Agriculture Students & Faculty are Partners

That ability to communicate with our fine young men and women in agriculture and home economics continues to be a reality for the faculty of the College of Agriculture.

And, keeping open these communications channels pays dividends, too.

We know we have the finest of the present generation.

We know these young people will make an excellent contribution to state and nation.

We know, too, that they shall be some of our finest leaders for tomorrow and today.

We know that you, the citizens of Arizona, will be as proud of them as their parents who sent them to the University of Arizona.

One of the reasons for our good rapport lies with Dr. Darrel S. Metcalfe, Director, of Resident Instruction for the College.

It is under his guidance that the counseling provides such meaningful contact.

Students turn to their advisors initially over the selection and assignment of class schedules. But, as the contacts continue the areas of confidences and discussion grow, frequently to matters that are personal.

Is the study load larger than the student is able to handle? Between them they usually find a workable solution.

Are there too many social diversions? And, again a solution is found.

Money problems? Romantic squalls? Frictions between groups? Concern with the draft... or a job... or obligations to the family?

Our advisors have generally heard them all and call upon their own youthful memories as well as adult judgment to help the student find a workable solution to his problem.

One of the signs which we feel speaks well for our advisors is that many students develop deep and lasting friendships which frequently continue long after graduation.

And, while these student-faculty relationships continue to be successful, Dr. Metcalfe is finding new ways to keep these relationships young, and vital, and alive, and meaningful.
Root rots of plants are caused by many and diverse fungi that live in the soil. These pathogenic fungi invade and destroy host root systems under varying conditions of moisture and temperature. The most common cause of death of a very large number of woody plants during the summer months in many areas of Arizona is a root rot caused by the soil-dwelling fungus, Phymatotrichum omnivorum. This fungus is indigenous in soils of much of the southwestern United States and parasitizes more than 2000 species of dicotyledonous plants.

Although the disease is known to occur at elevations as high as 5000 feet in Arizona, it is much more common and serious at elevations below 3500 feet where higher summer temperatures favor disease development. Symptoms of the disease consist of rapid wilting and death of infected plants, primarily during the hot months, June through September. The foliage dries rapidly and usually remains attached to the plant. Spore mats (cottony-white to tan in color, spreading, irregular in outline) of the fungus are often produced on the surface of soil around diseased plants following rain or irrigation during the summer months. Positive identification of the organism, however, usually requires microscopic examination of infected roots.

When the disease is detected before root damage is extensive a technique developed by Dr. R. B. Streets of the Department of Plant Pathology has been successfully used for a number of years in preventing or delaying plant death. This treatment consists of incorporation of manure, soil sulfur, and ammonium sulfate into the soil at the base of the infected plant. The method is described in detail in Folder 157, “Control of Texas Root Rot in Trees and Shrubs,” which may be obtained from the Cooperative Extension Service, University of Arizona.

Success of the method is attributed to creation of a soil environment favorable for plant growth but unfavorable for activity of the fungus pathogen.

When a plant dies, however, the fungus produces in the soil and on the dead roots specialized structures known as strands or filaments. These fungus structures enable the pathogen to survive for long periods of time in the soil and function as infective propagules. A method of soil treatment that would eliminate these infective structures would facilitate the planting of susceptible plants into the infested area. A successful chemical must be not only safe to use and highly active against the fungus, it must be able to penetrate the soil from surface application. During the past 2 years we have evaluated a large number of chemicals and fumigants to determine if they could be used to control Root Rot. The purpose of this paper is to report the results of these studies and to recommend the use of a specific soil fumigant for control of Root Rot in replant sites.

**SOIL STUDIES** — Laboratory studies consisted of incorporating chemicals at various concentrations into two very different soil types, Superstition sand from Yuma and Gila silt loam from Marana. The fungus was then introduced into the treated soils which were moistened and incubated. Soil samples were watered after different periods of time to determine the effect of the chemical on the fungus. Movement of the chemicals in soil was determined by adding the materials in water to the sur-
activity. A number of other chemicals were shown to be highly active against the fungus but were eliminated from further study because of lack of movement through soil. The comparative activity of Vapam** and 2 other fumigants shown to be active in preliminary studies, Vorlex (dichloropropene-dichloropropane mixture plus methylisothiocyanate) and Telone** (1,3-dichloropropene and related hydrocarbons), was studied. Vapam, when applied as a soil drench at a concentration of 250 ppm in enough water to wet the soil column, killed the fungus at 20 inch depths in the soil columns whereas Vorlex and Telone were inactive at this level. All three fumigants killed the fungus at the three soil levels (4, 12, and 20 inches) when applied at 500 ppm concentration (Table 1). In other studies, Vapam concentrations of 50 ppm or higher (based on soil weight) applied as a soil drench killed the fungus at 4, 12, and 20 inch depths in soil columns of Superstition sand and Gila silt loam. At 25 ppm the fungus was killed at depths of 20 inches in the sand but not in silt loam indicating deeper movement of the chemical in the sand (Table 2).

