the user to evaluate these characteristics, including cost per unit of nitrogen and costs of application, and decide which features are most important to him.

How much nitrogen do we need annually for turf in California with essentially a 12 month growing season? This will vary for the different grasses and uses. Six to eight lbs. of actual nitrogen per 1000 sq. ft. will give a good quality general lawn turf. The higher amount should be used if the lawn is bermuda or dichondra. Putting greens and bowling greens may require as much as 20-22 lbs. especially if the soil is of the high sand content we are now recommending for greens. Admittedly these are some fantastic amounts compared to what it used on most crops, but many studies and observations substantiate these recommendations.

The basic problem in turf fertilization is to apply the nitrogen, regardless of source, in a way that will produce a constant uniform rate of growth. Great flushes of growth following nitrogen application are undersirable as it necessitates removal of excessive amounts of top growth, produces a poor root system and leads to a weak soft turf highly susceptible to numerous fungus diseases. Here is where a knowledge of the characteristics of the nitrogen sources becomes important.

Let us look at the various ways we may use the available materials to accomplish this objective. We may use proprietary liquid formulations or solutions of such materials as ammonium nitrate or urea, applying them with a sprayer or a simple venturi system. As nitrogen from these materials is quickly available and readily leached, applications must be frequent and at low rates per application - 1/4 to 1/2 lb. of nitrogen per 1000 sq. ft. Here we have low cost material but higher labor costs because of the frequency of application. If liquids can be applied through a sprinkler system, labor will be eliminated and fertilization costs will be at a minimum. With a good injector, moderate amounts of nitrogen will be kept in constant supply and a nearly ideal fertilization program may be had.

Natural organic fertilizers like activated sewage sludge

or mixtures of organic and inorganic sources may be applied at approximately monthly intervals on greens or every two months on other types of turf.

Synthetic organics, the ureaforms, because of their SLOW availability, may be used in larger amounts per application and less frequently. We have found that during the first year of ureaform use it may be necessary to supplement it with light applications of a soluble material until a reserve of ureaform nitrogen is accumulated in the soil.

The new slow release fertilizers, the coated materials and the metal ammonium phosphates, have shown much promise in experimental tests so far. However, I believe that we need more observations in field use before we can make specific recommendations on rate and frequency of application.

During the period of extreme summer temperatures, it seems advisable to limit the amount of nitrogen to only what is needed to keep a satisfactory turf. High levels of nitrogen at this time may leave turfs of cool season grasses extremely vulnerable to pathogens which multiply rapidly at high temperatures. Warm season grasses, not as susceptible to disease as the cool season, will just grow too rapidly, producing excessive thatch.

Warm season grasses will grow longer and retain better color in the fall if given a constant supply of readily available nitrogen. In fact, with lawns of improved bermudas and zoysias, it may be possible this way in a normal year to keep satisfactory color all winter in the milder parts of the state.

One more element should be mentioned briefly. Remarkable response of turf to applications of iron is often seen. Iron may be applied either as one of the chelates or as foliar sprays of iron sulfate (the ferrous sulfate form). The rate of application for foliar sprays should be 2 to 3 ozs. per 1000 sq. ft. Two or three applications annually may be sufficient for general lawns but putting greens may require application as frequently as once every 2 or 3 weeks. Chelates should be applied according to manufacturers' directions.