COOPERATIVE
IMPACT ASSESSMENT
REPORT

THE BIOLOGIC AND ECONOMIC ASSESSMENT OF

BENOMYL

UNITED STATES
DEPARTMENT OF
AGRICULTURE

IN COOPERATION WITH
STATE AGRICULTURAL EXPERIMENT STATIONS
COOPERATIVE EXTENSION SERVICE
OTHER STATE AGENCIES
U.S. ENVIRONMENTAL PROTECTION AGENCY

TECHNICAL BULLETIN
NUMBER 1678

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BENOMYL

A report of the Benomyl assessment team to the rebuttable presumption against registration of Benomyl

Submitted to the Environmental Protection Agency in 1978-1979

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PREFACE

This report is a joint project of the U.S. Department of Agriculture, the State Land-Grant Universities, and the U.S. Environmental Protection Agency, and is the twelfth in a series of reports recently prepared by a team of scientists from these organizations in order to provide sound, current scientific information on the benefits of, and exposure to, benomyl.

The report is a scientific presentation to be used in connection with other data as a portion of the total body of knowledge in a final benefit/risk assessment under the Rebuttable Presumption Against Registration Process in connection with the Federal Insecticide, Fungicide, and Rodenticide Act.

This report is a slightly edited version of the reports submitted to the Environmental Protection Agency in 1978-1979. The editing has been limited in order to maintain the accuracy of the information in the original reports.

Sincere appreciation is extended to the Assessment Team Members and to all others who gave so generously of their time in the development of information and in the preparation of the report.

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SUMMARY

Benomyl is an outstanding broad-spectrum fungicide of great economic value to agriculture in the United States. It was introduced in the United States in 1969 as the first of a group of fungicides in the benzimidazole class. Benomyl is currently registered for use on 43 food crops and 41 ornamental crops, including turf. Current use of benomyl in the United States exceeds 3.0 million pounds of active ingredient annually. Benomyl is sold as Benlate® and Tersan® 1991, and is also repackaged and sold under other trade names for use on ornamentals.

Applicator Exposure

Estimates of applicator exposure to benomyl show safety margins for home garden applicators ranging from 3,472 to 48,077 relative to the no-observable-effect-level (NOEL) for teratogenesis. Safety margins for inhalation exposure of field applicators range from 6,818 to 37,500 relative to the NOEL for reduction in spermatogenesis. Further studies are needed to determine the extent of dermal absorption of benomyl.

Toxicity to Earthworms

Annual application rates of benomyl are 1 pound or less per acre. Tests in wheat fields indicate that these levels would have no adverse effect on earthworms. Experience indicates that use of high levels of benomyl reduces earthworm populations. Populations recover upon discontinued use of the fungicide. No evidence was found to indicate that plant growth or productivity is affected because of adverse effects of benomyl on earthworms.

Aquatic Hazard

No documented evidence was found that application of benomyl to ricefields constitutes an aquatic hazard. Samples of water in drainage ditches receiving water from ricefields treated with recommended doses of benomyl usually had nondetectable levels of the fungicide (less than 0.02 p/m). Occasional levels of 0.02 to 0.04 p/m were found. These levels are well below those regarded as harmful for aquatic organisms with the possible exception of the channel catfish, which is reported to be highly sensitive to benomyl. There is need for further studies regarding sensitivity of this species.

Rates and Frequency of Application

Benomyl is effective at low rates. In most agricultural areas where benomyl is used, the annual application rate is 2 to 16 ounces of active ingredient (ai) per acre. Owing to its unique systemic properties, benomyl is applied on a 14-day to 21-day interval rather than on a 7-day to 14-day interval as with alternate materials. This results in a reduction of relative costs and energy utilization. In many situations, producers wait until the disease is present before initiating a treatment program. This reduces considerably the number of fungicide applications necessary in a growing season. Because benomyl is used at lower rates per acre than alternative fungicides, the amount of total chemical added to the environment is reduced. Benomyl also has therapeutic properties within plant tissues, a feature that is lacking in contact fungicides.

For preharvest use on citrus for control of scab and greasy spot, benomyl is applied in far less quantities than copper fungicides, ferbam, or captafol, with no harmful effects to tree or fruit. For postharvest citrus application, benomyl and thiabendazole (TBZ), another benzimidazole fungicide, are the most effective postharvest citrus fungicides, but benomyl is applied at one-half to three-quarters the dosage of TBZ. For control of mummy berry disease of blueberries, benomyl is applied at one-half the frequency of the alternatives ferbam or captan, using about one-third the gallonage of spray.

One of the most significant results of benomyl use in orchards has been the reduction of inoculum levels of several important pathogens. This has reduced by as much as 50 percent the amount of all fungicides used in many eastern orchards.

In the treatment of mangoes, 7 applications of benomyl give better disease control than 40 applications of copper, which was used prior to benomyl registration. In bananas, benomyl is somewhat more effective than the alternate fungicide, thiabendazole, which is used at about twice the concentration to achieve a level of disease control equivalent to that provided by benomyl.

Disease Control With Benomyl and Alternatives

Since its introduction, benomyl has displayed effective control of many of the most destructive plant pathogens that previously were either controlled less effectively or were not controlled at all.

Rice

On rice, benomyl is the most effective fungicide with a Federal label for foliar application. It controls the two most serious rice diseases--blast (the most devastating disease affecting human nutrition in the world) and stem rot. Blast and stem rot combined cause an estimated 12 to 15 percent yield loss in rice-producing States each year. If benomyl is not available, producers will have to rely on cultural control methods: Early planting, crop rotation, resistant varieties, and fertility and water management. At this time, none of these methods is effective in reducing or controlling diseases of rice.

Soybeans

In 1977, three major diseases of soybeans, Diaporthe pod and stem rot, Cercospora, and anthracnose, caused an estimated loss of 127.2 million bushels. Minor diseases pushed this yield loss to over 140 million bushels. Benomyl substantially reduces yield losses from soybean diseases. The only alternatives to benomyl in soybeans are Mertect® 340-F, Topsin®-M, and Bravo®. Previous years' data have indicated that these fungicides are not as effective as benomyl. Costs are more per acre, and they do not have the yield increase potential of benomyl.

Pineapple

The pineapple diseases, butt rot and black rot, are effectively controlled by dipping "seed pieces," preplant for butt rot and fresh fruit prepacking for black rot, in a suspension of benomyl and water. The preplant dip treatment is also effective on sugarcane. There is no equivalent alternative to benomyl available for control of these diseases.

Wheat

Cercosporella foot rot is a limiting factor in the production of winter wheat on approximately 700,000 acres of the most productive wheat-producing land in Washington, Oregon, and Idaho. At present, benomyl is the only pesticide available that gives effective control.

Trees and Small Fruits

Benomyl is used extensively to control 20 or more diseases on trees and small fruits. An estimated 43 percent of tree fruits (pome and stone), 46 percent of grapes, and 67 percent of the strawberries are treated with two to four applications annually. No other fungicide registered to date is as effective as benomyl against as many pathogens that attack fruit crops. Captan (pre-RPAR) and EBDC fungicides (RPAR) have been widely used since the early 1950's, but they lack the high anti-sporulation action against many fungi that benomyl provides.

Stone Fruits

The principal use of benomyl on all stone fruits is for brown rot control, both the blossom blight and fruit rot stages; the fruit rot is initiated by inoculum produced by the blossom blight. A major advantage of benomyl results from its systemic property, which permits the fungicide to penetrate through the unopened flower to protect the internal parts from infection after the flower opens. Therefore, the timing of a single benomyl application is much less critical than the timing of a purely protective fungicide, such as captan or maneb.

In field studies, benomyl applications gave 100 percent control of brown rot when unprotected blossoms were 61 percent infected. Benomyl has been one of the most effective fungicides registered against this disease, and it is used on more than 104,000 acres of stone fruits in eastern orchards.

Citrus

Numerous trials in California, Florida, and other citrus-producing areas of the world clearly show that benomyl is superior to other treatments in preventing infection of harvest-related sites and in conferring resistance to treated fruit against later infection. Another benefit of benomyl is that strains of *Penicillium* with fungicide resistance emerge much more slowly in packinghouses that use benomyl than in those that use repeated alternate fungicides. More careful handling of the fruit to prevent injuries is neither an economical nor a practical alternative to pesticide control. Low temperature is also not a suitable alternative to fungicides for postharvest disease control; low temperature merely delays the development of decay. Benomyl is the only fungicide suitable for preharvest application for postharvest disease control in citrus.

Strawberries

Commercial strawberry production in Eastern States occurs on about 20,600 acres, 68 percent of which is treated with benomyl. Benomyl is highly effective for control of the three major diseases of strawberries and has a 5 to 20 yield increase compared with the alternative fungicides captan and thiram.

Ornamentals

Benomyl is listed in State pesticide recommendations for ornamental crops more frequently than alternative fungicides. Grower response indicated that benomyl is more efficacious than alternate chemicals. Maximum disease control is the primary consideration in the ornamental industry because of the high value of these crops, and even slight defects caused by disease detract significantly from the value of the crop. Similar defects in plant appearance resulting from phytotoxicity and excessive residue may significantly reduce crop value. Benomyl is used on many ornamental plants because it is an effective broad-spectrum fungicide, which usually causes no phytotoxicity or offensive residues.

Efficacy data for key floral crops were reported in *Fungicide and Nematicide Tests* from 1970-1977. Alternatives tested included ferbam, triforine, and maneb. In most tests, benomyl produced significantly better disease control than alternative fungicides.

Based on the published recommendations from 33 States, benomyl is the preferred treatment for control of the diseases on specified shade trees and woody ornamentals. It is the only material now available for control of Phomopsis tip blight, black knot of plum, Diplodia tip blight of pine, sycamore anthracnose, Diaporthe twig blight on laurel, and *Diplocarpon* sp. on *Pyrus*.

Vegetables

Bean, tomato, and cabbage seed crops would be seriously affected by loss of benomyl. Benomyl either is the only registered fungicide or it is far superior to all alternatives. Nonchemical methods of control of many of the damaging diseases on vegetables are ineffective.

Benomyl is one of only two registered fungicides for use on mushrooms to control certain pathogenic fungi, which can reduce both quantity and quality of the crop. The other one is zineb, which is also under RPAR review by the U.S. Environmental Protection Agency. Malathion and methoxychlor are listed as alternatives to benomyl and zineb, presumably on the basis that controlling fly populations will control dissemination of fungal spores. Since flies are not the only means of spore dissemination, however, insecticides cannot be regarded as effective alternatives to fungicides.

Turfgrass

Several diseases of turfgrass are effectively controlled by benomyl, thiophanate, and thiophanate-methyl. Severity of dollar spot disease can be reduced by maintaining high nitrogen fertility levels and removing guttation water. Severity of brown patch can be reduced by maintaining low nitrogen fertility levels and removing guttation water. Stripe smut severity can be reduced by low nitrogen fertility levels, especially when resistant cultivars are used. Fusarium blight disease can be contained if the top 1/2 inch of the root zone is kept moist. Severity of the disease is reduced with the use of resistant cultivars. Since turfgrass remains in an area for an extended length of time, however, the chances are high for the development of virulent races of the pathogen.

Peanuts

The most destructive disease of peanuts throughout the world is Cercospora leafspot. Initially, benomyl was very effective in the control of this disease; however, races of the pathogen have developed that are resistant to benomyl. For this reason, the addition of maneb to benomyl has been recommended as an effective alternative. Chlorothalonil is an equivalent alternative to benomyl for control of Cercospora leafspot. It has no effect, however, on Sclerotinia blight (a disease against which benomyl has been shown to exhibit some degree of control), and in some instances chlorothalonil has been observed to enhance the severity of Sclerotinia blight.

Blueberries

Benomyl is the most effective fungicide available for control of mummy berry of blueberries. When benomyl is used in combination with captan, it controls Botrytis gray mold. Fungicide applications should be used in conjunction with clean cultivation practices, as the primary inoculum of both diseases overwinters in decaying blueberry fruit and stem parts.

Yield and Quality

The use of benomyl frequently provides a substantial increase in crop yield and quality. When benomyl was applied to rice at a rate of 0.25 to 0.5 lb active ingredient (ai) per acre, yields increased an average of 500 lb per acre over a 4-year period. Another source reported yield increases averaging 531 lb per acre over 21,000 acres with benomyl use.

Data from the Chocolate Bayou Company, which keeps detailed records on over 22,000 acres of rice, indicated that the higher quality obtained with the use of benomyl increased profits by an average of $15.17 per acre.

When benomyl was applied to soybeans at a rate of 0.25 lb ai per acre, yield increased an average of 6 bushels per acre; in some areas increases of 7.3 bushels per acre were noted. The three most damaging soybean diseases are seedborne. This will cause deterioration of the seed in storage and result in a lower germination rate. In many instances the germination level will fall below 80 percent, which is the level required for seed beans, and the producer is forced to sell the beans for feed at a half the price. Benomyl controls these three seedborne diseases of soybeans. When it is used, it not only allows many producers the option of producing seed beans, but it also increases the grade of the seed.

When benomyl is used in wheat, a single 0.5 lb ai per acre application can increase wheat yields by 30 or more percent.

Vegetable crops also experience yield increases. When benomyl was applied to cucumbers to control specific diseases, researchers noted an 18-percent increase in yield over the most effective alternative. Control of celery blight with benomyl resulted in yield increases of 7 percent over the most effective alternative and 54 percent over the nontreated check. There is no alternative fungicide to benomyl for cabbage seed production, and yield losses range from 35 to 100 percent (33-1,200 lb per acre). Nonchemical control methods for the above-mentioned diseases are ineffective. Over the last 20 years, programs to develop genetic resistance to diseases of vegetables have not been successful. Crop rotation is not successful because not enough suitable vegetable production land is available for this purpose. Suggested procedures for avoiding disease in vegetables, such as planting when the causal organism is not present, do not work. There are no known biological control agents of these specific vegetable diseases.

The use of benomyl has also substantially increased fruit quality. Benomyl's systemic control provides disease-free fruit during most of the year, without which all produce would have to be marketed within 3 to 4 months of harvest. Benomyl has provided better postharvest decay control than any other fungicide registered for this use.

Frequently, fungicides registered for control of certain pathogens cannot be used at the proper time because of damage caused to fruit. Copper fungicides cannot be used for control of greasy spot in citrus if the fruit is intended for the fresh market, because they discolor the rind. This is also true for thin-skinned avocados. Applications of copper fungicides, which are the only other fungicides registered for control of greasy spot, must be avoided in groves that have already accumulated high and potentially toxic concentrations of copper in the soil because of previous excessive use. Captafol cannot be applied preharvest to most citrus varieties, except when the trees are dormant. Dodine, which is an alternative to benomyl for use on pecans, cannot be used safely on all pecan cultivars because of its phytotoxicity.

Before benomyl, no compounds were available that aided in Dutch elm disease (DED) control. Injections of benomyl, together with pruning and prompt sanitation of diseased material, have saved diseased trees. The programs initiated before benomyl was registered employed sanitation, pruning, and methoxychlor spraying and were merely preventive measures. They would not save trees that were already infected with DED.

Failure to reregister benomyl for agricultural and ornamental crop uses would result in marked increase in disease losses, which would be reflected in increased cost of production, reduced quality, and higher prices to the consumer.

Keywords: Benomyl, carbendazim, MBC, fungicide, pesticide registration, biologic assessment, economic impacts, RPAR, human exposure, environmental exposure, crop losses, alternatives to benomyl.

CONTENTS

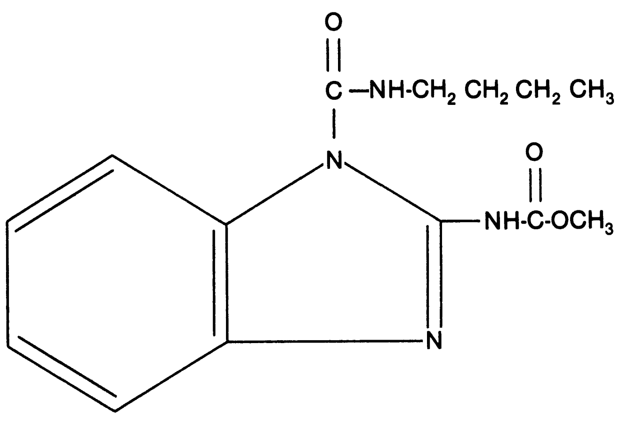
PART 1
AN EVALUATION OF THE TRIGGERS AND THE IMPORTANCE OF BENOMYL TO AGRICULTURE

Introduction

The purpose of this report is to evaluate the benefits and risks of the fungicide benomyl (methyl 1-(butylcar= bamoyl)-2-benzimidazolecarbamate), manufactured under the trade name Benlate® by E. I. DuPont De Nemours & Co., Inc. In this section, Part 1: An evaluation of the triggers and the importance of benomyl to agriculture, special emphasis is given to the presumed risks as stated by the Environmental Protection Agency (EPA). Only a general summary of the importance of benomyl will be included because Part 2 will be concerned primarily with the benefits of the fungicide to agriculture.

Chemical and Physical Properties

Benomyl is the accepted common name for the fungicide methyl 1-(butylcar= bamoyl)-2-benzimidazolecarbamate. The compound is sold under the trade names of Benlate®, Lignasan® BLP, and Tersan® 1991. Benomyl (MW-290) is a non-volatile white crystalline solid that is described as insoluble in water and oil (78)[1/]; however, its biological activity implies that it has at least a slight solubility in water. The compound has the following structural formula:



Under neutral or acidic conditions, aqueous preparations of benomyl break down to methyl 2-benzimidazolecarbamate (MBC) and butyl isocyanate (111). MBC is hydrolyzed to 2-aminobenzimidazole (2-AB) under alkaline conditions, but direct treatment of benomyl with alkali yields the derivatives 3-butyl-sec tri= azino (1,2a) benzimidazole-2,4 (1H,3H) dione (STB) and 2-(3 butylureido) ben= zimidazole (BUB) (21). These various conversions of benomyl are illustrated on page 2:

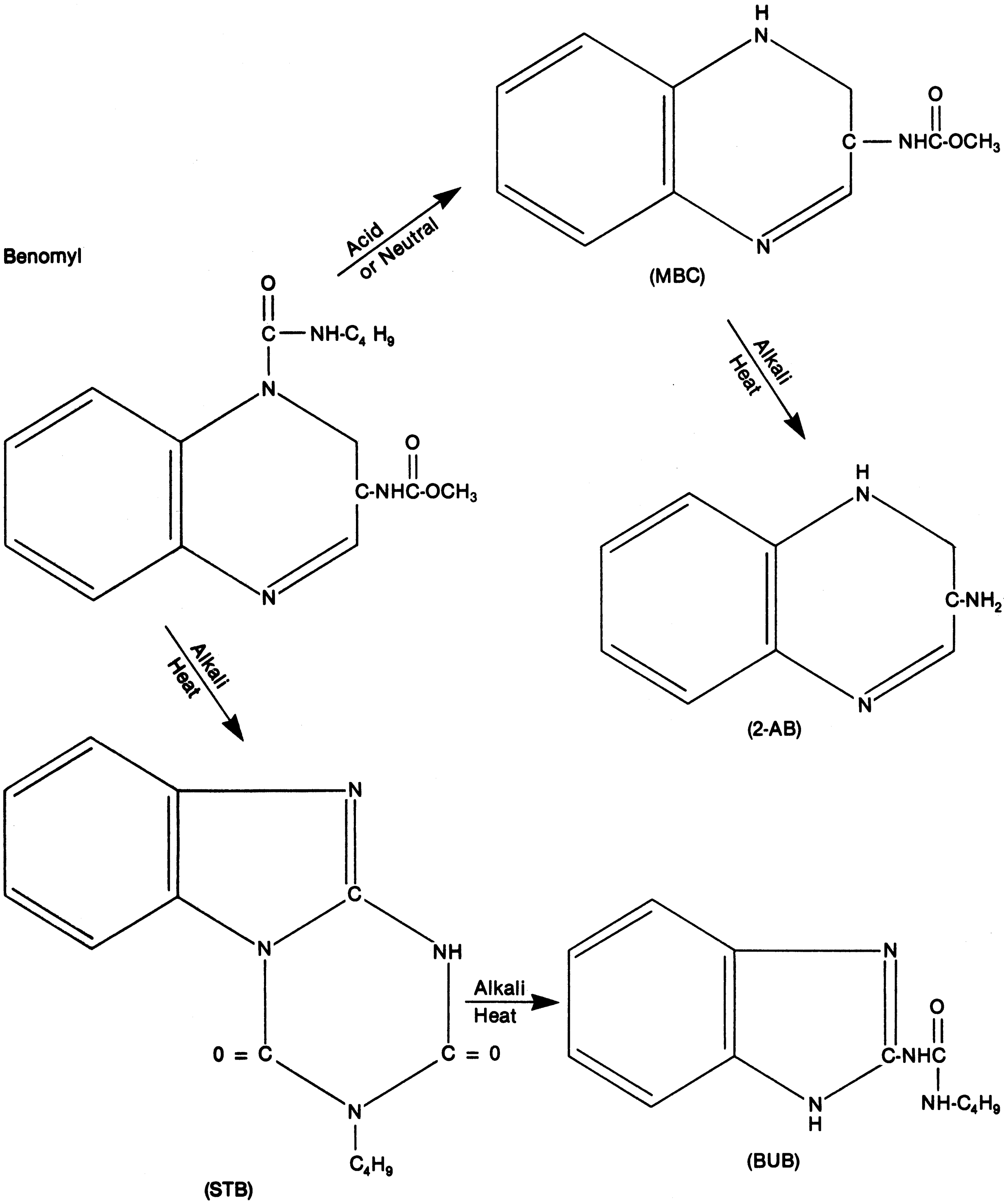
MBC, commonly referred to as carbendazim, is formed from benomyl on or within plant and animal tissues (75, 97, 265, 266). The compound is of particular interest because it is considered to be an intermediate through which the fungitoxic activity of benomyl is mediated (55). The alkaline conversion products STB and BUB are not formed readily under mild pH or biological environments. The 2-AB derivative is a minor degradation product of benomyl in soil and turf (22) and is reported to occur as a metabolite of benomyl in plants (265) and animals (75).

The MBC molecule can exist as the neutral form (non-ionic) or as a cationic form depending on the solution pH. The pH at which equivalent amounts of the neutral and cationic forms exist (pKa_1) is approximately 4.0 (161). Therefore, approximately 90 percent of the MBC exists as the cation at pH 3, 99 percent at pH 2, and 99.9 at pH 1. Approximately 90 percent of the MBC exists as the neutral molecule at pH 5, 99 percent at pH 6, and 99.9 percent at pH 7. The interconversion between the two forms of MBC is illustrated as follows:

$$\text{MBC} + H^+ \rightleftharpoons \text{MBCH}^+$$

This ready interconversion is highly significant in regard to aqueous solubility of MBC. The neutral molecule is reported to be soluble only to the

1/ Numbers in parentheses refer to the references at the end of this publication.



extent of 8 μg/ml at pH 7.0 (262), but solubilities of several thousand μg/ml of the cationic (salt) form in acidic solutions are reported (85). A number of MBC salts, such as the hydrochloride, nitrate, and lactate, have been prepared by acidification with the appropriate acid (85).

Biological and Environmental Fate

Fate in Plants and Micro-organisms

When applied to plants as a spray suspension, much of the benomyl remains intact for periods up to 3 weeks. The principal residual product other than benomyl is MBC (21). MBC, in fact, appears to be the main breakdown product of benomyl found as plant residues. Benomyl penetrates plant leaf surfaces more readily than MBC (21), but MBC appears to be the fungitoxic product found within plant tissue and translocated from the roots to the upper parts of the plant (230, 265, 266).

MBC is rather resistant to degradation in plant tissue. Four days after application of ^{14}C-benomyl to roots of pea plants, 92 percent of the label in the plant tissue was recovered as ^{14}C-MBC (265). After 52 days, 78 percent of the total label recovered was MBC. Traces of 2-AB and some unidentified components were present. Degradation of MBC in strawberry is more rapid than in peas (264). Considerable amounts of 2-AB and of unidentified compounds were present in strawberry tissue after 88 days.

The following metabolites in the relative proportions indicated were found in leaves of melon plants exposed for 2 months to 20 μg/ml of benomyl in the nutrient solution: MBC (free and conjugated), 53.5 pct; 2-AB (free and conjugated), 27.5 pct; benzimidazole, 8.8 pct; ortho-amino-benzonitrile, 8.4 pct; and aniline, 1.8 pct (251). Photochemical reactions were possibly involved in formation of the last two compounds, which results from benzimidazole ring cleavage (251). Identity of these compounds remains doubtful because it was based on chromatographic evidence only. The benzimidazole ring of MBC is relatively resistant to degradation in plant tissues. Solel and others (274) found that 1.56 pct of ^{14}C-ring labeled MBC applied to cucumber leaves was metabolized to $^{14}CO_2$ during a 14-day period.

MBC persists for considerable periods in elm seedlings treated with benomyl, inasmuch as appreciable amounts of fungitoxic activity were found 110 days after the last application of benomyl to the roots (126). Various microorganisms are reported to degrade benomyl and MBC. Among the fungal breakdown products, 2-AB and 5 hydroxy-MBC have been identified (148).

Fate in Animals

Mammals rapidly metabolize benomyl or MBC and excrete the metabolites via the urine and feces. Rats eliminated nearly 90 percent of administered benomyl or of MBC via these routes in 24 hours and nearly 98 percent in 48 hours (97). About 99 percent of benomyl was eliminated in the urine and feces of a dog in 48 hours (97). In mice dosed with benomyl, 94 to 96 percent of the dose was excreted in 96 hours (75). The metabolites of benomyl found in urine and feces of mice, rabbit, and sheep were 2-aminobenzimidazole, MBC, 5-hydroxy-2-aminobenzimidazole, 5-hydroxy-MBC, and conjugates of these 5-hydroxy derivatives (75).

The major breakdown products excreted by rats and dogs that were fed benomyl were 5-hydroxy-MBC and MBC (97). Milk from dairy cows and eggs from chickens contained detectable amounts of residues (0.1 p/m or less) only when dietary levels (25-50 p/m) of benomyl were fed (97).

The ability of mammals to metabolize benomyl and MBC and to excrete the metabolites are important factors in reducing toxicity and preventing accumulation in the tissues.

Fate in Air

Benomyl is a non-volatile compound (78). There are no indications that it is hazardous as an air contaminator.

Fate in Soil and Turf

The half-life of benomyl in alkaline silt loam (pH 8.3) of irrigated cotton beds can be estimated from the data of Hine and others (125) to be about 3 months for application rates of 10 or 20 lb/acre of active ingredient applied in the top 3 inches of soil. Determinations were based on fungitoxic bioassays and therefore indicated only the residues, benomyl and MBC.

An extensive study made by Baude and others (22) to determine the fate and behavior of benomyl under field conditions showed that the half-life of total benzimidazole-containing residues was about 3 to 6 months in turf and about 6 to 12 months on bare soil in different agricultural regions of the United States. MBC and 2-amino= benzimidazole constituted the major portion of the residues remaining after 12 months in soils at Delaware, North Carolina, and Florida locations.

The type of soil, temperature, and sterilization influence the rate of disappearance of MBC from the soil, indicating that micro-organisms are probably involved in the breakdown of the compound (148). Soil fungi and bacteria have been isolated that are reported to degrade benomyl (148). The behavior of benomyl in soils indicates that the breakdown product MBC degrades gradually. Application of levels of benomyl as high as 80 pounds active ingredient (ai) per acre (the usual rates in practice range from 0.25 to 2.0 pounds (ai) per acre/year) has no long-term effect on the soil microflora (225). Benomyl and MBC are bound, degraded, or inactivated by some other manner in soils. Other tests demonstrate that follow-up crops in subsequent growing seasons do not take up benomyl residues (22). Since benomyl and MBC residues are strongly retained by soils, they do not constitute a hazard to water sources through leaching.

Fate in Water

In dilute aqueous solutions, benomyl breaks down rapidly to MBC (55), but in aqueous suspensions (600 μg/ml) only about 5 percent is converted to MBC in 49 hours (21). At the end of this period, 99 percent of the product consists of benomyl and MBC. Most of the remaining 0.9 percent consists of STB. Slow conversion of benomyl to MBC in water is probably determined by the slow rate of solubilization of benomyl.

The relatively long stability of MBC in soil (22) indicates that it should be relatively stable in water, possibly having a half-life of 3 months or longer. There are indications that decomposition may be hastened by light, particularly at pH's in the vicinity of 9.0 (355). Adsorption of benomyl (and MBC) on soil particles appears to be an important factor involved in reducing the level of the compound in water. This is evident from a study of benomyl levels in water and mud of flooded ricefields (79). The high resistance of the compound to leaching in soils implies that it would be bound and retained on soil particles in the presence of water.

Summary - Biological and Environmental Fate

Principal residues found on plants treated with benomyl are benomyl and MBC. The presence of 2-aminobenzi= midazole and traces of other metabolites are reported several weeks after applications of benomyl to plants.

Mammals rapidly metabolize benomyl and excrete the metabolites and the parent compound via the urine or feces, or both. Metabolism and excretion play important roles in preventing mammalian toxicity.

The half-life of benomyl residue is approximately 3 to 6 months in turf and about 6 to 12 months in bare soil. The principal residues are MBC and 2-amino= benzimidazole. Benomyl residues are strongly retained by soils and show little tendency for leaching.

Benomyl suspensions slowly convert to MBC under neutral and acidic conditions in water. Adsorption on soil particles appears to be an important factor in reducing the levels of benomyl and MBC in water.

Summary of Presumptions Against Benomyl

Acute Toxicity: Hazard to Wildlife, Aquatic Species

Title 40, 162.11(a)(3)(i)(B)(3), of the Code of Federal Regulations (CFR) for the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) provides that a rebuttable presumption shall arise if a pesticide "results in a maximum calculated concentration following direct application to a 6-inch layer of water more than 1/2 the acute LC_{50} for aquatic organisms representative of the organisms likely to be exposed as measured on test animals specified in the Registration Guidelines."

On the basis of scientific studies and information summarized in the Position Document, the Environmental Protection Agency has concluded that this risk index has been exceeded by all registrations and applications for registration of pesticide products containing benomyl which are for direct application to water, and that a rebuttable presumption against new or continued registration of such products has therefore arisen.

Mutagenicity

40 CFR 162.11(a)(3)(ii)(A) provides that a rebuttable presumption shall arise if a pesticide "induces mutagenic effects, as determined by multi-test evidence."

On the basis of scientific studies and information summarized in the Position Document, the Agency has concluded that this risk index has been exceeded by all registrations and applications for registration of pesticide products containing benomyl, and that a rebuttable presumption against new or continued registration of such products has therefore arisen.

Other Chronic or Delayed Toxic Effects

40 CFR 162.11(a)(3)(ii)(B) provides that a rebuttable presumption shall arise if a pesticide "produces any other chronic or delayed toxic effect in test animals at any dosage up to a level, as determined by the Administrator, which is substantially higher than that to which humans can reasonably be anticipated to be exposed, taking into account ample margins of safety."

On the basis of scientific studies and information summarized in the Position Document, the Agency has concluded that the risk index for teratogenicity has been exceeded by all registrations and applications for registration of pesticide products containing benomyl which are for home use, and that a rebuttable presumption against new or continued registration of such products has therefore arisen.

On the basis of scientific studies and information summarized in the Position Document, the Agency has concluded that the risk index for reduction in spermatogenic activity has been exceeded by all registrations and applications for registration of pesticide products containing benomyl and that a rebuttable presumption against new or continued registration of such products has therefore arisen.

Population Reductions in Non-target Organisms

40 CFR 162.11(a)(3)(ii)(C) provides that a rebuttable presumption shall arise if a pesticide "can reasonably be anticipated to result in significant local, regional, or national population reductions in non-target organisms."

On the basis of scientific studies and information summarized in the Position Document, the Agency has concluded that the risk index for population reductions in non-target organisms has been exceeded by registrations and applications for registration of pesticide products containing benomyl which are for outdoor use, and that a rebuttable presumption against new or continued registration of such products has therefore arisen.

Biological Effects Related to Exposure

Hazard to Wildlife, Aquatic Species

Benomyl is toxic to several species of fish. The LC_{50} values for

Lebistes reticulatus is 3.4 p/m; MBC is not toxic at 8 p/m (49). The LC_{50} of benomyl is 0.48 p/m and the LC_{50} of MBC is 1.8 p/m for *Salmo gaindneri* (49). The EPA-Benomyl Position Document 1 cites references to the effect that the LC_{50} of benomyl to bluegill sunfish ranges from 0.2 to 2.6 p/m and that the LC_{50} for Channel catfish ranges from 8 to 12 p/b. The LC_{50} values for the water flea, *Daphnia magna*, are reported to be 0.64 p/m for benomyl and 0.46 p/m for MBC (49).

The EPA working group has calculated the possible occurrence of 734 p/b of benomyl in water of ricefields sprayed with benomyl formulation for disease control and considered this level to be a hazard for aquatic organisms. A monitoring of the benomyl levels in water of ricefields and drainage systems was carried out at four locations in 1977 (79). These tests showed that water in the main drainage ditches that received water from fields sprayed with recommended amounts of benomyl 16 to 29 days previously usually contained nondetectable levels (less than 0.02 p/m) of the fungicide. Occasional levels from 0.02 to 0.04 p/m were recorded. These studies indicated that adsorption of benomyl (and MBC) by soil particles is an important factor in reducing the concentrations of fungicide in water.

Except for one undocumented report of suspected catfish kill by benomyl when water from a ricefield was used to fill a catfish pond, no evidence was found of aquatic hazards arising from the use of benomyl in ricefields. The monitoring studies (79) indicate that drainage water from ricefields 16 to 29 days following application of benomyl does not constitute a hazard for aquatic organisms. A possible exception in certain instances is the Channel catfish, which is reported to be highly sensitive to benomyl. Further studies are needed to confirm the reported sensitivity of this species in view of the lack of evidence for detrimental effects of benomyl in practice.

Exposure Related to Chronic or Delayed Effects

Teratogenic Effects

The EPA-Benomyl Position Document cites the no-observable-teratogenic-effect level of 62.5 mg/kg/day in Wistar rats as the basis for determining margins of safety and has concluded that a pregnant woman might be exposed to hazardous levels of benomyl in home garden use. Assuming 10 percent dermal absorption, the EPA working group estimated a theoretical dermal absorption of 28.5 mg/kg per application or 0.48 mg/kg for a 60-kg woman. In the present report, estimates of potential exposure of a home gardener to benomyl were made using applicator exposure measurements made by Wolfe and others (354) as a basis for calculations. Although the measurements made by Wolfe and others involved field applicators using power equipment, it is believed that these exposure rates would be greater than those experienced by home applicators using low-pressure equipment.

The dermal exposure values reported by Wolfe and others were based on the assumption that the applicator wore a short-sleeved, open-necked shirt, no gloves or hat, and that clothing gave complete protection to the area covered.

In calculating potential home garden applicator exposure to benomyl, the spraying period was assumed to be one hour; the rate of application at 0.5 pound active ingredient per acre; dermal absorption, 10 pct; respiratory absorption, 100 pct. The calculated potential exposures of home garden sprayers to benomyl are presented in table 1. The exposure values range from 0.0013 mg/kg to 0.018 mg/kg, which represent respectively 48,077 and 3,472-fold safety margins relative to a 62.5-mg/kg no-effect level for teratogenesis. The highest value for respiratory plus 10 percent dermal exposure (0.018 mg/kg) is less than 4 percent of that (0.48 mg/kg) calculated by the EPA working group for 10 percent dermal exposure alone.

Table 1.--Calculated values[1/] for potential exposure of home garden applicators to pesticides via respiratory and dermal routes while making applications for 1 hour at the rate of 0.5 pound active ingredient per acre

Activity used as basis for estimating exposure [2/]	Respiratory (mg/h)	Dermal (mg/h)	Dose (mg/kg/h) 100 pct respiratory + 10 pct dermal (60-kg person)	Safety margin [3/]
Operating power air-blast machine spraying orchard.	0.00625	3.38	0.006	10,417
High-pressure power handgun spraying fruit trees in nursery.	.0025	.775	.0013	48,077
Operating power air-blast machine.	.0066	3.44	.006	10,417
High-pressure power handgun spraying orchard cover crop.	.004	1.25	.002	31,250
Operating power duster applying pesticide to pole beans.	.255	8.21	.018	3,472
High-pressure power handgun spraying from ground position near portable tower sprayer-citrus groves.	.0180	9.40	.016	3,906

1/ Calculations based on mean exposure values determined by Wolfe and others (354) for applicators exposed to various pesticides. Application rates in data of Wolfe and others adjusted to 0.5 lb (ai) per acre for making comparisons with benomyl.

2/ These activities are listed in table 2 of Wolfe and others (354) in the following order: 4, 6, 8, 12, 16, and 24.

3/ Ratio of 62.5 mg/kg/day no-observable-teratogenic-effect level to mg/kg/h applicator exposure. The 62.5 mg/kg value is cited in the EPA-Benomyl Position Document 1.

The highest dermal exposure (activity 24, table 1) is about 3 percent of the exposure calculated by the EPA working group. The wide safety margins indicate that benomyl does not constitute a hazard to home garden applicators.

The values calculated in this report probably overestimate exposure because it is highly doubtful whether dermal absorption approaches 10 percent and whether use of low-pressure, home gardener application equipment leads to as much exposure as use of power equipment.

Reduction in Spermatogenic Activity

The EPA working group used the no-observable-effect level on spermatogenesis in rats of 7.5 mg/kg as a basis for evaluating safety margins for inhalation exposure to benomyl. They calculated 0.24 mg/kg as the amount of benomyl an applicator would inhale during 4 hours of spraying and they concluded that this dose was too high relative to the dose that has produced a decrease in spermatogenic activity in animals.

Data from the study of Wolfe and others (354) on applicator exposure to pesticides have been used as a basis for calculating respiratory exposure of applicators to benomyl. Although the measurements of Wolfe and others (354) were made for applicator exposure to pesticides other than benomyl, they are regarded as a sound basis on which to develop estimates of inhalation exposure to benomyl.

Table 2.--Calculated values[1/] for potential respiratory exposure of spray applicators to pesticides while making applications at the rate of 0.5 pound active ingredient per acre for 4 hours

Activity[2/]	Mg/4 h	Mg/kg/4 h (60-kg person)	Safety margin[3/]
Operating power air-blast machine spraying orchard.	0.03	0.0005	15,000
High-pressure power handgun spraying fruit trees in nursery.	.01	.0002	37,500
Driving tractor pulling high-pressure handgun sprayer in orchard.	.01	.0002	37,500
Operating power air-blast machine spraying fruit orchard.	.03	.0005	15,000
Chemical thinning apple blossoms by power air-blast machine.	.06	.0010	7,500
High-pressure power handgun spraying orchard cover crop.	.02	.0003	25,000
Operating power air-blast machine spraying fruit orchard.	.02	.0003	25,000
High-pressure power handgun from ground position near portable tower sprayer-citrus groves.	.07	.0011	6,818
Operating tractor-mounted boom ground sprayer in row crops.	.04	.0007	10,714

1/ Calculations based on mean exposure values determined by Wolfe and others (354) for applicators exposed to various pesticides. Application rates in data of Wolfe and others adjusted to 0.5 lb (ai) per acre for making comparisons with benomyl.