Table 1. Comparative activity of the soil fumigants Vapam, Vorlex, and Telone against *Phymatotrichum* when applied as a soil drench.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Depth of Fungus</th>
<th>Fungus viability</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(ppm)</td>
<td>(Gila silt loam)</td>
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<tr>
<td>Vapam</td>
<td>500</td>
<td>4 inches</td>
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<td>20</td>
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<td>250</td>
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<td>12</td>
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<td></td>
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<td>20</td>
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<tr>
<td>Vorlex</td>
<td>500</td>
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<td></td>
<td></td>
<td>12</td>
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<td></td>
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<td>20</td>
</tr>
<tr>
<td>Telone</td>
<td>500</td>
<td>4</td>
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<td>12</td>
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<td>Check</td>
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</table>

1 A 500 or 250 ppm active solution of each chemical applied to soil surface with sufficient water to wet soil column.
2 Fungus placed at depth of 4, 12, and 20 inches in column of soil.
3 Fungus viability determined by recovering the fungus 48 hours after treatment and plating on agar. A minus sign indicates no fungal growth (not viable), a plus sign indicates no effect on fungus.

Figures were also designed to determine the minimum concentration of sodium methylthiocarbamate (Vapam or VPM) necessary to kill the fungus in soil without considering the penetration characteristics of the fumigant in soil. In these experiments the chemical was added directly to soil infested with *Phymatotrichum omnivorum* in pint-sized plastic containers. The containers were sealed after treatment and attempted recovery of the fungus to determine its viability.

More than 60 chemicals were evaluated. Sodium methylthiocarbamate, (sold under the trade names, Vapam**-Stauffer Chemical Co. and VPM**-DuPont) a water soluble chemical that decomposes in moist soil to release a volatile fraction highly toxic to the Root Rot fungus, was shown to be the most active chemical with fumigant activity.
Table 2. Activity of Vapam against *Phymatotrichum* when applied as a soil drench to two soil types.

<table>
<thead>
<tr>
<th>Application Rate Chemical concentration&lt;sup&gt;1&lt;/sup&gt; (ppm)</th>
<th>Depth of fungus&lt;sup&gt;2&lt;/sup&gt; in soil column</th>
<th>Fungus viability&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Soil Type</th>
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<tbody>
<tr>
<td></td>
<td>Gila silt loam</td>
<td>Superstition sand</td>
<td></td>
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<tr>
<td>100</td>
<td>4 inches</td>
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<td>25</td>
<td>4</td>
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<tr>
<td></td>
<td>12</td>
<td>+</td>
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<td></td>
<td>20</td>
<td></td>
<td></td>
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<tr>
<td>0 (Check)</td>
<td>4</td>
<td>+</td>
<td></td>
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</table>

<sup>1</sup> Parts per million of active ingredient based on weight of air-dry soil in column. Fumigant added with sufficient water to wet soil column to a depth of 20 inches.

<sup>2</sup> Fungus placed 4, 12 and 20 inches from surface of column.

<sup>3</sup> Fungus viability determined by recovering the fungus 48 hours after treatment and plating on agar. A minus sign indicates no fungal growth (not viable), a plus sign indicates no effect on fungus.

Fungus was made after 48 hours of exposure to the fumigant. Concentrations of 10-20 ppm Vapam were sufficient to kill the Root Rot fungus. Telone was inactive at low concentrations (Table 3).

Table 3. Comparative effects of the soil fumigants Telone and Vapam against *Phymatotrichum*.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Chemical concentration&lt;sup&gt;1&lt;/sup&gt; (ppm active-air-dry soil weight basis)</th>
<th>Fungus viability&lt;sup&gt;2&lt;/sup&gt; (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapam</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Telone</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>100</td>
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<td>100</td>
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<td></td>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

<sup>1</sup> Fumigants were added to pint volumes of moist, infested Gila silt loam.

<sup>2</sup> After 48 hour exposures the fungus was removed and cultured on agar. Data based on total of 60 recovered fungus plantings at each concentration.

Replicated field plots treated with Vapam were established during August, 1969 at the University of Arizona's Marana Farm to determine if *Phymatotrichum omnivorum* could be eliminated from the roots of diseased plants. Vapam, at the rate of 1 qt./100 sq. ft. of surface area, was added to the soil at the base of cotton plants killed by Root Rot. Water was added at the rate of two acre inches to diked-plots to move the chemical into the soil. One week after application roots were removed from the treated and check plots and fungus viability determined by scoring fungal strands, placing them on agar in the laboratory, and observing fungus growth, if any, after 72 hrs. All strands were killed by the Vapam treatments, indicating that the chemical had penetrated into the soil with the water. Strands removed from roots from the check plots were alive.

**Characteristics of Vapam and VPM** — Sodium m ethylthiotetrachloroacetate is a water soluble compound that in moist soil releases a gaseous chemical that is active against weed seed, fungi and nematodes. The chemical is presently recommended for controlling a number of other soil-borne fungus organisms, including *Rhizoctonia* sp., *Pythium* sp., *Pythium* sp., and Armillaria mellea. The recommended rate for controlling *Phymatotrichum omnivorum* in replant sites is 1-1/2 (sandy soil) to 2 qts. (heavy soil)/100 sq. ft. Sufficient water should be added to wet the soil to a depth of 4 to 6 feet. A minimum well-basin diameter of 3 to 4 feet should be treated. The chemical should never be applied closer than 3 feet to the drip line of living plants, shrubs, or trees because it is phytotoxic. Plots established in the Tucson area indicate that the material is safe to use if this recommendation is followed. It should be emphasized that this recommendation is for replant sites only. The fumigant should not be used around living plants.

Directions for use of Vapam or VPM for treatment of sites to be replanted may be summarized as follows:

1. Apply to soil which has been thoroughly cultivated and kept moist for at least 5 days prior to application.
2. Apply Vapam or VPM when soil temperature is between 60°F and 90°F. Mix required amount in 2 to 3 gallons of water and apply evenly over basin.
3. Apply with sufficient water to wet soil to a depth of 4 to 6 ft. (Approximately 6 inches of water in heavy soil and 3 inches in sandy soils).
4. Cover the treated area with a tarp for 5 to 7 days after treatment.

**Precautions:**

1. Do not apply Vapam or VPM within 3 feet of the drip line of living plants, shrubs or trees.
2. Do not apply in confined spaces without adequate ventilation.
3. Do not apply to dry soil.
4. Keep off of desirable lawns and plants.
5. Material should not be allowed to contact skin or eyes. Contaminated clothing should be removed and laundered. Follow label recommendations.

**Final Step** — After fumigant treatment, which is designed to eliminate or greatly reduce the amount of *Phymatotrichum* in the soil, a further treatment to prevent or reduce the chances of reinvasion by the fungus into the treated site, is recommended. This method consists of incorporating manure (up to one-fifth of soil volume), soil sulfur (one-quarter pound per cubic foot of tree hole), and ammonium sulfate (one ounce per cubic foot) into the replant site. The technique is described in Folder 158, “Preparing Tree Holes for Root Rot Control.” These treatments including the fumigation, should be made 30 to 60 days before planting time.

The methods described above are presently considered to be the best available for control of Root Rot.
Cotton Insect Control in Arizona

by T. F. Watson & Leon Moore*

Insect problems in Arizona cotton have become progressively worse in recent years in spite of continuous advancements in the development of insecticides and their increased use. To reduce existing insect problems and minimize new ones it is important that growers more effectively utilize the best combinations of cultural, chemical, and biological control methods. This integrated control approach requires a consideration of the total environment, or agro-ecosystem, with its interrelated complex of organisms and physical elements, all affected by the activities of man.

The general concept of insect control should be revised to include pest population management rather than the mere destruction of pest populations with insecticide applications. This, in turn, implies the need for much greater understanding of the role played by all insects, both destructive and beneficial. We must also tolerate the presence of sub-economic population levels of harmful insects whose presence does not justify the expense or hazards of control treatments. The pest-management approach would not be a feasible practice if it were necessary to maintain the cotton completely free of any pest. For most insect pests, economic levels have been established and in many instances populations never rise above the economic threshold unless released from biological control restraints as a result of the unwise use of insecticides.

The practice of cotton insect control has undergone continuous change over the years. Advancing technology, particularly the development of synthetic organic insecticides and specialized methods for their application, associated with improved cotton production practices in general, has provided the means of producing consistently higher yields. These advances have not come without certain undesirable consequences, particularly from the standpoint of the development and use of insecticides. Probably the single most detrimental consequence with regard to insecticides has been their unquestioned acceptance as the panacea for insect control. Insecticides are of unquestionable value but their use must be within a realistic ecological and economic framework.

For several years an insect problem or potential problem could be handled easily and inexpensively with any of a number of highly effective insecticides. Thus, these new tools seemed to eliminate pest problems with little outward indication of the need for their judicious use. Possible widespread secondary effects on the total environment were largely unanticipated.

Develop Tolerance

The first unanticipated problem was the development of insecticide tolerance or resistance in certain pests. This initiated a chain reaction which complicated and compounded the problems of cotton insect control. Increasingly higher dosages and shorter application intervals were required to achieve the results to which the grower had become accustomed. New materials with different modes of action were continually introduced to replace those which had become ineffective and thus the chain reaction has continued. A prime example is the bollworm problem in cotton. Initially, the bollworm was highly susceptible to DDT. After only a few years of continuous exposure to this insecticide, field populations developed resistance to the point where higher dosages were required and finally, where DDT became virtually ineffective. Subsequent control of the bollworm required the use of such short-residual compounds as methyl para-thion which necessitated shorter application intervals. In some areas, the development of resistance to this insecticide has reached the point where unusually large dosages are required.

Another Problem

A second problem resulting from the use of insecticides has been the rise to major pest status of insects which were originally of only minor importance. For example, prior to the need of multiple applications for control of the pink bollworm over most of the cotton acreage of Arizona the
cotton leaf perforator was only an occasional pest. However, during the past two years it has become a major problem. The cause of this shift from an incidental or minor pest status to one of major economic importance was apparently due largely to the destruction of natural enemies which had kept the leaf perforator under control. The larger number of pest species requiring control has resulted in the need for a greater variety of insecticides applied more frequently over a longer period of the growing season.

Another concern which has progressively intensified with the continued and even greater reliance upon chemicals to control cotton pests is the residue problem associated with food and feed crops. This problem culminated in the establishment of lower tolerances, particularly for the persistent chlorinated hydrocarbon insecticides.

Residue Is Concern

Primarily as a result of the residue problem in milk and on alfalfa and other feed crops, DDT and other persistent chlorinated insecticides have been banned or are no longer recommended to control pests of agricultural crops, particularly cotton. This has necessitated the use of shorter-residual, highly toxic organophosphate insecticides. These alternative materials, while possibly reducing the residue problem in general, have concurrently induced new problems. A direct health hazard stems from the acute toxicity of many of the phosphorus insecticides. It is primarily the persons who may come into immediate contact with these insecticides, such as applicators, loaders, flaggers, and field workers, who are subjected to additional risks. The potential effect upon the balance of pests and beneficial insects is tremendous, however, when large quantities of these insecticides are applied to large areas on a fairly rigid schedule. This approach can lead, in a relatively short time, to serious ecological problems which may take years to correct.