2/ These activities are listed in table 2 of Wolfe and others (354) in the following order: 4, 6, 7, 8, 11, 12, 21, 24, and 28.

3/ Ratio of 7.5 mg/kg no-effect level in rats to mg/kg/4 h applicator exposure. The 7.5 mg/kg value is cited in the EPA-Benomyl Position Document 1.

In making estimates of applicator exposure, nine applicator situations from the studies of Wolfe and others (354) resembling benomyl applicator situations were used as a basis for developing exposure values. The values are presented in table 2.

Respiratory exposure values range from 0.0010 mg/kg/4 hours to 0.0002 mg/kg/4 hours, which represent respectively 6,818 and 37,500-fold safety margins relative to a 7.5 mg/kg no-observable-effect level on spermatogenesis. The highest estimated exposure value (0.0010 mg/kg) is less than 1 percent of the value (0.24 mg/kg) estimated by the EPA working group.

The values (table 2) do not indicate a hazard for applicators from benomyl acquired by the inhalation route. Since no information was available on dermal absorption of benomyl, no attempt was made to calculate the amount of benomyl acquired by this route. There is need for studies on this aspect of the toxicological considerations relating to applicator exposure.

Antimitotic Activity

Antimitotic activity is well established as the mode of action of benomyl and MBC (111), and threshold limits can be established for this activity. These limits are in the same order of magnitude as those established for teratogenicity and reduction in spermatogenic activity. The potential exposure values and safety margins for these are given in tables 1 and 2. It is reasonable to apply these exposure values and safety margins for the antimitotic effects of benomyl because it can be deduced that the same cellular mechanism is involved that is involved in teratogenesis and in reduction in spermatogenic activity. Applicator safety margins for antimitotic activity are very favorable. These range from 3,472 to 48,077 for home applicators and from 6,818 to 37,500 for field applicators (tables 1 and 2).

Summary - Exposure Related to Chronic or Delayed Toxic Effects

Estimates of home garden applicator exposure to benomyl or MBC indicate safety margins ranging from 3,472 to 48,077 based on a 62.5 mg/kg no-observable-teratogenic-effect level. These values are regarded as conservative, that is, they probably exceed actual exposure.

Estimates of inhalation exposure of field applicators to benomyl indicate safety margins ranging from 6,818 to 37,500 based on 7.5 mg/kg no-observable-effect level for reduction in spermatogenic activity.

Threshold limits can be established for antimitotic activity. The limits are of the same order of magnitude as those established for teratogenicity and reduction in spermatogenic activity cited in those sections of this report. Applicator safety margins for antimitotic activity are very favorable. These range from 3,472 to 48,077 for home applicators (table 1) and from 6,818 to 37,500 for field applicators (table 2).

Calculated exposure values indicate that benomyl is not a hazard to home garden applicators via the dermal and respiratory routes or to field applicators via inhalation exposure.

Population Reductions in Non-target Organisms

Toxicity to Earthworms

Benomyl was shown to have repellent effects on the feeding of the earthworm Lumbricus terrestris (286). Worms fed normally on leaves treated with 0.43 $\mu g/cm^2$ of benomyl but were completely repelled by those treated with 1.75 $\mu g/cm^2$ or greater. Benomyl, MBC, and thiophanate-methyl were equally repellent in these tests.

The effect of simple contact with benomyl was studied by Stringer and Wright (286). Worms were dipped into suspensions of benomyl for 1 minute and rinsed. Those treated with 5000 µg/ml died by the 13th day and those treated with 500 µg/ml died by the 27th day. Worms treated with 50, 5, or 0.5 µg/ml all survived but failed to eat for 14 days; all were fully recovered and fed normally by the 27th day.

A drench of soil in pots with 7.75 or 1.55 kg/ha (6.9 and 1.4 lb (ai)/acre) resulted in respective earthworm kills of 100 percent for 7.75 kg/ha and 60 percent for 1.55 kg/ha 14 days after treatment (286). Stringer and Lyons (285) found that 11 applications of benomyl per year, or a total of 3.64 kg/ha (3.2 lb/acre (ai)), during 1972 to a commercial orchard at Biddestone, England, led to marked reduction of four of six species of earthworms in samples taken in January 1973. Other tests made at the Long Ashton Experiment Station showed that seven sprays of benomyl per year for 2 years, or an annual application rate of 1.96 kg/ha (1.7 lb (ai)/acre), led to a marked reduction in the population of several species of earthworms (289). On the other hand, earthworm populations were not reduced in soil at harvest time on October 2 in wheat fields previously sprayed three times with 0.50 kg/ha of benomyl (once each in April, May, and June) for a total application of 1.50 kg/ha (1.34 lb (ai)/acre) (220). Earthworms subsequently cultured for 13 months in a mixture of soil and straw from the treated plots reproduced normally. Weight losses of straw, buried at harvest time (October 2, 1973) and measured on July 1, 1974, did not differ in control samples from those of the 1.50 kg/ha benomyl treatments. Samplings made 21 days after application of 7.8 kg/ha (6.9 lb (ai)/ acre) to pasture showed that earthworm populations were reduced about 95 percent (302). Application of 36 g/m^2 (32 lb (ai)/acre) of benomyl to Flanagan silt loam by pressure injection at the Illinois Natural History Survey Arboretum in May of 1974 led to a marked reduction in numbers of earthworms in July, August, and September (28). Counts made in August 1974 on plots similarly treated with this unusually high level of benomyl in 1973, 1972, 1971, and 1970 (18 g/m^2 in 1970) showed normal populations of worms. These tests demonstrate that although earthworm populations are reduced by benomyl, they return to normal within a year and remain at that level thereafter. Stringer and Lyons (285) also found recovery of earthworm populations in apple orchards after benomyl sprays were discontinued. Within 2 years, populations of all species had completely recovered except for those of Lumbricus terrestris and Allolobophora clorotica, which were significantly lower than normal.

The experience with benomyl indicates that application of the fungicide at sufficiently high rates could reduce earthworm populations; however, no evidence was found that practical use of benomyl has led to a lowering of plant vigor or productivity because of an adverse effect on earthworm populations.

The majority of agricultural applications of benomyl involve the use of 1 pound or less (ai) per acre/year. Experience based on the use of benomyl in wheat fields (220) indicates that these levels of benomyl would have no adverse effects on earthworms.

Although it is widely believed that earthworms are beneficial organisms, it is difficult to assess to what extent an orchard would suffer from the absence of or reduction in earthworm populations due to the use of fungicides (285). Nutrient status of apple trees appeared to be unaffected in orchards in which earthworms were almost totally lacking because of heavy use of copper fungicides (285). It has been observed that vegetative vigor and crop yield were as good in black currant fields lacking earthworms as in those with high earthworm populations (285). Although it is evident that earthworms are beneficial in improving soil conditioning, it has not been proved that they are essential (285). Benomyl is known to be active against plant-parasitic nematodes in the soil (189). The benefits derived from reduction in numbers of these parasites would compensate for any reduction in beneficial effects of earthworms that may occur.

Any adverse effects on earthworm populations that might result from practical use of benomyl would be confined to the site of application because benomyl and its degradation products show practically no tendency to move in soil away from the area of application (22, 125, 250). A return of earthworm populations to normal would also be expected within a year or two following discontinued use of the fungicides (28, 285).

Summary - Non-target Organisms

Experience indicates that benomyl at sufficiently high concentrations can reduce earthworm populations.

In most agricultural areas of the United States where benomyl is used, the annual rate of application is less than 1.34 lb (ai)/acre, a level that had no adverse effects on earthworms in wheat field tests.

There is no evidence that the use of benomyl has led to a lowering of plant vigor or productivity because of adverse effects on earthworms.

Any adverse effects on earthworms that might result from practical use of benomyl would be confined to the area of application, since it or its degradation products show little or no tendency to move in soil away from the site of application.

In tests where high levels of benomyl reduced earthworm populations, there was recovery of populations upon discontinued use of the fungicide.

Importance of Benomyl to Agriculture

Benomyl was first used in the United States in 1969. It was the first of a group of fungicides in the benzimidazole class. Benomyl is a broad-spectrum fungicide in that it controls a wide range of diseases. It is effective at low rates, from 2 to 16 ounces of active ingredient (ai) per acre. (Note: Benomyl is the active ingredient in Benlate®)

Benomyl is the first major fungicide with systemic activity inside plant tissues. This important characteristic improves disease control, prevents excessive loss of the fungicide from heavy rainfall, and controls fungal infections after they have become established. When this fungicide was introduced, it changed the concept of chemical disease control. Previously, the only materials available for disease control were contact-type preventive treatments, which had to be applied on a strict schedule. Benomyl allowed more flexibility in the timing of applications; in many instances producers now wait until a disease is present before beginning treatment. Owing to its systemic activity, benomyl is applied on a 14- to 21-day interval rather than on a 7- to 14-day interval, such as is used with alternate materials. If benomyl were not registered for use, growers would be forced to apply fungicides more frequently, resulting in increased labor and application costs.

Current benomyl registrations include 43 food crops and 41 ornamentals including turf. Benomyl is sold as Benlate®, Tersan® 1991 and Lignasan®. It is also repackaged and sold under other trade names for ornamental use. Current use of benomyl in the United States exceeds 3.0 million pounds of active ingredient annually (table 3). Benefits from the use of fungicides can be measured in many ways, such as increased yields and quality or decreased production costs. These benefits can be measured directly by increase in net income to the producer; however, benefits to the consumer also accrue through lower retail prices and higher-quality products. The economic impact of benomyl will be more thoroughly covered in Part 2 of this report. In the following sections, the assessment team has attempted to give an overview of the use of benomyl on the major and specialty crop areas.

Soybeans

During 1977, 57.9 million acres of soybeans were grown in the United States, and of this acreage 1.5 million acres were treated with benomyl (table 4). The major use areas include the Southeast, and Louisiana and Texas soybean-producing areas where warm temperatures and high humidity prevail. It is in these areas that plant-pathogenic organisms are causing serious disease losses. Based on estimates compiled by the Southern Soybean Disease Workers, annual disease losses amounted to 1.114 million bushels in 1976. Benomyl is recommended at the rate of 0.25 to 0.50 pound per acre depending on disease pressure. Two applications are suggested: The first is applied at early pod set and the second application in 14 to 21 days. Applications are made primarily by agricultural aircraft; only a small percentage is applied by ground application equipment. Three major diseases are controlled with benomyl, diaporthe pod and stem rot, anthracnose, and cercospora (leaf spot and purple seed stain). Yield data obtained with the use of benomyl consistently show increases averaging 5.5 bushels per acre (9).

In addition to increases in yield, the quality of soybean seed from fields treated with benomyl is also improved.

Table 3.--Use of benomyl fungicide in the United States - 1977 1/

Crop	Total pounds (ai) used
Soybeans	761,000
Stone fruits	344,000
Rice	299,250
Citrus	259,694
Bananas 2/	200,000
Grapes	173,692
Peanuts	158,500
Vegetables	151,500
Turf	150,000
Ornamentals	125,000
Pecans	100,000
Apples	96,184
Berries (Strawberries, Blueberries, Raspberries).	71,911
Almonds	63,800
Sugarcane	26,000
Sugar beets	13,500
Wheat 3/	11,150
Mushrooms	11,034
Pears	10,928
Elm	7,010
Mangoes	6,000
Avocados	1,628
Pineapples	1,506
Macadamia nuts	100
Total	3,043,387

1/ Total use based on actual surveys conducted by the benomyl assessment team.

2/ Although the bananas were actually grown and treated in Central and South America, the impact would be on the United States because most of the crop is exported to this country.

3/ Benomyl use data based on 1976 season owing to the extreme drought in 1977.

The benomyl treatment prevents disease organisms from penetrating the pod and infecting the seed; this results in more vigorous stands when these soybean seeds are planted. The effect that this has on yields is difficult to measure, but seed producers often charge a premium of $0.50 to $1.00 per bushel for soybean seed from fields treated with benomyl. Fields set aside for seed production that have not been treated with benomyl often fall below the required standard of 80 percent germination. These soybeans have to be sold in regular market channels rather than for seed. An application of benomyl in these instances would probably be worth $4 to $5 per bushel--the difference between what the grower would have received for seed versus market soybeans.

Fruit Crops - General

Fungicides are used to control more than 40 diseases in the commercial production of non-citrus fruit crops in the United States. Benomyl is used extensively in sprays applied from the ground and air and in postharvest dips. It is highly effective against more than 25 pathogens infecting deciduous tree fruits, grapes, blueberries, strawberries, and raspberries (table 5). Some of the common diseases affecting these crops include the following:

Almonds - brown rot, blossom blight

Apple and Pear - scab, powdery mildew, sooty blotch, fly speck, Botrytis rot, Penicillium rot, Gloeosporium rot, black rot.

Stone fruits including Apricots, Cherries, Nectarines, Peaches, Plums, Prunes - brown rot, blossom and fruit rot, peach scab, powdery mildew, cherry leaf spot, Alternaria rot.

Small fruits including Grapes, Strawberries, Blueberries, and Raspberries - Botrytis gray mold, powdery mildew, leaf scorch, leaf blight, leaf spot, mummy berry.

Table 4.--Total harvested soybean acreage and benomyl use by region and State, 1977

Region and State	Acres harvested 1/	Treatment with benomyl		
		Percent of acres	Total acres	Total pounds (ai) per State
	Thousand acres		-------Thousand acres-------	
Southeast				
Alabama	1,600	8.8	140.6	70.30
Florida	327	4.4	14.5	7.25
Georgia	1,090	12.8	139.8	69.90
North Carolina	1,320	3.9	52.3	26.15
South Carolina	1,300	9.4	122.0	61.00
Total	5,637		469.2	234.60
Delta				
Arkansas	4,600	6.0	276.0	138.00
Kentucky	1,360	2.5	34.4	17.20
Louisiana	2,680	8.6	229.5	114.75
Mississippi	3,650	3.7	134.8	67.40
Missouri	4,800	1.9	90.0	45.00
Tennessee	2,200	1.9	42.0	21.00
Total	19,290		806.7	403.35
Southern Plains				
Oklahoma	275	5.7	15.9	7.95
Texas	760	18.6	142.0	71.00
Total	1,035		157.9	78.95
Other Regions	31,949	.28	88.2	44.10
Total United States	57,911	2.6	1,522.0	761.00

1/ Source: (310).

All of these crops must be treated with fungicides from 4 to 12 times each growing season to produce profitable high-quality crops. Benomyl is used in every region where fruits are grown.

The estimated amount of benomyl used was derived from information obtained by consulting fruit specialists in major fruit-growing areas. For example, in the case of apples, figures from detailed pest-management projects in Michigan, New York, Pennsylvania, and North Carolina were used in determining actual amounts used by a limited number of growers. It should be noted that the estimated amounts applied per acre per year are generally below the rates recommended in most States and are believed to be a realistic estimate of actual amounts used in most commercial orchards. The calculated amounts are based on usage patterns during the past 2 years and the anticipated usage in 1978 in areas where tolerant strains of pathogens have developed. Tolerant strains of the pathogen causing apple scab and brown rot of stone fruits have been reported to occur in Michigan, New York, Maine, North Carolina, and South Carolina.

It is estimated that 702,832 pounds of benomyl are used annually on 658,595 treated acres of non-citrus fruit crops (table 5). Disease problems are generally more severe in the Eastern States because of higher rainfall and more favorable conditions for symptom development. Exceptions to this are

Table 5.--Deciduous fruit crops treated with benomyl in the field and estimated amount used in the United States

Crop and location	Total acres 1/	Acres treated: Number acres 2/	Acres treated: Percent	Number of applications	Amount per acre per year (pounds ai) 2/	Total benomyl used (lb ai)
Almonds						
West	266,065	100,000	37.6	---	0.64	63,800
Apples						
East	500	75,421	23.2	4.0	1.28	96,184
West	(Postharvest only, see text for explanation)					
Apricots						
East	500	450	90.0	4.0	1.50	675
West	27,500	20,000	72.7	---	0.94	18,750
Blueberries						
East	20,800	15,200	73.0	---	---	16,175
West	7,575	425	6.0	---	---	425
Cherries (tart and sweet)						
East	50,058	15,011	37.5	3.3	0.90	13,435
West	10,400	7,000	67.3	---	0.54	3,750
Grapes						
East	80,801	45,181	55.9	4.1	1.94	87,442
West	588,000	150,000	25.5	---	0.58	86,250
Peaches and nectarines						
East	143,369	104,919	73.0	4.6	1.00	105,359
West	87,135	66,500	76.3	---	0.90	121,538
Pears						
East	17,465	8,015	46.0	3.8	1.36	10,928
West	(Postharvest only, see text for explanation)					120,500
Plums and prunes						
East	12,642	8,647	68.0	4.6	1.34	11,560
West	97,400	10,000	10.3	---	1.13	11,250
Raspberries						
East	3,800	950	2.5	---	0.91	780
West	5,635	2,550	45.3	---	0.90	2,740
Strawberries						
East	20,582	13,926	67.7	2.0	1.25	17,391
West	19,800	14,400	72.3	---	2.38	34,400
Total						
East	664,849	287,720	43.3	---	1.27	359,929
West	1,109,510	370,875	33.3	---	0.74	342,903
Grand total	1,774,559	658,595	37.0	---	0.969	702,832

1/ Includes bearing and nonbearing acreage and was obtained from State surveys (1972-76) or from estimates by fruit specialists in each State.

2/ Estimates based on usage patterns during 1976 and 1977 or anticipated in 1978 in regions where tolerant strains of pathogens have developed.

strawberries, grown under frequent irrigation, and cling peaches, which are highly susceptible to brown rot. Approximately 43 percent of 664,849 acres of fruits grown commercially in 30 Eastern States are treated annually with benomyl, and 33 percent of the 1,109,510 acres of non-citrus fruits grown in Western States are treated (table 5).

In the Eastern States benomyl is used on pome and stone fruits in sprays throughout the growing season to protect fruit and foliage. An estimated 83,436 acres of apples and pears are sprayed annually. On these crops in the West, benomyl is used almost entirely as a postharvest dip to protect fruit in storage. The introduction of benomyl has helped to extend the marketing season of apples and pears 3 months longer while concurrently decreasing the incidence of decay. Without benomyl the resultant adjustment of the marketing program would cause a much less orderly supply of apples and pears and subsequently higher consumer prices. In the United States, a total of 39,836 pounds are used annually in postharvest dips on 100.7 million bushels of pome fruits plus an additional 7,000 pounds on stone fruits. Benomyl is used to treat approximately 332,527 acres of stone fruits in the United States, which utilize 288,679 pounds annually. Grapes are grown commercially in 10 or more States on 195,181 acres and are treated with approximately 173,692 pounds. Annual usage on grapes has shown a rapid increase. Other small fruits including strawberries, blueberries, and raspberries are grown commercially in many States; an estimated 66,136 acres are treated with 86,784 pounds of benomyl.

A common specialty use of benomyl by the fruit industry is the treatment of walls and floors of fruit cold storages to retard fungal growth. An estimated 500 pounds are used annually for this purpose. The amount of benomyl used by home fruit growers is relatively small because the product is not widely distributed in small packages. An estimated 3,000 pounds per year are used by this group. These specialty uses by commercial fruit producers and handlers and home fruit growers amount to 15,500 pounds per year.

Since the introduction and general adoption of benomyl, substantial improvement in the level of disease control on several fruit crops has resulted. Particularly important has been the dramatic reduction in brown rot of stone fruits and the significant reduction in losses due to scab and powdery mildew on apple; black rot and powdery mildew of grapes; and Botrytis fruit rot of strawberries. Prestorage treatment of apples has substantially reduced blue mold storage decay, and the shelf-life of peaches and nectarines has been increased by several days as the result of postharvest treatment with benomyl. No other fungicide is as efficient as benomyl against a large group of pathogens attacking fruit crops. Captan and mancozeb, also under RPAR review, have been widely used since the early 1950s, but they lack the high antisporulation action of benomyl against many fungi. The loss of benomyl for use in orchards would soon result in increased inoculum levels of several pathogens, which would require an increase in fungicide usage by as much as 25 to 40 percent. A measure of benomyl's importance to orchardists is illustrated by the extreme care that many growers take to use the fungicide as directed in order to prevent the development of resistant strains of pathogens. For example, California stone fruit growers use benomyl only in combination with other fungicides. Pacific Northwest apple and pear growers use benomyl only for postharvest disease control. These techniques reduce the possibility of development of tolerant strains, and help ensure long-term usefulness of this fungicide.

Pineapple

Benomyl provides outstanding control of "butt rot" of pineapple "seed pieces" (crowns), caused by Thielaviopsis paradoxa, in Hawaii. Very poor stands result when planting material is not treated with benomyl. The "seed pieces" are dipped in a suspension of 0.63 pound benomyl/100 gal water before planting. No alternate fungicides are registered for this use. There are 43,000 acres of pineapple in the State, about 10,000 acres of which are replanted each year.

Benomyl is not used on pineapple plants during the growing season, but the fruit is dipped in a suspension of 1 to 2 pounds benomyl/100 gal water before packing for shipment. This treatment is very effective in controlling black rot (caused by T. paradoxa) on fresh fruit during marketing. The alternative fungicide, o-phenylphenol, is much less effective. In 1976, 1,506 pounds of benomyl were used for postharvest applications on pineapples in Hawaii.

Sugarcane

Seed pieces in Hawaii are dipped in a suspension of 0.25 pound benomyl/100 gal water to prevent seed piece decay caused by T. paradoxa (pineapple disease). Benomyl is not applied to the crop in the field.

Twenty-six thousand pounds of benomyl were used in Hawaii to treat seed pieces in the 1976 planting season. There are 222,000 acres of sugarcane in Hawaii; approximately 95 percent of the acreage was planted with benomyl-treated seed pieces. No alternate fungicides are registered. "Pineapple disease" is not a serious problem in other sugarcane production areas of the United States.

Sugar Beets

In 1977, 1.2 million acres of sugar beets were harvested in the United States compared with 1.5 million acres in 1975 and 1976 (310). Benomyl is used extensively in the irrigated areas where Cercospora leaf spot is a problem. During 1977, 13,500 pounds of benomyl were used on sugar beets (table 3). Recommended rates are from 0.375 to 0.5 pound of benomyl per acre. One to three applications may be required depending on length of the growing season and disease pressure. Applications are made at 14- to 21-day intervals and are made almost exclusively by aircraft. Although benomyl is labeled only for control of Cercospora sp., additional benefits are also gained by control of powdery mildew and Rhizoctonia root rot. Alternate materials registered for use on sugar beets do not control these secondary diseases. One of the main advantages is the clearance for livestock feeding of beet residues when the crop has been treated with benomyl. Alternate materials do not have this clearance.

Macadamia

One hundred pounds of benomyl were applied to macadamia trees in Hawaii in 1976 to control Botrytis blossom blight. There are 11,000 acres of macadamia trees in Hawaii. This use of benomyl is decreasing because of the development of strains of Botrytis resistant to benomyl. Captafol is preferred over benomyl because of the resistance problem; therefore, benomyl has been assigned the status of a back-up treatment.

Bananas

Benomyl has been used extensively in Central America and South America and the Caribbean to control sigatoka disease caused by Mycosphaerella musicola and other species. It is usually applied in oil on a 14-day schedule. Resistance of strains of M. fijiensis (black leaf streak) and M. fijiensis var. difformis (black sigatoka) are currently giving problems in the use of benomyl.

Benomyl is widely used as a postharvest dip treatment for control of the "crown rot" complex - Colletotrichum, Fusarium, Verticillium, and Thielaviopsis and anthracnose caused by Colletotrichum musae. Benomyl is outstanding for control of anthracnose because it penetrates into the peel of the fruit to inhibit the development of latent infections. Benomyl seems to be somewhat more effective than the alternate fungicide, thiabendazole, for control of crown rot, but actual choice seems to be based on pricing of the two fungicides. Approximately 200,000 pounds of benomyl are applied annually to control diseases of bananas produced in Central America and South America. Approximately 90 percent of the benomyl is applied to the banana plant for control of sigatoka disease. The remaining 10 percent is applied to the harvested fruit to control crown rot and anthracnose during marketing. About 60 to 65 percent of the bananas produced in Central America and South America are shipped to the United States.

Rice

During 1977, 1,941,000 acres of rice were grown in the Delta States and Texas; 22 percent, or 422,300 acres, was treated with benomyl (table 6). Benomyl is not currently cleared for use on rice in California. Owing to the unique conditions under which rice is grown, diseases are a common problem. Two of the most serious diseases, rice blast (caused by <u>Piricularia oryzae</u>) and stem rot (caused by <u>Sclerotium oryzae</u>), are controlled with benomyl. Estimates of losses from these two diseases range from 10 to 15 percent depending on weather conditions. Yield increases from the use of benomyl consistently average 500 pounds per acre, and when diseases have reached epidemic proportions yield increases of 3,000 pounds per acre have been attained (105).

Diseases are becoming an increasing problem in the rice belt for two reasons. The first is the lack of varietal resistance to race 16 of <u>Piricularia oryzae</u>. Once a minor race, race 16 has become the major race of blast and the only control now available to producers is benomyl. The second factor causing increased disease problems is the loss

Table 6.--Total harvested rice acreage and benomyl use by region and State, 1977

State1/	Acres harvested 2/	Treatment with benomyl: Percent of acres	Treatment with benomyl: Total acres	Treatment with benomyl: Total pounds active ingredient per acre	Treatment with benomyl: Total pounds active ingredient per State
	Thousand acres		Thousand acres		Thousand pounds
Arkansas	837	9.6	80.4	1.0	80.40
		1.4	11.7	.5	5.85
		11.0	92.1		86.25
Louisiana	475	13.6	64.6	1.0	64.60
		2.4	11.4	.5	5.70
		16.0	76.0		70.30
Mississippi	111	3.0	3.3	1.0	3.30
Missouri	17	2.0	.3	1.0	.30
Texas	501	5.5	17.6	1.0	27.60
		44.5	223.0	.5	111.50
		50.0	250.6		139.10
Total 5 States	1,941	22.0	422.3		299.25

1/ Benomyl is not labeled for use in California.
2/ Source (310).

of available farmland to industrialization and urbanization. Loss of this land has forced producers to use shorter rotations, resulting in a buildup of disease organisms. All of the benomyl applied to rice is by agricultural aircraft. Generally two applications are made; the first is applied at the booting stage and the second is applied 14 to 21 days later at the heading stage of growth. Harvest follows in 30 to 35 days. Recommendations are from 0.25 to 0.5 pound of benomyl per application. Approximately 85 percent of the benomyl applied to rice in Texas is applied at the lower rate because of a State label. Applications in the remaining rice-producing States are made at the higher rate (table 6). At this time no other fungicides are cleared for use on rice. If benomyl were not available, rice producers could sustain severe losses to disease.

Citrus

Preharvest: Florida

Greasy spot disease (caused by Mycosphaerella citri) must be controlled by chemicals every year on all citrus varieties without regard to ultimate market (that is, fresh or processing). If this fungus is not controlled, it can cause serious premature defoliation, tree deterioration, and reduction of fruit yield and pounds of solids per acre. Infected fruit results in rind blemishes, "pink pitting" in grapefruit and green blotches in other varieties, which reduce acceptability for the fresh market.

To provide maximum control, fungicides are generally applied in June or July. The presently recommended spray treatments control greasy spot only on leaves that have emerged prior to spraying. Therefore, if the disease is likely to be severe, a second spray is needed in August or September to protect later summer growth.

Scab (caused by Elsinoë fawcetti) is a fungal disease of economic importance on several citrus varieties grown for the fresh market and is also a problem in citrus nurseries in the growing of certain susceptible rootstocks, such as sour orange and rough lemon.

The persistence of the different fungicides has an important bearing on the timing of their application for scab control. Benomyl gives short-term protection and should not be applied too long before petal fall.

Scab can be very difficult to control in years when the bloom commences early and extends over a long period. In such years, a minimum of two benomyl sprays would be essential to assure a good quality product--the first at early signs of shoot growth or bloom and a second 4 to 6 weeks later.

Decay control with a single postharvest fungicide application is not satisfactory (especially in degreened fruit) for fruit that is injured mechanically during harvesting or for specialty fruits that are prone to decay, because several days elapse between picking and fungicide application.

Postharvest decay (stem-end rot and green mold) in fruit can be reduced by spraying benomyl at 1 to 2 pounds per acre 3 weeks prior to harvest. This treatment provides protection against decay initiated prior to subsequent postharvest fungicide treatments.

Preharvest treatments of benomyl are applied by dilute ground equipment with volume ranging from 500 to 1,500 gallons of water per acre, depending on tree height. Benomyl is recommended at 0.5 to 0.75 pound per 500 gallons depending on disease organism and severity of infection. A summary of preharvest uses of benomyl is given in table 7.

Postharvest: California and Arizona

No benomyl is applied to citrus fruits before harvest in California or Arizona because fruit and leaf-spotting fungi are not a significant problem owing to the scant precipitation during the period of fruit development.

Table 7.--Summary of benomyl use on Florida citrus--preharvest

Disease	Varieties	Total acreage	Acres treated with benomyl	Average annual treatments	Average rate (pounds /acre)	Total pounds' benomyl (ai)
Greasy spot	All	800,000	300,000	1	0.75	225,000
Scab	Lemons	7,000	2,800	1.5	.75	3,150
	Temples	22,000	8,800	1.5	.75	9,900
	Murcotts	9,000	3,600	1.5	.75	4,050
	Grapefruit	116,000	2,000	1.5	.75	2,250
Stem-end rots and molds.	Grapefruit	116,000	7,500	1	.5	3,750
Total						248,100

Benomyl is commonly added to the fruit coating (wax) applied postharvest to control Penicillium molds during marketing of the fruit. The wax formulation usually contains 1,000 to 2,000 p/m benomyl. A total of 7,287 pounds of benomyl was applied to 2,345,500 tons of citrus fruits (mostly oranges and lemons) or 71 percent of fruit shipped fresh during the 1976-77 citrus season (table 8). Benomyl is superior to alternate treatments (thiabendazole, o-phenylphenol, biphenyl, sec-butyl=amine) because (a) it penetrates into the peel, making the fruit highly resistant to subsequent infection; (b) benomyl residues of 2 to 3 p/m on the fruit inhibit sporulation of Penicillium on the fruit surface; (c) the development of resistant strains is a much less serious problem than it is for thiabendazole.

Postharvest: Florida

By Florida law, all fresh market citrus must be treated with a postharvest fungicide.

It is estimated that 75 percent of the present crop is treated with benomyl applied as either a water-based wax or as a water suspension at 600 p/m concentration. Postharvest use of benomyl on Florida citrus is summarized in table 8.

Table 8.--Summary of benomyl use on citrus--postharvest

State	Disease organism(s)	Total packed (tons x 1,000)	Benomyl-treated (tons x 1,000)	Concentration (p/m)	Total pounds' benomyl (ai)
California and Arizona.	Penicillium	3,304	2,346	1,000-2,000	7,287
Texas	Penicillium	349	209	1,000-1,500	1,750
Florida[1/]	Diplodia, Phomopsis, and Penicillium.	2,852	1,705	600	2,557
Total					11,594

1/ Florida law requires that all citrus shipped fresh market be treated with a postharvest fungicide.

Postharvest: Texas

Citrus production in Texas amounted to 35 million boxes (7/10 bushel-box) in 1976-1977 (table 8). Of this, approximately 48 percent of the production was sold as fresh fruit. Of the 17 million boxes of fruit marketed for fresh use, approximately 60 percent had been treated with benomyl. Benomyl is used at the rate of 1,000 to 1,500 p/m either in solution or mixed with wax. It is estimated that during 1977 1,750 pounds of benomyl were used on citrus fruit to control postharvest decay.

Peanuts

Peanuts are grown annually on about 1.5 million acres in the United States (table 9). Sales at the farm level exceed $700,000,000. One of the most destructive diseases of peanuts is Cercospora leafspot, caused by the fungi *Cercospora arachidicola* and *C. personata* (*Cercosporidium personatum*). This foliage disease occurs wherever peanuts are planted. Without proper control measures, peanuts could not be grown economically in the United States. Crop rotation is currently practiced in many areas, but it aids only partially in control. No commercially acceptable varieties are available that are resistant to the Cercospora leafspot fungi. Control is, therefore, dependent upon prevention or eradication with fungicides.

Many fungicides are currently available that provide a certain degree of control of the Cercospora leafspot fungi of peanuts; however, it is doubtful whether any fungicide will ever have the impact on leafspot disease control that benomyl had when it first became available in 1970. Up until this time fungicides containing copper and sulfur were used almost exclusively for leafspot control. Benomyl quickly gained widespread acceptance and was used on an estimated 49 percent (73) of all peanuts produced in the United States in 1973. In 1973 strains of *Cercospora* resistant to benomyl were found in Georgia. Resistant strains were later reported in Florida and Alabama. Since this time, the amounts of benomyl used in these areas have declined drastically.

In 1977 benomyl was used on an estimated 332,000 acres of peanuts in the United States (table 9). If three applications of benomyl were applied to this acreage at the rate of 0.125 pound per acre, the total estimated poundage of benomyl used in 1977 for control of Cercospora leafspot fungi was about 124,500 pounds.

Table 9.--Total peanut acreage grown in each State and the percent of acres within each State using benomyl in 1977

State	Acreage 1/	Percent treated with benomyl	Acres treated
Georgia	519,000	2	10,380
Texas	303,000	45	136,350
Alabama	212,000	10	21,200
North Carolina	166,000	50	83,000
Oklahoma	125,000	15	18,750
Virginia	102,000	60	61,200
Florida	55,000	2	1,100
South Carolina	15,000	--	--
Mississippi	7,400	--	--
New Mexico	9,600	--	--
Total	1,514,000	--	331,980

1/ Source: (310).

The current recommendations for use of benomyl to control Cercospora leafspot are similar in all States where this fungicide is used. Benomyl is used at the rate of 0.125 to 0.25 pound per application. The number of applications ranges from 3 to 6. The amount of water per application used ranges from 5 to 25 gallons per acre and may be applied either by ground or by aerial applicators. Since the Cercospora fungus has developed resistance to benomyl, a combination of benomyl and either Manzate® or Dithane® (1.5 lb/acre) is now recommended.

As mentioned earlier in this report, benomyl is no longer recommended for use against Cercospora leafspot in Georgia, Alabama, or Florida; however, benomyl and Bravo® are used extensively on peanuts in Virginia, North Carolina, Texas, and Oklahoma. These fungicides provide effective leafspot control in all of these States. In Virginia, North Carolina, and Oklahoma another peanut disease, called Sclerotinia blight (causal agent Sclerotinia sclerotiorum), causes considerable crop losses. This disease caused an estimated 5 percent loss of the peanut crop in Virginia in 1976. Benomyl has exhibited some degree of control over S. sclerotiorum. On the other hand, Bravo® will not provide any control of this disease and seems to enhance disease severity wherever it is used in fields having the causal organism. Without the availability of benomyl, Virginia growers would no doubt resort to Bravo® almost entirely for leafspot control and as a result might greatly increase the incidence of a non-target organism, S. sclerotiorum.

Vegetables

Benomyl is used on tomatoes, cucumbers, watermelon, cantaloup, squash, snap beans, dry beans, celery, and the cabbage seed crop for control of several organisms attacking the leaves and fruit. Use estimates on a national basis for 1977 are about 151,500 pounds of benomyl per year on 32.8 percent of the 2,936,820 acres devoted to these crops (table 10). The pathogens controlled by benomyl are Sphaerotheca fuliginea, Sclerotinia sclerotiorum, Septoria apii, Mycosphaerella melonis, Botrytis spp., Cercospora apii, Alternaria spp., Colletotrichum lindemuthianum, and Cladosporium fulvum.

Benomyl is used to control powdery mildew, gummy stem blight, and anthracnose on cucumbers, cantaloups, watermelons, and squash. These cucurbit crops are treated with about 44,500 pounds of benomyl per year applied to 342,125 acres. Note in table 11 that 90 percent of the squash and 79.5 percent of the cantaloup acreages were treated--mostly for the control of powdery mildew. Most of the benomyl is applied to acreage in the very humid Southeastern United States.

Benomyl is used to control Botrytis leaf mold, gray leaf mold, and white mold on tomatoes. As shown in table 11, there are 90,929 acres treated with about 42,000 pounds of benomyl per year.

Table 10.--Benomyl fungicide use patterns on vegetables in the United States by region and commodity, 1977

Commodity	Benomyl use by region (pounds ai)				Total
	Northeast	Southeast	Midwest	Far West	(pounds ai)
Cucurbits	3,500	32,000	1,000	8,000	44,500
Tomatoes	2,000	25,000		15,000	42,000
Celery	2,500	4,500		9,000	16,000
Beans	16,500	8,000	14,000	9,000	47,500
Cabbage seed				1,500	1,500
Total	24,500	70,000	15,000	42,000	151,500

Table 11.--Benomyl fungicide use pattern in the United States on 9 major vegetable crops

Commodity/Site	Site production[1/] (acres)	Percent site treated[2/]	Percent U.S. production[1/]	Percent U.S. production treated[3/]	Benomyl usage (pounds ai)
Cucumber					
North Carolina	36,500	20	19.6	3.9	
Michigan	27,400	0	14.7	0.0	
Florida	16,700	75	8.9	6.7	
Texas	15,500	78	8.3	6.5	
South Carolina	13,900	100	7.4	7.4	
Wisconsin	9,800	0	5.2	0.0	
Virginia	7,900	91	4.2	3.8	
Other	70,577	40*	31.7	15.1	
Total U.S. Cucumbers				43.9	8,700
Cantaloups					
California	40,500	92	49.5	45.3	
Texas	17,800	89	21.7	19.1	
Arizona	10,450	0	12.7	0.0	
Georgia	4,500	100	5.5	5.2	
South Carolina	3,500	100	4.2	4.2	
Florida	3,000	90	3.6	3.2	
Other	2,000	78*	2.4	2.4	
Total U.S. Cantaloups				79.5	9,700
Watermelons					
Florida	65,000	69	25.1	17.3	
Texas	62,000	43	23.9	10.3	
Georgia	33,400	69	12.9	8.5	
South Carolina	20,000	88	7.7	6.8	
Alabama	15,000	80	5.8	4.6	
Mississippi	14,000	86	5.4	4.6	
Other	49,200	72*	8.0	13.6	
Total U.S. Watermelons				66.7	21,000
Squash					
Florida	10,800	90	68.1	38.6	
Texas	4,500	90	28.3	16.2	
Mississippi	2,700	90	1.9	9.6	
South Carolina	1,253	90	0.4	4.4	
Other	5,950	90*	2.3	21.2	
Total U.S. Squash				90.0	5,100
Tomato					
California	305,700	4	62.2	2.4	
Florida	45,000	79	9.2	7.2	
Ohio	22,300	0	4.5	0.0	
Indiana	14,800	0	2.9	0.0	
New Jersey	14,600	0	2.9	0.0	
Virginia	10,600	50	2.1	1.0	
South Carolina	9,200	88	1.8	1.6	
Alabama	8,400	80	1.7	1.3	
Other	60,000	38*	12.2	4.6	
Total U.S. Tomatoes				18.4	42,000

Table 11.--Benomyl fungicide use pattern in the United States on 9 major vegetable crops (continued)

Commodity/Site	Site production[1/] (acres)	Percent site treated[2/]	Percent U.S. production[1/]	Percent U.S. production treated[3/]	Benomyl usage (pounds ai)
Celery					
California	19,700	96	56.9	54.7	
Florida	10,600	96	30.6	29.4	
Michigan	2,500	10	7.2	0.7	
New York	600	40	1.7	0.6	
Other	1,170	60*	3.3	2.1	
Total U.S. Celery				87.5	16,000
Snap beans					
Wisconsin	72,000	2	19.3	0.6	
New York	57,700	34	15.4	5.2	
Florida	39,100	90	10.4	9.4	
Oregon	33,100	93	8.8	8.2	
Michigan	20,500	0	5.3	0.0	
Tennessee	16,300	30	4.3	1.3	
North Carolina	8,600	10	2.3	0.2	
Other	125,090	37*	34.2	12.4	
Total U.S. Snap beans				37.3	13,300
Dry beans					
Michigan	525,000	50	35.3	16.6	
Colorado	185,000	10	12.4	1.2	
California	179,000	0	12.0	0.0	
Idaho	159,000	20	10.7	2.1	
North Dakota	139,000	10	9.3	0.9	
Nebraska	126,000	16	8.4	1.3	
New York	40,000	34	2.6	0.6	
Other	132,300	20*	9.0	1.5	
Total U.S. Dry beans				24.2	34,200
Cabbage seed production					
Oregon-Idaho	1,140	100	50.9	50.9	
Washington	1,100	100	49.1	49.1	
Total U.S. Cabbage seed production				100.0	1,500

1/ Based on 1977 crop production statistics of USDA/SRS/CRB (pub. no. VG 1-2 (77), VG 2-2 (77), and Agricultural Statistics - 1977) and on State crop production statistics developed by State vegetable statisticians.

2/ Percent of States total production of a crop that is treated with benomyl. Estimates obtained by personal communication with Pesticide Impact Assessment Program State Liaison Coordinator and State extension plant pathologists familiar with current crop production practices in their respective areas. See * below.

3/ Calculated as percent U.S. production x percent site treated x 100.

* Represents States not sampled, calculated as average of estimates from all sampled States.

Most of the material is used in the very humid Southeastern United States where 79 percent of the extremely important Florida acreage, 88 percent of the South Carolina acreage, and 80 percent of the Alabama acreage is treated.

Benomyl is used to control late blight and early blight of celery. Late blight may quickly destroy an entire celery crop. As shown in table 11, 30,820 acres are treated with 16,000 pounds of benomyl per year. This represents 87.5 percent of the United States' crop. Control of these diseases is extremely important to California and Florida, which produce most of the United States' crop (over 90 pct) and treat 96 percent of their respective acreages.

Benomyl is used to control Botrytis and white mold of snap beans and dry beans. Control of these diseases is essential in the seed production areas and dry bean areas of the Western United States. As shown in table 11, 499,524 acres are treated with 47,500 pounds of benomyl annually.

White mold is very devastating in the cabbage seed production areas of Northwestern United States. As shown in table 11, these areas treat 100 percent of their acreage with 1,500 pounds of benomyl annually.

Crops that use benomyl for protection the most are 100 percent of the cabbage seed production, 90 percent of the squash, 87.5 percent of the celery, and 79.5 percent of the cantaloup acreages. As shown in table 11, the very humid Southeastern United States is the region using the largest amount of benomyl on all vegetables and is the major U.S. source of winter vegetables for the national diet. The far western area of the United States is the second highest user of benomyl. The most poundage is used on beans, cucurbits, and tomatoes.

Published recommendations for use of benomyl on these crops are available from State Extension Service groups in the site States. Benomyl is used nationwide as a 50 percent wettable powder, generally at the rate of 2 to 4 oz of active ingredient per acre--a very small amount for a fungicide. Benomyl is usually not applied to tomatoes, cucumbers, cantaloups, and squash until the specific diseases appear. Benomyl is then applied either alternately with other fungicides or every 14 days. On snap beans and dry beans, benomyl is first applied at the start of the bloom period, and again at full bloom. On celery, benomyl applications are started in the seedbed and continue until harvest at 7- to 14-day intervals.

Thus, 2 applications per crop season are made on snap beans and dry beans; 3 to 4 are generally made on cucumbers, cantaloup, squash, watermelons, and tomatoes; 7 on greenhouse tomatoes; and 10 on celery. Benomyl is applied to vegetables by both airplane and hydraulic ground spray equipment.

Turfgrass

Turfgrass is grown on many diverse areas, such as golf courses, bowling greens, tennis courts, parks, and sports fields, for our recreational enjoyment. It is used in lawns and roadsides for aesthetic value, for reduction of noise and dust, and for heat abatement. Turf is important in cemeteries for aesthetic beauty as well as for the prevention of soil loss through wind and rain. It functions on roadsides and ski slopes as an erosion preventer. Turf is used nationwide for each of these many purposes.

Turfgrass is a perennial crop. Once established, usually from seed in the North, it remains on that site for years. The one exception to this is sod, which is usually also started from seed and then moved to a site after the turf has become mature and knitted together. Then the turf is watered, fertilized, mowed, and treated for pests on a regular schedule or on an as-needed basis, depending on the maintenance level.

Normal means of evaluating agricultural commodities cannot be applied to turf, with the exception of sod, since it is actually sold and therefore can be assigned a dollar value. The other portions of the turfgrass industry have to be evaluated by different criteria. The three basic methods of evaluation according to Beard (23) are (a) the initial capital investment required to develop and establish the turf; (b) the annual cost for maintaining that turf; and (c) the turfgrass acreages. In addition, turf has other values that cannot be measured in dollars and cents. It is difficult to place a dollar value on beautification, contributions to physical and mental health, dust suppression, noise abatement, and soil erosion; yet these are important to our well being and happiness now and will become more important as we become more overpopulated and more urbanized.

The turfgrass acreage in the United States in 1965 was estimated to be over 20 million acres and the annual maintenance cost was estimated at $4.3 billion (212). There is little doubt, considering inflation since 1965, that this figure has greatly increased and is probably closer to $10 billion today, especially when new homes, schools, park areas, and golf courses that have been built since 1965 are taken into consideration.

Benomyl is labeled for the control of five major turfgrass diseases. The diseases, rates, and approximate number of treatments are listed in table 12. Approximately 150,000 pounds of active ingredient benomyl are used per season to control these turfgrass diseases in the United States. The geographic breakdown by region is shown in table 13. The loss of this important fungicide could cause severe problems for the turfgrass industry. In fact, these valuable turf areas could be destroyed by diseases if adequate means of disease control are not available for use.

Table 12.--Turf diseases controlled by benomyl and thiophanate-methyl; rate and average number of treatments

Disease	Efficacy	Rate (oz/1,000 ft^2)	Average number of treatments per season
Dollar spot	G[1/]	1	3
Brown patch	G	2-4	2
Fusarium patch	G	2-4	2
Fusarium blight	G	5-8	2
Stripe smut	G	6	1

1/ G = Good control.

Table 13.--Breakdown by region of the usage of the 150,000 (ai) pounds of benomyl used on turf in the United States

Region	Percent of usage	Major usage States
Midwest	50	Mich., Ohio, Ill., Ind.
Northeast	39	N.Y., N.J., Pa., Del., Md., Mass.
Southeast	7	N.C., Ga.
Southwest	1	
Far West	3	Calif., Oreg.

Ornamentals

Approximately 125,000 pounds of benomyl are used annually to control ornamental diseases throughout the United States (table 3). Approximately 75,000 to 100,000 pounds are used annually by homeowners and pesticide applicators; the remainder is used in nurseries. Consumption east of the Mississippi accounts for 75,000 to 90,000 pounds. The bulk of this use (80-90 pct) occurs in the Northeastern and Southeastern States and the remainder in the Midwest. Approximately 31,000 pounds are used in the Western States (table 14). New York and Florida are the largest users in the East, and California is the major user in the West.

Some of the major diseases that are controlled include: Botrytis flower and stem blight, Fusarium wilt, Cercospora leaf spot, Rhizoctonia stem and root rot, Sclerotinia stem rot, Ascochyta stem blight, fusarial black stem rot, Cylindrocladium leaf spot, and stem and root rot, Fusarium corm rot, Penicillium bulb rot, anthracnose (caused by *Colletotrichum* spp.), seed treatments for *Alternaria*, *Cercospora*, *Colletotrichum*, *Fusarium*, and *Stemphylium* spp., powdery mildew, Phomopsis twig blight, Cercospora and Phyllosticta leaf spot, black spot of rose (caused by *Diplocarpon rosae*), and Entomosporium leaf spot.

Recommendations for the use of benomyl vary depending on the crop, the disease, and the geographic location.

Table 14.--Benomyl use on ornamentals in the Western States

Ornamentals	Pounds of benomyl
Oregon	5,468
Washington	1,484
California	20,000
Colorado	2,500
All other States	1,500
Total	30,952

As a field and greenhouse disease spray, general recommendations for application are at 10- to 14-day intervals through the growing season, commencing with the onset of the disease. Label rates include: 0.25 lb per 100 gal for powdery mildew and Botrytis gray mold; 0.5 lb per 100 gal for anthracnose, black spot of roses, Cercospora, Entomosporium, Ramularia, and Septoria leafspots; Ascochyta and Phomopsis blight, Didymellina and Corynespora leafspots, Ovulinia and Sclerotinia blight of azalea and rhododendron, and scab of Pyracantha and flowering crab. For aerial application, recommendations are for 0.25 lb per acre. For preplant dip and drench treatments, 0.5 lb per 100 gal is recommended for Botrytis, Fusarium, Rhizoctonia, Sclerotinia, Cylindrocladium and Thielaviopsis stem, crown, and root rots. Drenches are to be applied at 1 to 2 pints per square foot at 2- to 4-week intervals.

In most ornamental diseases, alternative chemicals are recommended. These recommendations may vary with the specific crop-disease combination and with the State. In some instances none, or only a single alternative, was recommended. In addition, some of the recommended alternatives are currently undergoing RPAR review.

Pecans

Benomyl is used to control pecan scab (caused by *Fusicladium effusum*) and other foliage diseases, such as zonate leafspot, brown leafspot, downy spot, fungal leaf scorch, powdery mildew, and liver spot. These diseases if left uncontrolled will result in an annual loss of 60,000,000 pounds in the United States (340).

In the United States, there are 527,500 (40) acres of pecans under some type of a management program. All of the pecans are grown in areas that would be subject to one or more of the abovementioned diseases. About 40 percent of the acreage in the Southeast is treated with benomyl. In Texas and other areas of the Southwest, benomyl is used on 70 percent of the pecan acreage. Texas, in particular, has a large acreage of native pecans intercropped with grass for livestock grazing. This acreage is dependent entirely on benomyl for disease control. Benomyl is currently the only product cleared for use in areas grazed by cattle.

Benomyl is used at 0.25 to 0.5 pound per acre for 3 to 12 applications per year, depending upon disease incidence, which is predicated upon seasonal rainfall patterns. In Texas and other Southwestern areas, benomyl is used almost entirely with alternate applications of Du-Ter® during the year to suppress the development of resistant strains. In the Southeast, where resistant strains now exist, benomyl is used with Du-Ter® on an alternating schedule.

Fungal leaf scorch and sticky shuck (stem-end blight) are two diseases that are now causing serious losses in the arid region of Texas. Benomyl is the only material that has shown activity against this group of diseases.

Based on average usage patterns the past 3 years, approximately 100,000 pounds of benomyl are used per year for pecans (table 3). As the pecan acreage shifts from the high rainfall areas of the Southeast to the more arid regions of Texas, New Mexico, Arizona, and Oklahoma, the use of benomyl increases.

Wheat

Benomyl had an emergency label (section 18) in the States of Washington, Oregon, and Idaho during 1976 and 1977. Approximately 5 million acres of wheat were grown in these three States in 1977. Foot rot (caused by <u>Cercosporella herpotrichoides</u>) is a serious problem in this area. During 1976, 22,300 acres were treated with benomyl, but only 380 acres were treated in 1977 because of a record drought (table 15). Single applications were made at 0.5 pound per acre with both ground and air equipment. There are currently no other registered materials that give effective control of Cercosporella foot rot, and no resistant varieties are available. If the price of wheat increases and benomyl is registered for use, the amount of treated acreage will predictably increase considerably. Worldwide, benomyl is used more on wheat than on any other crop (270).

Mushrooms

In the United States from July 1, 1976 to June 30, 1977, 347.1 million pounds of mushrooms were produced on 117.7 million ft^2 of commercial beds (228). Pennsylvania, the leader in mushroom production, alone produced 198.6 million pounds at a value of $137.0 million. California produced another 78.5 pounds at a value of $64.3

Table 15.--Use of benomyl on winter wheat in Washington, Oregon, and Idaho

State1/	1976			1977		
	Acres harvested 2/ (thousands)	Acres treated3/	Pounds (ai) used4/	Acres harvested (thousands)	Acres treated	Pounds (ai) used
Washington	2,885	10,000	5,000	2,800	200	100
Oregon	1,220	12,000	6,000	1,130	170	85
Idaho	890	300	150	830	10	5
Total	4,995	22,300	11,150	4,760	380	190

1/ Approved use in 1976 and 1977 through section 18, EPA regulations.
2/ Source: (310).
3/ Based on reports submitted by county agents and custom applicators.
4/ Application rate of 0.5 pound (ai) per acre as approved by EPA.

million (255). Production in these two States accounts for approximately 80 percent of U.S. commercial mushroom production. Mushrooms are also produced commercially in at least 25 other States in the United States. Total value of U.S. production is $255.7 million.

Benomyl is used on mushrooms to control Verticillium spot or dry bubble, caused by the fungus *Verticillium fungicola* (*malthousei*). In 1972, 11.3 percent (about 11.7 million ft^2) of the U.S. crop was infected with this disease (95). Mushrooms infected with dry bubble are not marketable.

Benomyl is applied at the rate of 1 oz/1,000 ft^2 of bed as a drench or coarse spray starting at the time of casing and continuing throughout production. The initial applications of benomyl are made routinely as a preventive treatment after casing. Subsequent applications during the production cycle are dependent on the presence of pathogenic fungi. The number of applications per crop ranges anywhere from one to seven, with three being average.

Benomyl is used on approximately 50 percent of the U.S. mushroom crop or about 58.85 million ft^2 (256). Approximately 11,034 pounds of benomyl were used by mushroom growers during the 1976-77 production year (table 3). This figure is based on an average of three applications per crop. The percentage of the crop treated with benomyl varies in the different mushroom-growing regions around the country. For example, approximately 30 to 35 percent of the Pennsylvania crop is treated with benomyl and 50 to 60 percent of the California crop is treated. At least 80 percent of the mushroom crop grown outside of the Northeast U.S. and California receives applications of benomyl. There is only one registered alternative fungicide for control of *Verticillium* spot/dry bubble and other spot-type diseases of mushrooms. Tolerance to benomyl has been demonstrated in *Verticillium*.

Dutch Elm Disease

Dutch elm disease (DED), a vascular wilt disease of elms, is caused by the fungus *Ceratocystis ulmi*. The disease is distributed essentially throughout the contiguous continental States of the United States (307) and is important in Canada and Europe. The disease has eliminated the majority of mature, aesthetically valuable elms in the Northeastern States (307) and in many cities in the Midwest. About the time the disease was discovered in 1930, there were about 77 million elms in incorporated areas in the United States; however, by 1976, there were only about 34 million elms in these same incorporated areas (307). Cities that abandoned their control program in areas where Dutch elm disease is prevalent have lost 50 percent of their elms in 7 years (48).

Symptoms in the spring are rather widespread, often with whole limbs or a major part of the tree foliage wilting. Internal symptoms (staining of the outer sapwood) generally have spread much more than the foliage wilt symptoms. These spring infections are generally thought to be undetected infections from the previous year.

The amount of Dutch elm disease infection varies from year to year and probably depends in large part on the bark beetle population in the preceding year.

DED infection for an American elm means death, usually within 1 or 2 years, unless a fungicide is injected or the tree is rigorously pruned of the infected limbs when infection is very slight. The loss of an elm to a homeowner may significantly affect the landscape characteristics of the property and shading of the home, thus affecting the monetary value of the property.

Elm losses for the city is money lost due to expense associated with removing elms at a high rate (once they are dead they soon become a health and property hazard because of falling limbs and bark). It is less expensive to maintain a good Dutch elm disease control program than to lose all or most elms in a short time, because the short-term loss of all of the elms magnifies the problem of tree removal and disposal and tree replanting and subsequent maintenance (48). By far the greatest monetary loss to a community where there is no control of Dutch elm disease is the reduction of property value associated with loss of shade trees, while the loss in aesthetic value greatly overshadows all losses (48). Furthermore, when cities lose their elms in a short period it drastically alters their character and image.

Community-wide, the single most effective Dutch elm disease control measure is the prompt removal of all Dutch elm-diseased trees (sanitation). On an individual elm basis, removal of nearby diseased trees is most important, followed by methoxychlor spraying of the trees. In addition, it has been shown that individual elms can be therapeutically pruned to eliminate the disease (123). Pruning of infected limbs is effective in saving about 60 percent of the diseased elms providing the infected portion of the tree is 5 percent or less (123).

Prompt removal of all diseased elms in a community is possible for most communities, but there are problems in instituting and effectively maintaining such a program. So, in practice, only a few cities have kept such a program going continuously. Such a program does not eliminate Dutch elm disease losses but holds them to low levels.

Currently, most cities with active Dutch elm disease control programs spray their elms in the spring with methoxychlor to control bark beetle inoculation of the trees. Methoxychlor application has been shown to reduce new cases of Dutch elm disease (19).

Lignasan® BLP, a phosphate salt of methyl 2-benzimidazolecarbamate, is labeled as an aid in Dutch elm disease control. This fungicide is applied through holes drilled into the wood of the lower trunk or exposed roots. In the United States in 1977, about 120,000 gallons of Lignasan® BLP (7,009.8 pounds' active ingredient) were used to inject approximately 100,000 elms (141). About 45 percent of the use was east of the Appalachian mountains and much of the other 55 percent was concentrated in the Minneapolis-St. Paul and Chicago areas (141).

Lignasan® BLP used for injection is an aqueous solution of the phosphate salt of methyl 2-benzimidazolecarbamate. It is marketed as a 0.7 percent solution of the active ingredient. The average cost per gallon of the 0.7 percent is estimated to have been about $10.00 in 1977.

Although the exact details of application vary, the generalized application procedure is to drill a hole into the wood (1/4 to 1/2 inch in diameter) and affix some fluid-tight device into the hole in the tree. To this device is attached flexible tubing capable of withstanding pressure, through which either pressurized or gravity-fed, diluted fungicide solution is put into the tree. About one injection site per 6 inches of circumference is used. The labeled rate for therapeutic application is about 0.8 gram of active ingredient per inch of diameter. Label directions recommend reinjection whenever Dutch elm disease symptoms recur or if the disease continues to progress. Statements at a recent DED symposium (199) are supported by data (260), which indicate that the therapeutic dosage recommended on the Lignasan® label is too low to be effective. So, in actual practice, immediate reinjections may be occurring as an effort to increase dosage to a more effective level. The label calls for annual preventive injections of 0.4 gram per diameter inch.

Lignasan® BLP injection is a promising prophylactic or therapeutic treatment for use on elms. It must be applied at a rate higher than that stated on the existing label and, because of the cost, Lignasan® BLP should probably be reserved for elms of high value. It should be used in conjunction with prompt sanitation and methoxychlor spraying. It should not be thought of as a substitute for these proved Dutch elm disease control practices.

Mangoes

There are 1,600 acres of mangoes in Florida. About 50 percent, or 800 acres, are treated with benomyl to control anthracnose. Applications begin at first bloom, usually in early February, and continue on a 2-week schedule until some time in May. After May, there are about three monthly applications up to 15 days prior to harvest. This results in a spray program of 10 applications at 1.5 pounds benomyl per acre for each treatment, or 15 pounds per acre total benomyl (table 16).

Avocados

There are 6,200 acres of avocados in Florida. About 5 percent, or 310 acres, are treated with benomyl to control scab, Cercospora spot, and anthracnose. Benomyl at the rate of 0.75 pound per acre is applied at monthly intervals for 7 months beginning in February (table 16).

Federal and State Regulatory Use

A significant part of the benomyl fungicide use picture is its application in regulatory programs. Although such uses are small, they are essential in preventing the establishment or spread of plant pathogens. History has shown repeatedly that a pathogen, once introduced into a new area, can cause an epidemic under favorable conditions. Regulatory programs attempt to prevent the spread of introduced pathogens.

Summary - Agricultural Uses

Benomyl is an essential fungicide for plant disease control on agricultural and ornamental crops. Benomyl is currently registered for disease control on 43 food crops and 41 ornamental crops. Approximately 3.0 million pounds are used annually by growers in the United States.

Major crop uses on soybeans, stone fruits, rice, and citrus account for over 50 percent of the benomyl used in the United States. When applied to soybeans in the Southern U.S., benomyl increases yields on the average of 5.5 bushels per acre and improves quality of seed beans. Use of benomyl on stone fruits allows greater flexibility in spray schedules owing to the systemic activity of benomyl. Use of postharvest treatments prevents storage rots and decay and spreads the marketing season over a longer period of time, thus allowing greater stability of prices and higher-quality fruit. Benomyl is the only fungicide cleared for use on rice, and without this important disease control fungicide rice producers would be at the mercy of a new devastating race of rice blast. Citrus producers in Florida are dependent on benomyl for

Table 16.--Benomyl use on avocados and mangoes - 1977

Crop	Disease	Total acreage	Acres treated with benomyl	Average annual treatments	Average rate (lb/acre)	Total pounds (ai)
Avocados	Scab Cercospora Anthracnose	6,200	310	7	1.5	1,628
Mangoes	Anthracnose	1,600	800	10	1.5	6,000

preharvest control of greasy spot and scab, two diseases that could seriously reduce fresh fruit production. Postharvest applications are important for control of postharvest diseases in Florida, California, Arizona, and Texas. Benomyl is superior to all alternate treatments because of its ability to penetrate the rind as well as inhibiting sporulation on fruit surfaces.

Crop uses are often broken down into major and specialty use categories based on total use. These terms tend to be ambiguous. For example, benomyl use on wheat is referred to as a minor use; however, it is the only fungicide cleared for use for control of foot rot. To a wheat producer, the potential disease control afforded by benomyl would be considered important.

In many instances on both food and ornamental crops, benomyl is the only material cleared for control of a particular disease. If benomyl were not available, serious disease losses would occur. Many of the alternate materials are also under review (EBDC's, PCNB, thiophanate-methyl).

It is critical to agricultural producers and consumers of agricultural products that benomyl be available for use. Alternate materials do not provide yields and quality controls comparable to benomyl in many instances. Cancellation of benomyl would result in greater expenditures of our energy sources since additional applications of other products would be necessary. Consumers will be forced to pay higher prices and accept agricultural produce that is less wholesome.

Recommendations for Additional Research

The benomyl assessment team, during the course of its duties, identified specific areas in which additional research is needed. These are:

1. Degradation of benomyl in rice water and toxicity to fish at 7-day intervals up to 28 days after final application. Data are not available on the stability or fate of benomyl in natural bodies of water. Data indicate that benomyl is rapidly adsorbed by soil particles and little or no benomyl is released from ricefields, but there are no substantiating data to support this hypothesis.

2. Exposure of homeowners to pesticide drift. EPA is currently estimating that a homeowner will be exposed to one pint of spray mix. This is based on the presumption that the clothes of a fully dressed adult will absorb one pint of liquid. This presumption is not based on research, and data should be generated that will document this. The data generated from this work could help other assessment teams as well as EPA.

Note: Use typical homeowner applicators, that is, hose-on-sprayer, pump-up (Hudson type), trombone, and so forth.

3. Earthworms are generally found in areas with high organic matter and high moisture. Most of the work conducted on earthworms and population reductions is from orchard situations. Earthworms are primarily present in turf situations. A study or survey on population dynamics of the earthworm should clarify this situation.

Our committee feels that these areas are critical and that additional research would give EPA and the assessment team the data necessary to make scientific judgments. At the present time, assumptions have been made in these areas without research to support them. In two areas, homeowner exposure and earthworm population, this research could be useful to other assessment teams.

PART 2
AN ANALYSIS OF CURRENT BENOMYL USES, THEIR BENEFITS, THE ROLE OF ALTERNATIVES, IMPACTS TO AGRICULTURE FROM CHANGES IN BENOMYL USE PATTERNS, AND APPLICATOR EXPOSURE

Introduction

In this section, Part 2: An analysis of current benomyl uses, their benefits, the role of alternatives, impacts to agriculture from changes in benomyl use patterns, and applicator exposure, special emphasis is given to the benefits of benomyl.

A detailed economic analysis has been done only on rice.

Soybeans

Soybean diseases can seriously reduce yields in the Southern United States, especially in the high humidity, high rainfall, and long growing season areas (330, 346). Annual losses due to diseases exceed 21 percent per year (276). Benomyl is currently registered for use as a foliar-applied fungicide on soybeans for control of the following diseases: Cercospora leaf spot, caused by Cercospora sojina; purple seed stain, caused by Cercospora kikuchii; pod and stem blight, caused by Diaporthe phaseolorum var. sojae; brown leaf spot, caused by Septoria glycines; and anthracnose, caused by Colletotrichum spp.

During 1977, 57.9 million acres of soybeans were grown in the United States; 2.6 percent of this acreage, or 1.52 million acres, was treated with benomyl (table 4, part 1). The primary area of use was in the Southeast, Delta, and Southern Plains States, which have severe disease problems.

Disease Situation

Fungal diseases attacking the foliage and pods of soybeans cause substantial losses in yield and quality (332). Three of the major diseases, Diaporthe pod and stem rot, Cercospora, and anthracnose, cause losses in both yield and quality. In the 12 major southern soybean-producing States, these three major diseases caused an estimated loss of 127.2 million bushels of soybeans in 1977 (276). These diseases are carried on the seed and cause deterioration on the seed in storage, resulting in lower germination. In many instances, the germination level will fall below the 80 percent required for seed beans and the producer is forced to sell the beans for purposes other than seed. Seed beans normally sell for twice the regular market price. When a seed producer is forced to sell his or her beans, he or she also loses drying and storage costs on the beans, which could be substantial because of high energy costs. Not only do these major diseases affect beans during storage, but they are carried over to the next year's planting on the seed, which results in reduced stands due to seedling diseases (259). Research has shown that benomyl increases germination by 10 percent and significantly reduces the fungal organisms carried over on the seed (259). Use of benomyl increases yields an average of 6 bu per acre (330, 346, 352). It has been shown that a portion of this yield increase is due to control of Cercospora spp., which cause soybeans to defoliate up to 2 weeks prematurely, resulting in small seed size (332). Investigations on the use of foliar fungicides on soybeans have determined that benomyl use is necessary in the Gulf Coast States to produce high-quality soybeans (332). During the harvest season of October and November, numerous showers occur, which can delay harvest up to 3 weeks past maturity. This delay in harvest causes deterioration of quality and a loss of $0.25 to $0.50 per bu depending on the grade. Prior to the use of foliar fungicides, southern soybean producers seldom produced a #1 grade of beans.

Although only the three major diseases controlled by benomyl were discussed, it should be pointed out that such diseases as brown leaf spot, caused by Septoria glycines, caused a loss of 6.4 million bushels of soybeans in 1977 (276). Other minor diseases, such as powdery mildew, target spot, and others, caused a 5.2-million bushel loss in the Southern soybean-producing States (276). The total estimated loss due to fungal organisms in the Southern States was 138.8 million bushels in 1977 (276). All of these disease losses are substantially reduced with applications of benomyl (104, 128, 276, 328, 332, 346, 352).

Fungicide Applications

The first application of benomyl is made at early pod set, when approximately 60 percent of the pods are set. During this stage of growth, the pods will range in size from 1/8 inch to 1 inch but have not started to fill. This is the most important application, as research has shown that both Diaporthe spp. and Cercospora spp. infection takes place during the blooming stage (259). These diseases can be controlled early by the unique systemic action of benomyl, which penetrates the young pods. A second application is made 14 to 21 days later, during the pod-filling stage of growth. Essentially all applications of benomyl to soybeans are made by air. Recommendations include using 5 to 7.5 gallons of water per acre, and by flying the material on using this high volume of water coverage is increased and drift is reduced. Benomyl is recommended at a rate of 0.25 to 0.50 pound (ai) per acre. Essentially all of the benomyl used is applied at the 0.25 lb (ai) per acre rate (table 4, part 1).

Efficacy and Cost of Application

When applied at the rate of 0.25 lb (ai) per acre, benomyl has increased yields an average of 6 bu per acre. This average was obtained over a 4-year period (328, 346). In 1976 and 1977, Dr. A. R. Gerlow maintained computer records on more than 20,000 acres of soybeans in Liberty County, Texas (104). These data show that applications of benomyl increased yields an average of 7.3 bu per acre (table 17). If the average increase of 6 bushels per acre were used on the total acres treated (table 4, part 1), soybean yields were increased by 9 million bushels in the United States during 1977. As mentioned previously, not only are yields increased, but quality is also increased.

Table 17.--Soybean yield study "Benomyl vs. no benomyl" treatment, Liberty County, Texas 1/

Year	Number of applications 2/	Number of fields	Total acres	Average yield (bushels/acre)	Yield increase
1976					
Benomyl-treated	2	41	4,993	32.5	5.9
No benomyl		40	4,613	26.6	---
1977					
Benomyl-treated	2	71	8,307	36.5	8.6
No benomyl		37	3,373	27.9	---
Average, 2-year study					
Benomyl-treated	2	112	13,300	34.5	7.3
No benomyl		77	7,986	27.2	---

1/ Study conducted by Dr. A.R. Gerlow, Area Economist and Farm Management Specialist, Texas A&M University.
2/ Rate used was 0.25 lb ai/acre per application.

Producers are often able to produce seed beans, which they could not do without the use of benomyl. Grade is also increased at least one step, resulting in an additional increase in income. The average cost of Benlate® to the soybean producer during 1977 was $7.30 per pound. Aerial application costs were $2.00 per application. But, approximately 20 percent of the applications were tank mixes with insecticides for insect control, so costs of application would have to be pro-rated.

Although only two applications of benomyl are used during the growing season on soybeans, research has shown that additional applications will result in increased disease control and some additional increase in yield. Rather than try to eradicate or completely control diseases with fungicide applications, however, researchers endeavored to maximize profits. By using only two applications of benomyl producers are able to realize a $3 return per dollar invested, with less than 100 percent disease control. This approach is felt to be the most beneficial for both the producer and the environment. The producer obtains the maximum return from his disease-control investment and less pesticides are used.

Alternate Methods of Control

The only currently recommended alternative to benomyl is thiabendazole (TBZ). It is currently registered for 6 to 12 ounces of product per acre. Benomyl is currently registered for control of five major diseases on soybeans. TBZ is registered for control of only three. Neither Cercospora sojina nor C. kikuchii is on the TBZ label. These two diseases are responsible for leaf spots, premature defoliation, and purple seed stain. TBZ was first registered for use on soybeans in 1977, but because of late registration it was not used in significant amounts in soybean-producing States. Benlate® currently sells for $7.30 per pound of product. TBZ sells for $76.70 per gallon. Most plant pathologists throughout the Southern States are recommending TBZ at the 8-oz per acre rate. TBZ costs producers $9.58 per acre compared with $7.30 for Benlate®. This is an increase in cost of fungicide of $2.28 per acre.

In a 3-year study conducted by N.G. Whitney and W.J. Walla (328, 346), benomyl and TBZ were compared in 24 different tests. When compared at the recommended rates, the average increase in yields was 6.35 bushels per acre for benomyl and 3.90 bushels per acre for TBZ. Based on these data, benomyl had a 2.45-bushel per acre yield advantage over TBZ. Because of this yield advantage, some States, such as Louisiana, will not be recommending TBZ for soybean disease control in 1978 (26).

Currently, some commercial varieties are available that have disease resistance; however, most of the resistance has been developed for cyst nematode control, not for pod and foliar disease control. Although some genetic material with resistance to several of the diseases is available, the varieties are not marketed commercially and are not available to producers. Estimates from plant breeders indicate that it would take from 6 to 8 years before varieties with resistance to some of the diseases will be available to producers.

Hazard to Wildlife

Since benomyl was registered for use on soybeans in 1974, there have been no reports of any adverse effects either to non-target species or to the environment from its use. Two of the major considerations involved in non-target species would be fish and earthworms. Since benomyl is rapidly absorbed by soil particles (USDA, EPA, Assesement Team Report #1), leaching into bodies of waters containing fish is not a problem. Earthworms are generally found in moist soils that are high in organic matter. This is not the case in the soils used for soybean production. Earthworms are seldom found in cultivated soils in the Gulf Coast. Earthworms are present in some home lawn situations or in uncultivated areas adjacent to river or creek bottoms. Laboratory tests conducted by

Stringer and Wright (287) and Wright (360) indicate that both benomyl and Mertect® 340-F (thiabendazole) have the same mechanism of action and toxicity to earthworms. As Mertect® 340-F is the only reasonable alternative material at this time, it would have no advantage over benomyl as far as non-target species are concerned.

Western Stone Fruits

The principal use of benomyl on all stone fruits is for control of brown rot, both blossom blight and fruit rot stages. In general, the fungus Monilinia laxa is responsible for blossom blight of all stone fruits, except peach, and for fruit rot of apricots and cherries. M. fructicola causes blossom blight on peaches and fruit rot on all stone fruits, except apricots and cherries (215). The blossom blight stage of the disease usually does not cause an economic loss, with the exception of almonds and apricots, but is important because it furnishes inoculum for the fruit rot stage, which may cause serious economic losses if rainfall occurs as the fruit approaches maturity. Clingstone peaches are most strongly affected by brown rot because they are not harvested until full maturity, a time when they are highly susceptible to infection. Fresh-market peaches, on the other hand, are harvested in an immature state and thus are more resistant to brown rot infection.

M. fructicola infects the internal parts of the flower; therefore, the flower must be open for the disease to be initiated. For this reason, protectant fungicides are most effective when they are applied at full bloom. If bloom is prolonged in a wet spring, it is advantageous to apply a second blossom spray. This is difficult to accomplish practically, however, in large orchards with ground spray equipment because of the time required for the spraying operation. This problem is compounded if the soil is very wet. Protectant fungicides are not effective for blossom protection when they are applied by aircraft (215).

In California, peach trees are sprayed at the pink-bud stage with a mixture of benomyl (1 lb/acre) and captan or maneb (8 lb/acre). This mixture is required by a 1977 California Supplemental Label. The purpose of the combination of benomyl with a broad-spectrum fungicide is to discourage the emergence of strains of Monilinia sp. that are resistant to benomyl. In years with prolonged wet weather during bloom, a second application of benomyl combined with captan or maneb may be required at full-bloom, although captan alone is usually recommended for the second blossom spray. Benomyl, however, may be applied effectively by aircraft; this is an important advantage when conditions are such that application of a second spray by ground spray equipment is difficult.

A major advantage of benomyl is its systemic nature, which permits this fungicide to penetrate through the unopened flower to protect the internal parts from infection after the flower opens (247). Therefore, the timing of a single benomyl spray is much less critical than the timing of protective fungicides like captan and maneb. A single application of a protective fungicide may provide satisfactory control of brown rot when dry weather prevails during the blossoming period (10 pct disease situation), however, and benefits of benomyl would therefore be minimal under such conditions. But, during a season with a wet spring, a single benomyl application is considered to be more effective than a single application of a protectant fungicide. In fact, a single benomyl spray may be more effective than two sprays of a protectant fungicide because of difficulties in applying the protective fungicide at the optimum state of flower development with conventional ground-spray equipment. In such years, benomyl would be more effective than a protective fungicide program in preventing a high incidence of blossom blight, which would result in a high inoculum level throughout the season and heavy crop losses. It is estimated that in a season with disease incidence of 20 percent in unsprayed plots, a protective fungicide program could reduce this level of disease to 10 percent and benomyl (1 or 2 sprays) could reduce disease losses further to 5 percent of the crop.

A spray of benomyl combined with captan or maneb is applied 3 weeks before harvest to most cling-stone peaches and many free-stone varieties to control brown rot infection of the fruit. Both benomyl and protective fungicides are effective, but only if they are applied before rain. Incipient infections are not eradicated by either benomyl or the protective fungicides (213). Benomyl is a highly effective preharvest treatment because it penetrates into the fruit (234, 248). This provides a residue that protects against infection but that is more resistant to erosion by rain than the conventional protectant fungicide. Alternate fungicides for this preharvest application (captan or sulfur), which function as surface protectants only, do not retain their effectiveness as long as benomyl and must be applied several times (up to 3 days of harvest). Benomyl protects the fruit for approximately 3 weeks after application, captan for 2 weeks, and sulfur for only 3 days. Fungicide applications several days before harvest cannot be made with ground sprayers because the props supporting the tree-laden branches prevent the movement of ground sprayers through the orchard at this time. Aircraft application is inferior to ground sprayer application because the lower volume of air application does not give sufficient coverage (215). Preharvest application of benomyl, captan, or sulfur to cling peaches to control fruit rot is essential to prevent heavy crop losses in the event of rain during the last few weeks before harvest. In 1965, late-season rains resulted in a 200,000-ton loss of the California cling-peach crop (261). In 1974, rain during the period of fruit maturity caused a 25,000-ton loss to the industry overall, but those orchards that were sprayed with benomyl preharvest suffered minimal crop loss.