The primary factor which handicaps the full realization of the pest-management approach to cotton insect control is the presence of the pink bollworm, a key pest species which is strictly almost entirely to cotton. In Arizona, the pink bollworm presently occurs at such population densities that much of the state’s cotton may require several insecticide applications to prevent serious losses. Therefore, the most logical approach to integrated insect control or pest-management is to first remove the need for repeated applications of insecticide to control the pink bollworm. This can be done by a concerted effort of the growers to initiate certain essential changes in cotton production practices.

Fewer Pinkies

Reducing or eliminating the numbers of young bolls available for pink bollworm attack early in the fall (during October) will greatly reduce populations of this pest the following year. This practice eliminates a high proportion of the larvae before they become physiologically adapted (in diapause) for winter survival.

The practice of early crop termination, plus good fall plowing and clean-up operations, would reduce the pink bollworm to such low levels that economic infestations would not develop at all or at least not until late in the following summer. Even under present conditions pink bollworm infestations during the growing season often fail to reach economic levels. Regular field checking has demonstrated that in such situations customary applications of pesticides can often be delayed or even eliminated. An overall-cultural-control effort would minimize the need for chemical control of the pink bollworm.

Better All Around

A reduction of the pink bollworm problem would greatly enhance the potential of total pest-management or integrated insect control. Most of the other pests, especially those of importance during the major fruiting cycle of the cotton plant, are not restricted entirely to cotton. This indicates the possibility of managing other crops to minimize the problems normally encountered in cotton.

An example of a pest-management practice which is gaining prominence is the strip-cutting of alfalfa fields or strip-planting of alfalfa in cotton. This practice results in the maintenance of lygus populations in the alfalfa and eliminates or reduces the need for lygus control in cotton. Used in this manner, alfalfa is a trap crop. Benefits from this non-chemical approach in lygus control are far greater than the mere savings of materials and application-costs directly associated with lygus control. Predator and parasite populations, which are reduced or destroyed by lygus control treatments, are preserved at a critical time in the growing season when outbreaks of other pests, such as the bollworm, are most likely to occur. In many instances, where the environment has not been previously upset by pesticide applications, bollworm outbreaks are prevented and population levels are maintained at sub-economic levels by beneficial insects alone. Even where insecticidal control becomes necessary, beneficial insects will generally delay its need and result in the saving of one or more applications.

No Set Program

In the integrated insect control approach, a predetermined insect control program is not possible. The choice of insecticides and timing of applications are based upon a specific set of circumstances as they exist at a given time in a given field. Decisions on whether to chemically control a pest should, therefore, be made by the grower or his representative and should be based upon recorded information provided by regular field checking. Such information includes: 1) the population density of the pest or degree of plant damage; 2) the trend of the pest population based on previous records; 3) the presence and abundance of beneficial species which are known to attack the pest in question; and, 4) the likelihood of releasing from natural control another pest which is currently present at sub-economic levels.

The problem of cotton insect control may become increasingly difficult and costly if we continue to rely primarily upon insecticides instead of using integrated insect control principles which employ the best aspects of chemical, cultural, and biological methods of control.

Adopting the new approach will help growers feel secure in their insect control program from the standpoints of effectiveness, justification of environmental contamination, and cost. (Turn Page)
Figure 2. Close examination of plant terminals and other plant parts is the key to correct timing of insecticide applications. Regular and properly recorded field examinations are necessary to understand population trends of both harmful and beneficial insects.

Figure 1. A good job of shredding plant (above right). Both are essential steps.

Figure 3. Beneficial insects are an important part of pest management. This bollworm larva (right) was killed by a parasitic fly.

Figure 4. Alternately-cut strips of alfalfa (right) keep lygus bugs in the alfalfa field and minimize damage to adjacent cotton.
facilitates good coverage

control of the pink bollworm.

Figure 5. Properly applied insecticides are necessary when pest populations exceed economic threshold levels.

Figure 6. Maturing cotton for early harvest, below, is an essential step in the cultural control of the pink bollworm. Photo below illustrates the effects of various irrigation cut-off dates on plant maturity. Plot on right hand half of picture shows signs of early water cut-off.
Effects of Air Pollution on Vegetation

by Roger L. Caldwell

Losses to Agriculture

It has been estimated that air pollution damage to crops, ornamentals and forests amounts to over $500 million nationally per year. Of this approximately 25 per cent occurs in southern California. Included in this figure is non-visible damage which is represented as reduced growth and yields; for example, citrus yields in southern California may be reduced as much as 50 percent because of photochemical smog. By the use of filtered air, effects of air pollution on the growth and yields of a number of plants have been determined in several parts of the country. In certain areas susceptible crops can no longer be grown, due to the increasing air pollution problem.

What is Air Pollution

Smog. Photochemical smog is really a combination of two oxidants, ozone (O₃) and peroxyacetyl nitrate (PAN). PAN is formed as a result of the interaction between hydrocarbons (chemicals containing only carbon and hydrogen) and nitrogen dioxide (NO₂), both produced in the process of combustion (gasoline, diesel, coal, fuel oil). Normally, smog damage relates to only that damage due to PAN. PAN produces a bronze-like color on the lower leaf surface; young leaves are the most susceptible.