In conclusion, benomyl appears to offer a slight advantage over a well-timed program of a protective fungicide, such as captan, in a year with little rain during flowering and fruit maturity. Benomyl would be expected to show a clear superiority over protective fungicides in a wet season in which conceivably 1/3 to 1/2 of the crop could be lost if benomyl were not applied.

Benomyl is used on nectarines, plums, and prunes in much the same manner as peaches for control of brown rot. Benomyl also provides effective control of blossom blight of cherries and apricots. Apricot flowers are more susceptible to infection by Monilinia sp. than other stone fruits, so it is necessary to spray early at the red-bud stage, taking advantage of the systemic properties of benomyl to penetrate to the inner parts of the unopened flower. Spraying before harvest to prevent fruit infection of apricots and cherries is not widespread. Control of blossom blight sufficiently reduces the inoculum level at this early period of the season, before peaches begin to ripen.

Almonds are sprayed to control blossom blight only. Protectant fungicides would probably be sufficient in most years since the principal variety, Non-Pareil, is not highly susceptible to blossom blight. In years with a wet spring and with susceptible varieties, such as Ne Plus and Drake, the systemic properties of benomyl would provide better protection of the flower and reduce crop loss (247).

Brown rot is not a field problem of stone fruits in Washington and Colorado because of scant rainfall during the critical periods when flower and fruit infection occur. Benomyl is highly effective for control of powdery mildew on the peach fruit in Colorado. This disease does not cause a yield reduction but rather a reduction in grade of the fruit. Sulfur, the alternative treatment, may cause phytotoxicity if it is applied during hot weather; this injury to the tree could result in a 10-percent reduction in yield. On peaches and cherries, benomyl is the only fungicide that can suppress Cytospora canker, a disease initiated by infection of pruning cuts and other tree injuries. All stone fruit trees in western Colorado are threatened by this disease, and benomyl is the only promising fungicide for control of Cytospora canker. Benomyl is not currently registered for this application, but a special local need (24c) label has been prepared and submitted to Colorado authorities.

Postharvest Treatment With Benomyl

Fresh-market peaches, nectarines, plums, cherries, and apricots are usually treated after harvest with a combination of benomyl and dicloran (Botran®) in a water-based wax formulation. Dicloran aids in controlling brown rot but is considerably less effective than benomyl. It is estimated that 67 percent of the fresh peaches shipped from California were treated with the benomyl-dicloran mixture after harvest in 1977. Benomyl is not applied postharvest in Colorado because brown rot during shipment is not a significant problem. Benomyl is applied as a postharvest treatment on peaches and cherries in the State of Washington.

Postharvest treatment of peaches with benomyl provides excellent control of brown rot, caused by Monilinia fructicola, but has no effect upon Rhizopus rot. Before the introduction of benomyl, dicloran was used alone for control of both brown rot and Rhizopus rot, the two most serious marketing diseases of peaches.

Dicloran is highly effective against Rhizopus rot, but has only modest activity against Monilinia brown rot. To control both diseases it was necessary to have rather high residues of dicloran (10 to 15 p/m) to obtain satisfactory control of brown rot (213, 235). Although it is possible to achieve such high residues on the peach because of the surface characteristics of this fruit, it is not possible in commercial practice to load sufficient dicloran on smooth-skinned stone fruits (nectarines, plums, and cherries) to control brown rot of the fruit. Even if it were possible to accomplish this practically, the visible yellow residue from such a high concentration of dicloran would be repulsive to the consumer. The "dicloran only" alternative treatment is presently recommended only for peaches for canning or freezing, but not for fresh-market fruit. The combination of benomyl and dicloran provides highly effective control of both diseases, with residues of each fungicide of about 2 to 3 p/m on the fruit.

Postharvest treatment with the benomyl-dicloran mixture is essential to the orderly marketing of fresh stone fruits. Marketing losses of 20 to 50 percent of the fresh-market stone fruits were not uncommon a decade ago. Treatment of fresh fruit after harvest with the benomyl-dicloran combination results in market losses of 2 to 3 percent or less in most lots of fruit.

Rice

Benomyl was first registered for foliar application on rice in 1975. It is the only material currently cleared for control of rice diseases in the United States. The two major fungal diseases of rice, rice blast caused by Piricularia oryzae and stem rot caused by Sclerotium oryzae, cause an estimated 12 to 15 percent loss in Southern rice-producing States each year (327, 347). Additional diseases controlled by benomyl and labeled in Texas include sheath rot (caused by Acrocylindrium oryzae), narrow brown leaf spot (caused by Cercospora oryzae), panicle blight (caused by Cercospora spp.), sheath blight (caused by Rhizoctonia solani), and leaf smut (caused by Entyloma oryzae).

During 1977, 1,941,000 acres of rice were grown in the United States. Twenty-two percent of this acreage, or 422,300 acres, was treated with benomyl (table 6, part 1). Benomyl is not cleared for use in California because the only prevalent disease is stem rot and resistant rice varieties are available; however, some new races of the stem rot pathogen have developed and are attacking previously resistant varieties.

Disease Situation

Rice blast (caused by the fungus Piricularia oryzae) economically is the most important rice disease in the world and one of the most important rice diseases in the United States. Generally, controls have been effective with resistant varieties, but recently a new race of blast, race 16, has spread throughout rice-producing areas of Louisiana and Texas. This new race often causes up to 50 percent losses (347). Unlike previous races of blast, race 16 frequently will not show up in a field until the heading stage of growth; it then attacks the base of the flag leaf where it joins the sheath. As the panicle emerges, it is infected by the organism, causing a lesion at the base of the panicle. The infection that follows causes a decrease in the size and weight of the panicle, and the panicle can rot completely through and break off the stalk. Because of the delay in appearance of race 16, it is impossible to predict disease development, and rice producers must use a fungicide as a preventive measure. Blast is usually more severe on late-planted rice owing to the increase in inoculum potential from early-planted rice.

Stem rot, caused by the fungus Sclerotium oryzae, also a major disease of rice in the United States, affects the sheath and stalk of the rice plant at or below the water line. The fungus attacks the plant during the panicle differentiation stage but does not manifest itself until about 2 weeks before harvest (13, 14, 329). Stem rot reduces yields by reducing total grain weight of the panicle and by causing lodging, which is the most serious effect. Infection weakens the stalk, which causes lodging and makes harvest more difficult. When the rice plant lodges it often falls into the flood water; this causes the grain to deteriorate, which further reduces its yield and quality. S. oryzae overwinters on infected rice straw and will remain in the soil for years (14, 329). Once a field is infested with this organism, it will cause problems whenever rice is planted. The disease is spread by equipment and by migratory birds. Incidence of stem rot can be predicted if accurate field records are maintained.

Fungicide Applications

The first application of benomyl is made at the booting stage of growth; it is followed by a second application in 14 to 21 days, at the heading stage. All applications to rice are made aerially. Recommendations include using 5 to 7.5 gallons of water per acre and flying the material on at a height of 8 to 10 feet above the crop. By using a high volume of water and flying close to the crop, coverage is increased and drift is reduced. Benomyl is recommended and used from 0.25 to 1.0 pound ai/acre/application (table 6, part 1). Only two applications are made during the growing season, and benomyl is not used on ratoon or stubble crop rice. At this time, there are no other fungicides registered for foliar application to rice.

Alternate Methods of Control

As no other fungicides are registered for control of rice diseases, if benomyl is not available producers will be forced to rely on cultural control methods. Cultural disease control for rice includes early planting, crop rotation, resistant varieties, and fertility and water management. If all rice was planted early, at or near the same date, severity of blast could be reduced. This is impossible, however, because of the large acreages planted by individual producers and the frequent showers during the planting season that delay planting. Also, it would be extremely difficult to harvest the crop, as all of the rice would mature on the same day. Crop rotation could reduce severity of stem rot, but land suitable for rice production is not suited for production of other crops because of poor drainage and water-holding capacity. In past years producers allowed rice land to lie fallow as graze for cattle, but urbanization and industrialization have reduced available farmland to the point where this is no longer possible. At the present time, no rice varieties are available that are resistant to the prevalent races of blast and stem rot. To compound the problem, there are no known sources of genetic resistance, and breeders are currently subjecting rice material to irradiation in an attempt to develop a mutant with resistance. Water management does not reduce blast in the United States and is used only on transplanted seedling rice in Asiatic countries. Even in countries where water management does help, fungicides are used extensively, and as many as 10 to 12 applications are made during a growing season. Reduction of nitrogen fertilizer will, in some instances, reduce the effect of diseases, but yields are also drastically reduced when fertility rates are lowered. At this time, recommendations for rice disease control include a totally integrated program of cultural control methods and applications of benomyl in problem areas. Rice producers are urged to apply fungicides only on areas where there has been a history of stem rot or where blast is a problem, and cultural control methods are inadequate.

Efficacy and Cost of Application

When applied at the 0.25 to 0.5 lb (ai) per-acre rate, benomyl has increased yields an average of 500 pounds per acre. This average was obtained over a 4-year period (327, 347). In 1976 and 1977, Dr. A.R. Gerlow maintained computer records on more than 21,000 acres of rice in Liberty County, Texas (103). These data show that applications of benomyl increased yields by an average of 531 pounds per acre (table 18). If the average yield increase of 500 pounds per acre were achieved on the total acres treated, rice yields were increased by 2.1 million hundredweights. Average price received by rice producers in 1977 was $10.05 per hundredweight (143). Increase in quality is also obtained through the use of benomyl. Data from the Chocolate Bayou Company, which keeps detailed records on more than 22,000 acres of rice, indicated that increase due to "peck" control increases profits by $15.17/acre (143). The use of benomyl at a rate of 0.5 lb (ai) per acre on Chocolate Bayou Farms increased the net profit $31.91 per acre.

Table 18.--Rice yield study "Benomyl vs. no "benomyl" treatment, Liberty County, Texas 1/

Year	Number of applications 2/	Number of fields	Total acres	Average yield (lb/acre)	Yield increase
1976					
Benomyl-treated	2	48	4,841	5,158	446
No benomyl		60	5,186	4,712	--
1977					
Benomyl-treated	2	31	3,433	5,099	616
No benomyl		86	7,987	4,483	--
Average, 2-year study					
Benomyl-treated	2	79	8,274	5,138	531
No benomyl		146	13,173	4,597	--

1/ Study conducted by Dr. A.R. Gerlow, Area Economist and Farm Management Specialist, Texas A&M University.
2/ Rates used varied from 0.25 to 0.50 lb ai/acre per application.

The average cost of Benlate® to the rice producer in 1977 was $7.30 per pound. Aerial application cost was $2.00 per application, if 100 percent of the cost was charged to the fungicide application. But, approximately 25 percent of the time, the second application at the heading stage also included an insecticide for insect control.

Hazards to Wildlife

Since benomyl was registered for use in 1975, it has been used extensively throughout the rice-producing area. Information from rice producers, research and extension personnel, and aerial applicators in the rice-producing States indicates that in the 2 years that benomyl has been widely used there has been only one suspected case of fish kill. The incident involved a rice producer who also raised catfish. In this instance the producer drained his field directly into his catfish pond. After draining, he noticed that his catfish came to the surface and several died (181). Because the rice water temperature during July was extremely high when the incident occurred, the fish kill could have been caused by the high temperature of the water and the lack of oxygen in the water. It should be noted that the producer drained his fields into his ponds in direct violation of the benomyl label. The toxicity of many pesticides to fish is well known, and labels contain warnings to this effect.

Economic Analysis for Benomyl Use on Rice

Introduction and Summary

Purpose of Analysis

This report is an economic impact analysis of benomyl use on rice. The analysis is intended as an input to the risk/benefit decision by the Administrator of EPA as to the continued registration of benomyl under the Federal Insecticide, Fungicide, and Rodenticide Act, as amended (FIFRA) (7 U.S.C. 136 et seq.).

Notice of rebuttable presumption against registration (RPAR) of benomyl was issued in the Federal Register, Vol. 42, No. 234, on December 6, 1977. The RPAR notice led to analyses by the Hazard Evaluation Division (HED) in the Office of Pesticide Programs, EPA, to determine if human health and environmental risks were successfully rebutted and if adequate safety margins either exist or could be further enhanced with regulatory options other than cancellation.

This report is preliminary and subject to further analysis and revision during the RPAR process.

Scope and Approach

The information presented in this report corresponds to a specification of requirements for an economic impact analysis that appeared in the Federal Register, Vol. 41, No. 102 on May 25, 1976. The notice requires the analysis to estimate the quantities utilized, identify the registered alternatives, and evaluate the regulatory impact upon crop production and retail prices.

The general approach taken in this analysis is to evaluate impacts at the user level (for example, change in farm income for rice producers) in affected areas and then project resulting impacts at the commodity and consumer levels. Economic impacts on users are considered by State/region and at the U.S. level. Impacts are estimated on a per-acre basis, as well as aggregated for a geographic area. Social/community effects, which are possible from economic dislocations caused by a pesticide cancellation, were not investigated in detail because of the generally low level of impacts upon users and consumers indicated in the economic impact analysis.

The 1978 crop year was used as a base for this analysis. The major portion of the analysis relies heavily upon information obtained from agricultural scientists.

Summary of Findings

Benomyl was used on approximately 422,000 acres, or about 22 percent, of the U.S. planted rice acreage in 1977. Texas, Arkansas, Louisiana, Mississippi, and Missouri used about 299,000 pounds active ingredient (12 percent of total U.S. benomyl use).

If benomyl use on rice is canceled, the value of rice production in terms of both quantity and quality would decline by about $22.8 million, or 2.4 percent of the total value of 1978 U.S. rice production. The total economic impact, after accounting for the cost savings of discontinued benomyl treatment, would be a loss of about $15 million. Net returns over direct production costs would decline by $23 to $38 per impacted acre.

A cancellation of benomyl use on rice would be expected to have little or no impact on the overall price, consumption, or exports of U.S. rice; however, impacts would be of great significance to the growers with narrow profit margins in the disease-affected areas.

Economic Analysis

There has been considerable variation in rice acreage in the United States in recent years (table 19). In 1978, growers harveted rice from 3.1 million acres, an increase of 40 percent over the 2.2 million acres harvested in 1977. Growers indicate that they intend to plant 2.9 million acres of rice in 1979 (313). Rice acreage is located mainly in the Southern States of Arkansas, Mississippi, Texas, and Louisiana, with small acreages in Missouri.

Table 19--Rice acreage, yield, and production, by State and total U.S., 1975-78[1/]

State	1975	1976	1977	1978
	Acres harvested (1,000 acres)			
Arkansas	898	848	837	1,170
California	525	399	308	499
Louisiana	658	568	475	587
Mississippi	171	144	111	215
Missouri	18	14	17	30
Texas	548	508	501	558
Total U.S.	2,818	2,480	2,249	3,059
	Yield (pounds per acre)			
Arkansas	4,540	4,770	4,230	4,480
California	5,750	5,520	5,810	5,260
Louisiana	3,810	3,910	3,670	3,820
Mississippi	3,900	4,200	4,000	4,250
Missouri	4,210	4,200	3,700	4,330
Texas	4,560	4,810	4,670	4,700
Total U.S.	4,558	4,663	4,412	4,505
	Production (1,000 cwt)			
Arkansas	40,775	40,362	35,396	52,470
California	30,179	22,017	17,913	26,248
Louisiana	25,064	22,203	17,445	22,425
Mississippi	6,665	6,048	4,440	9,138
Missouri	758	588	629	1,298
Texas	24,996	24,430	23,400	26,226
Total U.S.	128,437	115,648	99,223	137,805

1/ Sources: (310, 311).

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS: BENOMYL USE ON RICE

A. USE: Benomyl use on rice.

B. MAJOR PESTS CONTROLLED: Rice blast, stem rot, sheath rot, brown leaf spot, sheath blight, and leaf smut.

C. ALTERNATIVES:

Major registered chemicals: None.

Nonchemical controls: Cultural disease control includes early planting, crop rotation, resistant varieties, fertility management, and water management.

State recommendations: Arkansas, Louisiana, Mississippi, Missouri, and Texas.

Comparative performance: Early planting would reduce the severity of rice blast, but large farms would not be able to plant all acreage early enough. Also, frequent showers during planting season hamper early planting. Crop rotation was used in the past to reduce the severity of stem rot, but given existing demand for rice, this is now non-economic. Pressures of urbanization have reduced land available for rice production and affected the feasibility of crop rotation. There are no rice varieties that are resistant to the prevalent strains of blast and stem rot. Reduction of nitrogen fertilizer will, in some cases, reduce the effect of diseases, but yields are also drastically reduced. Water management does not reduce rice blast. At this time, cultural control methods are not effective for reducing or controlling rice diseases.

Comparative costs: Not applicable since there are no alternatives.

Conclusion: As no other fungicides are registered for control of rice diseases, if benomyl is not available rice producers will have to rely upon cultural control methods, which are not effective in reducing or controlling rice diseases.

D. EXTENT OF USE:

Units treated basis (1977): Total harvested rice acreage and benomyl use by State, 1977

State	Harvested acres	Treatment with benomyl Percentage	Acres	Total lb (ai)
			(000')	(000's)
Arkansas	837	11.0	92.1	86.3
Louisiana	475	16.0	76.0	70.3
Mississippi	111	3.0	3.3	3.3
Missouri	17	1.8	.3	.3
Texas	501	50.0	250.6	139.1
	1,941	21.8	422.3	299.3

E. ECONOMIC IMPACTS:

User: It is estimated that, by the use of benomyl, average rice yields increase throughout the 5 States by 500 pounds per acre for a total value of approximately $17.8 million. Furthermore, benomyl reduced "peck" (a discoloration of the rice kernel), thereby increasing the milling quality of rice. This results in an increase in quality of approximately 30 cents per hundredweight (at current prices) or $5.0 million. After deducting benomyl costs, the net benefit is about $15 million. Although this is not significant in terms of the entire rice industry, it is significant to the rice producers in the impacted areas.

Market/consumer: Insignificant impacts are expected.

Macroeconomic: None.

F. SOCIAL/COMMUNITY IMPACTS: None.

G. LIMITATIONS OF ANALYSIS: A base year was assumed. The year 1978 was considered to be typical although rice production has varied significantly in recent years from a low of 99,223,000 cwt in 1977 to a recent high of 137,805,000 cwt in 1978.

California also has a significant rice acreage.

The major rice-growing areas where benomyl is used include the Grand Prairie of Arkansas, northeast Arkansas, the Mississippi River Delta (including Missouri), southwest Louisiana, and the Gulf Coast of Texas (fig. 1). The other major rice-producing areas, which do not use benomyl, are the Sacramento and San Joaquin valleys of California. The only prevalent disease in California is stem rot, and resistant rice varieties are available for use there.

Exports of U.S. rice from 1975 to 1978 ranged from 56 to 73 million hundredweight per year, or 40 to 50 percent of total U.S. rice supply (108).

Benomyl Use Analysis

Benomyl is registered and used to control rice blast, stem rot, sheath rot, brown leaf spot, sheath blight, and leaf smut. There are no other foliar chemicals registered for control of these diseases on rice (315).

One of the most important rice diseases in the United States is rice blast, which is caused by the fungus Piricularia oryzae. Benomyl was first registered for foliar application on rice to control this disease in 1975. Benomyl also controls the other major fungal disease, stem rot caused by Sclerotium oryzae. These two diseases cause an estimated 12 to 15 percent loss in rice production each year (315).

All applications of benomyl to rice are aerially applied, with only two applications per growing season. Benomyl is currently registered and recommended for use at 0.25 to 1.0 pound (ai) per acre per application (315). Research indicates that yields can be increased about 500 pounds per acre when ricefields are treated with benomyl (315).

In 1977, approximately 422,000 acres out of 1.9 million acres of rice were treated with benomyl (table 6, part 1). Approximately 22 percent of the harvested acres were treated with about 299,000 pounds (ai) of benomyl, which was about 12 percent of benomyl use in the United States in 1977 (315). In 1978, it was estimated that 509,000 acres of rice were treated with 369,000 pounds of benomyl (table 20).

Cultural Alternatives to the Use of Benomyl

Cultural practices are not effective in reducing or controlling rice diseases (315). Early planting can reduce the severity of rice blast, but because many farmers have large acreages of rice, they would not be able to plant all their acreage early enough to avoid the disease. Frequent showers during the season also hamper planting. Planting all rice early would result in a problem at harvest time, since it would all tend to mature at the same time.

Crop rotations were used in the past to reduce the severity of stem rot; however, the practice of allowing land to lie fallow or using it for grazing cattle is not as profitable as using it for rice production given existing rice demand and prices. Land is generally not suitable for other crops because of poor drainage and water-holding capacity. At the present time, there are no rice varieties that are resistant to the prevalent races of both blast and stem rot diseases. Thus, planting different rice varieties does not present a solution. Reduction of fertilizer (nitrogen) use would, in some cases, reduce the impact of the above diseases, but yields also would be drastically reduced. Water management is not effective in controlling rice bast. Thus, cultural practices are currently not effective in reducing or controlling rice diseases.

Economic Analysis: Assumptions

The economic anlaysis of benomyl use on rice was based on the following assumptions.

(1) A rice price of $7.00 per hundredweight was used in the analysis.

FIGURE 1. MAJOR U.S. RICE AREAS

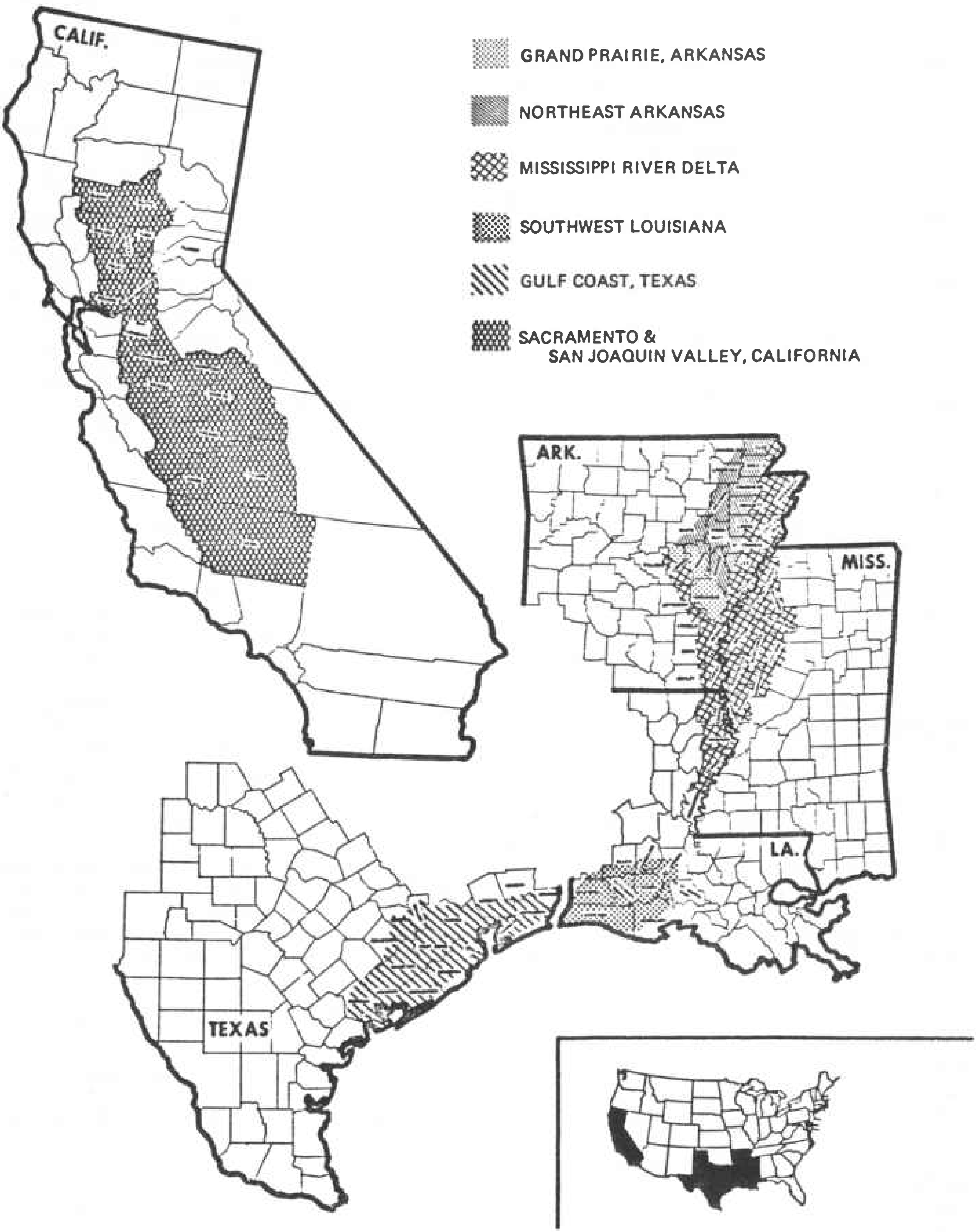


Table 20.--Total harvested rice acreage and benomyl use by State, 1978

State[1/]	Acres harvested [2/]	Treatment with benomyl [3/]			
		Percent of acres	Total acres	Pounds (ai) per acre per season	Total pounds (ai) per State per season
	Thousands		Thousands		Thousands
Arkansas	1,170	9.6	112.3	1.0	112.3
		1.4	16.4	.5	8.2
		11.0	128.7		120.5
Louisiana	587	13.6	79.8	1.0	79.8
		2.4	14.1	.5	7.0
		16.0	93.9		86.8
Mississippi	215	3.0	6.4	1.0	6.4
Missouri	30	1.8	0.6	1.0	0.6
Texas	558	5.5	30.7	1.0	30.7
		44.5	248.3	.5	124.2
		50.0	279.0		154.9
Total 5 States	2,560	19.9	508.6		369.2

1/ Benomyl is not labeled for use in California.
2/ Source: (311).
3/ The percent of acres treated with benomyl and application rates were assumed to be the same in 1978 as they were in 1977 as reported in (315).

This is the midpoint of the $6.50 to $7.50 per hundredweight price forecast by USDA for the 1978 season (312).

(2) The 500 pounds per acre yield increase with benomyl is assumed to be the average for treated acres in the five-State region (12, 315).

(3) The percent of rice acres treated with benomyl in 1978 was assumed to be the same as in 1977 (315).

(4) Rice yields, as shown in crop production budgets, were assumed to be produced in the absence of diseases and therefore to be representative of the benomyl-treated acreage (108, 315).

(5) Price of benomyl is $16.32 per pound (ai) ($8.16 per pound of Benlate® 50 WP) as indicated in the Texas Gulf Coast rice production budgets (108).

(6) Application costs for custom aerial application of benomyl are $2.00 per acre for the first application. For the second application, a charge of $1.50 per acre was used because about 25 percent of the time the second application includes an insecticide (315).

(7) Growers in Texas and southwest Louisiana would receive a milling premium of 30 cents per hundredweight because of improved grain quality (reduction of "peck") on the benomyl-treated acreage (12, 315).

(8) For either the 0.5 or 1.0 pound (ai) application rate per acre, per season equal yield increases (500 pounds) would be attained. Application rates, to achieve disease control, vary by infestation level (315).

Economic Analysis: Aggregate Impact

The use of benomyl to control rice diseases results in increased yield per acre and, in certain production areas, increased milling quality.

Production costs.--The use of benomyl on rice in 1978 added $7.8 million to rice production costs (table 21).

Table 21.--Treatment costs and value of production changes for benomyl use on rice, by State, 1978

State	Treatment costs 1/			Production changes 2/			
	Material cost	Application cost	Total cost	Value of yield increase	Value of quality increase	Total value of production changes	Economic impact 3/
	Million dollars						
Arkansas	1.97	0.45	2.42	4.50	--	4.50	2.08
Louisiana	1.42	.33	1.75	3.29	1.04	4.33	2.58
Mississippi	.10	.02	.13	.22	--	.22	.09
Missouri	.01	(4/)	.01	.02	--	.02	.01
Texas	2.53	.98	3.51	9.76	3.93	13.69	10.18
Total	6.03	1.78	7.82	17.79	4.97	22.76	14.94

1/ Taken from table 22.
2/ Taken from table 23.
3/ Total value of production changes minus total treatment costs.
4/ Less than $5,000.

Table 22.--Cost of benomyl treatment on rice, 1978

State	Acres treated 1/	Pounds (ai) per acre per season 1/	Total pounds (ai) per season per State 1/	Treatment costs		
				Material 2/	Application 3/	Total
	Thousands		Thousands	Thousand dollars		
Arkansas	112.3	1.0	112.3	1,833	393	2,226
	16.4	.5	8.2	134	57	191
	128.7		120.5	1,967	450	2,417
Louisiana	79.8	1.0	79.8	1,302	279	1,581
	14.1	.5	7.0	114	49	163
	93.9		86.8	1,416	328	1,744
Mississippi	6.4	1.0	6.4	104	22	126
Missouri	0.6	1.0	0.6	10	2	12
Texas	30.7	1.0	30.7	501	107	608
	248.3	.5	124.2	2,027	869	2,896
	279.0		154.9	2,528	976	3,504
Total 5 States.	508.6		369.2	6,015	1,778	7,803

1/ Taken from table 20.
2/ Costs are based on material price for benomyl of $16.32 per pound (ai) as used in the Texas production budgets published in (108).
3/ Costs are based on $3.50 per acre per season as reported in (315).

The bulk of this increase is accounted for by material costs of $6.0 million, with application costs of $1.8 million.

Total treatment costs in Texas, at $3.5 million, were the highest in the five-State region.

Table 23.--Value of yield and quality changes on benomyl-treated rice acres, 1978

State	Acres treated1/	Change in production: Quantity2/	Change in production: Value3/	Quality change on treated acres: Yield per acre4/	Quality change on treated acres: Total production5/	Quality change on treated acres: Value6/
	Thousands	Thousand cwt	Million dollars	Cwt	Million cwt	Million dollars
Arkansas	128.7	643.5	4.50	--	--	--
Louisiana	93.9	469.5	3.29	37.1	3.48	1.04
Mississippi	6.4	32.0	0.22	--	--	--
Missouri	0.6	3.0	0.02	--	--	--
Texas	279.0	1,395.0	9.76	47.0	13.11	3.93
Total	508.6	2,543.0	17.79	--	16.59	4.97

1/ Taken from table 20.
2/ Based on a 500-pound increase in yield per acre with benomyl use (315).
3/ Based on $7.00 per cwt price, the midpoint of the $6.50-$7.50 price forecast by USDA in (312).
4/ Taken from table 25. The yield for Texas is a weighted average of yields in the two production areas in that State.
5/ Acres treated (column 1) times yield per acre (column 4).
6/ Milling premium of $0.30 per cwt as reported in (12, 315).

Production changes.--The use of benomyl on ricefields increases yields. In 1978 this increased production was valued at an estimated $17.8 million (table 21). Over half of this increase occurred in Texas, where rice production increased $9.8 million. "Peck" control resulting from use of benomyl on rice acreage in southwest Louisiana and the Texas Gulf Coast improves the quality of rice, and millers paid growers a premium estimated at nearly $5.0 million in 1978. The total value of the rice crop increases resulting from yield and quality increases was $22.8 million. This amount is equivalent to 2.4 percent of the value of the U.S. rice crop in 1978, which was valued at $965 million. The impact on total value was greatest in Texas, where it rose $13.7 million, equal to 7.5 percent of the $184 million value of the 26 million hundredweight of rice produced there.

Net changes.--The economic impact on rice growers of a benomyl cancellation would amount to $15 million (table 21). Growers would save $7.8 million in material and application costs because there are no chemical alternatives; however, the value of rice production would decline by about $22.8 million--$17.8 million from reduced yields and $5.0 million from loss in quality. This is insignificant both in terms of the total value of U.S. rice production and the total U.S. economy and would have little or no impact on prices, consumption, and U.S. rice exports; however, it is significant to the rice producers in the areas affected by diseases controlled with benomyl.

Economic Analysis:
Impact on Returns per Acre

In untreated ricefields, estimated returns over direct production costs ranged from $2.52 per acre in northeast Arkansas to a loss of $57.62 per acre in the Lower Gulf Coast of Texas (table 24). With the use of benomyl at 0.5 lb (ai) per acre per season, returns were estimated to range from $25.86 per acre in northeast Arkansas to a loss of $19.79 per acre in the Lower Gulf Coast of Texas.

The difference in returns over direct production costs between 0.5 and 1.0 lb (ai) per acre is the cost of benomyl. The higher rate is used when

Table 24.--Per-acre returns over direct production costs on rice acreage treated with benomyl and untreated, by regions, 1978 1/

Region	Benomyl treatment per season: 0.50 lb (ai) per acre 2/	Benomyl treatment per season: 1.0 lb (ai) per acre 3/	Untreated 4/
	Dollars		
Northeast Arkansas	25.86	17.70	2.52
Grand Prairie, Arkansas	18.84	10.68	-4.50
Mississippi Delta	-16.53	-24.69	-39.87
Southwest Louisiana	30.18	22.02	-4.29
Texas Gulf Coast			
Upper Counties	-6.75	-14.91	-43.74
Lower Counties	-19.79	-27.95	-57.62

1/ Does not include general farm overhead, land, or management costs.
2/ Taken from table 25.
3/ Taken from table 26.
4/ Taken from table 27.

Table 25. Summary of per-acre gross receipts and direct production costs on rice acreage treated with benomyl at the rate of 0.50 pound (ai) per acre, per season, by regions, 1978 1/

Item	Unit	Northeast Arkansas	Grand Prairie, Arkansas	Mississippi Delta	Southwest Louisiana	Texas Gulf Coast: Upper counties	Texas Gulf Coast: Lower counties
Yield per acre. 2/	Cwt	45.2	46.2	42.1	37.1	45.5	48.3
Value of production. 3/	Dollar	316.40	323.40	294.70	259.70	318.50	338.10
Premium for quality. 4/	Dollar	--	--	--	11.13	13.65	14.49
Gross receipts	Dollar	316.40	323.40	294.70	270.83	332.15	352.59
Direct production costs. 5/	Dollar	290.54	304.56	311.23	240.65	338.90	372.38
Return over direct production costs.	Dollar	25.86	18.84	-16.53	30.18	-6.75	-19.79

1/ Based on application rate of 0.25 pound (ai) per acre applied twice during the season.
2/ Yields are from production budgets published in (108).
3/ Based on a $7.00 per cwt price, the midpoint of the $6.50-$7.50 price forecast by USDA in (312).
4/ Based on a 30-cents per cwt milling premium for "peck" control, as estimated in (12, 315).
5/ Includes variable costs and ownership costs, but not general farm overhead, land or management costs, as found in (108).

Table 26. Summary of per-acre gross receipts and direct production costs on rice acreage treated with benomyl at the rate of 1.0 pound (ai) per acre, per season, by regions, 1978[1/]

Item	Unit	Northeast Arkansas	Grand Prairie, Arkansas	Mississippi Delta	Southwest Louisiana	Texas Gulf Coast	
						Upper counties	Lower counties
Yield per acre.[2/]	Cwt	45.2	46.2	42.1	37.1	45.5	48.3
Value of production.[3/]	Dollar	316.40	323.40	294.70	259.70	318.50	338.10
Premium for quality.[4/]	Dollar	--	--	--	11.13	13.65	14.49
Gross receipts	Dollar	316.40	323.40	294.70	270.83	332.15	352.59
Direct production costs.[5/]	Dollar	298.70	312.72	319.39	248.81	347.06	380.54
Return over direct production costs.	Dollar	17.70	10.68	-24.69	22.02	-14.91	-27.95

1/ Based on application rate of 0.5 pound (ai) per acre applied twice during the season.
2/ Yields are from production budgets published in (108).
3/ Based on a $7.00 per cwt price, the midpoint of the $6.50-$7.50 price forecast by USDA in (312).
4/ Based on a 30-cents per cwt milling premium for "peck" control, as estimated in (12, 315).
5/ Includes variable costs and ownership costs, but not general farm overhead, land or management costs, as found in (108).

Table 27. Summary of per-acre gross receipts and direct production costs on rice acreage not treated with benomyl, by regions, 1978

Item	Unit	Northeast Arkansas	Grand Prairie, Arkansas	Mississippi Delta	Southwest Louisiana	Texas Gulf Coast	
						Upper counties	Lower counties
Yield per acre.[1/]	Cwt	40.2	41.2	37.1	32.1	40.5	43.3
Price per cwt.[2/]	Dollar	7.00	7.00	7.00	7.00	7.00	7.00
Gross receipts	Dollar	281.40	288.40	259.70	224.70	283.50	303.10
Direct production costs.[3/]	Dollar	278.88	292.90	299.57	228.99	327.24	360.72
Return over direct production costs.	Dollar	2.52	-4.50	-39.87	-4.29	-43.74	-57.62

1/ Rice yields presented in tables 25 and 26 were reduced 500 pounds per acre to reflect the loss due to disease if benomyl is not used (315).
2/ Based on a $7.00 per cwt price, the midpoint of the $6.50-$7.50 price forecast by USDA in (312).
3/ Includes variable costs and ownership costs, but not general farm overhead, land or management costs, as found in (108).

disease pressure is intense, but the growers would still only attain the 500-pound per-acre yield increase.

Based on the data presented in table 24, the economic viability of rice producers might be questioned. Rice producers face very high production costs and typically operate with a narrow margin of profitability; however, two factors might mitigate this situation and make rice production a profitable venture over time. First, the season average price of $7.00 per hundredweight assumed for 1978 is low relative to prices prevailing in most recent years. While 1976 prices were also low, at $7.02 per hundredweight, prices for other years in the 1973-77 period have ranged from $8.35 to $13.80 per hundredweight (312).

Second, the government rice program provides for deficiency payments to participating producers when the market price falls below an established target level. For the August 1978-July 1979 marketing year, the target price is $8.53 per hundredweight (312). Rice harvested from the 1.8 million national allotment acres, which amounts to 58 percent of the 3.1 million acres harvested in 1978, is eligible for a deficiency payment of $1.53 per hundredweight if the market price is $7.00 per hundredweight.

Therefore, while increases in net returns of $23 to $38 per acre appear small in an absolute sense, they are significant increases relative to the typical per-acre net returns experienced in rice production.

Florida Citrus-Preharvest

Summary

Benomyl is effective for the control of two major fungus diseases that affect citrus fruit yield and quality --scab and greasy spot.

The timimg of benomyl applications for the control of scab and greasy spot is quite different from that required for the control of postharvest decay. Generally, the previous crop has already been harvested before a benomyl spray is applied for scab or greasy spot control. Benomyl is applied for scab control no later than May and for greasy spot control no later than August.

Very few fungicides have proved effective for scab control. Copper fungicides and ferbam, which are registered for use against this disease, are unreliable and are now seldom used. They have been primarily replaced by captafol (Difolatan®) and benomyl. Captafol cannot be applied to most varieties except when the trees are dormant, as it can injure fruit and young leaves. When captafol is applied during the dormant season, high rates are required to assure control. Benomyl has exhibited no harmful effects to tree or fruit.

Scab is particularly a problem on some of the more popular varieties grown primarily for the fresh market. Before benomyl became available to citrus growers, the production of scab-susceptible varieties was hazardous and losses of over 50 percent marketable fruit were commonly experienced in scab years, in spite of the application of four or more sprays of copper fungicides or ferbam annually. Now the growers obtain good control of scab with only one or two applications of benomyl.

Registered fungicides that have consistently provided good control of greasy spot are copper fungicides and benomyl. The annual oil spray that is applied almost routinely to Florida citrus groves as a multi-purpose pesticide can reduce greasy spot severity, but it is often insufficient for this purpose. A copper fungicide or benomyl has to be added to this oil spray to provide an acceptable level of control when the disease potential is heavy. Copper fungicides cannot be used for this purpose if the fruit is intended for the fresh market, because they can cause a rind blemish. Furthermore, copper sprays have to be avoided in groves that have already accumulated high and potentially toxic concentrations of copper in the soil because of excessive usage in the past.

Greasy spot can seriously reduce fruit yields in Florida citrus groves. Yield increases of 22 percent (344) for oranges and 82 percent (138) for grapefruit have been reported from controlled and replicated spray experiments. Greasy spot also causes a rind blemish on some varieties. On grapefruit the blemish can be severe enough to cause rejection of fruit for the fresh market. Oil sprays have proved to be unreliable for preventing greasy spot rind blemish (198).

Benomyl is also applied preharvest to control postharvest citrus decay (42, 43). This application is essential for grapefruit shipped to Japan, as Japan will not accept fruit treated with benomyl postharvest. There is no other approved fungicide suitable for preharvest application for postharvest decay control.

Mid and Early Season Oranges

Process.--There are 290,300 acres of mid and early season orange varieties for processing (91), 115,000 acres of which are treated one time per season with benomyl for greasy spot control at the average rate of 0.75 lb (ai) per acre (table 28). This is applied in combination with 0.5 percent oil. A copper (1.8 to 3.75 lb metallic per acre) plus 0.5 percent oil treatment is applied to 13,400 acres. This treatment is as effective as benomyl plus oil but cannot be used where a copper toxicity potential exists (94). This situation will be discussed later. The remaining 61,900 acres receive a 1-percent oil spray alone. If benomyl were not available, the entire acreage would receive the 1-percent oil treatment. The current price of Benlate® 50W is approximately $8.20/lb, or $12.45 per acre-treatment. If 750 gallons of water were applied per acre, a 0.5-percent oil treatment would require 3.8 gallons of oil at $.90 per gallon. A 1-percent oil treatment alone would require 7.6 gallons of oil (94).

Benlate® + 0.5 percent oil - $15.87 per acre-treatment for materials.

1 percent oil - $6.84 per acre-treatment for materials.

Copper + 0.5 percent oil - $9.04 per acre-treatment for materials.

Fresh.--There are 16,300 acres of these citrus varieties grown for the fresh market (91), 11,000 acres of which are treated with a 1-percent oil alone. The economics are the same as outlined above. Copper cannot be used on fruit for the fresh market (94).

Table 28.--Summary of preharvest use of benomyl on Florida citrus - by variety

Variety	Process: Total acres 1/	Process: Acres - benomyl-treated 2/	Fresh: Total acres	Fresh: Acres - benomyl-treated
Early and mid oranges	290,300	115,000	16,300	11,000
Valencias	276,200	60,500	11,000	8,300
Grapefruit	81,300	54,000	37,900	35,000
Temples and Murcotts 3/	--	--	31,000	12,400
Lemons 3/	--	--	7,000	2,800
Limes 3/	--	--	4,600	1,000
Miscellaneous 3/	--	--	44,400	
Totals	647,800	229,500	152,200	70,500

1/ Acreage obtained from State agricultural statistical reports.
2/ Total acres treated obtained from pest-management personnel.
3/ These varieties are generally grown for fresh market only. Fruits from these varieties go into the process market after being culled for fresh fruit.

Benomyl + 0.5 percent oil reduces the percent leaf drop over 1 percent oil alone. It is not known if this further reduction in leaf drop is of economic significance.

Valencia Oranges

Process.--There are 276,200 acres of this variety grown for processing (91), 60,500 acres of which are treated with a 0.75 lb (ai) benomyl and a 0.5-oil combination spray one time per year to control greasy spot (table 28). The remaining acreage is treated with 1 percent oil alone or in combination with copper. The same statement regarding copper toxicity is true for Valencias. The material economics are the same as for the early and mid varieties.

Fresh.--There are 11,000 acres of Valencias grown for the fresh market (91), 8,300 acres of which are treated with 0.75 lb (ai) benomyl + 0.5 percent oil for greasy spot control. The remaining acreage is treated with 1 percent oil. Copper cannot be used on fruit intended for the fresh market.

Grapefruit

Process.--There are 81,300 acres of grapefruit grown for processing, 54,000 acres of which are treated with benomyl (table 28). Benomyl at 1.5 lb (ai) (1,500 gallons of water per acre) plus 0.5 percent oil is used to control greasy spot. Oil plus copper is used on the remaining 27,300 acres where copper toxicity is no problem. Oil alone is not sufficient to control greasy spot on grapefruit varieties.

Fresh.--There are 37,900 acres of grapefruit going into the fresh market. Thirty-five thousand (35,000) acres are treated with benomyl (1.5 lb ai/acre) plus 0.5 percent oil to control greasy spot. Of this acreage, 10,000 receive benomyl in the spring to control scab disease. Almost all grapefruit (7,500 acres) exported to Japan receives a preharvest application of benomyl to control postharvest rots. There is no alternative for this use and it is estimated that at least 10 percent of the fruit would be lost due to spoilage during shipment if benomyl were lost. Japanese laws preclude the use of benomyl postharvest to control these diseases.

Captafol would be the alternative treatment for scab control if benomyl was not available. The cost comparisons are: Benomyl (1.5 lb ai) - $24.90/acre; captafol (13 gallons) - $139.75/acre. Copper cannot be used on fresh fruit and, as above, oil alone is not sufficient for control of greasy spot on grapefruit leaves and fruit.

Temples and Murcotts

Fresh.--There are 31,000 acres of Temples and Murcotts grown for the fresh market, 12,400 acres of which receive a benomyl treatment for scab control (table 28). There are one or two applications per year based on disease severity. Oil alone is not sufficient for greasy spot control. Captafol at 5 gallons per acre can be used dormant for scab control. If benomyl were not registered, it could be replaced by captafol on Temples, as this variety can tolerate a bloom application; however, captafol is phytotoxic to Murcotts postdormant. Benomyl and captafol are interchanged to delay any resistance problem. Captafol cannot be applied to either variety if the mature crop is not harvested prior to bloom. This situation occurs on about 7,500 acres annually. On this acreage, there would be no alternative to benomyl for scab control. This would probably result in next year's crop being culled for processing rather than selling on the fresh market because of scab.

Lemons

Fresh.--There are 7,000 acres of lemons grown for the fresh market (table 28). In general, 4,000 acres receive a delayed dormant application of captafol, followed by benomyl treatment on 2,800 acres for scab control. Fruit production that represents about 3,000 acres goes into processing as culls.

Limes

Fresh.--There are 4,600 acres of limes grown for the fresh market (table 28). Benomyl is applied one time per season to approximately 1,000 acres. The use pattern is similar to that of lemons. Fruit production that represents about 2,200 acres goes into processing as culls.

Miscellaneous Varieties

There are approximately 44,400 acres of miscellaneous varieties of citrus grown for the fresh market (table 28). No benomyl is generally applied to this acreage as most varieties are resistant to scab.

General Comments

1. Oil cannot be applied to any citrus variety that is in a wilt or stress condition (94). Under these conditions, the use of oil as discussed by varieties would be eliminated.

2. Prior to the early 1950's, copper sulfate was applied to the soil with fertilizer. At that time, it was determined that excessive copper in the soil was phytotoxic to the trees. Essentially all groves (400,000 acres) planted prior to that time currently have excessive copper in the soil (90). Lime is added to the soils in the form of dolomite at one ton per acre every 3 years to maintain the soil pH at about 6.5. This averages about $5.00 per year (198). At this pH, the copper is bound to the soil and is not available for uptake by the tree (90). If benomyl was canceled the use of a copper fungicide would require the application of more dolomite. In addition to material and application costs, this would create two larger problems: (1) Rootstocks of rough lemon and trifoliate orange and its hybrids cannot be grown in soil pH of 7 or greater. (2) The native cover crop of high pH soils is feather-geranium (Chenopodium botrys), which is the preferred host of the green citrus aphid. This aphid transmits the tristeza virus, a severe disease of citrus.

California and Arizona Citrus

Benomyl is not applied in citrus groves in California or Arizona because the low rainfall during the growing season in this area is not conducive to the development of diseases of the citrus tree or fruit in the field; however, benomyl is a very important treatment for the prevention of postharvest decay of fruit during marketing.

The most important sites of infection on fruit after harvest in California and Arizona are injuries in the peel, which are created unavoidably during harvesting and handling the fruit. The most common postharvest diseases of citrus fruit in California and Arizona are green mold (caused by Penicillium digitatum) and blue mold (caused by Penicillium italicum). These two fungi often occur together and, collectively, produce the disease known as "blue-green mold" of citrus fruits. This disease has two important consequences: (1) Infected fruit is unmarketable. (2) The Penicillium molds sporulate on the surface of diseased fruit and the spores are shed onto adjacent sound fruit, giving rise to a condition known as "soilage." "Soilage" substantially reduces the market value of fruit.

Three strategies are employed in the use of fungicides to control postharvest decay of citrus fruits: (1) Prevent infection at injury sites that are created at the time of harvest. (2) Apply a protective coating of a fungicide that will prevent infection of subsequent injuries that arise while handling the fruit after treatment. (3) Cover the fruit with a fungicide deposit that will prevent sporulation of Penicillium molds on decaying fruit.

Lemons and oranges are invariably treated with a fungicide solution before short-term or long-term bulk storage, primarily to prevent infection of harvest-related injuries. Fungicide solutions for this purpose normally contain 500 to 1,000 p/m benomyl, 1,000 to 2,000 p/m thiabendazole, 1 percent sodium o-phenylphenate, or 1 to 2 percent sec-butylamine. Numerous trials conducted in California, Florida, and in other citrus-producing areas in the world clearly show that benomyl is superior to the other treatments in preventing infection at harvest-related injury sites and in conferring resistance to treated fruit against later infection (76). Another benefit of benomyl is that strains of Penicillium sp. with fungicide resistance emerge much slower in packinghouses using the benomyl treatment than in those making repeated use of other alternate fungicides (132).

Citrus fruits usually receive a second fungicide treatment just before the fruit is packed, to prevent decay during shipment. The fungicide is added to the wax formulation or, less commonly, the fungicide may be applied in water followed by the wax treatment. The principal purpose of this treatment is to prevent infections that could lead to decay during marketing. In addition, benomyl or thiabendazole could be applied at this time to control the condition known as "soilage." Wax formulations may contain 1,000 p/m benomyl, 1,000 p/m thiabendazole, or 2 percent sodium o-phenylphenate for decay control. Higher dosages of benomyl and thiabendazole are required to prevent fungus sporulation.

The final fungicide treatment for lemons and many oranges consists of a sheet of paper impregnated with biphenyl placed at the top and bottom of the shipping container. This treatment provides an atmosphere of biphenyl vapor in the carton that inhibits the sporulation of Penicillium molds and thereby reduces the problem of "soilage" during marketing. Biphenyl has been used for about 30 years to prevent this aspect of the "blue-green mold" disease, but the treatment has an adverse effect on the natural fragrance of the citrus fruit and therefore places it at an economic disadvantage to fruit that is not so treated. It has been demonstrated that dosages of thiabendazole and benomyl in the wax, at somewhat higher levels than those required for decay control, prevent sporulation of Penicillium sp. on the decayed fruit at least as effectively as the biphenyl treatment. Deposits of thiabendazole in the range of 5 to 6 milligrams per kilogram of fruit, or benomyl at 2 to 3 milligrams per kilogram of fruit, are required to produce this effect (77). Benomyl is the choice for this application because the lower dosage rates are easier to apply in a water-based wax and benomyl has the required solubility in solvent waxes. Thiabendazole may be applied for sporulation control in water-based waxes, but the limited solubility of thiabendazole in solvent-based waxes restricts the usefulness of this fungicide for control of "soilage."

The unique benefits of benomyl over alternate fungicides registered for control of "blue-green mold" on citrus fruits are: (1) Strong posttreatment protective action that is lacking in alternatives, (2) control of spore "soilage" in all existing packinghouse treatment systems, (3) delay in development of fungicide-resistant strains of Penicillium sp. to a greater extent than alternate fungicide treatments. The last point should be amplified for a better understanding of the "resistance problem" in the control of postharvest diseases of citrus fruits.

Benomyl is not the solution to the resistance problem--it is only an important component of the practical solution. Several fungicides are applied, in sequence, to citrus fruits as they move from the grove to the consumer. Pairs of these fungicides (for example, benomyl and thiabendazole; o-phenylphenol and biphenyl) exhibit "cross-resistance"; that is, a fungus strain that emerges under the selection pressure of one member of the pair will be resistant to the other member of the pair as well. Therefore, o-phenylphenol and biphenyl or thiabendazole and benomyl should never be applied in sequence (over an interval of several days) to the same lot of fruit since the fungicide last applied will invariably fail to provide disease control. This dilemma can be solved by applying fungicides that are not "cross-resistant" in sequence or by interrupting the sequence of two cross-resistant fungicides with a third fungicide that does not share this cross resistance. Examples of such sequences of fungicides used in lemon packinghouses to control the "resistance problem" are:

(1) o-phenylphenol - benomyl (thiabendazole) - biphenyl.
(2) sec-butylamine - benomyl (thiabendazole) - biphenyl.

The point is that several unrelated fungicides are required to make this entire system function.

De-registration of one fungicide (for example, benomyl) will have an impact upon the total system.

Two alternatives to chemical fungicides that are frequently discussed are: (1) Careful handling of the fruit to prevent injuries that are the sites of infection; and (2) low-temperature storage to prevent the development of decay in infected fruit. Citrus fruits are handled today as carefully as economics and labor availability permit. Any additional care in handling would be reflected in an increase in price of citrus fruits in domestic markets and a loss in competitive positions abroad. Current economic trends almost certainly mandate faster and less labor-intensive fruit-handling systems for the future, which will lead to a greater degree of injury and necessitate the more efficient use of fungicides.

Low temperature is not a workable alternative to fungicides for control of postharvest diseases of lemons or grapefruit, which are injured by storage at less than 50°F, a temperature that does not prevent growth of decay-causing fungi. Even with oranges, which can be stored at 35°F, the benefit of low temperature is a delay in the development of decay, not a cure. Infected fruit will decay during marketing or in the consumer's home unless the fruit was treated after harvest with an effective fungicide.

Florida Citrus-Postharvest

Summary

Florida State regulations specify that fresh citrus fruit shipped by a registered packinghouse must be treated postharvest with an approved fungicide. As evidence of such a treatment, fruit must have a minimum residue set by the Florida Department of Citrus (93). Five fungicides are currently approved for such use (93, 334):

	Fungicide	Federal maximum residue (p/m)	Florida minimum residue (p/m)
1.	Benomyl	10	0.1
2.	Thiabendazole (TBZ)	10	0.1
3.	Sodium o-phenyl=phenate (SOPP).	10	0.5
4.	Sec-butylamine (2-aminobutane).	30	0.5
5.	Biphenyl (diphenyl)	110	*

* 2 grams per 4/5 bushel box.

During the 1975-76 season, 126,263,660 cartons (4/5 bushel) of Florida citrus were treated postharvest. Of this total, 75,758,196 cartons were shipped fresh market and the remaining 40 percent, or 50,505,464, were eliminated and sent to the cannery (92).

Benomyl and TBZ

These two benzimidazoles are similar in fungicidal activity and are the most effective postharvest citrus fungicides (180). It is estimated on postharvest disease control that 75 percent of the present crop is treated with benomyl and 10 percent with TBZ (table 29).

SOPP

Sodium o-phenylphenate is more effective for controlling decay of oranges than of grapefruit or mandarin-type fruits. SOPP reduces stem-end rot and green mold (180). Of fruit exported to Japan, 8 percent is treated with SOPP (180).

Table 29.--Postharvest fungicides - Florida citrus

Fungicide	Rate (p/m)	Cost/carton
Benomyl	1/ 600	0.4¢
TBZ	1,000-2,000	0.7¢

1/ One gallon treats 10,000 pounds of fruit.

Diphenyl

This fungicide controls stem-end rot and green mold, but it is not effective against sour rot. Sporulation of green mold is suppressed. Diphenyl-impregnated pads are effective in controlling susceptible fungi while fruit is in shipment (180). Approximately 7 percent of fresh fruit is treated with diphenyl.

SOPP and diphenyl are frequently used in combination. Fruit is treated with SOPP in the packinghouse and diphenyl pads are placed in the cartons for shipment, especially to foreign markets (180).

2-Aminobutane

This fungicide is rarely used on Florida citrus.

Penicillium molds on stored lemons have developed strains resistant to benomyl and TBZ. This is not yet of economic concern to the Florida citrus industry.

Benomyl is generally recognized as being the best fungicide available for the control of postharvest decay of citrus fruit (178). A ban on the use of benomyl would adversely affect both grower and consumer, since consequently blemished fruit would be diverted from the fresh market. Also, more fresh fruit leaving the packinghouse would be lost through rot during storage and marketing (table 30).

Table 30.--Decay control of 'Pineapple' and 'Valencia' oranges and 'Murcott Honey' tangerines with benomyl

Citrus and treatment	Percent decay after picking	
	3 weeks	4 weeks
'Pineapple' orange		
Benomyl, 500	0.5	0.8
Check	7.4	10.2
'Valencia' orange		
Benomyl, 1,000 p/m	2.2	4.1
Check	17.6	25.4
'Murcott Honey' tangerine		
(Non-degreened)		
Benomyl	2.4	2.6
Check	9.4	11.2
(Degreened)		
Benomyl	6.3	9.7
Check	29.2	36.7

Texas Citrus

Texas regulations do not specify that fresh citrus fruit shipped by packinghouses must be treated postharvest with an approved fungicide; however, fruit is routinely fumigated with ethylene dibromide (EDB) and most packinghouses treat fruit with a fungicide. As a result, almost 100 percent of the fruit receives some form of treatment. Currently, the following fungicides are commonly used in Texas: Benomyl, thiabendazole (TBZ), sodium o-phenylphenate (SOPP), and biphenyl (diphenyl).

Benomyl and TBZ

These two benzimidazoles are similar in fungicidal activity and are the most effective postharvest citrus fungicides. It is estimated that 60 percent of the present citrus crop is treated with benomyl for postharvest disease control.

SOPP

This fungicide is more effective for controlling decay of oranges than decay of grapefruit or mandarin-type fruits. SOPP reduces stem-end rot and green mold and is approved for use on fruit exported to Japan.

Diphenyl

This fungicide controls stem-end rot and green mold. Sporulation of green mold is suppressed. Diphenyl-impregnated pads are effective in controlling susceptible fungi while fruit is in shipment. A large percentage of Texas fruit is treated with diphenyl.

SOPP and diphenyl are frequently used in combination. Fruit is treated with SOPP in the packinghouse and diphenyl pads are placed in the cartons for shipment, especially to foreign markets.

There have been reports of the occurrence of strains of Penicillium spp. that have developed resistance to benomyl, particularly on lemons. Dr. Bill Carter, USDA, Weslaco, Texas, has not found any resistant strains present in the Rio Grande Valley. Personal communication has indicated, however, that resistant strains have been identified on citrus fruit shipped from the Valley upon arrival at European markets.

Benomyl is generally recognized as being the best fungicide available for the control of postharvest decay of citrus fruit. A ban on the use of benomyl would adversely affect both grower and consumer, as consequently blemished fruit would be diverted from the fresh market. Also, more fresh fruit leaving the packinghouse would be lost through various rots during storage and marketing.

Postharvest Fungicides-Texas Citrus

Fungicide	Rate
Benomyl	1,000-1,500 p/m
TBZ	2,000 p/m

Bananas

Preharvest Use of Benomyl

Approximately 60 to 65 percent (2 million tons) of the bananas produced in Central America and South America are imported annually into the United States. Almost all bananas offered for sale in the United States are from this source (154).

The most serious foliar diseases of the banana plant are sigatoka (caused by Mycosphaerella musicola), black sigatoka (caused by M. fijiensis var. difformis), and black leaf streak (caused by M. fijiensis). Lesions resulting from attack by these fungi may reduce the functional leaf surface of the plant drastically, thereby lowering the photosynthetic efficiency and yield of bananas. At moderate disease severity, the size of the bunches and individual fingers is reduced and the fruit ripens prematurely and has an abnormal color and flavor. In severe disease situations, the fruit does not mature (282). The commercial exportation of bananas from Central America and South America to the United States is possible only because of effective fungicides to control these leaf-spotting diseases.

Foliar diseases of bananas are controlled by aerial applications of benomyl (2 oz/acre) in petroleum spray oil (1 gallon/acre) and of Dithane® M-45 (mancozeb - 2 pounds 80 percent ai/acre) in oil. The benomyl and the mancozeb applications are alternated on a 14- to 21-day spray schedule (194). The interval depends upon the rainfall. Also, benomyl and mancozeb may be blended together in an oil-in-water emulsion. Approximately 12 sprays of each fungicide per year are applied to banana plants, although 30 to 37 sprays may be required when black sigatoka and black leaf streak are established problems. The cost for 12 sprays per year is approximately $40/acre. This includes 18 pounds Dithane® M45 (80 pct ai), 21 oz Benlate® (50 pct benomyl), and 18 gallons petroleum spray oil (194).

Experiments conducted in the early 1970's revealed that benomyl in oil was much more effective than the ethylene bisdithiocarbamates in oil. The curative and systemic properties of benomyl made possible spray intervals of longer duration than was possible with the dithiocarbamates alone. It was demonstrated that benomyl moved in the banana plant to protect leaf surfaces that were not directly contacted by the spray (20). At that time the superior performance of benomyl made it seem likely that this fungicide would replace the ethylene bisdithiocarbamate fungicides as the principal fungicide for control of sigatoka on banana (282). The continuous use of benomyl alone, however, soon resulted in the buildup of secondary diseases that were previously controlled by the ethylene bisdithiocarbamate fungicides, such as leaf rust (caused by Uromyces musae), leaf/fruit freckle (caused by Phyllostictina musarum), and other minor diseases. Furthermore, it was reported in 1977 that resistant strains of the fungi responsible for sigatoka and black sigatoka had built up to damaging levels on farms in Honduras where benomyl had been applied exclusively under heavy disease pressure (283). Tolerant strains of the pathogens did not appear on farms sprayed with a mixture of Dithane® M-45 and benomyl. For these reasons--control of secondary pathogens and benomyl-resistant strains of the sigatoka pathogen--the banana industry of Central America has adopted a spray schedule consisting of both benomyl and the ethylene bisdithiocarbamates, either in combination or on an alternating basis.

Fungicides presently registered for the control of sigatoka on bananas are benomyl, bordeaux mixture (copper), copper oxide, mancozeb, maneb, petroleum oil, and thiophanate-methyl. Bordeaux mixture is not a suitable alternative to benomyl in any major banana production operation because the large volume of spray required is not compatible with aircraft application techniques, which are required in modern banana production (282). Fixed coppers (Perenox®) are fairly effective and suitable for aerial application, but were discontinued in the early 1960's because of phytotoxicity problems, which are estimated to reduce banana yield by 10 percent. Thiophanate-methyl cannot be considered as an alternative to benomyl because, like benomyl, it forms MBC, the active fungicide, in situ. Maneb and mancozeb are ethylene bisdithiocarbamate fungicides and are currently involved in the RPAR process. Both of these fungicides are inferior to benomyl because they lack systemic action and do not persist well during the rainy season. Hence, a shorter spray schedule is required for equivalent effectiveness in controlling sigatoka (284). The ethylene bisdithiocarbamate fungicides would be obsolete for banana production except for fungus resistance to benomyl and to control secondary diseases.

In Latin America, where black sigatoka is not present, the principal alternate to the benomyl-maneb-oil spray program would probably be maneb/mancozeb-oil, which was used effectively during the 1960's and early 1970's (284). The main limitation of this treatment is that it does not persist well to protect the foliage during periods of rainy weather. Yields might remain at present levels, but total rates of application and costs would increase (194). Where black sigatoka is present, primarily in Honduras, a maneb-oil program would not provide satisfactory disease control (284) and it would be necessary to add fixed coppers to the program to control black sigatoka. This would result in significant phytotoxicity and yield losses of up to 10 percent could be expected (194). A more major impact would come from lessening of the effectiveness of disease control. Black sigatoka would spread through Central America at a faster pace. There is current agreement within the industry that the combination of yield loss and increased pesticide cost would amount to only 1 percent of current production values if benomyl registration were withdrawn (194); however, management and logistic flexibility would be reduced if the mixed spray schedule currently in use were abandoned. The fungicide Bravo® has recently been registered for use on bananas. Although it is effective against sigatoka disease, it is quite costly in comparison with the current programs and cannot be used in combination with oils. Many banana pathologists feel that oil is a much needed part of the total disease control program.

Postharvest Use of Benomyl

Benomyl is widely used as a postharvest dip or spray treatment (100 to 300 p/m benomyl) for banana hands for control of the "crown rot" complex (caused by *Colletotrichum*, *Fusarium*, *Verticillium*, and *Thielaviopsis*) and anthracnose, caused by *Colletotrichum musae* (165, 282). Benomyl is outstanding for control of anthracnose because the fungicide penetrates into the peel of the fruit to inhibit the development of latent infections established before harvest (165). Benomyl is somewhat more effective than the alternate fungicide, thiabendazole, which is used at approximately twice the concentration to achieve disease control equivalent to that provided by benomyl.

Since a substantial portion of the bananas shipped to the United States today are treated either with thiabendazole or benomyl, it appears that the choice of fungicide is mainly economic and that thiabendazole, at a somewhat higher application rate, could successfully substitute for benomyl in this application, but at a higher cost.

Peanuts

Peanuts rank 13th in importance among crop plants throughout the world (325). Peanuts are grown on about 1.5 million acres in the United States and have a farm value exceeding $700 million annually. Seven States account for 98 percent of the production. To facilitate marketing, three production areas have been designated (underlined State is one of seven major peanut-producing States): The Virginia-Carolina area, including Virginia, North Carolina, and Tennessee; the Southeastern area, including Georgia, Florida, Alabama, South Carolina, and Mississippi; and the Southwestern area, including Texas, Oklahoma, Louisiana, Arkansas, and New Mexico.

Peanuts (*Arachis hypogaea* L.) are self-pollinated, one- to six-seeded, annual herbaceous plants. The oil from these seeds is of high quality and a large percentage of the world production of peanuts is utilized as an edible oil source. In the United States, approximately 65 percent of the production goes into the shelled trade, the end product being roasted or salted peanuts, peanut butter, and confections.

Botanically, peanuts may be divided into three main types--Virginia, Spanish, and Valencia--based on plant branching order, pattern of branching, and number of seeds per pod. Runner peanuts, the fourth type sold commercially, are genetically related to Virginia-type nuts and are grown extensively in the Southeast and Southwest.

Disease Situation

The most destructive disease of peanuts throughout the world is Cercospora leafspot, caused by the fungi *Cercospora arachidicola* and *C. personata* (142). In the United States, where chemical measures are used extensively, the average annual losses are estimated at 10 percent (305). Losses (339) in Texas, Virginia, and Florida exceeded these estimates in 1977 (table 31). The monetary loss in these three States was $20 million in 1977.

Table 31.--Yearly peanut loss estimates due to Cercospora leafspot for 1975, 1976, and 1977

State	Peanut loss estimate (pct) 1/		
	1975	1976	1977
Virginia	10	12	15
North Carolina	10	8	6
Georgia	3	3	3.5
Alabama	--	2	5
Florida	--	--	12
Texas	12	15	15
Oklahoma	4.5	3	3

1/ Estimates obtained from a survey of extension plant pathologists.

Infection of peanut leaflets is first noticed as small chlorotic spots (lesions), which enlarge and become brown to black, subcircular, 1 to 10 mm or more in diameter and with one to many lesions per leaflet. Lesions may coalesce to form larger lesions. Petioles and stems are also commonly attacked. A chlorotic halo usually surrounds each lesion caused by C. arachidicola but not lesions caused by C. personata. The fungus sporulates (produces asexual spores called conidia) rapidly in the necrotic areas of the leaf under humid conditions. Conidia and conidiophores (structures bearing conidia) in old lesions assume a sooty appearance. Peanut leaflets infected with Cercospora sp. usually shed and drop to the soil. If defoliation is severe, yields can be drastically reduced. In fact, under severe disease pressure and severe defoliation, pods may shed into the soil (lost as far as the farmer is concerned) at the rate of 83 lb/acre/day (238). Thus, severity of leafspot and defoliation are directly related to defoliation and pod shedding. Under controlled conditions, pod yields decreased significantly when 33 percent of the leaf area was removed (109). Yields in plots with 10 to 15 percent of the leaf area removed were 4,270 lb/acre, whereas 50 percent leaf loss averaged 2,504 lb/acre compared with 4,443 lb/acre in the fully leaved plots.

Plant diseases are commonly controlled by resistant varieties, cultural practices, or fungicides. Without proper chemical and cultural control measures, peanuts could not be grown economically in the United States. Breeding for resistance to Cercospora leafspot of peanuts has not been successful. Resistance to leafspot when it is found in wild peanut species is usually associated with lack of fruit-set, which renders them agronomically unacceptable (121). Cultural practices, such as deep plowing, to bury crop refuse, and crop rotation will aid in leafspot reduction but will not prevent infection from occurring since conidia are wind-disseminated. Control of Cercospora leafspot in the United States is therefore dependent upon prevention of the disease or eradication of the fungus with fungicides. Almost all growers in all regions use several applications of fungicides each growing season. Several applications are required because of the short life cycle of the leafspot fungus. In 1977 over 95 percent of the peanut acreage in North Carolina received at least three applications of a fungicide for leafspot control (339).

Many fungicides are currently available that provide control of the Cercospora leafspot fungi of peanuts; however, it is doubtful whether any fungicide will ever have the impact on leafspot control that benomyl had when it first became available in 1970. Up until that time fungicides containing copper-sulfur were used almost exclusively for leafspot control in the Southeast. Benomyl quickly gained widespread acceptance (11, 50, 114, 238, 269) and was used on an estimated 49 percent (99) of all peanuts produced in the United States in 1973. Benomyl was used to the exclusion of other materials in Georgia, Alabama, and Florida. In 1973, strains of Cercospora sp. resistant to benomyl were found in Georgia (163). Resistant strains were later reported in Florida and Alabama (53). Since that time, the amounts of benomyl used in these areas have declined. Benomyl still gives control in the States where resistance was found, but it should be used only in combination with other fungicides.

In 1977 benomyl was used on an estimated 332,000 acres of peanuts in the United States (table 9, part 1). If 3.5 applications of benomyl were applied to this acreage at the rate of 0.25 lb active ingredient (50 WP), the total estimated poundage used for leafspot control would be about 291,000 pounds.

The systemic properties of benomyl are observed in Cercospora leafspot control of peanuts. Unfurled leaflets remain protected for some time following application of benomyl (240, 268).

The presence of benomyl on peanut leaflets delays progression of the epidemic by arresting disease development of established lesions, suppressing sporulation, and reducing the rate of defoliation (269, 288). Benomyl is the only material currently available to growers that possesses even limited systemic properties. Other fungicides must be used on a preventive schedule. The most desirable fungicide would be one possessing both systemic and contact activity (130).

The current recommendations for the use of benomyl for the control of Cercospora spp. are similar in all States where this fungicide is used. Inasmuch as Cercospora sp. has developed resistance to benomyl, a combination of benomyl and either Manzate® or Dithane® (1.5 lb/ acre) is now recommended to alleviate this potential hazard. The number of applications ranges from three to six. The amount of water used per application ranges from 5 to 25 gallons per acre and may be applied by either ground or aerial applicators.

Other fungicides are also available that are effective in controlling Cercospora leafspot. Table 32 lists these fungicides, the amount used, and the cost per acre. The cost values given are based on current consumer prices (331).

Benomyl and chlorothalonil are currently used on the majority of the peanut acreage in the Southwest and the Virginia-Carolina area. Tables 33-38 show a comparison of the efficacy of these two fungicides in all peanut-growing areas of the United States (15, 99, 112, 114, 160, 238, 289, 290, 325, 338). Therefore, if benomyl becomes unavailable, peanut growers in the Southwest and the Virginia-Carolina area would probably switch almost entirely to chlorothalonil.

Utilization of benomyl for leafspot control has several beneficial effects. In Virginia, North Carolina, and Oklahoma another peanut disease, called Sclerotinia blight (causal agent, Sclerotinia sclerotiorum), causes considerable crop losses. This disease caused an estimated 5 percent loss of the peanut crop in Virginia in 1976 and cost growers an estimated 3.5 million dollars (241). Benomyl has exhibited some degree of control over S. sclerotiorum (27). On the other hand, chlorothalonil will not provide any control of this disease and seems to enhance disease severity (239). Without benomyl, growers in these three States would resort to chlorothalonil for leafspot control and as a result would greatly increase the incidence of a non-target organism, S. sclerotiorum. The end result would greatly reduce grower income in areas where Sclerotinia blight was severe.

Table 32.--Fungicides, and relative cost of each, that are available to peanut growers for control of Cercospora leafspot

Fungicide	Amount/acre 1/	Cost/acre 2/
Benomyl + maneb	0.5 lb + 1.5 lb	6.90
Bravo®	1.5 pt	5.75
Difolatan®	3 pt	4.10
Dithane® M-45	2 lb	2.50
Du-ter®	6 oz	2.90
Kocide® 404S	2 qt	4.50
Polyram®	2 lb	2.00
Copper Count N®	.75 gal	4.20

1/ Rates based on label recommendations.
2/ Does not include application.

Table 33.--Results of fungicide screening trials in Virginia for control of Cercospora leafspot of peanuts in 1968-69

Treatment	1968	1969	Mean
		Percent infection	
Untreated	1/ 24a	100a	62
Benomyl 2/	2b	9b	6
		Percent defoliation	
Untreated	65a	100a	83
Benomyl	15b	6b	11
		Pounds of pods per acre 3/	
Untreated	2,710a	1,307b	2,009
Benomyl	3,208a	3,076a	3,142
		Pounds of pods per acre 4/	
Untreated	2,044b	317b	1,181
Benomyl	3,729a	3,392a	3,561

1/ Values within columns followed by same letter are not significantly different at the 5-pct level.
2/ Benomyl applied at 8-oz formulation per acre on a 14-day interval.
3/ Harvest date-early.
4/ Harvest date-late (2 weeks later than early).

Table 34.--Results of fungicide screening trials in Virginia for control of Cercospora leafspot of peanuts in 1974-77

Treatment	1974	1975	1976	1977	Mean
		Percent infection			
Untreated	99	--	10	8	39
Chlorothalonil 1/	21	--	1	3	8
Benomyl 2/	15	--	1	--	8
Benomyl + maneb 3/	--	--	0	2	1
		Percent defoliation			
Untreated	78	--	8	4	30
Chlorothalonil	2	--	2	0	1
Benomyl	0	--	2	--	0
Benomyl + maneb	--	--	1	1	1
		Pounds of pods per acre			
Untreated	1,660	--	1,598	2,613	2,077
Chlorothalonil	3,280	--	2,910	3,049	3,080
Benomyl	3,480	--	3,105	--	3,293
Benomyl + maneb	--	--	3,060	3,872	3,466

1/ Chlorothalonil applied at rate of 1 pt in 1974 and 1.5 pt in 1976 and 1977.
2/ Benomyl applied at 6 oz in 1974 and 8 oz in 1976.
3/ Benomyl applied at 4 oz in 1976 and 8 oz in 1977 and maneb applied at 1.5 lb in 1976 and 2 lb in 1977.

Table 35.--Results of fungicide screening trials in Oklahoma for control of Cercospora leafspot of peanuts in 1975-76[1/]

Location - Ft. Cobb	Pounds of pods/acre					
			Test 1		Test 2	
Treatment	DI [2/]	1975	DI	1976	DI	1976
Untreated	9	2,262	57	2,501	20	2,622
Chlorothalonil 3/	2	4,382	5	3,711	5	3,791
Benomyl 4/	1	4,053	5	3,590	--	--
Benomyl + maneb 5/	1	4,251	5	3,186	5	3,670

1/ Data obtained from extension plant pathologist.
2/ Disease index scale on basis of 0 = no defoliation and 9 = 90 pct defoliation.
3/ Chlorothalonil applied at 1.5 pt per acre.
4/ Benomyl applied at 6 oz per acre.
5/ Benomyl applied at 4 oz per acre and maneb applied at 1.5 lb per acre.

Table 36.--Results of fungicide screening trials in Texas for control of Cercospora leafspot of peanuts in 1970

Treatment	Disease index[1/]	Pounds of pods/acre
Chlorothalonil [2/]	8.0	3,494
Benomyl [3/]	7.2	3,336
Untreated	1.3	1,898

1/ DI - 0 = completely defoliated and 10 = little to slight infection.
2/ Chlorothalonil applied at 1.5 lb formulation per acre.
3/ Benomyl applied at 8 oz formulation per acre.

The addition of maneb to benomyl not only reduces the chance of buildup to resistant strains of Cercospora sp. but also provides elemental manganese to peanuts growing in manganese-deficient soils. In fact, five applications of benomyl + maneb at recommended rates to peanuts growing in manganese-deficient (3 p/m) soils in 1977 provided the necessary manganese for normal plant growth and resulted in yield increases worth over $70.00/acre (7).

Hay collected from fields treated with benomyl following harvest can be used for livestock. Hay from plants treated with chlorothalonil cannot be used for livestock feed because of label restriction (160, 289, 338).