Ozone. While very minor amounts of ozone (O₃) may be formed as a result of lightning during electrical storms, the major production is as a result of reaction between sunlight and nitrogen oxide. Ozone injury is evident on the upper side of the leaf and is identified by a flecked appearance consisting of many small chlorotic areas; ozone affects leaves of intermediate age.

Sulfur Dioxide. Sulfur dioxide (SO₂) was one of the first air pollutants to be identified and has been extensively studied for over 50 years. Nationwide, the major source of SO₂ is in the use of coal and oil fired power generation plants. In Arizona, the major source is in the smelting of copper ore. Sulfur dioxide injury results in an interveinal bleaching of leaves, or in some mild cases, a chlorotic pattern. Leaves of intermediate age appear to be more susceptible than either young or old leaves.

Fluorides. Fluoride damage is restricted to industrial areas containing aluminum smelters, phosphate plants, and certain chemical industries. Fluoride toxicity is indicated by a bleaching of the tips and margins of leaves; dead tissue may flake off producing a ragged edge.

Ethylene. Ethylene is a plant growth hormone, and as a result can have an effect at very low concentrations.

Ethylene is primarily produced by certain chemical industries and by automotive combustion. The presence of ethylene may cause leaf-drop or failure of certain flowers to open.

Particulate. Particulate matter is generally considered as any fine airborne solid material that will settle out after some length of time. In areas of dusty roads and certain industrial plants this may deposit on the leaf surface. Normally, unless concentrated, particulate matter is of small concern in plant damage.

Diagnosis of Air Pollution Damage

While the presence of any of the symptoms described above would lead one to suspect air pollution damage, many other factors must enter into the decision. Other problems, such as herbicide injury, insect damage, plant diseases, and nutritional deficiencies or excesses in many instances produce symptoms similar to those of air pollution damage. Thus, it is extremely difficult to diagnose air pollution damage to vegetation. However, certain critical factors may aid in the diagnosis, such as, the proximity of a large industrial plant or symptoms naturally occurring indicator plants (susceptible wild plants) in the area.

Factors Influencing Pollution Damage

The basis for plant damage by air pollution is very complicated. Persistent inversion layers, high temperatures and humidities, and the speed and direction of winds can influence the degree of damage. The relative amounts of the various pollutants can vary throughout the year, due to changes in traffic and heating, and industrial production.

The action of one pollutant may be enhanced by the presence of an additional pollutant (synergism), thus lowering the concentration needed to damage vegetation. The time of exposure is very important as related to damage. In general, the longer the exposure, the lower the concentration that is required to effect damage.

Nutritional status of the plant, the type of soil in which it is grown and irrigation schedules also influence the plant sensitivity to pollutants. Plants, themselves, have a wide range of sensitivity to various pollutants. Even varieties of a given plant differ in their response.

The Problem of Air Pollution in Arizona

Arizona is fortunate in not yet having a major air pollution problem. Sulfur dioxide injury has been re-
ported on crops and ornamentals in the vicinities of copper smelters. Fluoride injury to trees has been found in the vicinity of an aluminium smelter. The occurrence of ozone injury to vegetation has been suggested in a metropolitan area of the state. With increasing automobile registrations and projected population and industrial growth, it would appear that the incidence of damage due to air pollution in Arizona will increase.

What is Being Done

The U.S. Department of Agriculture and several states (such as California and Pennsylvania) have programs involved in fundamental studies into the biochemical effects of air pollution on vegetation. The long term effects of low levels of pollutants, resulting in reduced growth and other than visible symptoms, and the apparent lowering of the effective level of a pollutant when in combination with other pollutants, are also being studied. In some areas of the country, plant breeding activities have produced varieties that are resistant to damage from air pollution. This has been particularly effective in the case of onion and tobacco.

In Arizona, the state legislature is considering strengthened laws concerning air pollution. Strong laws are needed to minimize the possibility of pollution reaching the level where damage to vegetation will readily occur. Several counties of southern Arizona (Pima, Pinal, Maricopa, Gila and Santa Cruz) are included in the new Federal Air Quality Control Region, which became effective in April, 1970, where standards of various pollutants and control measures will be required.

The State of Arizona, Department of Health, has recently obtained a portable trailer to investigate air pollution effects on vegetation. The trailer permits the comparison of the effects of filtered air with non-filtered air on plants grown under identical conditions. This will permit us to identify potential problem areas within the state and, as a consequence, to suggest measures appropriate to a given locality to limit damage to crops or ornamentals.

While I have only discussed air pollution damage to vegetation, it should be realized that there are other effects that concern all of us. The effects of air pollution on human and animal health, building materials, clothing, rubber goods, and the esthetic quality of the surroundings are all very important. Studies in these areas are also in progress.

Summary

The major air pollutants, sulfur dioxide, PAN, ozone, and fluoride, all occur in Arizona. Our weather conditions and our production of sensitive crops indicate the potential for increased air pollution damage to vegetation. While the effects and symptoms of air pollution damage to vegetation are known, it is often difficult to rule out other types of injury, as herbicide, insect, and nutritional effects, and plant diseases due to fungi, viruses, and bacteria.

Current investigations into the distribution patterns of various pollutants in Arizona will lead to a better definition of problem areas. Steps then can be taken to minimize damage of susceptible crops in the area.