Conclusions

Unavailability of benomyl would adversely affect peanut growers. Most growers would then switch to chlorothalonil, which provides excellent Cercospora leafspot control; however, the wide use of one fungicide could possibly cause a resistance problem that will increase the incidence of Sclerotinia blight. The loss of one alternate fungicide, such as benomyl, would reduce the number of fungicides available and increase the possibility that resistance may develop to any of the materials used (129). In Texas, where recommendations indicate the need for alternating or combining fungicides throughout the year to control rust

Table 37.--Results of fungicide screening trials in Alabama for control of Cercospora leafspot of peanuts in 1971-74

Treatment	1971	1972	1973	1974	Mean
		Percent infection			
Untreated	[1/]97a	86a	65a	93a	87a
Chlorothalonil [2/]	56b	9b	16b	25b	36b
Benomyl	41c	7c	21b	[3/]89a	26c
		Percent defoliation			
Untreated	[1/]80a	53a	44a	64a	59a
Chlorothalonil [2/]	43b	6b	6b	15c	23b
Benomyl	25c	6b	6b	[3/]55b	18c
		Pounds of pods per acre			
Untreated	[1/]1,851	3,176	2,389	2,817	2,558c
Chlorothalonil [2/]	3,589	3,283	3,531	4,653	3,889a
Benomyl[2/]	3,792	3,594	2,926	[3/]2,834	3,286b

1/ Values within columns followed by same letter are not significantly different at the 5-pct level.
2/ Chlorothalonil applied at 1.5 lb per acre and benomyl applied at 6 oz per acre on a 14-day interval.
3/ Resistance to benomyl developed in 1973-74 seasons.

Table 38.--Results of fungicide screening trials in Alabama for control of Cercospora leafspot of peanuts in 1975-76

Treatment	1975	1976	Mean
		Percent infection	
Untreated	79	72	76
Chlorothalonil[1/]	65	42	53
Benomyl[2/]	74	69	71
Benomyl + maneb[3/]	65	55	60
		Percent defoliation	
Untreated	59	48	54
Chlorothalonil	38	25	31
Benomyl	50	44	47
Benomyl + maneb	40	35	37
		Pounds of pods per acre	
Untreated	2,984	3,521	3,253
Chlorothalonil	3,981	3,761	3,871
Benomyl	3,056	3,325	3,190
Benomyl + maneb	3,427	3,688	3,557

1/ Chlorothalonil applied at 1.5 pt per acre on a 14-day interval.
2/ Benomyl applied at 6 oz per acre on a 14-day interval.
3/ Maneb (1.5 lb) combined with benomyl (4 oz) (on a 14-day interval) to alleviate resistance problems.

and Ascochyta web blotch diseases as well as leafspot, resistance to benomyl has not developed (160, 269). A different situation exists in the Southeast where benomyl-resistant strains of Cercospora sp. prevail. During 1971-73 this area utilized benomyl almost exclusively for leafspot control, and resistance developed. In the Virginia-North Carolina area benomyl resistance is not a problem because most growers use alternating fungicide spray schedules. Peanut hay (vines collected from the surface of the soil following harvest) is a valuable commodity for livestock feeding. Hay from plants treated with benomyl can be utilized for this purpose.

Vegetables

Nonchemical methods of control are ineffective for powdery mildew, gummy stem blight, and anthracnose of cucurbits; early and late blight of celery; white mold of beans; white mold of cabbage seed; and Botrytis sp., white mold, and gray leaf mold of tomato. Over the last 20 years, programs to develop genetic resistance to these diseases have not been successful. Tolerance to gray leaf mold in a few Florida-developed tomato varieties represents the highest achievement in this area (61, 62, 116).

Crop rotation is not successful because not enough suitable vegetable production land is available for this purpose. Where desirable land is extremely limited, such as the soil type for celery, the cost of crop rotation would increase the cost of production significantly. To control many of these diseases, a given crop would have to be absent from a specific area for more than 3 years. High land taxes, intense population pressures, and inflationary production costs prohibit obtaining enough land for this purpose or allowing such land to be idle for the necessary time.

Disease escape procedures for vegetables are extremely difficult. Host plants would either die from freezing, fail to produce vegetable fruit under high heat conditions, or would not mature in time to fill the only national market slot available for a given geographical area.

There are no known biological control agents for these specific vegetable diseases.

Alternate fungicides (table 39) used in the past for vegetable disease control were perhaps more effective than no fungicide at all, but were not as effective as benomyl.

Beans, tomatoes, and the cabbage seed crop would be most seriously affected by loss of benomyl. For beans, 14 States that recommend benomyl for control of white mold have no alternatives, and several that do recommend alternative fungicides indicate that they are less effective than benomyl. In addition, 9 States that recommend benomyl for control of bean gray mold have no alternative recommendations. Producers of either field-grown or greenhouse tomatoes would be seriously limited in choice of fungicides if benomyl were lost. There are no alternatives in any States that recommend benomyl for control of white mold in either type of culture. Several States also have no alternative for tomato leaf mold. Choices for tomato gray mold are somewhat less limited, but several alternatives are on RPAR (EBDC's) and another (captan) is a candidate. For celery, the most widely recommended alternatives (EDBC's) are on RPAR evaluation. For cucurbits (cucumber, cantaloup, watermelon, squash, pumpkin) disease-control alternatives for powdery mildew control are totally ineffective. For the other cucurbit diseases, gummy stem blight and anthracnose, the major alternatives (EDBC's) are on RPAR evaluation and captan and folpet are RPAR candidates. There are no alternatives available for controlling white mold in the production of cabbage seed (2, 10, 47, 56, 57, 71, 86, 100-102, 113, 137, 139, 140, 149, 166, 172, 174, 188, 191-193, 196, 201, 203-206, 208, 209, 218, 219, 221, 227, 275, 298, 299, 324, 335, 342, 353).

Table 39.--Use patterns and cost of benomyl versus alternate fungicides

Commodity/material	Formulation (pct WP)	Rate per acre (lb ai)	Number of applications per season	Spray interval (days)	Price per pound (dollars)
Cucumber, squash, cantaloup, watermelon.					
Karathane®	22.5	0.09-0.1	4	10	1.95
Chlorothalonil	75	1.2-2.0	5	7	5.95
Maneb	80	1.0-2.4	6	7	4.00
Difolatan®	75	2.2	6	7	2.41
Benomyl	50	.25	3	14	8.00
Celery					
Dyrene®	50	1.5	10	7	
Chlorothalonil	75	1.2-2.0	10	7	5.95
Maneb	80	2.4	10	7	4.00
Polyram®	80	1.6	10	7	.98
Kocide®	50	1.7	10	7	1.65
Benomyl	50	.25	10	7	8.00
Beans					
Botran®	75	2.25	3	7	
Benomyl	50	.25	2	14	9.95
Tomatoes					
Maneb	80	2.4	7	7	4.00
Chlorothalonil	75	2.0	7	7	5.95
Difolatan®	75	2.2	7	7	2.41
Benomyl	50	.25	4	14	8.00
Cabbage seed production (no alternates)					
Benomyl	50	0.25	8	7	8.00

Efficacy of benomyl as opposed to alternate fungicides is demonstrated by the following examples. For control of cucumber powdery mildew, benomyl was 60 percent more effective than no spray and 40 percent more effective than the best alternative material (maneb) (113). Against cucumber gummy stem blight, benomyl was 75 percent more effective than the best alternative fungicide (maneb) (113). For control of celery late blight, benomyl was 82 percent more effective than no spray and 14 percent more effective than the best available alternate (maneb) (326). Maneb is also under RPAR review. Against bean white mold, benomyl was 42 percent more effective than either no spray or the most effective alternative fungicide (PCNB) (281). Additionally, benomyl was 71 percent more effective than no spray in controlling squash powdery mildew (267), 43 percent more effective than no spray in controlling tomato gray leaf mold (35), and 90 percent better than no spray for control of bean white mold in Oregon (322). Many other examples of efficacy data exist in the annual publications of Fungicide and Nematicide Test Results (published by the American Phytopathological Society) for all the years that benomyl has been available for testing by State Experiment Stations.

Several fungicides are used as less effective alternates for benomyl in commercial vegetable production. Dinocap and PCNB are difficult to obtain. Both chlorothalonil and captafol are available but they are more expensive. Maneb (EBDC), which is the most effective alternative fungicide, is readily accessible but it is also under RPAR evaluation. The homeowner may conveniently obtain only maneb and captafol at local gardening stores, and there is a possibility that these may soon become restricted-use fungicides that can be purchased only by a certified applicator.

The alternative fungicides are applied both by air and by ground hydraulic equipment. It is extremely difficult to obtain data on air vs. ground application of vegetable fungicides. In many areas, the mode of application is entirely dependent on weather, a factor that is variable. When weather conditions do not allow for ground application (soggy, wet fields) the same area will switch to aerial application. When weather conditions do not allow for aerial application (gusty winds), the same area will switch to ground application. The alternates are applied 3 times during a crop season to beans, 6 times to cucurbits, 7 times to tomatoes, and 10 times to celery. Generally, these fungicides are applied on a 7-day schedule. On vegetables, all the possible alternative fungicides are recommended at higher rates of active ingredient per acre and are applied more frequently than benomyl (table 39). Neither the alternative fungicide nor benomyl was phytotoxic when used at recommended rates. Examples of field increases from benomyl for plant disease control are illustrated by the following tests.

The use of benomyl to control specific diseases resulted in an 18-percent cucumber yield increase (483 bu/acre) over the most effective alternative, maneb (397 bu/acre), and a 17-percent yield increase over the control (400 bu/acre). When used for controlling powdery mildew, benomyl produced a 10-percent yield increase (150 bu/acre) over the check (135 bu/acre) (267). For control of celery blight, benomyl produced a 7-percent yield increase (30 tons/acre) over the most effective alternative fungicide, maneb (28 tons/acre) and a 54-percent increase over no spray (14 tons/acre) (326). When used on beans to control white mold, benomyl produced a 38-percent yield increase (2,180 lb/acre) over the most effective alternative PCNB (1,358 bu/acre), and a 50-percent increase over the control (1,101 bu/acre) (281). On cabbage plants used for commercial seed production, there is no alternative fungicide, and yield losses range from 25 to 100 percent (330-1,200 lb/acre) (342).

The use of all possible alternate fungicides is more expensive than the use of benomyl. The costs per pound are: Benlate®-$8.00, Bravo®-$5.95, maneb-$1.50, captafol-$2.41, Karathane®-$1.95. Also to be included are the costs of the needed additional application in terms of gasoline, tractor depreciation, worker-hours, and other costs. None of these plant diseases is controlled by hand labor in the United States. If growers were required to utilize knapsack sprayers (hand labor) (as are now used in the developing countries) at current minimum wage rates, then technology, yields, and price would place American agriculture where it was 200 years ago. Land costs, land availability, and the necessity for filling a specific slot in the national marketing structure preclude cultural procedures. Biologically, 7 to 10 years are required to develop and refine an improved or new plant variety. The world cannot afford to reduce production in the interval. It also cannot afford to gamble on the possibility of the variety being worthless when subjected to regional environmental fluctuations or on a plant disease rapidly mutating around a genetic barrier.

Yield Impact of Loss of Benomyl on Vegetables

Economically, the loss of benomyl would be disastrous to the producers of crucifer seed (cabbage, turnips, and others) in the Pacific Northwest. In this area, where 30 percent of the free world's cabbage seed is produced, vegetable seed ranks fourth by dollar value.

Without benomyl, losses have ranged from 25 to 100 percent on normal average yields of 1,200 pounds of seed per acre.

There are no suitable alternatives to benomyl for beans. East of the Mississippi River and in the Pacific Northwest, growers' losses average 30 percent without benomyl. Additionally, if more than 5 percent of a truck load of processing beans has white mold when inspected at the receiving station, the entire load is rejected by the processor, and often the entire field producing that particular load of beans is also rejected by the processor. In the drier Midwestern areas of dry-bean production, the losses range from 12 to 20 percent on yields from 1,000 to 1,800 pounds per acre.

Benomyl is used on watermelons, cantaloups, cucumbers, and squash. One illustration of yield loss for cucurbits reveals that in the Winter Garden, Texas area, 1,000 acres of cantaloups suffered a 15-percent loss to powdery mildew. When losses from the same disease occur in the 15,650-acre watermelon crop, and the 3,000-acre cucumber crop, the economic impact on this area is significant. Without the use of benomyl, the yield of Mississippi watermelons would drop from 30,000 lb/acre to less than 10,000 lb/acre. Other U.S. cucurbit production areas have similar results (65, 226).

The high number of benomyl applications to celery each growing season (10 applications) indicates the magnitude of loss to be suffered by producers. Losses have been as high as 100 percent (253).

Without benomyl, the Illinois field tomato crop losses may reach 20 percent, Florida field tomato crop losses 50 percent, and Hawaii greenhouse tomato crop losses 35 percent (98, 153, 341).

In addition to economic losses resulting from decreased yield as a result of increased vegetable diseases, there is a domino socio-economic effect. Reduced production means less fertilizer, seed, pesticides, equipment being manufactured and purchased, which would severely curtail these related agribusiness endeavors and reduce income for all workers in those areas. Migrant labor harvests most of the fresh-market vegetables in the United States. One example reveals that if Florida tomato growers were denied benomyl, the loss in yield would idle 7,000 migrant tomato harvesters (115). Many workers in the food-processing industry would not be employed, particularly in the tomato and bean areas, if benomyl were unavailable. As a result of the domino effect, the consumer could expect a drastic increase in price for fresh and processed vegetables if benomyl could not be used for vegetable disease control.

Turfgrass

Dollar Spot

Dollar spot attacks turf in all areas of the United States except for the arid regions of the West. On golf courses it is the most commonly occurring disease.

Symptoms

The disease is characterized by round, bleached to straw-colored spots. These spots range in size from that of a quarter up to a silver dollar, from whence the disease got its name. The spot appears as sunken areas, especially in turf mowed at 1/2 inch in length or less. As the disease progresses, individual spots may coalesce and destroy the turf in large undefined areas. If the fresh spots are observed in the morning while the grass is still wet, the grayish-white fluffy mycelium of the fungus can be seen. The disease is spread mechanically, primarily by mowers and other maintenance equipment carrying infected plant tissue. Infected plant tissue is also carried by golf shoes and carts. Because of this method of transmission and the fact that the disease is controlled only on the greens, its recurrence will usually first be noticed on the side of the green from which the traffic approaches from the infected areas and fairway.

Occurrence

Dollar spot occurs at temperatures between 60° and 90°F. There appear to be two strains of the causal organism of the disease and they are distinguished by their temperature specificity: One strain occurs during cool weather when the temperature is below 75°F; the other strain is favored by temperatures of 80°F plus. The development of the disease is favored by high humidity, warm days, and cool nights.

Brown Patch

Symptoms

The disease is characterized by circular brown patches ranging in size from a few inches up to several feet in diameter. The infected leaves first appear water-soaked and dark, eventually drying, becoming withered and dark brown. Brown to black sclerotia are sometimes found beneath the leaf sheath or on the stolons. When high humidity is present, a so-called "smoke ring," which consists of the mycelium of the fungus, surrounds the outer margins of the diseased area. The "smoke ring" will disappear as the foliage dries.

Turfgrass areas destroyed by brown patch or other diseases are usually invaded by broadleaf weeds or weedy grass. Most of the broadleaf weeds and annual grass can be controlled with selective herbicides, but the perennial weedy grasses cannot--they require a complete renovation. If the disease is widespread, the entire turf area will have to be replaced at considerable cost to the homeowner or professional turf person.

Occurrence

Rhizoctonia solani survives periods of extreme heat or cold as sclerotia or as mycelium in plant debris. It can also survive as a saprophyte in the turf thatch. When soil temperatures rise into the 60's the sclerotia begin to germinate and the fungus grows. The fungus grows in a circular pattern, as most fungi do, but apparently does not parasitize the grass plant until the air temperature rises to the mid-80's, with high humidity and nighttime temperatures that remain in the 70's or higher. At lower temperatures, R. solani is a weak parasite growing as a saprophyte or causing minute infections; serious infection does not take place because the grass plant is in good growing condition. It is only after the grass plant is put under heat stress and begins to go through high-temperature growth stoppage that the balance switches in favor of the fungus, resulting in disease development. R. solani usually infects the roots first, then the stolons, and finally the leaves. It can enter the grass plant through the cut ends of the grass blades, stomates, or by direct penetration.

Snow Mold

Introduction

In the Pacific Northwest, Fusarium patch is the most important turfgrass disease. This is mainly due to the extended periods of cool, wet weather without snow cover that are experienced there. The disease is also important in many other northern areas that experience cool, wet springs or falls or that have snow cover in the winter months. In annual bluegrass, creeping bentgrass, velvet bentgrass, colonial bentgrass, and perennial ryegrass the fungus can enter the crown and result in the complete loss of the grass plants.

Symptoms

The disease occurs without snow cover as reddish-brown spots ranging in size from less than an inch to about 8 inches in diameter, although large spots are found occasionally. When the disease occurs under snow, the circular spots are usually 2 to 3 inches, up to 1 to 2 feet in diameter, and are tan to whitish-gray or reddish-brown in color.

If the spots are seen shortly after the snow has melted, they will often have the pink mycelium of the fungus present in the margins, from whence the disease got its common name, pink snow mold.

Occurrence

The fungus can survive as mycelia and conidia in the thatch. It will grow actively on the grass residue. Infection takes place when the temperatures are below 60°F, especially if accompanied by wet weather. The disease can occur under snow cover at temperatures just above freezing.

Fusarium Blight

Introduction

Fusarium blight is one of the most destructive diseases of Kentucky bluegrass on golf courses and home lawns. Large acreages of valuable sod are lost to this disease every year.

Symptoms

The disease appears as circular spots ranging in size from 6 to 24 inches in diameter. The center of these spots appears as healthy grass surrounded by a band of dead or dying turf. This symptom is commonly referred to as a "frog eye." Under severe conditions, however, or on some of the more susceptible varieties like Pennstar, Flyking, and Nugget, the entire circle of grass will be killed. In areas of 90°F or higher temperatures and high humidity, the disease can be seen as a foliar blight. In the more northern areas and in California the disease occurs as a root and crown rot.

Plants infected with Fusarium blight have shortened root systems that are poorly developed. Even when the grass begins to recover in these spots, the roots and shoots remain stunted. In these areas, the spots first appear as wilted turf (dark blue to purple), and if the turf is not treated it will turn straw-colored to light tan.

On centipedegrass, the primary symptoms on the plant are blighting at the cut end of the blades and mid-blade discoloration, which is sometimes accompanied by tissue collapse. The root systems of infected plants are brown.

Occurrence

The fungus can overwinter in the thatch and in infected plants. Fusarium sp. is also a good saprophyte and is often found in plant debris. In the more southern region where Fusarium blight occurs, the high temperature and humidity stress appear to be conducive to disease development. The fungus can infect the grass plant crowns. Plants whose crowns are infected usually die.

On centipedegrass, most of the injury occurs in the early spring. The centipedegrass either fails to initiate new growth or the new growth soon deteriorates. It has both a leaf blight and a root rot stage.

Stripe Smut

Introduction

Stripe smut and Fusarium blight are the most destructive diseases in Helminthosporium sp.-resistant Kentucky bluegrass cultivars. Stripe smut is a systemic perennial, which means that once a plant becomes infected it will remain so for life. Also, all plants arising from that mother plant will be infected. A smut-infected plant is always in a weakened condition compared with a healthy plant and, consequently, any additional stress will result in death. The most common form of stress is drought, and it is not unusual to see loss of entire lawns that are heavily infected with stripe smut when people go on vacation in the summer and neglect to have someone water their lawns.

Symptoms

From a distance, an infected turf area will appear clumpy. This is a result of the stripe smut organism causing a more upright growth of the infected bluegrass plant. Stripe smut is a disease that tends to kill individual plants, leaving bare spots that contribute to the clumpy appearance. The smut-infected plants do not tiller as profusely as healthy plants and consequently bare areas are not readily filled in; this results in weed grass and broadleaf weeds moving into these bare areas.

Light yellow blades of grass are the first symptoms to appear. As the disease advances, the leaf blades begin to curl and have black stripes running parallel up and down the length of the blades, from which a black soot-like dust can be rubbed off. This soot-like dust is the spores of the stripe smut fungus. Older infected blades will be twisted, curled, and shredded from the tips down.

Occurrence

The stripe smut fungus overwinters as mycelium in the crown and other vegetative parts of an infected plant. It can also overwinter for many seasons as teliospores in the soil. Infection of seedlings can occur through the coleoptiles or through auxiliary crown buds or rhizome nodes.

Stripe smut symptoms occur most commonly in the spring and fall during periods of wet, cool weather when the day temperatures are below 70°F, and they gradually disappear as the temperatures become warmer. Although the symptoms are most evident during periods of cool weather, very little turf is lost. Most of the infected turf is lost during the hot, dry weather of the summer when the grass is under heat and drought stress or in open winters when the plants are subject to desiccation and cold temperature stress.

Stripe smut is a systemic disease that is perennial in the grass plant. Systemic means that the fungus is internal and can spread throughout the vascular system (veins) of the plant. The striping effect of the grass blades is due to the fungus growing only in the veins. Perennial means that once a grass plant is infected it will remain so for life.

Although visual symptoms may not always be present, this simply means that the grass is resistant to the prevalent stripe smut races of today, most of which are specific for 'Merion' and 'Windsor'. The possibility for developing new races that can attack other cultivars occurs prior to every new infection.

The diseases controlled by benomyl, the rates/1,000 ft^2, and the average number of treatments applied in a season are listed in table 12, part 1.

Dollar Spot

Nonfungicidal Control

Maintaining high nitrogen fertility levels and removing the guttation water are the two cultural means of reducing disease severity. There are two schools of thought on nitrogen, one of which says, "more infection will occur at higher nitrogen fertility but the damage will be less severe." The other says, "that at low fertility, while there may be fewer actual spots, they will be larger and cause more permanent damage." From a practical point of view, it is necessary to keep the nitrogen levels up during periods of severe dollar spot development to reduce the severity and make the fungicide program more effective. "Removing the dew" to reduce dollar spot severity is also a common cultural practice on golf course greens. These practices are not adequate to prevent extensive loss from the disease. Therefore, chemical fungicides are required.

If dollar spot is not controlled with fungicides, it can be severe enough to destroy the majority of the turf on a golf course in a matter of a month to 6 weeks. Loss of turf would make playing golf impossible, with a resulting revenue loss, and it could eventually lead to the bankruptcy of the golf course. The expense of reseeding the greens, tees, and fairways with desirable species would cost over $3,000 in seed alone, not to mention the cost of labor, machinery, fertilizer, and herbicides.

Alternatives

Alternatives to benomyl for control of dollar spot are given in table 40. When applied on a 10- to 14-day schedule, these alternatives give control comparable to benomyl, but when applied on a 1-month schedule only thiophanate and thiophanate-methyl give equivalent control (317, 318). Only 1 oz/1,000 ft^2 is required for month-long control with benomyl, thiophanate-methyl, and thiophanate, whereas the cadmiums, cycloheximide, cycloheximide-thiram, chlorothalonil, anilazine, PCNB, and cycloheximide-PCNB all require 2 to 6 oz/1,000 ft^2 per treatment to be effective. Therefore, where benomyl, thiophanate, and thiophanate-methyl are being used there is less fungicide being added to the environment. The common names, chemical names, and trade names for fungicides and fungicide mixtures used on turf are given in tables 41 and 42.

Benomyl, thiophanate, and thiophanate-methyl are the cheapest fungicides to use because they require only one application per month, whereas the other alternatives require multiple applications to give equivalent control (table 43). The exceptions are cycloheximide-PCNB and cadmium chloride, which are cheaper even at multiple applications. It should be noted that although thiophanate could be substituted directly for benomyl, enough of this fungicide is not available to meet the needs if both benomyl and thiophanate-methyl registrations are canceled.

RPAR's have been issued against the PCNB and cadmium products, which means that PCNB, cycloheximide-PCNB, and cadmium may not be available, depending on the outcome of their RPAR's. Without benomyl, thiophanate-methyl, and cycloheximide-PCNB, the cost of controlling dollar spot in turfgrass could double.

Brown Patch

Nonfungicidal Control

Two major cultural practices that help to reduce the severity of brown patch are maintaining low levels of nitrogen during periods when brown patch may be a problem and removing guttation water as soon as possible in the morning. The cultural practices will help to reduce the severity of the disease, but they will not give a satisfactory level of control to prevent turf loss. For acceptable levels of control, fungicides are necessary.

Alternatives

Alternatives to benomyl for control of brown patch are given in table 40. Chlorothalonil, cycloheximide, cycloheximide-thiram, cycloheximide-PCNB, PCNB, mancozeb, thiophanate, thiophanate-methyl, and thiram all give control equivalent to benomyl. Benomyl gives effective control of brown patch at a 2 oz/1,000 ft^2 rate. The cost of benomyl at 2 oz/1,000 ft^2 is equivalent to the alternatives since one application will give control for one month compared with two applications required of the other fungicides to give effective control over the same period. If three applications of the alternatives were required, as sometimes happens, benomyl would be cheaper. The exceptions are thiophanate and thiophanate-methyl, which give equivalent duration of control at equivalent cost, and cycloheximide-PCNB, which would cost less even with multiple applications (table 43).

Less fungicide enters the environment when benomyl, thiophanate, and thiophanate-methyl are used compared with the alternatives, even though the costs may be the same. RPAR's have been issued against the PCNB products and mancozeb, making their use as alternatives questionable pending the outcome of their reviews. It is doubtful whether enough thiophanate would be produced to fill the demand if registration of both benomyl and thiophanate-methyl were canceled.

Table 40.--Turfgrass diseases controlled by benomyl products, the hosts they occur on, and effective alternatives to them

Disease and causal organism	Hosts	Effective alternatives to benomyl
Brown patch		
Rhizoctonia solani	Annual bluegrass	Chlorothalonil
	Bahiagrass	Cycloheximide
	Bermudagrass	Cycloheximide-PCNB
	Centipedegrass	Cycloheximide-thiram
	Colonial bentgrass	Thiophanate
	Creeping bentgrass	Thiophanate-methyl
	Fine leaf fescues	Thiophanate-thiram
	Kentucky bluegrass	Thiram
	Meadow fescue	Mancozeb
	Perennial ryegrass	PCNB
	St. Augustinegrass	
	Tall fescue	
	Velvet bentgrass	
	Zoysiagrass	
Dollar spot		
Sclerotinia homoeocarpa	Annual bluegrass	Chlorothalonil
	Bahiagrass	Anilazine
	Bermudagrass	Cycloheximide
	Centipedegrass	Cycloheximide-thiram
	Colonial bentgrass	Cycloheximide-PCNB
	Creeping bentgrass	Thiophanate
	Fine leaf fescues	Thiophanate-methyl
	Kentucky bluegrass	Thiophanate-thiram
	Perennial ryegrass	Thiram
	St. Augustinegrass	Thiabendazole
	Zoysiagrass	Cadmium compounds
		PCNB
Fusarium patch		
Fusarium nivale	Annual bluegrass	The mercuries
	Colonial bentgrass	Mancozeb
	Creeping bentgrass	Thiophanate
	Fine leaf fescues	Thiophanate-methyl
	Kentucky bluegrass	
	Perennial ryegrass	
	Tall fescue	
	Velvet bentgrass	
Fusarium blight		
Fusarium roseum	Kentucky bluegrass	Thiophanate
Fusarium tricinctum	Centipedegrass	Thiophanate-methyl
Stripe smut		
Ustilago striiformis	Kentucky bluegrass	Thiophanate
	Creeping bentgrass	Thiophanate-methyl

Table 41.--Fungicides used on turf

Common name	Chemical name or mixture	Trade name
Anilazine	2,4-dichloro-6-(o-chloroanilino)-s-triazine	Dyrene, Proturf Fungicide III
Benomyl	methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate	Tersan 1991, Proturf Fertilizer + DSB fungicide
Cadmium compounds	cadmium chloride	Caddy
	cadmium chloride (8.3 pct) plus thiram (75 pct)	Cad-trete
	cadmium sebacate 5 pct, potassium chromate 5 pct, malachite green 1 pct, auramine 0.5 pct, thiram 16 pct	Kromad
	cadmium succinate 60 pct (29 pct cadmium)	Cadminate
Captan	N-[(trichloromethyl)thio]-4-cyclohexene-1,2-dicarboximide	Orthocide Captan 50W, Captan 75W,
Chloroneb	1,4-dichloro-2,5-dimethoxybenzene	Tersan SP, Proturf Fungicide II
Cycloheximide	3-[2-(3,5-dimethyl-2-oxocyclohexyl)-2-hydroxyethyl]glutarimide	Acti-dione TGF
Chlorothalonil	2,4,5,6-tetrachloroisophthalonitrile	Daconil 2787, Proturf 101V
Maneb	manganous ethylenebis[dithiocarbamate]	Manzate
Mancozeb	coordination product of zinc ion and manganous ethylenebis[dithiocarbamate]	Fore
Maneb plus zinc sulfate	manganous ethylenebis[dithiocarbamate] plus zinc sulfate	Tersan LSR
Mercury compounds	Inorganic mercuric and mercurous chloride	Calo Clor, Calo Gran
PCNB	pentachloronitrobenzene	Terraclor 75, Scotts F + F II
PMA PMAS	phenylmercury acetate phenylmercury acetate	PMA, PMAS, Puraturf No. 10 Phenmad
Thiophanate	diethyl [(1,2-phenylene)bis(iminocarbonothioyl)]=bis[carbamate]	Cleary's 3336
Thiophanate-methyl	dimethyl [(1,2-phenylene)bis(iminocarbonothioyl)]=bis[carbamate]	Fungo, Spot Kleen, Scotts Systemic Fungicide
Thiram	bis(dimethylthiocarbamoyl) disulfide	Tersan 75, Spot-Treat, Thiramad
Dinocap	2-(1-methylheptyl)-4,6-dinitrophenyl crotonate	Karathane, Mildex
Terrazole	5-ethoxy-3-(trichloromethyl)-1,2,4-thiadiazole	Koban
Thiabendazole	2-(4-thiazoyl)benzimidazole	Mertect 160, Tobaz

Table 42.--Fungicide mixtures

Trade name	Generic make-up of mixture
Acti-dione thiram	Cycloheximide + thiram.
Acti-dione RZ	Cycloheximide + PCNB.
Bromosan	Thiophanate + thiram.
Scotts Fertilizer and Fungicide.	PMA + thiram

Fusarium Patch

Nonfungicidal Control

High nitrogen fertility, which makes turfgrass lush and vigorous, will increase susceptibility to Fusarium patch. It will also make control with fungicides more difficult. Although avoiding such nitrogen fertility practices will reduce disease severity, fungicides are necessary to prevent turfgrass from being lost to Fusarium patch.

There are no creeping bentgrass cultivars resistant to Fusarium patch. All cultivars require chemical treatment to prevent disease development. Annual bluegrass also requires chemical treatment. Kentucky bluegrass and annual bluegrass appear to be more susceptible to Fusarium patch than creeping bentgrass. Fusarium patch has been observed to select out the annual bluegrass patches in golf course greens, leaving the creeping bentgrass alone.

Alternatives

Alternatives to benomyl for control of Fusarium patch are given in table 40. They are mancozeb, thiophanate, thiophanate-methyl, and the mercuries. They all give equivalent control of Fusarium patch where multiple applications can be made. The mercury fungicides give the best control in areas where snow cover remains on the ground for a month or longer and multiple applications cannot be made. On the basis of a single application, the costs of thiophanate, mancozeb, and phenylmercury acetate solution are equivalent to but much cheaper than the mercurous and mercuric chloride fungicides. The most critical point, with the exception of thiophanate, which could not alone meet the demand if benomyl and thiophanate-methyl were canceled, is that the alternatives have serious limitations. One alternative, mancozeb, is in the RPAR process and its availability as an alternative is questionable; this leaves the mercuries as the other alternatives. EPA's position on hazards of the mercuries to people and the environment was well-documented during the mercury hearings; however, removing benomyl, thiophanate-methyl, and mancozeb would leave the mercuries and thiophanate as the only effective alternatives for control of Fusarium patch.

Fusarium Blight

Nonfungicidal Control

High nitrogen fertility early in the season will increase severity of Fusarium blight. In areas where disease is a problem, fertilizing in early fall and the dormant season is advisable, with light but frequent applications through summer.

Moisture stress is the key to development of symptoms in the North. Watering recommendations for healthy turf usually state "water once a week to a depth of 6 inches to encourage deep root development," but for turf infected with Fusarium blight, this is not a good recommendation. What is needed in Fusarium blight-infected turf is light, frequent watering to keep the top inch or half inch of the root zone moist. Because of the shortened root system, even with the top inch or half inch of soil being moist, the infected plants may still wilt and die on days when the temperatures are above 80°F. Minimal turf loss on these days can be obtained by syringing during the warmest part of the day.

Table 43.--Fungicide cost comparison for commercial turfgrass use

Fungicide [1]	Cost/lb	Cost/oz	Rate/ 1,000 ft^2	Cost/ 1,000 ft^2	Cost/ acre [2]
	-----Dollars-----		Ounces	----Dollars----	
Anilazine (Dyrene)	2.83	0.18	4	0.71	30.63
Benomyl (Tersan 1991)	10.05	.63	1	.63	27.00
Cadmium succinate	14.95	.93	1/2	.47	20.21
Cadmium chloride	16.50/gal	.12	1	.12	5.16
Chloroneb (Tersan SP)	6.02	.38	9	3.38	145.00
Chlorothalonil (Daconil 2787)	3.50	.21	4	.84	36.21
Cycloheximide (Acti-dione TGF)	7.60	.47	1	.47	20.50
Cycloheximide and PCNB (Acti-dione RZ)	5.04	.32	1/2	.161	6.78
Cycloheximide-thiram (Acti-dione Thiram)	4.90	.31	2	.61	26.33
Mancozeb (Tersan LSR)	1.70	.11	4	.52	22.36
Mercurous and Mercuric Chloride (WP)	16.99	1.06	3	3.09	132.87
Mercurous and Mercuric Chloride (G)	1.22		(6 lb)	7.32	314.76
PMAS 10 pct	9.33	.50	1	.50	21.50
PCNB (Terraclor)	2.10	.13	4	.52	22.36
Proturf F + F [3] II (PCNB)				2.00	86.00
Thiophanate	9.93	.58	1	.58	25.08
Thiophanate-methyl (Fungo)	9.95	.62	1	.62	26.74
Thiram (Tersan 75)	2.03	.13	4	.52	22.36

1/ Costs were rounded off for all treatments.
2/ Cost/acre is based on 43,000 ft^2/acre.
3/ Also contains fertilizer, which adds to the cost.

The following cultivars appear to be resistant at this time, although they are certainly not immune: Adelphi, Majestic, Parade, Vantage, and Touchdown; however, these cultivars have not been widely grown long enough to know if they are really resistant or if they will become susceptible as new races of Fusarium roseum develop.

Stripe Smut

Nonfungicidal Control

Cultural practices will help to reduce disease severity. They consist of applying minimum amounts of nitrogen during the summer months and no more than 1/2 lb nitrogen/application/month. A stripe smut-infected turf should not be allowed to become dry. Unlike a healthy Kentucky bluegrass turf, which enters dormancy if not watered and recovers when water is applied, a stripe smut-infected lawn will die.

Resistant Cultivars

There are several Kentucky bluegrass cultivars available today that are believed to be resistant to stripe smut; however, this resistance is probably only temporary because of the numerous races that the stripe smut fungus has the potential to produce. Once a Kentucky bluegrass becomes widely grown, a race of the stripe smut fungus that can attack it will probably develop.

Alternatives for Fusarium Blight and Stripe Smut

The only alternatives to benomyl for the control of Fusarium blight and stripe smut are thiophanate and thiophanate-methyl (317, 319-321). Since thiophanate is similar to thiophanate-methyl and benomyl, similar rates are used and costs are approximately the same. It is highly unlikely, however, that enough thiophanate would be made available to meet the demand for the control of these two diseases, not to mention the demand for the treatment of dollar spot, brown patch, and Fusarium patch. Also, it is not known how EPA would judge the toxicity of thiophanate vs. thiophanate-methyl and benomyl.

Ornamental Plants

The ornamental plants industry is an extremely diverse and complex segment of agriculture. It is composed of hundreds of thousands of different crop plants grown under greatly diverse conditions. Therefore, the diversity of disease problems and control measures corresponds to the diversity of crops and growing conditions. In addition to aspects of disease control under production conditions in nurseries, we must also consider disease control in the maintenance of these plants following sale. Reliable information about these latter aspects is difficult to obtain but represents a large segment of pesticide use. These users would include landscape managers, grounds keepers, and homeowners. Pesticide volume in this use area, as well as the value of the plant treated outside of the nursery situation, is difficult to determine accurately; however, the value of a plant once established in the landscape is many times greater than the value of the plant in the nursery or greenhouse. Thus, a significant portion of the benefits from the use of benomyl accrues as a result of control of ornamental plant diseases by these consumers. This use of benomyl amounts to 100,000 to 125,000 pounds (ai) annually.

A detailed analysis of the benefits of benomyl in controlling the diseases of major ornamental crops would be impossible. In most cases, information relating to total units or acres in the nursery, or chemical use patterns, is not available at the local, State, or national level. More use and benefits information is available for certain key crops, such as roses, chrysanthemums, geraniums, azaleas, and some others.

An attempt will be made to summarize the major uses of benomyl by designating the principal categories of ornamental plants and including the most significant crops within each category. These uses will include crops produced in the greatest volume or with the greatest economic value.

It is significant that benomyl is recommended for a wide range of diseases on many plant species in the nursery, in the greenhouse, and in environmental plantings. It is relatively nonphytotoxic, has a broad spectrum of activity, and is more effective than most compounds. Benomyl is more expensive than most recommended alternative chemicals, but its increased efficacy outweighs cost differences because of the high value of the crops treated. In addition, "second best" alternatives are frequently of no value since partial control that results in inferior appearance may reduce the value of the crop by 80 to 100 percent.

The repeated use of benomyl has resulted in the appearance of tolerant strains of some pathogens. This problem is minimized by alternating benomyl with other fungicides. It has been reported that benomyl-tolerant strains may be more sensitive to other fungicides (363).

It would be difficult to list all of the crops and diseases for which benomyl is recommended. It may be noted, however, that from published recommendations from 33 States, benomyl is recommended in one or more States for disease control in 65 species of flowers and ground covers. In addition, several States have general recommendations for control in "floral crops," "foliage crops," "bedding crops," and others (80).

Economic and biological information will be presented by dividing nursery crops into general classes and enumerating available information relating to these classes or specific crops within these classes (tables 44-47). It is estimated that approximately 25,000 pounds of benomyl are used annually in nurseries in the United States.

Floral Crops (Potted)

The major pot crops are chrysanthemums, poinsettias, geraniums, lilies, and hydrangeas in order of their 1977 wholesale value. They represent a total wholesale value of $155.7 million. The five top producing States and the number of units sold in millions are:

State	Units (millions)	Acres (estimates)
	Chrysanthemums	
California	7.6	1,800
Florida	3.7	900
Texas	2.8	600
Ohio	2.3	550
Michigan	1.3	220
	Poinsettias	
California	3.5	800
Ohio	2.0	350
Michigan	1.2	200
Illinois	1.2	200
New York	1.2	200
	Geraniums	
Ohio	8.2	
Michigan	6.1	
New York	4.8	
Massachusetts	3.2	
Pennsylvania	2.8	
	Pot lilies	
California	1.6	
Michigan	0.6	
Illinois	0.5	
Ohio	0.5	
New York	0.3	

$ Sales at wholesale (millions)*	Units sold (millions)	Square feet (millions)
	1976	
Pompom chrysanthemums		
$34	36 bunches	37.4
Potted chrysanthemums		
$53	26 pots	27.0
Gladioli		
$17.2	182 spikes	8.300 acres
Tea roses		
$59	397 blooms	23.4
Sweetheart roses		
$16	115 blooms	5.2
Foliage		
$236	--	116.3
Snapdragon		
$3	14 stems	2.5

(continued)

$ Sales at wholesale (millions)*	Units sold (millions)	Square feet (millions)
	1976	
	Potted geraniums	
$30.4	46 pots	14.8
	Potted lilies	
$14	7 pots	5.8
	Potted hydrangeas	
$5	2.2 pots	3.0
	Flowering bedding plants	
$61.4	20 flats	31.9
	Standard chrysanthemums	
$29	140 blooms	22.4
$46	518 blooms	28.8
	Miniature carnations	
$6	5 bunches	2.7
	Hydrangeas	
$5.6	--	2.6

*From: Flower and foliage plants, production and sales, 1975 and 1976. Intentions for 1977. Crop Reporting Board, SRS, USDA, March 1977.

Bedding Crops

Bedding plants are a big crop; the 1977 wholesale value of floral bedding crops was $124.6 million and represented 31.1 million flats.

Foliage Crops

The total area in foliage crops in 1977 was 123 million square feet, which represented a sales value of $272 million. Foliage plants are the number one ornamental crop in the United States. The major foliage crops include schefflera, dracaena, philodendron, pleomele, croton, Norfolk Island pine, and spathiphyllum. Florida is a major producer of tropical foliage plants with an estimated 750,000 acres in production (368).

Floral Crops (cut)

The major cut flower crops in order of their wholesale value are roses (tea and sweetheart), carnations (standard and miniatures), chrysanthemums (standard and pompoms), gladiolus, snapdragons, and anthurium.

1977 Sales at wholesale	Million dollars
Roses, tea	62
Roses, sweetheart	17
Carnations	42
Carnations, miniature	6
Mums, standard	29
Mums, pompoms	36
Gladiolus	17
Snapdragons	3
Anthurium	3

The top producing States in 1977 in terms of millions of blooms:

	Roses
California	146.0
Colorado	23.9
Pennsylvania	21.2
Indiana	18.6
New York	17.9
	Carnations
California	351.3
Colorado	129.5
Pennsylvania	7.7

Pompoms

Main producing States in terms of millions of bunches:

California	21.3
Florida	8.9
Pennsylvania	1.2
Ohio	0.8
Minnesota	0.6

Standard mums

U.S. production: 111.7 million blooms.

Gladiolus

Production mainly in Florida.

Snapdragons

Production mainly in Massachusetts.

Anthurium

Hawaii: A $3 million crop with 17 million blooms.

Information regarding recommendations for the use of benomyl and alternative fungicides is derived from pesticide labels and State pest control bulletins. Information and data regarding disease control achieved by benomyl and alternative fungicides is derived from: (1) Fungicide and Nematicide Tests, 1970-1977; (2) grower associations; (3) extension plant pathologists; (4) growers.

As might be expected because of the diversity of crops and growing conditions, recommendations regarding

Table 44.--Major Pot Crops: Production area, units sold, wholesale value[1], percent of crop treated with benomyl, diseases, and alternative chemicals, 1976

Host	Production area (million ft^2)	Number of units sold (millions)	Value of sales at wholesale (millions)	Percent of crop treated with benomyl	Disease	Alternative chemicals [2]
Chrysanthemum	17.6	25.8	$52.9	95	Powdery mildew.	cycloheximide dinocap folpet sulfur piperalin
					Septoria leaf spot.	captan ferbam folpet maneb zineb
					Botrytis	captan chlorothalonil DCNA maneb zineb
Poinsettias	21.6	14.9	$35.5	75	Botrytis	chlorothalonil
					Thielaviopsis root and stem rot.	Banrot
					Rhizoctonia root, stem, and crown rot.	Banrot
Geranium	14.8	46.1	$30.4	40	Botrytis	chlorothalonil DCNA zineb
					Stem, crown, and root rot.	Banrot captan chlorothalonil
Lilies	5.8	6.7	$13.9	95	Botrytis	bordeaux mixture chlorothalonil
					Flower and leaf spots.	chlorothalonil zineb
					Bulb rot	PCNB
Hydrangea	3.0	2.2	$5.0	50	Botrytis	DCNA
					Powdery mildew	dinocap

1/ From: Flowers and foliage crops. Production and sales 1975 and 1976. Intentions 1977. CRB-SRS, USDA. 1977.
2/ Chemicals with Federal labels only (State labels excluded).

Table 45.--Major Cut Floral Crops: Production area, units sold, wholesale value 1/, percent of crop treated with benomyl, diseases, and alternative chemicals, 1976

Host	Production area (million ft ^{2})	Number of units sold (millions)	Value of sales at wholesale (millions)	Percent of crop treated with benomyl	Disease	Alternative chemicals 2/
Carnations						
Standard	28.8	517.9 blooms	$45.6	95	Fusarium wilt	captan
Miniature	2.7	4.7 bunches	5.6			
Total	31.5	--	$51.2			
Chrysanthemum						
Standard	22.4	140.4 blooms	$29.3	95	Botrytis	basic copper sulfate.
Pompom	37.4	35.6 bunches	34.2			bordeaux mixture
Total	59.8	--	$63.5			DCNA
						captan
						copper oxy-chloride.
						chlorothalonil
						mancozeb
						maneb
						zineb
Gladiolus	362.9	181.7 spikes	$17.2	95	Botrytis	folpet
						thiabendazole
						thiram
Roses	28.2	341.3 blooms	$74.4	90	Powdery mildew.	cycloheximide
						dinocap
						folpet
						parinol
						piperalin
						sulfur
						triforine
					Black spot	captan
						chlorothalonil
						ferbam
						folpet
						mancozeb
						maneb
						metiram
						sulfur
						zineb
					Botrytis	chlorothalonil
						ferbam
						zineb

1/ From: Flowers and foliage crops. Production and sales 1975 and 1976. Intentions 1977. CRB-SRS, USDA. 1977.

2/ Chemicals with Federal labels only (State labels excluded).

Table 46.--Major Foliage Crops: Production area, wholesale value[1/], percent of crop treated with benomyl, diseases, and alternative chemicals, 1976

Host	Production area (million ft ^{2})	Value of sales at wholesale (millions)	Percent of crop treated with benomyl	Disease	Alternative chemicals [2/]
Foliage Plants				Soilborne Diseases	
Total	116.3	$235.8	70	Rhizoctonia	Banrot
				Sclerotium	chlorothalonil [3/]
				Thielaviopsis	mancozeb[3/]
				Fusarium	PCNB[3/]
				Leaf Spots and Blights	
				Cercospora	chlorothalonil [3/]
				Botrytis	mancozeb[3/]
				Fusarium	
				Alternaria	

1/ From: Flowers and foliage crops. Production and sales 1975 and 1976. Intentions 1977. CRB-SRS, USDA. 1977.
2/ Chemicals with Federal labels only (State labels excluded).
3/ Registered only in States where foliage plant production is concentrated - no Federal label.

rates and frequency of applications vary over a wide range. Therefore, average usage or range of usage will be supplied as available. Information relating to percent of crop treated is meager and unreliable on a State or national basis. Specific information from individual growers for specific crops is a guide for general use patterns. Likewise, information regarding losses, increased production costs, and so forth, in the absence of benomyl or resulting from the use of alternatives is minimal. Here again, examples available should be representative of the industry.

Benomyl is recommended for control of many important diseases of the major floral, foliage, bulb, and bedding plant crops. Included are foliar and flower diseases, such as Botrytis gray mold, powdery mildew, black spot of roses, and Septoria, Cercospora, and Entomosporium leaf spots. Stem, crown, and root rots caused by Botrytis, Fusarium, Rhizoctonia, and Thielaviopsis are also serious problems.

Benomyl recommendations for control of foliar diseases range from 3 to 4 oz/100 gallons for African violets to 4 to 8 oz/100 gallons for chrysanthemum stock plants (136). Sprays are applied at about 200 gallons per acre, with great variability depending upon the crop. Frequency of spraying also varies greatly with the crop. Although label recommendations call for 10- to 14-day intervals throughout the growing season, humid, wet, weather necessitates more frequent spraying. Increased frequency is necessary in southern areas or under greenhouse conditions where high humidity routinely occurs. Preventive disease control is practiced by many growers, but others delay spraying until disease symptoms appear. Mum growers spray root cuttings three times a week; flowering chrysanthemums or stock plants are sprayed 15 to 26 times a year. Foliage or bedding plant seedlings are often sprayed weekly (136).

As a soil drench, benomyl label recommendations call for 8 oz ai/100 gal

Table 47.--Flowering Bedding Plants: Production area, units sold, wholesale value[1/], percent of crop treated with benomyl, diseases, and alternative chemicals, 1976

Host	Production area (million ft^2)	Number of units sold (millions)	Value of sales at wholesale (millions)	Percent of crop treated with benomyl	Disease	Alternative chemicals [2/]
Flowering Bedding Plants						
Total	31.9	29.7	$61.4	95		
Celosia					Leaf spots	chlorothalonil
Chrysanthemum					Powdery mildew	piperalin
					Ascochyta	chlorothalonil zineb.
					Botrytis	captan, mancozeb chlorothalonil.
Dahlia					Powdery mildew	piperalin
					Botrytis	bordeaux mixture, basic $CuSO_4$, C-O-C-S, mancozeb, zineb.
Hollyhock					Leaf spot	bordeaux mixture, ferbam, Cu oxychloride, basic $CuSO_4$, mancozeb.
Impatiens					Leaf spot	chlorothalonil
Marigold					Leaf spot	chlorothalonil, basic $CuSO_4$.
Nasturtium					Leaf spot	chlorothalonil, C-O-C-S, basic $CuSO_4$.
Pansy					Anthracnose	mancozeb, zineb
					Leaf spot	zineb
					Botrytis	chlorothalonil
Petunia					Botrytis	chlorothalonil
Phlox					Powdery mildew	piperalin
					Leaf spot	Cu oxychloride, basic $CuSO_4$, sulfur.
Stock					Leaf spot	Cu oxychloride basic $CuSO_4$.
Sweet pea					Anthracnose	Cu oxychloride
Zinnia					Powdery mildew	piperalin, parinol
					Alternaria	folpet, mancozeb.

1/ From: Flowers and foliage crops. Production and sales 1975 and 1976. Intentions 1977. CRB-SRS, USDA 1977.
2/ Chemicals based on State experiment station bulletins.

applied at 1 to 2 pints/ft^2, repeated at 2- to 4-week intervals. Here again, applications vary up to 40 per year on a weekly basis. Frequent drench applications are necessary with hydrangeas and poinsettias to control Thielaviopsis root rot. The poinsettia crop in New York represents a wholesale value of about $2.5 million. The disease symptoms usually appear 2 to 4 weeks prior to sale and the disease may cause losses from 10 to 100 percent of the crop where ineffective control is practiced (351).

Benomyl is recommended for control of Fusarium and Penicillium rots on bulbs, including gladiolus, tulips, and lilies, at 0.83 lb ai/100 gallons. It is used to treat a high percentage of all bulbs in both the field and greenhouse. Virtually 100 percent of the 12 million lily bulbs sold annually are treated with benomyl (64). Loss of gladiolus due to corm rot, without benomyl treatment, is estimated at about 35 percent.

Botrytis gray mold is the most serious disease on chrysanthemums. Benomyl is the only effective therapeutic fungicide; however, successive applications produce phytotoxicity, so prophylactic treatments and alternate therapeutic treatments are made with other fungicides. Benomyl is incorporated with rooting hormones, which results in increased root production. Because of the systemic nature of benomyl, protection of cuttings continues during shipping. It is the only fungicide that shows this systemic protection. Benomyl use is reported to increase production of chrysanthemums by 5 to 22 percent depending upon the disease susceptibility of the variety (216).

Pan American Plant Co. (135) reported African violet foliage plant seeding production of 2.5 million units/year and bedding plant seeding production of 9.5 million units/year. Powdery mildew and Botrytis are major problems and received benomyl treatments 1 to 4 times per month. Annual cash value at wholesale is $2 to $3 million. Losses without benomyl are difficult to determine because without its use there would be no salable crop; however, even a 10-percent annual loss of crop would mean a $200,000 to $300,000 loss.

Alternative Fungicides

The chief source of information on the efficacy of benomyl and its alternatives for disease control is from: (1) Surveys of growers; (2) State pest control recommendations; and (3) Fungicide and Nematicide Tests.

A number of the more commonly listed alternatives include: Dinocap, chlorothalonil, captan, zineb, maneb, thiram, thiophanate-methyl, folpet, and mancozeb. Benomyl is recommended in State pesticide recommendations more frequently than alternative fungicides (80). Also, grower response indicates that benomyl is more efficacious than alternative chemicals. In the ornamental industry, maximum disease control is the primary consideration because of the high value of the crop, and even slight defects caused by a disease detract significantly from the value of the crop. Similar defects in plant appearance resulting from phytotoxicity and excessive residue may significantly reduce crop value.

Benomyl is widely used because it is a relatively broad-spectrum fungicide. It is labeled for use on many ornamental plants. With few exceptions, as mentioned above with chrysanthemums, it can be used effectively with no phytotoxicity or offensive residue.

Chlorothalonil.--Considered as effective as benomyl on some disease problems where both are recommended. It has a limited label on ornamentals, however, and can cause phytotoxicity on more sensitive crops or sensitive varieties of tolerant crops. Its cost is about 2/3 that of benomyl.

Ziram, thiram, and ferbam.--These alternatives are not as effective as benomyl. Thiram is effective as a seed treatment, but benomyl is more effective after disease develops. Ferbam produces a black residue and would, therefore, not be suitable for foliar treatments, particularly near harvest.

EBDC's (nabam, mancozeb, maneb, zineb, and metiram).--These compounds are currently RPAR'd. They are used in combination with, and alternated with, benomyl. Surveys indicate that although EBDC fungicides are effective, benomyl shows superior control for many diseases. The EBDC's are used in conjunction with benomyl to delay or prevent development of benomyl-tolerant fungus strains (72, 135).

Captan.--It is a pre-RPAR candidate that can be used in combination with benomyl, as are the EBDC's. Grower surveys indicate that captan is less effective than benomyl.

Coppers and sulfur.--Fungicides containing these materials generally cause phytotoxicity and leave objectionable residue. Sulfur causes phytotoxicity above 85°F and is not effective below 60°F. Copper produces phytotoxicity when it accumulates in soil after repeated treatments.

Banrot®.--A combination product that contains thiophanate-methyl (TPM) (25 pct) as one of the active ingredients. It is comparatively more expensive than benomyl because TPM produces only half as much MBC as benomyl.

DCNA.--Effective for control of Botrytis diseases in field, greenhouse, and during storage. Unsightly residue may result if applied near harvest.

Dinocap.--Provides good control of powdery mildew on many ornamental crops. It is phytotoxic to some plants, particularly if applied during periods of high temperature.

Cycloheximide.--This chemical is effective for control of powdery mildew. It is unstable in storage and may cause phytotoxicity under unfavorable environmental conditions.

Folpet.--Relatively effective for control of powdery mildews and other foliar diseases and several soilborne diseases. It is useful during early stages of plant production but may leave undesirable residue. It is comparatively nonphytotoxic and inexpensive but is not registered on many crops.

PCNB.--Registered on a wide variety of ornamental plants for control of soilborne disease. It is a good alternative to benomyl for control of Rhizoctonia but does not control Thielaviopsis. It is more phytotoxic than benomyl.

Thiabendazole.--Registration is limited to control of a few soilborne diseases of bulb crops. TBZ is less effective than benomyl.

Parinol.--Registration is limited to control of powdery mildew on roses and zinnias. It is less effective than benomyl.

Piperalin.--More effective than benomyl for control of powdery mildew but not widely used because of high cost. Registration is limited to seven crops.

Triforine.--Recently registered for control of powdery mildew on greenhouse roses. Registration is more limited than benomyl. It is more effective than benomyl for control of many powdery mildews (74, 147, 170, 231, 242).

Zyban®.--A combination product that contains 15 percent thiophanate-methyl and 60 percent Dithane® M-45 (a coordination product of zinc ion and manganous ethylenebis[dithiocarbamate]). It has a broad spectrum of activity and test reports indicate that it is as effective as benomyl for the control of many diseases (124, 233).

Efficacy data for key floral crops were reported in Fungicide and Nematicide Tests from 1970-1977. Alternatives that were tested included ferbam, triforine, and maneb. In most tests, benomyl produced significantly better control than the tested alternatives (74, 81, 82, 147, 170, 232, 242, 358).

Shade Trees and Woody Ornamentals

As with the foliage and floral crops, there are a great number of shade trees and woody ornamental shrubs. Again, key crops and diseases must be used to exemplify the benefits of benomyl in this segment of the industry. Table 48 summarizes the major woody shrubs and shade trees and the diseases controlled by benomyl and alternative chemicals.

As with other crops, sources of efficacy data include: (1) Grower and commercial applicator surveys; (2) State pest control recommendations; and (3) grower associations.

Based on the published recommendations from 33 States, benomyl is the preferred treatment for control of the diseases on the crops listed. Benomyl is the only material now available for control of Phomopsis tip blight, black knot of plum, Diplodia tip blight of

Table 48.--Major Shade Tree and Woody Ornamental Crops: Diseases and alternative chemicals

Host	Disease	Alternative chemicals 1/
Dogwood	Botrytis blight	none
	Anthracnose	maneb
	Septoria leaf spot	none
Hawthorn	Scab	none
	Fabraea leaf spot	none
Pyracantha	Scab	Zyban
Flowering crab	Scab	dodine
		captan
		mancozeb
	(F&N) Powdery mildew	dinocap
Sycamore	Anthracnose	bordeaux mixture
Azalea	Ovulinia petal blight	mancozeb
	Powdery mildew	sulfur
	Cylindrocladium	none
Juniper	Phomopsis twig blight	Zyban
Rhododendron	Powdery mildew	sulfur
	Ovulinia petal blight	Zyban
Maple	Phyllosticta leaf spot	none
Flowering almond	Brown rot	captan
Euonymus	Powdery mildew	cycloheximide
Lilac	Powdery mildew	
Viburnum	Powdery mildew	none
Arborvitae	Phomopsis blight	none
Ash	Anthracnose	none
	Cylindrosporium leaf spot	none

1/ Chemicals with Federal label. Chemicals with State label are excluded.

pine, sycamore anthracnose, Diaporthe twig blight on laurel, and Diplocarpon sp. on Pyrus (89, 136).

Junipers represent a major portion of production of woody ornamentals. Phomopsis twig blight is a major disease under wet or humid conditions. The disease can be controlled by two fall applications of benomyl. Bordeaux mixture, previously recommended, required eight applications and produced inconsistent results. Phenylmercury compounds are no longer labeled. Generally recommended application rates for benomyl are 0.25 lb/100 gallons to control powdery mildew and Botrytis gray mold and 0.5 lb/100 gallons for most other diseases of woody ornamentals including anthracnose, hawthorn leaf blight, Phomopsis blight, scab on pyracantha and flowering crab, brown spot, and powdery mildew. Fungicide and Nematicide Tests reported results on control of diseases of some woody ornamental and shade trees.

Mancozeb.--Control is equal to benomyl for leaf spots on maple, ash, horsechestnut, dogwood, and mountain ash and was better than benomyl for leaf spot on hawthorn (67, 68, 356, 357, 359).

Folpet.--Benomyl is superior for control of powdery mildew and leaf spot of ash and maple (357) and leaf spot of dogwood (359).

Captan.--Benomyl controlled apple scab equally well (363).

Information on the use patterns of benomyl for shade trees and woody ornamentals in the nursery is less clear than for foliar and floral crops. Equally scanty is information on benomyl use for maintenance of plants outside the nursery by homeowners and landscape applicators.

Estimates indicate that 4 or 5 times the amount of chemical is used outside the nursery situation as is used by nurseries (100,000-125,000 lb (ai) vs. 25,000 lb (ai)). In addition, the dollar value of plants sold at wholesale can be established and has been indicated previously. The value of these same plants established in a landscape setting is virtually impossible to determine, but may range from 5 to 10 times or more the value when sold at retail. It is important to realize that values increase annually. Thus, some appreciation for the value of landscape plantings may be gleaned from the fact that, in 1975, wholesale value of nursery plants was $907 million and retail value of nursery stock was $2.7 billion (131).

Pesticide application in the nurseries is a routine procedure and is predominantly preventive in nature. Among homeowners and commercial applicators, disease control is intermittent and, because of costs involved, primarily therapeutic in nature.

Pecans and Macadamia Nuts

Benomyl is used to control scab, a foliar, twig, and shuck disease, caused by the fungus Fusicladium effusum. It is responsible for 95 percent of disease losses in pecans and macadamia nuts. Benomyl also suppresses zonate leaf spot and powdery mildew, two other major diseases of these crops.

Benomyl is used as a 50 percent WP at 0.5 to 1 lb/acre for 3 to 12 applications per year depending on disease incidence, which is correlated with seasonal rainfall patterns. In South Carolina, Georgia, and Alabama, benomyl is used with the alternate pesticide Du-Ter® for scab control, because of the development of resistant strains of the organism. Based on average usage patterns the past 3 years, approximately 100,000 pounds of benomyl are used per year for pecans.

Benomyl is used on macadamia nuts in Hawaii to control Botrytis blossom blight early in the growing season. Of the 400 acres in cultivation, 80 percent is sprayed with either benomyl or captafol, an alternate fungicide.

Benomyl is used to control four of the major fungus diseases of pecans, scab (caused by *Fusicladium effusum*), powdery mildew (caused by *Microsphaera alni*), zonate leaf spot, and Phyllosticta sticky shuck. Benomyl is the only fungicide that is effective against zonate leaf spot, which affects approximately 10 percent of the pecan orchards in the Southeast.

For control of scab, the most important disease of pecans, benomyl is used in combination, or in alternation,

Table 49.--Role of benomyl in the control of major pecan diseases

Disease	Acres affected[1/]	Acres treated with benomyl	Percent control[2/] with: Benomyl	Alternative	Reference
Scab	225,000	98,000	94	75	(345)
Powdery mildew	22,500	22,500	92	50	(345)
Zonate leaf spot	40,000	40,000	100	0	Personal communication[3/].
Phyllosticta sticky shuck.	22,500	22,500	100	0	Personal communication[3/].

1/ Total pecan acreage, not including nonbearing orchards and unimproved native stands, is 358,278 acres (see table 50).
2/ Tested on the disease-susceptible cultivar Schley.
3/ Dr. J.A. Payne, U.S. Department of Agriculture, P.O. Box 87, Byron, Ga.

Table 50.--Pecan acreage in the United States

State	Acreage[1/]	Source
Alabama	36,210	U.S. Dep. Commerce Census, 1969
Arizona	14,686	do.
Arkansas	10,355	do.
California	200	Personal communication, S. Sibbett, Farm Advisor, Visalia, Calif.
Florida	10,000	U.S. Dep. Commerce Census, 1969
Georgia	125,000	Personal communication, T. Crocker, Univ. of Ga.
Louisiana	27,965	U.S. Dep. Commerce Census, 1969
Mississippi	25,000	do.
New Mexico	9,630	Personal communication
North Carolina	1,297	U.S. Dep. Commerce Census, 1969
Oklahoma	20,000	Personal communication, G. Barnes, Univ. of Oklahoma, Stillwater.
South Carolina	5,172	U.S. Dep. Commerce Census, 1969
Tennessee	75,000	do.
Texas	47,000	Personal communication
Total	358,278	do.

1/ Acreage under management, not including nonbearing orchards and unimproved native stands.

with either Du-Ter® or Cyprex® (dodine) to reduce the likelihood of development of resistant strains of the pathogen. Nevertheless, benomyl is the most effective of the three fungicides (table 49). Benomyl also is the only material that effectively controls powdery mildew and Phyllosticta sticky shuck, diseases that affect about 10 percent of pecan orchards.

In the United States, there are approximately 350,000 acres of bearing pecan orchards under management, not including nonbearing orchards and unimproved native stands (table 50). A total of 250,000 acres are in the Southeast, half of them in Georgia, and 98 percent of the acres are in the range of the major fungus diseases of pecans. About 40 percent of the acreage in the Southeast is treated with benomyl.

Benomyl is used as a 50 percent wettable powder at 0.5 to 1 lb/acre for 3 to 12 applications per year, with an average of 4 applications per year. Since the 1977 season, benomyl has not been recommended alone in Alabama, Georgia, Florida, Oklahoma, and South Carolina because of the development of resistant strains of the fungus (164). Tank mixes with Du-Ter® or alternating sprays with Du-Ter® or dodine are recommended.

The most effective nonchemical control method for pecan diseases is the use of tolerant cultivars. Many cultivars, such as Barton, Elliott, and Curtis, are tolerant of scab, and in years of light disease incidence such tolerance is 50 to 75 percent effective in reducing disease losses (340). In normal or severe disease years, however, cultivar resistance and tolerance reduce disease incidence by only 5 to 10 percent.

The use of alternative fungicides dodine and Du-Ter® presents problems. Dodine cannot safely be used on all cultivars; it is phytotoxic to Moore and Van Deman cultivars. Du-Ter® is required at more frequent intervals to provide scab control equivalent to that of benomyl. Thus, the cost of controlling scab with Du-Ter® is approximately 20 to 50 percent more than with benomyl mixes or alternating sprays (personal communications, G.L. Barnes, Oklahoma State University, Stillwater.)

Benomyl is used on macadamia nuts in Hawaii to control blossom blight caused by *Botrytis cinerea*. It is used for two or three applications at 0.5 lb/100 gallons. Approximately 80 percent of the 400 acres of macadamia nuts is treated with benomyl. At the rate of 50 gal/acre, or 0.25 lb benomyl/acre, a total of 2,400 pounds of benomyl (3 applications) is used per season.

An equivalent alternative material to benomyl for the control of blossom blight is captafol, but because of continuous complaints of skin irritations resulting from the use of this compound, benomyl is preferred by spray operators (personal communication, M. Aragala, University of Hawaii, Hawaii).

Fruit Crops East of the Mississippi (Non-Citrus)

Commercial fruit crops (non-citrus) grown east of the Mississippi River generally must be protected against fungus and bacterial disease attacks each year. The control of more than 40 diseases on tree and small-fruit crops requires one to five fungicide sprays annually. Disease incidence varies in intensity among regions, and the number of fungicide sprays required for control varies from crop to crop and even among cultivars depending on the level of susceptibility. This report recognizes these variables in assessing the importance of benomyl in managing diseases in commercial fruit culture.

Pome Fruits (Apple and Pear)

Benomyl is used to control 15 or more diseases that attack fruit and foliage of apple and pear grown in Eastern States. An estimated 23 percent of the 83,436 acres of apples and pears grown are sprayed annually and the amount used per acre varies with the severity of the disease, which is influenced by climatic region and cultivar susceptibility (5). The high efficacy level of benomyl as a protectant against several diseases (fruit and leaf spotters and fruit decay) is widely recognized. Additionally, it also suppresses sporulation of the apple scab fungus, both the asexual (6) and the sexual stages (58, 183, 190). This inhibition of sporulation has resulted in substantial reduction of inoculum levels in orchards and subsequently has reduced the management problem of this disease. Apple scab is the most troublesome of all apple diseases in the Northeast and Midwest regions. McIntosh and Rome Beauty, two of the most highly susceptible cultivars of apple, are planted extensively in the Northeast, making up 53 percent of the acreage grown. Under the ideal environmental conditions for scab development in this region, 100 percent of the fruit on highly susceptible cultivars may become infected unless protective fungicides are applied in a seasonal spray program (106, 144). Benomyl used in seasonal spray programs (8 to 10 sprays) under these severe conditions reduced losses to less than 3.0 percent. In the mid-Atlantic and Southeastern regions where environmental conditions are somewhat less favorable and cultivars are less susceptible to scab, benomyl has reduced scab losses to less than 1.0 percent (119, 162). Many commercial apple growers who use benomyl have obtained complete control of scab for 3 or more years. Unfortunately, the apple scab fungus has developed benomyl-tolerant strains in several parts of the world where this fungicide has been used extensively for more than 3 years (145, 211, 348). In such cases, benomyl is used in combination with other fungicides.

Many of the registered alternative fungicides to benomyl for apple scab control are on RPAR or pre-RPAR lists (EBDC fungicides, captan, captafol, folpet). Such fungicides as dodine, dichlone, glyodin, and sulfur are generally less effective than benomyl (table 51) and are limited in use because of phytotoxicity or narrow spectra of disease activity (120, 134, 222). Dodine is highly effective against scab but controls only this disease on apple and pear (106). It lacks the strong suppressive action of benomyl against established lesions (144) and does not control powdery mildew. The use of dodine on yellow cultivars often results in poor finish, and drops in grade of 20 percent or more are common. In addition to scab and powdery mildew, several fungi causing diseases during the late summer months (summer diseases: sooty blotch, fly speck, black rot, Botrytis rot) are also present in most commercial orchards and must be controlled.

Powdery mildew is a major disease problem in many eastern orchards and can cause extensive crop losses on highly susceptible cultivars. It is more severe in the mid-Atlantic region where highly susceptible cultivars, such as Jonathan, Rome Beauty, and Stayman Winesap, make up 20 percent of the production. Moderately susceptible cultivars comprise 50 percent of the acreage and Delicious, which is only slightly susceptible, is planted on approximately 30 percent of the acreage. Accurate records of the crop losses caused by various diseases, particularly powdery mildew, are very limited (120) or lacking. Hickey and Lewis estimated (personal communication) that a crop reduction of 90 percent would result in susceptible cultivars if 80 to 85 percent of leaves were infected for more than 2 years; that 40 percent would be lost with 40 to 45 percent of leaves infected; and that 10 percent would be lost with 20 percent of leaves infected. Benomyl has provided better control than other fungicides on the highly susceptible cultivars (119) and has performed very well on cultivars moderate to low in susceptibility (107, 162). Dinocap and sulfur are two alternative fungicides but both have major limitations. Dinocap only controls mildew and provides poor control under severe conditions (119). Sulfur is highly effective but is phytotoxic to most cultivars at temperatures above 32°C (90°F).

Table 51.--Activity spectrum of apple fungicides

Fungicide	Control of: Scab	Powdery mildew	Rust	Black rot	Sooty blotch and fly speck	Mite suppression 1/
Benomyl	++++	++++	0	++	++++	++
Captafol	+++	0	0	-	-	0
Captan	+++	0	0	+++	++	0
Dichlone	+++	-	-	-	-	-
Dikar	+++	+++	+++	+++	+++	+++
Dodine	2/ ++++	0	+	+	+	0
Ferbam	++	0	+++	++	+++	0
Folpet	+++	-	-	+++	+++	-
Glyodex	+++	0	+	++	++	+
Glyodin	+++	0	+	++	++	++
Dinocap	0	+++	0	-	-	+++
Kolo 100	+++	+++	+	++	++	0
Mancozeb	+++	0	+++	+++	+++	0
Niacide-M	++	0	+++	+++	++	-
Metiram	+++	0	+++	+++	+++	0
Sulfur	++	++++	+	++	++	0
Thiram	++	0	+++	+++	++	0
Zineb	+	0	+++	-	+++	0

- = Unknown or does not apply. + = Slight. +++ = Good.
0 = None. ++ = Fair. ++++ = Excellent.

1/ Indicates degree of mite suppression of the product when used on a full-season schedule.

2/ Except in orchards where dodine resistance is present.

Stone Fruits
(Peach, Nectarine, Cherry, Plum)

The most destructive disease of stone fruits in eastern orchards is brown rot (caused by Monilinia fructicola), a fungal disease that affects blossoms, twigs, and fruits. Severity varies with environmental conditions and all cultivars are susceptible enough to require full-season protective sprays. Against blossom blight, benomyl has been one of the most effective fungicides registered and is used on more than 104,000 acres of stone fruits in eastern orchards. It is also used extensively for postharvest treatment of stone fruits in all parts of the United States. In greenhouse tests where unprotected blossoms were 100 percent infected, benomyl gave 99 percent control (293). In field studies, MacSwan (169) obtained complete control with benomyl sprays when the unprotected blossoms were 61 percent diseased. As a fruit protectant, benomyl has provided 75 to 100 percent control in many field experiments (51, 52, 54, 157, 158, 366). It is estimated, based on the study of several field experiments, that benomyl provides 25 percent better disease control than sulfur, an alternative fungicide. The difference in control between captan and benomyl is inconsistent among short-term tests, but the difference becomes greater with increase in time of usage because of strong sporulation suppression of the pathogen by benomyl. In addition to brown rot, excellent control of peach scab (caused by Cladosporium carpophilum), cherry leaf spot (caused by Coccomyces hiemalis), and powdery mildew of cherry have been obtained when benomyl is used in a seasonal spray program (107, 146, 151, 152, 366).

Grapes

The grape acreage in New York, Michigan, and Pennsylvania comprises the bulk of the 80,800 acres grown in the Eastern States. Benomyl is used on more than 37,000 acres for control of black rot (caused by *Guignardia bidwellii*), powdery mildew (caused by *Uncinula necator*), bunch rot (caused by *Botrytis cinerea*), and cane and leaf spot (caused by *Phomopsis viticola*). The major advantage of benomyl on grapes is its broad spectrum of activity against several diseases. Against black rot, it performs equal to or better than alternative fungicides, such as captan, ferbam, folpet, or copper (36, 37, 38, 39, 295, 365, 367). Captan and ferbam are ineffective against powdery mildew, which must be controlled on all cultivars or 75 to 90 percent loss would occur. Copper, although effective, is phytotoxic to most grape cultivars. At nonphytotoxic rates, copper provides unsatisfactory disease control. As an alternative for mildew control, copper is a poor choice and folpet (on pre-RPAR list) is generally less effective and also is phytotoxic when temperatures are above 32°C (90°F). Benomyl has performed well in the control of Botrytis berry rot, which at times affects all cultivars of grape (294). Grape cane and leaf spot and Eutypella canker are diseases that are present in many vineyards (ca. 40 pct). Captan and folpet are less effective but were used extensively before benomyl was available.

Strawberries

Commercial strawberry production in Eastern States amounts to approximately 20,600 acres, 68 percent of which is treated with benomyl. The major diseases affecting leaves and fruit are gray mold (caused by *Botrytis cinerea*), leaf spot (caused by *Mycosphaerella fragariae*), and leaf blight (caused by *Dendrophoma obscurans*). Benomyl is highly effective against all of these diseases and generally has been 5 to 20 percent superior to captan or thiram, which are alternative fungicides (1, 16, 17, 18, 133, 134). Gray mold has the potential of complete loss of the crop when conditions are favorable and no sprays are applied. Benomyl, because of its broad spectrum of activity and longer residual activity, has performed very satisfactorily on strawberries.

Conclusions and Summary

An estimated 316,923 pounds (ai) of benomyl are used annually on 623,749 acres of tree fruits, grapes, and strawberries grown east of the Mississippi. Benomyl is relatively nonphytotoxic to fruit crops and is used extensively to control 20 or more diseases on tree and small fruits. An estimated 43 percent of tree fruits (pome and stone), 46 percent of grapes, and 67 percent of strawberries are treated with two to four applications annually.

From 5 to 25 percent increases in the level of disease control on several fruit crops have resulted since the introduction and wide usage of benomyl. Particularly important is the dramatic reduction of an estimated 25 percent in losses due to brown rot of stone fruits over conventional alternative fungicides. One of the most significant results of benomyl usage in orchards has been the reduction of inoculum levels of several important pathogens. This reduction in inoculum level has made possible a reduction of as much as 50 percent in the amount of fungicides used in many eastern orchards. Apple scab and powdery mildew incidence in many commercial orchards has been lowered to all time lows with losses 15 to 20 percent lower than alternative fungicides would provide. Grape and strawberry growers are controlling most of the diseases attacking their crops with benomyl. Pre-storage treatment of apples has substantially reduced blue mold storage decay, and the shelf-life of peaches and nectarines has been increased by several days as the result of postharvest treatment with benomyl.

No other fungicide registered to date is as efficient as benomyl against a large group of pathogens attacking fruit crops. Captan (pre-RPAR) and the EBDC fungicides (RPAR) have been widely used since the early 1950's, but they lack the high anti-sporulation action of benomyl against many fungi. The loss of benomyl for use in commercial fruit plantings in Eastern States would soon result in increased inoculum levels of several pathogens, which could lead to a 25 to 40 percent increase in cost of control.

Apple and Pear-Postharvest

Introduction

The introduction of systemic fungicide treatments has had a stabilizing effect on the entire fruit industry. Considerable progress has been made on physiological problems of fruit and the limiting factor in long-term storage was decay. Benomyl treatment completed the missing link and provided the market with decay-free apples and pears during most of the year. A return to nonsystemic fungicide disease control would greatly increase losses to apple and pear producers because it would necessitate marketing the entire crop within 3 to 4 months of harvest. Without benomyl treatment, these fruits would be available for a relatively short period; their quality would be lower and the price would be higher. Rather than exporting apples and pears as we do now, it would be necessary to import these commodities to meet domestic needs.

Many fungi attack stored pome fruits in the United States (237). Some of the more common ones include *Penicillium expansum*, *Botrytis cinerea*, *Gloeosporium perennans*, *Cladosporium herbarum*, *Glomerella cingulata*, *Botryosphaeria dothidea*, *Physalospora obtusa*, *Rhizopus* sp., and *Mucor* sp. The frequency of occurrence and severity of individual pathogens vary from season to season and among geographic regions. The most frequently encountered fungus pathogen on stored pome fruit in the United States is *P. expansum* (66, 96). Because benomyl is so effective against *P. expansum*, it has been almost universally adopted as a postharvest treatment for apples and pears.

Among the few disadvantages of benomyl are its inability to control certain minor storage-rot fungi (63, 277) and resistance to the fungicide (70, 214, 349). Preharvest applications of benomyl have been reduced or discouraged in fruit-growing areas of Western United States to delay or prevent the development of resistant strains. In other areas, where preharvest benomyl is used, it is combined with other fungicides that broaden the spectrum of control and reduce the development of resistant strains. Fortunately, those fungi most frequently encountered in fruit decay are amenable to control by benomyl.