Air pollution effects the farmer and homeowner alike. The reduced yields on crops and visible damage to ornamentals both result in economic losses. While it is still early for Arizona to have the extent of vegetation damage that other areas have, it is easy to predict, with our weather conditions and diversity of crops, and our increasing population and industrial growth, that our problem may well get worse. As there is no known remedy for air pollution damage, it is all too true that with this problem an ounce of prevention is worth a pound of cure.
Developments in Production & Consumption of Livestock and Meat in the World.

by Elmer L. Menzie*

The relatively high prices for beef cattle, received by producers in Arizona and elsewhere in the United States, in the past months, have been reflected in higher prices in most other major world markets. An exception was Argentina where prices in the late months of 1968 and early 1969 were relatively lower. Since the United States is a major producer, consumer, and meat importer, it is not surprising to find this similarity in price movements.

Production of beef has been increasing fairly continuously in the United States for a number of years, but it has not maintained pace with increasing demand resulting from higher incomes and population growth. While imports have helped to fill some of the gap, artificial barriers tend to keep external supplies from flowing freely from other areas of the world. As a result, market prices tend to be higher in the United States than in some other producing areas.

World Livestock Numbers Increasing

World wide, cattle numbers have been increasing fairly steadily since World War II. Estimates for 1968 of nearly 1.2 billion head were up over 18 percent from the 1956-60 average.1 Numbers increased at an average of approximately two percent per year until the last two or three years when the rate declined to less than one percent. Part of the decline in growth has been due to reductions in dairy herd numbers and part to disease or drought conditions in Africa and South America.

World hog numbers exceeded 511 million in 1968, up about 19 percent from the 1956-60 average. While fluctuations in the growth of the hog population are much more rapid than for cattle, the upward trend in numbers has been equally consistent during the past 25 years.

Sheep numbers have also increased but at about one-half the rate of cattle and hogs. The world total was estimated to exceed one billion in 1968 which was nearly nine percent above the 1956-60 level. Numbers of sheep in the United States have been declining fairly steadily and were down about 50 percent in the past ten years. Numbers in Western Europe have also declined slightly.

In 1968 the United States was estimated to have had about 9.4 percent of the world's cattle, 10.8 percent of the hogs, and 2.2 percent of the sheep and lambs. The United States has declined relative to other countries of the world, in terms of both hog and sheep numbers, during the past ten years. There does not appear to have been much change in the distribution of cattle in the various regions of the world, but both South America and Western Europe have increased their share of hog numbers.

Total meat production, in 42 major producing countries, in 1968, was estimated to be nearly 130 billion pounds (carcass weight basis), an increase of about 34 percent over the 1956-60 average. The growth rate was almost double that of either animal or human population growth. This would suggest fairly significant improvements in productivity and in the quantity of meat consumed.

Productivity Levels Differ Significantly

Neither the growth in livestock numbers nor the increases in productivity are evenly distributed throughout the producing countries of the world. The distribution of

*Professor of Agricultural Economics Department.

meat production is significantly different from the distribution of animal numbers due to fairly extreme differences in productivity levels. Some of the range in productivity due to variations in animal weights and some to the output of fewer animals in relation to the basic herd.

The United States and Western Europe tend to have the highest levels of productivity. For example, the United States produces nearly 200 pounds (carcass weight) of beef and veal per cow and calf in the inventory. Eastern Europe and the U.S.S.R. produce less than 100 pounds and South America about 60 pounds. Mexico, with more than one-quarter the number of cattle and calves in the United States, produces less than five percent as much beef and veal. If data were available for Africa and Asia, with about 50 percent of the world’s cattle, the productivity levels there would undoubtedly be among the world’s lowest. A similar situation exists in production of pork, lamb, and mutton. Brazil, the major South American producer, turns out between 10 and 15 percent as much pork as the United States with a hog inventory estimated to be 20 percent larger.

Productivity changes in the livestock industry have tended to be slow even in the developed countries, except perhaps for pork. While the developing countries of the world have a major share of livestock inventories, the greatest source of increased production is, and likely will remain, in the more developed areas of the world. These are also the areas with the major markets since meat tends to be a relatively high cost source of food. Transfer costs, health regulations, trade restrictions, and other factors tend to restrict the flow of meat from developing areas to those with more lucrative markets. Since markets are generally poor in developing countries, there is, therefore, less stimulus for increased production.

**United States Consumption Highest**

Estimates indicate that the United States alone consumes the equivalent of about one-quarter of the production of red meat from 42 of the major world producers. Western Europe consumes about the same amount. Per capita consumption in the United States in 1967 was 178 pounds, whereas in Japan total red meat consumption was 20 pounds per capita. In most of the developing countries of the world, with a major part of the population, consumption is well below 100 pounds per capita.

While some further increases in per capita consumption of meat can be expected in the United States, the rate of growth will undoubtedly be reduced. As incomes continue to rise, the major emphasis will likely continue to shift to quality and service rather than significantly increased quantities. In Western and Eastern Europe, however, there is still room for substantial expansion in per capita consumption. As incomes grow, demand should continue to be strong.

**Government Policies to Stimulate Meat Production**

Favorable prices in the United States will stimulate production both through a shifting of resources and increased productivity. If the growth in demand tapers off as well, it can be expected that supplies will increase relative to demand in the near future. While Europe will likely be a major growth market, it will continue to try even harder to supply its own needs. Serious unfavorable imbalances in other sectors of European agriculture will provide a strong incentive to shift resources to livestock production. Government policies are already directed to stimulate meat production. Similar policies are being followed in other livestock producing countries such as Australia, New Zealand, and Argentina.

It would appear that meat producers in the United States can continue to expect relatively strong markets for the near future. However, the indications are that supply-demand relationships can be expected to shift as production expands in response to the strong incentives originating both in markets and in government policies of producing countries. Developing countries present potential markets for the more distant future, but the real capacity for production within many of these countries has hardly begun to be exploited. In the foreseeable future at least, these areas are likely to have more potential as producers of increased meat supplies than as growing markets, so far as the more developed countries of the world are concerned.

**Total Meat Production in Specified Regions (Carcass Weight Basis)**

<table>
<thead>
<tr>
<th>Country</th>
<th>Average 1956-60</th>
<th>1965</th>
<th>1966</th>
<th>1967</th>
<th>1968*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Million Pounds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>30,992</td>
<td>36,251</td>
<td>37,333</td>
<td>39,942</td>
<td>40,347</td>
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<tr>
<td>United States</td>
<td>27,215</td>
<td>31,535</td>
<td>32,622</td>
<td>34,238</td>
<td>35,275</td>
</tr>
<tr>
<td>South America</td>
<td>12,470</td>
<td>13,173</td>
<td>14,170</td>
<td>14,750</td>
<td>14,980</td>
</tr>
<tr>
<td>Europe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western</td>
<td>25,755</td>
<td>31,968</td>
<td>32,200</td>
<td>33,190</td>
<td>33,143</td>
</tr>
<tr>
<td>Eastern</td>
<td>7,099</td>
<td>9,148</td>
<td>8,881</td>
<td>9,419</td>
<td>9,625</td>
</tr>
<tr>
<td>USSR</td>
<td>12,220</td>
<td>15,850</td>
<td>17,690</td>
<td>18,760</td>
<td>18,940</td>
</tr>
<tr>
<td>Oceania</td>
<td>4,485</td>
<td>5,435</td>
<td>5,494</td>
<td>5,458</td>
<td>5,885</td>
</tr>
<tr>
<td>Total, 42 Major Producing Countries</td>
<td>96,650</td>
<td>116,025</td>
<td>120,718</td>
<td>126,184</td>
<td>129,520</td>
</tr>
</tbody>
</table>

*Classified as preliminary estimates.

One of the central figures of Brazilian folklore is the vaqueiro of the dry Northeast. Dressed in leather clothes for protection, this Brazilian version of our "brush-popper" pursues his lean, half-wild cattle through the thorny, almost impenetrable tangle of what must be some of the most difficult brush country in the world. He is a colorful individual, but, like so many romantic figures in our own West, one that will have to be consigned to the history books if Brazil is to develop a viable modern agricultural economy.

Ecologists generally refer to this brushland as a "tropical thorn forest." It covers large portions of several states in the semi-arid northeastern portion of Brazil just south of the Equator. Although the rainfall averages about 25 to 40 inches annually, it all falls in a period of only 4 to 5 months, leaving the remaining 7 to 8 months almost totally dry. This seasonal pattern, coupled with high year-round temperatures, great year to year variation and periodic severe drouths, create serious restrictions on the use of non-irrigated land. The brush ranges from scattered plants interspersed in a grassland composed of annual grasses and weeds to a very dense stand of brush and small trees supporting almost no herbaceous understory. In some areas the brush grades into a low dry-tropical forest. During the wet season both the woody and herbaceous vegetation present an aspect of lush greenness and ample, even excessive, moisture, but within a month after termination of the rain the grass and brush dries up and almost all the brush species lose their leaves, giving the country a very desolate appearance.

The prevailing pattern of land use makes it difficult to determine just what the "natural" vegetation of the

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**Figure 1.** Wet season clearing of a dense stand of brush with the rolling cutter. The cutter was filled with sand and water to increase its weight and usually two passes were made. The debris was burned during the dry season. This brush stand was at least 30 years old.

**Figure 2.** Wet season clearing of a dense brush stand with a bulldozer equipped with a brush hook. The brush was pushed into piles, or windrows, and later burned.
area might be. Each dry season the farmer cuts the brush and trees on an area of several acres, allows it to dry, then burns it. This treatment kills a large portion of the brush and also many of the grass and weed seeds. When the rain comes, he plants corn, beans and sometimes rice or cotton on this relatively clean seedbed among blackened stumps and keeps the crops weeded during this first year. All of these operations are done by hand. Cotton, a perennial variety, is harvested from the second to about the fifth year after clearing but usually the area is not weeded after the first year. A dense stand of grass and weeds results and the brush begins to resprout and re-invade very rapidly. The brush increases rapidly, with a corresponding decrease in understory vegetation, until after only 5 to 10 years it is distinguishable from its original condition only by size and species composition and provides scant feed for livestock. The farmer clears a new area every year, only returning to the same area every 10 to 30 years. This pattern is very common in tropical areas and has been practiced almost unchanged for about 300 years or more in northeast Brazil although the area affected and the frequency of return to a given area has undoubtedly increased as the population density has increased. The farmer does not farm the same piece of land year after year because of the difficulty of keeping out the very aggressive weeds and brush by hand methods and the decline in crop yield after the initial fertilizing effect from ash when the brush is burned. Without fertilizer, he receives more crop production for less work by following this system and the brush gradually rebuilds the fertility of his soil.

Due to the greatly increased production of forage when the brush is cleared, it would be of considerable benefit to the livestock growers to be able to clear larger areas of brush or at least to control the reinvasion of brush on land cleared by traditional methods and abandoned for crop raising. In 1968 and 1969 several experiments were started by the author and Prof. Ambrosio Araujo (Dept. of Animal Science, Federal University of Ceará) to investigate the effectiveness of various brush control methods. Until this time there was practically no information available regarding the use of chemical or mechanical brush control methods in the area.

In 1968 treatments of 2,4,5-T in diesel oil were made as a basal-trunk application on the three most common brush invader species, marmeleiro, jurema preta and mofumbo. All of these species sprout vigorously from stump and roots when cut by hand. Five rates of herbicide were used, 20, 10, 5, 2½, and 0 percent (ie. diesel alone) (active ingred. 100 g./liter) and an average of about 100 ml. of solution used for each tree. Virtually 100 percent kills resulted on marmeleiro and jurema at all rates, indicating that diesel oil alone is probably sufficient. Kills were erratic on mofumbo but so few trees were involved it was difficult to estimate the effectiveness on this species. A similar experiment was started in 1969 comparing 2,4,5-T in oil with Tordon 22K and Tordon 101 at several comparable rates. Dry and wet season applications were made. It is too early to draw conclusions from this study but based on the 1968 study it appears that these two species can be easily controlled in this manner. This method might be quite effective on sparse stands of brush or as a "mop-up" after other types of control. However on denser stands which run to 5,000 or more trees per hectare, the cost of materials would be uneconomical. (In Brazil, herbicide and machines are expensive but labor is very cheap).

Also, during the wet season of 1968, an experiment was made comparing foliar applications of 2,4,5-T, 2-4-D, Silvex and Tordon 22K each at rates of 3, 1½, ¾, and ½ kilos of active ingredient per hectare. The herbicide was applied to the foliage of a mixed stand of low growing brush with a back-pack sprayer. After one year,
Brush Control in Brazil

(From page 15)

kills ranged from practically 100 percent on some higher rates to less than 5 percent on some lower ones. Tordon gave the best results, followed by 2,4,5-T, Silvex and 2,4-D in that order. A great increase in grass production resulted, even in the first year. Although Tordon gave better results on all species, 2,4,5-T at 1½ kilos/hectare gave good enough control (about 70-80%) to achieve near maximum grass production. Respraying, burning or other follow-up measures might be necessary to maintain control. A similar experiment was performed in 1969 testing the same chemicals plus two additional ones, Tordon 101 and Aropen and using a tractor-mounted sprayer rather than the hand sprayer. It is too early yet to judge final results but preliminary indications are that Tordon and 2,4,5-T are again the best.

The biggest problem with foliar applications is that the brush is generally too dense and too tall to allow treatment with hand or tractor-mounted sprayers. Areas recently cleared by hand or mechanical means might be treated this way to control resprouts. The costs should be no more than hand clearing and the permanency of control much better. Obviously, the next step is to try airplane spraying, which should be cheaper yet, and it is hoped to do this in the near future.

Another experiment was started in the dry season of 1968, and is still continuing, to compare costs and effectiveness of various combinations of brush control methods and reseeding with perennial grasses. Main treatments include the use of a bulldozer, a rolling brush cutter, hand cutting and herbicides with follow-up measures of herbicide and burning treatments and reseeding. Again it is too soon to draw final conclusions from the study but a few points are already evident. Burning after hand or mechanical control is very helpful in controlling resprouts of the brush and the temporary control of the native grass and weeds provided is essential for successful reseeding with perennial grasses without cultivation. Fairly good stands of buffel grass, blue panic, giant bermuda, Wilman lovegrass, and Lehman lovegrass were achieved when the seed was broadcast onto an area which had been burned by a hot fire. It is not yet known whether these grasses will persist in competition with the native species.

Herbicide applied to fresh-cut stumps in the dry season gave nearly 100 percent kills even on hard to kill species such as mofumbo. This technique would be quite costly in terms of material on dense stands but might be useful as a follow up measure to kill resistant species. Costs of chemical and mechanical treatment range from somewhat less to considerably more than hand clearing but make the treatment of larger areas possible and can produce longer lasting control. Burning seems to show a lot of promise as a follow-up treatment but is not very effective unless the stand is sufficiently open to support a good stand of grass and weeds to carry the fire. Probably a combination of methods will be necessary to provide the most efficient control.

More than 30 years of brush control and reseeding research in this country have still not given us all the answers we need for range improvement and so two years of work in Ceará represent only a start. Much work needs to be done in the timing, methods and costs of control and types of ratio of herbicides for various brush species and soil types before adequate guidelines can be developed.

Two very important questions aside from those mentioned above need to be investigated. First, what are the returns in terms of livestock production that can be expected? It is very possible that no brush control or reseeding project for increased forage production will be economical unless the productivity of the livestock and managerial skill of the ranchers is increased. Second, what will the long-term effects of conversion from brush to grassland be on soil productivity and erosion? It could be that the best management of the pastures will not maintain the productivity of the soil without the periodic "brush rotation" now practiced, or the soils might be improved by the conversion. This question will not be easy to answer and the results of our experience in this country cannot be safely extended to a tropical environment. But the answer is very important for the future of Brazil.