Losses due to postharvest decay increase in proportion to the length of the storage period. Among other factors that may affect decay incidence are preharvest and postharvest handling procedures, fruit maturity, weather conditions during the growing season, fungicide applications (both preharvest and postharvest), and conditions under which the fruit is stored.

Because not all of these factors can be adequately controlled, application of an efficacious fungicide is an absolute requirement to guarantee good quality fruit over an extended storage period. Benomyl has provided better decay control than any other fungicide registered for this use.

Relative Effectiveness of Alternate Pesticides and Other Controls

The preharvest and postharvest history of fruit determine its potential susceptibility to postharvest decay. Under favorable conditions, certain fungi infect the fruit at an early stage of its development and remain latent to cause decay in storage (150). Other fungi contaminate the fruit during picking and preparation for storage (29, 31). Although a relatively large number of fungicides are listed as alternatives to benomyl (table 52), many are phytotoxic and most are considerably less effective for control of storage decay (3, 4, 24, 63, 66, 84, 167, 168, 279, 292).

Table 52.--Registration status of benomyl and alternative fungicides for use on apples and pears

Fungicide	Apples		Pears		Status		
	Pre-harvest	Post-harvest	Pre-harvest	Post-harvest	RPAR	Pre-RPAR	Not listed
Benomyl	x	x	x	x	x		
Captafol	x						1/ x
Captan	x		x			x	
Dichlone	x						x
EBDC 2/	x		x		x		
Ferbam	x		x				x
Folpet	x					x	
Glyodin	x		x				x
Ortho phenylphenol		x					x
SOPP 3/		x					x
Sulfur	x		x				x
Thiabendazole		x		x			x
Thiram	x					x	
Ziram	x		x				x

1/ Not currently listed, but toxicology data from Industrial Biotest Laboratory are under investigation.
2/ Includes all ethylene bisdithiocarbamates, that is Dithane® M-45, Dithane® M-22 plus zinc, Manzate® 200, Polyram®, zineb, and others.
3/ Sodium orthophenylphenate.

Also, exposure to residue or fumes from certain fungicides causes dermatitis or respiratory irritation among workers handling the treated fruit (168).

Other treatments suggested for decay control, chemically-treated wraps (271), gamma irradiation (175, 252), and heat (25), have serious limitations and provide only marginal decay control in commercial practice.

When all available alternatives are considered, only thiabendazole (TBZ) offers a practical means of storage decay control on apples and pears. In a recent review, Erwin (84) stated, "Thiabendazole, 2-(4-thiazol)benzimidazole (TBZ) has a similar fungitoxic spectrum to that of benomyl, but quantitatively is less effective against diseases that both will control." Research reports suggest that acceptable control of postharvest decay of apples and pears can be achieved with TBZ (200, 210, 236, 277, 278, 279).

A comparison of economic considerations of benomyl and its alternatives will be discussed in another part of this report.

Impact of Change to Alternative Programs

Several alternatives to benomyl treatment are available for control of apple and pear decay. Most are more costly and often less effective. An obvious choice is to place more emphasis on preharvest fungicides that might lower incidence of storage decay. In some cases this could reduce latent infections and surface contamination of fruit at harvest. Preharvest candidate fungicides that are not under RPAR include dichlone, glyodin, thiabendazole, and sulfur (table 52).

Although all of these materials provide a degree of protection, most are also phytotoxic on certain cultivars and some are not readily available commercially. Preharvest fungicides that appear on the RPAR or pre-RPAR list include captan, ethylenebisdithiocarbamates (EBDC), and folpet. The most effective and least phytotoxic fungicides are those in the RPAR group.

Many of these fungicides are already recommended for control of orchard diseases, particularly in areas where summer rainfall is sufficient to cause a continuing need for protective fungicides. In fruit-producing areas where summer rainfall is minimal, an increase in the number of orchard sprays would be necessary to protect the fruit during the unexpected infection periods. Protective fungicides must cover the fruit during the entire growing season to prevent latent infections which, although undetectable at harvest, decay the fruit during storage.

Intensification of preharvest spray schedules would require an estimated four to six additional fungicide applications per year to achieve minimal control of storage rot fungi. The required number of sprays in a given orchard depends on local environmental conditions, inoculum levels, and other factors that increase disease potential. Past experience suggests that even the most intensive preharvest spray programs using only protective (nonsystemic) fungicides would not achieve control comparable to a single postharvest application of a systemic fungicide.

Postharvest alternatives to benomyl include orthophenylphenol, sodium orthophenylphenate, and thiabendazole (TBZ). In western fruit-growing regions it is common practice to add benomyl or TBZ to fruit wax during the packing procedure. Most eastern fruit packers follow the practice of flooding or drenching the fruit with fungicide-charged water. A comparison of these fungicides, treatment procedures, and costs is outlined in tables 53-56.

Conclusions and Summary

Intensive preharvest spray applications would not provide control of storage decay fungi comparable to that currently achieved with postharvest benomyl or TBZ treatments. Successful control with preharvest treatments would require complete cooperation by all growers to eliminate contamination or infection of the fruit at the time it was removed from the orchard. It would further require extreme sanitary procedures during packing and processing. A single infected fruit could contaminate packing lines and serve as an inoculum source for all fruit processed subsequently. Preharvest treatment is also cost-inefficient and extremely demanding on the Nation's energy supplies. For example, the cost of each preharvest spray application may be conservatively estimated at $5 to $8 per acre (including labor, machinery, and fungicide). If 4 to 6 extra decay-control sprays are required for the crop, the total cost is $20 to $48 per acre. Average fruit yields range from 5 to 15 (or more) tons per acre and postharvest treatment of this quantity of fruit can be achieved for a total cost of $0.13 to $0.40 by adding benomyl to fruit wax during processing. Therefore, this approach should not be considered as a reasonable alternative to benomyl for control of storage decay.

Hot-water treatments, gamma irradiation, and fungicide-impregnated fruit wraps provide limited storage disease control, but do not offer an acceptable substitute for methods currently employed. Nonchemical methods have not shown sufficient merit to be seriously considered as a solution to long-term control of storage-disease fungi that infect pome fruits.

Although TBZ is somewhat less effective and more expensive for control of apple and pear decay, it is the most reasonable alternative to benomyl. Application of either TBZ or benomyl in fruit wax is a much more efficient method than drenching or flooding in

Table 53.--Fungicide cost for postharvest treatment of apples and pears

Fungicide	Percent active ingredient	Cost per unit	
		Formulated	Active ingredient
Benlate®, 50W (benomyl)	50	$9.85/lb	$19.70/lb
Mertect®, 340F (thiabendazole)	42.28	67.90/gal	159.65/gal
Stop-Mold "F"® (sodium o-phenylphenate).	1/31 2/23	6.50/gal	1/20.97/gal 2/28.26/gal

1/ Tetrahydrate, 31 pct.
2/ Anhydrous, 23 pct.

Table 54.--Dosage and quantity of fungicide used in water wash or dip

Fungicide	Dosage per 100 gallons (amount in oz)		Quantity of fruit 1/ treated per 100 gallons (U.S. tons)
	Formulated	Active ingredient	
Benlate®, 50W (benomyl)	8	4	25-30
Mertect®, 340F (thiabendazole)	16	6.67	25-30
Stop-Mold "F"® (sodium o-phenylphenate).	2/208	3/64.68 4/47.84	15-20

1/ Treatment solutions must be dumped and recharged frequently. Time varies depending on condition and quantity of fruit treated.
2/ Initial dosage. Add 16 oz (Form.) Stop-Mold "F" plus 20 gal water for each 3 U.S. tons of fruit treated.
3/ Calculation based on tetrahydrate, 31 pct.
4/ Calculation based on anhydrous, 23 pct.

Table 55.--Dosage and quantity of fungicide used in fruit wax

Fungicide	Amount (ai) per gallon wax (oz)	Quantity of fruit treated per gallon wax 1/ (U.S. tons)	
		Apples	Pears
Benlate®, 50W (benomyl)	0.1091	5-6	6-7
Mertect®, 340F (thiabendazole)	.1353	5-6	6-7
Stop-Mold "F"® (sodium o-phenylphenate).	Not used	---	---

1/ Quantities of fruit treated may vary depending on fruit size and thickness of wax applied. Figures listed are based on survey of packinghouses.

Table 56.--Current cost of preharvest fungicides registered for use on apples and pears1/

Fungicide	Formulation (percent)	Suggested dosage 2/ (per acre)	Grower cost
Benomyl3/	50 WP	8-12 oz	$9.85/lb
Captafol	4 F	3-5 gal	9.50/gal
Captan	50 WP	6-8 lb	1.16/lb
Dichlone	50 WP	2 lb	3.08/lb
EBDC (mancozeb)	80 WP	4-8 lb	1.58/lb
EBDC (Polyram®)	80 WP	4-8 lb	1.25/lb
EBDC (zineb)	78 WP	6-8 lb	1.30/lb
Ferbam	76 WP	6 lb	1.13/lb
Folpet	50 WP	6-8 lb	1.48/lb
Glyodin	30 EC	3-5 gal	7.00/gal
Sulfur	95 WP	24 lb	0.147/lb
Thiram	65 WP	4-5 lb	0.96/lb
Ziram	76 WP	6-8 lb	1.50/lb

1/ Costs may vary in different geographic areas. All fungicides are not registered for use on both apples and pears, nor are they registered for use in all parts of the United States.
2/ Dosage may vary. Follow label directions.
3/ Label specifies use only with certain other fungicides.

fungicide-charged water, and it eliminates the fungicide waste disposal problem. Sodium orthophenylphenate and related compounds do not provide protection over an extended storage period. The use of these compounds would require a change in the marketing procedure to dispose of the fruit before decay caused serious losses.

Postharvest treatment of apples and pears with benomyl applied in fruit wax is most desirable for the following reasons:

(1) More effective over a longer storage period.
(2) More efficient application.
(3) Less chemical applied in the environment.
(4) Less expensive than alternate methods.

It is recommended that benomyl be retained as a fungicide for control of storage diseases of apples and pears.

Blueberries and Raspberries

Blueberry - Mummy Berry

Mummy berry disease is caused by the fungus *Monilinia vacciniicorymbosi*. It attacks both cultivated and wild blueberries.

Losses caused by mummy berry result from: (1) Worthless, infected berries and (2) killed or blighted blossoms, blossom and leaf clusters, and young shoots. It may destroy a crop.

The mummy berries on the ground carry the fungus over the winter.

The fungus produces small cup or globe-shaped mushrooms (apothecia) from the mummy berry in the early spring about the time of new leaf growth on blueberry plants. Spores produced in the apothecia are discharged into the air and carried by wind to infect the new young leaf and flowers during periods of cool rainy weather. Unless moisture is present, the mummies do not produce spores; however, the fungus in the mummies can live for one or more years (173).

Alternative Fungicides

Use 3 pounds of ferbam (76 WP) or 3 pounds of captan (50 W) in each 100 gallons of water. Spray 200 to 300 gallons per acre at the loose bud stage (before greentip) and repeat at 7- to 14-day intervals through petalfall. Benomyl is applied at half this frequency and with one-third the gallonage of spray (41, 173, 217, 221).

Other Controls

Emphasis has been on clean cultivation in early spring to disturb the overwintering mummies. This cultivation can be a very effective control practice, because mummies that are disturbed or are covered with soil at this time either remain dormant or produce no spores. All mummies must be disturbed by cultivation because the number of spores that can be produced by a few apothecia can result in widespread disease. Cultivation between rows and raking under plants to disturb or cover all mummies should be done as early as possible in the spring and repeated after each heavy rain until after bloom; however, in some seasons when wet soil conditions prevail, it is difficult or impossible to follow this practice successfully (173).

Blueberry - Botrytis Blossom Blight

During wet springs, blueberry blossoms take on a brown, water-soaked appearance and die. Dense grayish powdery masses of Botrytis sp. spores cover such blossoms. Infections may move through the blossoms rapidly and often destroy the entire floral structure. The disease can also move from blossoms back into the fruit-producing wood. Varieties that tend to retain the floral structures over a long period are apparently more susceptible (221).

Alternative Fungicides

See "Mummy berry": (173, 182, 217, 221). Tolerant strains may become troublesome when benomyl is used exclusively in a spray schedule. To reduce the possibility of benomyl tolerance, alternate benomyl sprays with sprays of other fungicides (221).

Other Controls

Since the fungus overwinters on infected twigs, the removal of all affected parts during dormant pruning will give some control.

Conclusion and Summary

Benomyl is the most effective fungicide available for control of mummy berry (41, 173, 182, 217, 221) and when used in combination with captan, it controls Botrytis gray mold (173, 182, 304). Alternative fungicides may require twice as many applications per season and are less effective (95 to 100 pct control vs. 70 to 80 pct). The practice of clean cultivation to prevent sporulation of overwintering mummified fruit is only effective during seasons unfavorable for severe disease and it may reduce yield due to root damage from cultivation.

Raspberry - Powdery Mildew

Powdery mildew, caused by Sphaerotheca humuli, is a serious disease on foliage, new canes, and fruits of red raspberry. The fungus overwinters in the dormant buds of the stunted cane tips. Primary infections appear in mid-May from buds in which the fungus has overwintered, and by late June small lesions of the secondary infections appear on vegetative tissue and developing fruits. Through July, spread of mildew to fruit spurs and foliage continues.

Optimum conditions for spore germination and infection are 69°F to 80°F with relative humidity of 97 to 99 percent. Thus, powdery mildew is favored by warm, humid weather (221).

Alternative Fungicides

Apply dormant or delayed lime-sulfur spray at the rate of 10 gallons in 90 gallons of water. Lime-sulfur sprays may cause burning of foliage if they are applied during periods of warm weather.

Spray Karathane® 25 WD at 3/4 lb per 100 gallons of water and apply 200 gallons per acre. Concentrations above this rate may cause injury. Apply first spray when first blossoms open and at weekly intervals until all fruit is set (173, 217, 221).

Other Controls: None.

Raspberry - Anthracnose

Anthracnose (caused by Elsinoë veneta) causes circular sunken spots about 1/8 inch or more in diameter on lower canes. At first the infections are purplish and later turn gray. As the canes age, the anthracnose spots become deeper, and the margins are raised and purplish. This disease is particularly serious whenever rains continue late in the spring. Spots on the canes may be plentiful enough to retard sap flow, thus girdling the canes (221).

Alternative Fungicides

Spray with lime-sulfur at 10 gallons in 90 gallons of water applied as a delayed dormant just as the leaf buds begin to open. At least one nozzle of the sprayer should be aimed into the center of the plant. Later applications may cause leaf burning (217, 221).

Other Controls: None.

Conclusion and Summary

None of the alternative fungicides gives control equivalent to benomyl (217, 221). To approach the control of powdery mildew and anthracnose obtained with benomyl would require 2 to 4 more applications of the alternatives. Karathane® and the sulfur materials may be phytotoxic when applied during warm weather. Benomyl also gives control of other leaf spot diseases and prevents losses from Botrytis fruit rot.

Statistical Data
Blueberries

Acres affected	
East	90 pct
West	50 pct
Range of yield per acre.	1 - 1 1/2 tons/acre*
Average annual loss	450 lb/acre**
Application costs	
Benomyl @ 50-100 gal/acre	
Alternatives @ 200-300 gal/acre. Additional time, labor, and number of applications costs ($?).	

* Michigan Blueberry Growers Association. Letter dated March 16, 1978.
** Estimate based on RPAR letters submitted to EPA from growers.

Raspberries

Acres affected	
Powdery mildew	
West	80 pct*
East	60 pct
Anthracnose	
West	50 pct
East	30 pct
Average annual loss	8 pct

Price reduction if fruit has Botrytis gray mold: From $0.28 to $0.14/lb**.

* Percentage estimates based on RPAR letters submitted to EPA from growers.
** Washington and Oregon Berry Growers Association. Letter dated March 13, 1978.

Strawberries-Western

Benomyl is used to control Botrytis rot, powdery mildew, and Ramularia (Mycosphaerella) leaf spot of strawberries in California. When benomyl was first introduced for Botrytis control, its application at 0.25 to 0.5 lb/acre beginning at bloom and repeated at 10- to 14-day intervals provided excellent control of this disease.

More recently, the effectiveness of benomyl has decreased in fields where this fungicide has been applied more than several times during the season (202, 223, 224, 336). A supplemental label has been issued in California requiring that benomyl be combined with either captan or thiram for treatment of strawberries, in an effort to control the development of resistant strains of Botrytis.

In fields where significant resistance has not developed, benomyl is still an effective treatment for control of Botrytis sp. (336). In some areas, the only alternative fungicides for Botrytis sp. control, captan and thiram, may not be sufficiently effective to justify their use (202).

Although benomyl is not recommended solely for powdery mildew control, it is recognized that this fungicide does suppress powdery mildew incidental to its use for Botrytis sp. control (202, 336). The only registered alternative, sulfur, can cause serious injury to green fruit, particularly on the Tufts variety, if applied during hot weather. Thus, benomyl may be the only fungicide available for powdery mildew control during the summer. Many growers will continue to use benomyl throughout the season just for mildew control.

Benomyl is used less extensively in Oregon for Botrytis sp. control because of the short fruiting season. On about 50 percent of the acreage (3,300 acres) benomyl plus captan is applied at bloom followed by 2 or 3 captan sprays at 7- to 10-day intervals. Captan is the primary fungicide relied on for disease control.

Benomyl is the only fungicide registered for use as a plant dip for control of Ramularia leaf spot and storage molds caused by Botrytis sp. and Penicillium sp. These uses are essential for summer-planter varieties that are placed in cold storage for 7 months prior to planting and for those varieties that are susceptible to Ramularia leaf spot. Plants are also dipped in a benomyl suspension after storage to control Ramularia leaf spot in the field. Ramularia sp. could produce a 5-percent to 10-percent reduction in yield if benomyl were no longer available.

Grapes-California

"Bunch rot" of grapes is a serious midseason disease in California. The causal fungus, Botrytis cinerea, infects through the stigma of the flower at the time of bloom, but the fungus may also infect through dead flower parts adhering to the young berry. The fungus becomes latent in the developing berry until midseason, or later, when it resumes growth and rots the grapes. Although the fungus may rot individual berries and spread in a limited fashion in the absence of summer rains, spread of the disease throughout the cluster is greatly increased by late-season rainfall. Thus, the disease assumes catastrophic proportions in years with midseason rains, although bunch rot in 5 to 10 percent of the clusters of susceptible varieties is not uncommon in dry years. The disease is most serious in those varieties of white wine grapes that have tight clusters, such as Zinfandel, Barbera, White Riesling, and Chenin Blanc. Table grape varieties are intermediate in susceptibility, and bunch rot is not a significant problem on raisin grapes. The main raisin variety is Thompson Seedless, which does not form tight clusters.

In the case of broad-spectrum protective fungicides, such as captan, dicloran, and maneb, it is recommended that the first spray be applied at full-bloom to protect the flower parts from infection, followed by two additional sprays to protect the young berry from infection via adhering senescent flower parts. It is recommended that benomyl, a systemic fungicide, be applied at 1 percent bloom. If bloom continues for more than 14 days, a second spray is recommended. Benomyl can penetrate through the unopened flower to reach and protect internal flower parts from infection later when the flower is open. For this reason, timing of the benomyl to coincide with a period when most of the flowers are open is not as critical as it is for protective fungicides.

In a dry season (about 50 pct of recent years) and in vineyards without substantial worm, bird, or mechanical cracking of the berries, a single application of benomyl at early bloom can be expected to provide disease control equivalent to or slightly superior to a program of two or three sprays of captan, dicloran, maneb, or chlorothalonil. These protective fungicides are not generally effective in protecting against the initiation of latent infections when they are applied at full bloom. In seasons with significant summer rainfall or other environmental conditions that intensify disease severity (for example, sprinkler irrigations), the benefits of benomyl over a program of protective sprays are more evident. Of the alternate registered fungicides, maneb is involved in the RPAR process, captan is being reviewed for RPAR, and dicloran may cause phytotoxicity to grape vines under some conditions.

Sugarcane

Sugarcane in Hawaii is propagated from vegetative cuttings called "seed pieces" and is grown in 2-year cycles. Intensive sugarcane cropping on limited land area requires an optimum population (stand) of plant material, without gaps or poor growth. Seed-piece germination is the most important factor in establishing an optimum sugarcane population. One of the most important factors in seed-piece germination is the severity of seed-piece rot (pineapple disease) caused by the fungus *Thielaviopsis paradoxa* (*Ceratocystis paradoxa*). This fungus is common in soils used for sugarcane cultivation in Hawaii and invades the cane seed piece at the cut end. This disease seriously reduces germination of vegetative buds and, therefore, stand population can be severely limited and cane growth impaired. This disease is not significant in sugarcane cultivation in the Gulf States.

Germination in Hawaii is greatly improved by treatment of the seed pieces with benomyl before planting to prevent invasion by *Thielaviopsis*. Benomyl has a nonfood registration for sugarcane seed-piece treatment in Hawaii to prevent seed-piece decay. It is the only registered fungicide for sugarcane seed-piece treatment. Benomyl is applied as a suspension in cold or in hot water; 1/8 lb benomyl per 100 gallons of water at 50°C and 1/4 lb benomyl per 100 gallons cold water. Although both treatments are effective in controlling seed-piece rot, the heated solution is preferred because a lower concentration of the fungicide will suffice, and also because the heat stimulates bud germination and helps control other diseases, such as chlorotic streak (virus), ratoon stunting (bacterial), and smut (fungus). Benomyl has no effect upon these latter diseases; conversely, the hot-water treatment does not protect the seed piece from infection by *Thielaviopsis* sp.

Experiments conducted over the past 5 years and summarized by the Hawaiian Sugar Planters Association reveal that the treatment of seed pieces with benomyl before planting approximately doubles the level of seed-piece germination (122). Cancellation of the benomyl registration would have a substantial impact upon the Hawaiian sugar industry because no other fungicide is registered for seed-piece treatment. To maintain economic stands of sugarcane, it would be necessary to double the seed-piece planting rate to offset the reduction in germination of seed pieces brought about by seed-piece decay in the absence of an effective fungicide. A doubling of the seed-piece production would require the diversion of approximately 8,200 acres from the production of sugar and molasses.

Wheat

Cercosporella Foot Rot (Eye Spot or Strawbreaker)

Cercosporella herpotrichoides produces an eye-spot lesion on the outer leaf sheath of the wheat plant, which penetrates into the culm (stem) and weakens the stem. This results in lodging, or the wheat heads may fill poorly or not at all, or both may occur. Inoculum for infection is produced on infected stubble from the previous wheat crop. Under cool, wet conditions spores are produced that are splashed by rain onto the base of the wheat plant where infection occurs. The disease can be severe in years when fall wheat is planted early (prior to September 20th in the Pacific Northwest) and there is a mild winter with a cool, wet spring (350).

Alternative Fungicides: None.

Other Controls

Delaying date of fall seeding for winter wheat, rotation to nonsusceptible crops for 2 to 3 years, or planting spring wheat on infested land. All of the above practices have some serious disadvantages:

(1) Delayed fall seeding results in minimal ground cover during the winter months, and there is considerable wind and water erosion, which causes loss of topsoil and pollution problems (308).

(2) Delayed fall seeding results in reduced yields (10 to 20 pct) (46, 244).

(3) Rotation to other crops is not economically practical on over 70 percent of the wheat acreage in the Pacific Northwest.

(4) Spring wheat yields are more than 30 percent less than winter wheat.

Environmental Effects of Alternative Controls

Delayed fall seeding for control of Cercosporella foot rot increases soil erosion problems from wind and water. This results in air and water pollution, loss of topsoil, siltation of streams, and loss of aquatic habitat for fish and other stream and lake life (308).

Conclusions and Summary

Cercosporella foot rot is a limiting factor in the production of winter wheat on approximately 700,000 acres of the most productive wheat land in Washington, Oregon, and Idaho. At present, benomyl is the only pesticide "available" that gives effective control of foot rot (45, 46, 87, 244, 245, 246, 323). A single 0.5 lb ai/acre application can increase yield by 30 percent or more. Commercial applications made in Oregon during 1976 have an average yield increase of 7.0 bu/acre for 26 fields (approx. 10,000 acres) with a range of 7.0-27.0 bu/acre (245). Another advantage is that wheat growers can seed earlier in the fall to control wind and water erosion problems and increase yields.

Statistical Data

Wheat-<u>Cercosporella</u> sp.	
Acres affected -- (Oreg., Wash., and Idaho)	700,000*
Average yield per acre	56 bu/acre**
Range of yield per acre.	38-120 bu/acre**
Average annual yield loss (foot rot).	7 bu/acre***
Application cost	
Benlate® @ 1.0 lb/acre	$10.25****
Air (75 pct)†	$2.75-$3.00
Ground (25 pct)†	$1.25

Reduction in yield due to delayed seeding: 10 to 20 percent.

Loss due to erosion from delayed seeding.

Reductions in yield if spring wheat is planted: 20 to 50 percent.

† Note: If applied at time of herbicide application, these costs can be eliminated.

* Estimates made by plant pathologists in Oregon, Washington, and Idaho.

** Estimates made by agronomists in Oregon, Washington, and Idaho.

*** Results of 1976 commercial applications (245).

**** Pendleton Grain Growers (PGG), Pendleton, Oregon.

Mushrooms

Benomyl is one of only two fungicides registered for use on mushrooms to control certain pathogenic fungi that can reduce both the quality and quantity of the crop. The other registered fungicide is zineb, which is also under RPAR review.

Alternatives to Benomyl

Efficacy of Zineb for Control of Diseases Affecting Commercial Mushrooms

Zineb was first introduced in 1950 to control diseases of mushrooms (309). The worst disease was, and still is, Verticillium spot or dry bubble (caused by Verticillium fungicola (malthousei)) (95), for which zineb for many years was the only reliable fungicide for control. When benomyl became registered for Verticillium sp., it was even more effective than zineb; however, benomyl-tolerant strains of Verticillium developed in some commercial mushroom farms, thereby reducing the reliability of benomyl treatments for control of Verticillium sp. (155, 362). In mushroom-producing areas where tolerance has not occurred, however, benomyl provides excellent control of Verticillium spot/dry bubble (127).

Zineb is also an effective control for other diseases of the commercial mushroom, such as wet bubble (caused by Mycogone perniciosa) and "mildew" diseases that occasionally cause significant reduction in yields. Mildews are caused by Dactylium dendroides and Trichoderma sp. (364). About 3.7 percent of the U.S. crop is infected with wet bubble and about 0.6 percent by "mildew" (caused by Dactylium) (95).

Although benomyl is not specifically registered for use on mushrooms to control wet bubble and mildew, it nevertheless is a very effective control for these diseases (44, 273, 361). Furthermore, tolerance to benomyl has not been demonstrated in Mycogone, Dactylium, or Trichoderma (44, 361).

After nearly 28 years of use, zineb is still the most efficient chemical for control of Verticillium spot/dry bubble and provides good, but not always outstanding, control of the other spot diseases of mushrooms (309, 364). Inasmuch as zineb is the only alternative to benomyl, and is also under RPAR review, however, it is imperative that benomyl be retained for control of certain mushroom diseases.

Loss of either zineb or benomyl fungicide, or of both, to the mushroom industry would definitely result in significant yield reductions in mushroom production.

Efficacy of Other Controls (309)

Malathion and methoxychlor have been cited as alternatives to benomyl and zineb, presumably on the basis that controlling fly populations will control dissemination of fungal spores. Malathion is presently used at many farms in conjunction with benomyl and zineb as part of the total pest and pathogen control program; however, since flies are not the only mode of dissemination of fungal spores, insecticides cannot be regarded as effective alternatives to fungicides.

Manipulation of temperature and humidity is also impractical for control of mushroom diseases because any changes in environmental factors that negatively affect mushroom pathogens and disease development also adversely affect mushroom yield and quality.

Cost of Application

At the present time about 11,034 pounds of benomyl (ai) are used on about 50 percent of the mushroom crop grown in the United States (255, 361). Recent information on the cost of benomyl applications comes from studies in Ontario, where it was found that labor cost for all spraying (including benomyl, zineb, and insecticides) was 2.3¢/ft^2 (32). This amounts to only 4 percent of direct production wage costs (excluding the administration, sales, and distribution labor), and only 2 percent of total costs in Ontario.

Labor costs associated with the application of benomyl account for only a small portion of the 2.3¢/ft^2 total application costs reported in Ontario. Butler County Mushroom Farm, Worthington, Pennsylvania, reports labor costs for benomyl applications of only 0.12¢/ft^2 (44). The cost of benomyl fungicide based on current market prices is calculated at about 0.10¢/ ft^2 when the chemical is used at the label rate of one lb of 50 percent wettable powder per 100 gallons of water and applied to beds at the rate of 3 lb/ft^2. At an expected 4.3 percent increase in productivity from benomyl, the sales value of the increased volume of mushrooms sent to the market amounts to 11.6¢/ft^2 for fresh mushrooms and 9.4¢/ft^2 for processed mushrooms (195). The benefit to the grower is obvious.

Labor costs for applications of zineb dust (0.009¢/ft^2) are less than for benomyl (44); however, zineb is applied to mushroom beds between 10 and 18 times per crop compared with an average of only 3 benomyl treatments per crop. Fungicide costs per application are also down: 0.012¢/ft^2 for zineb vs. 0.10¢/ft^2 for benomyl (44).

When one considers that zineb is applied 3 to 6 times as often as benomyl per crop, the labor and material cost differences between the two fungicides is considerably diminished.

Current mushroom production and grower revenues are given in table 57. To achieve this volume of production requires the services of approximately 12,000 workers. A breakdown of employment in the mushroom industry in 1977 in the United States is given in table 58.

Table 57.--Current mushroom production and grower revenues

Grower category	Production volume (million lb/yr)	Average price (cents/lb)	Sales volume ($ millions/yr)
Domestic-fresh	151	83	125
Domestic-processing	196	67	131
Total	347		256

Source: (314).

Table 58.--Employment in the mushroom industry in the United States, 1977

Pickers	4,000
Other grower employees (administrative, sales, maintenance, and so forth).	1,000
Distribution, delivery, and wholesale personnel	1,000
Mushroom cannery workers	1,200
Other processing workers (soups, marinate, and so forth)	800
Associated workers (compost, fertilizer, pesticide, and other suppliers, construction workers, service organization workers, and so forth).	4,000
Total	12,000

Sources: General estimates by Tim King, Executive Director, American Mushroom Institute, Cannery worker estimates from International Trade Commission Data.

Efficacy of Benomyl Against Mycogone and Mildew

To demonstrate the effectiveness of benomyl against *Mycogone* sp., a series of experiments was undertaken using artificial inoculation. Each treatment was replicated in five trays of a 5-ft^2 surface area containing approximately 6-inch depths of compost. After spawn growth was completed, the trays were cased with spent compost soil and sprayed with benomyl or *Mycogone* sp. inoculum, or with both. The *Mycogone* sp. inoculum was prepared by macerating an agar plate culture, incorporating both spores and mycelium, with 5 oz of sand. The macerate-sand mixture from a single plate was sufficient to inoculate 25 ft^2 of bed surface. The results are presented in table 59.

To demonstrate the efficacy of benomyl against "mildew," an experiment similar to that previously described for *Mycogone* sp. was carried out using an unclassified "mildew" as inoculum (44). The results are presented in table 60. In this test (using the same base compost as that of the *Mycogone* sp. experiment) the yield was not as severely depressed as with *Mycogone* sp., but the influence of benomyl is nevertheless notable.

The effects of these artificial inoculations of *Mycogone* and mildew on mushroom yields have been averaged in tables 61 and 62, so that the data represent a wide spectrum of pathogen attack conditions.

According to these experiments, an epidemic of *Mycogone* or mildew in the absence of benomyl could reduce mushroom yields significantly. These experimental results are supported by the past history of mushroom culture. A 1978 study (249) showed that typical mushroom production rates before the introduction of modern fungicides were 1.5 lb/ft^2, only half of the approximately 3 lb/ft^2 obtained with modern fungicides, fertilizers, and control environmental factors.

Table 59.--Effect of benomyl on artificially inoculated *Mycogone* 1/

Treatment 1/	Yield lb/ft^2			Size lb/100 mushrooms			Bubble/tray			Percent spot		
	Exp. #1	Exp. #2	Exp. #3	Exp. #1	Exp. #2	Exp. #3	Exp. #1	Exp. #2	Exp. #3	Exp. #1	Exp. #2	Exp. #3
Mycogone, no benomyl	0.11	2.48	0.64	2.81	2.32	2.70	134.3	62.0	903.4	0	1.35	3.54
Mycogone, benomyl at 1 lb/100 gal.	.73	2.66	2.41	2.42	2.43	2.43	6.54	6.4	33.4	1.17	.15	0
Mycogone, benomyl at 2 lb/100 gal.	2.86	2.72	2.62	2.19	2.62	2.69	60.4	.2	9.0	0	0	0

1/ Benomyl applied at casing, 1/2 pt/5-ft^2 tray. *Mycogone perniciosa* inoculated immediately after casing for experiments 1 and 2, and 10 days later for experiment 3.

Table 60.--Effect of benomyl on artificially inoculated mildew

Treatment 1/	Yield (lb/ft^2)	Size (lb/100 mushrooms)
Mildew, no benomyl.	2.26	2.62
Mildew, 1 lb/100 gal benomyl.	3.09	2.10
Mildew, 2 lb/100 gal benomyl.	3.12	2.18

1/ Mildew inoculum and benomyl (1/2 pt/5 ft^2) applied immediately after casing.

Table 61.--Artificially inoculated Mycogone sp. yield averages

Treatment	Average yield (lb/ft^2)	Percent increase
Mycogone, no benomyl.	1.08	----
Mycogone, 1 lb/ 100 gal benomyl.	1.93	78.7
Mycogone, 2 lb/ 100 gal benomyl.	2.73	152.7

Table 62.--Artificially inoculated mildew yield averages

Treatment	Average yield (lb/ft^2)	Percent increase
Mildew, no benomyl.	2.26	----
Mildew, 1 lb/ 100 gal benomyl.	3.09	36.7
Mildew, 2 lb/ 100 gal benomyl.	3.12	38.1

Butler County Mushroom Farm efficacy experiments with zineb contained check tests where no fungicides or artificial inoculations were used (44). Yields averaged 2.49 lb/ft^2. The 1 lb/ft^2 improvement over 1948 levels of 1.5 lb/ft^2 is assumed to be due purely to improvement in environmental factors. Other Butler County Mushroom Farm experiments using zineb gave only an average of 2.87 lb/ft^2--an increase attributable to zineb of 0.38 lb/ft^2. Finally, the difference between 2.87 lb/ft^2 and the 1977 standard of 3.0 lb/ft^2--0.13 lb/ft^2--can be attributed to benomyl.

An alternative method of calculating the relative benefits of zineb and benomyl is to assume that zineb is effective solely against Verticillium and benomyl is effective against Mycogone and Dactylium. This is, of course, not the case on those farms where benomyl-tolerant strains of Verticillium have not yet developed. The normal losses due to these three diseases are 11.3 percent for Verticillium, 3.7 percent for Mycogone, and 0.6 percent for Dactylium. Thus, zineb would be potentially almost three times as effective overall as benomyl. This result is similar to the estimates above.

Dutch Elm Disease and Lignasan® BLP

Many compounds have claimed to control Dutch elm disease (DED), but only Lignasan® BLP (an MBC phosphate compound) and Arbotect® (TBZ) (a potential alternative fungicide) are recognized to have demonstrated merit and have been registered as aids in DED therapy. Only Arbotect® is a valid alternative to Lignasan® BLP as a preventive treatment. Large-scale comparative testing at label dosages should be done to determine whether Arbotect® is an adequate replacement for Lignasan® BLP.

Other types of control, namely prompt sanitation (prompt removal of DED trees) and pruning of symptomatic limbs, are not valid alternatives to Lignasan® BLP for DED control. Tree removal, although the most efficacious DED control, is unique in that most incorporated areas have requirements for DED tree removal, because of possible human injury and property damage.

The real question is whether removal will be soon enough to prevent DED spread to nearby elms. Pruning can be a reasonably successful therapeutic measure if it is applied rigorously to trees with less than 5 percent crown symptoms (123); however, to find trees in this early stage of disease development, frequent surveys must be made by well-trained personnel. Thus, pruning is not practical for widespread use. When pruning is coupled with Lignasan® BLP injection, however, trees are saved that have a greater percentage of symptoms (110). The exclusive advantage of pruning or of fungicide injection, or of both, is that they have the potential of saving a tree that already is infected with DED. On the other hand, prompt sanitation and methoxychlor spraying, which are essentials in a good municipal DED control program, are preventive measures that will not save an elm that is already infected. Optimally, all DED control measures should be considered for use in an integrated program in an incorporated area. Thus, they should not be considered as alternatives for Lignasan® BLP.

Lignasan® BLP and TBZ are generally regarded as roughly equivalent in their capacity to control DED when used at near optimal dosage. The only published work actually comparing the two materials (but not at labeled dosages) seems to support these opinions (207). The labeled dosage for Lignasan® BLP is of questionable adequacy for control of DED (260). Some availability problems for TBZ during 1977 were reported. The difference in cost of treatment should be the main consideration in substituting TBZ for Lignasan® BLP, since they are both applied with the same equipment and no differential problems exist in their application. At the labeled dosages, TBZ costs more per tree. The cost of either Lignasan® BLP or TBZ injection appears to be a major factor in the lack of widespread use of these fungicides by municipalities for DED control.

The environmental effects of TBZ, like Lignasan® BLP, appear to be virtually nil owing to the small amount that is applied through a closed system directly to the interior of the tree being treated. TBZ is rapidly hydrolyzed in water in ultraviolet light (a component of sunlight) and is very tightly bound to soil particles and deactivated in the soil environment. The LSD for TBZ for rats is about 4000 mg/kg and it has very low toxicity to certain fish and birds. It is said to have a 5-fold safety factor for elm phytotoxicity (156).

The economic impact due to loss of the use of Lignasan® BLP for DED control cannot be adequately assessed for lack of sufficient knowledge concerning the relative effectiveness of TBZ and Lignasan® BLP. If TBZ cannot equal the therapy and prophylaxis provided by Lignasan® BLP, then a certain loss will occur. It is known that the greatest economic loss that occurs when a homeowner loses an elm is the decrease in property value (48). One effect that is commonly observed when an area loses many of its elms in a short period of time is that many of the affluent homeowners move to other areas. Also, loss of the large elms from parks can change the character of parks and the values that people find in them.

Prompt sanitation and methoxychlor spraying are used consistently in municipalities with good DED control programs. Pruning, fungicide injection, or both, are useful adjuncts to such programs but are not substitutes for them. In a good integrated DED control program, fungicide injection or pruning, or both, offer the only hope for a tree infected with DED. If that tree is highly valued (that is, it is in a strategic position in a park or in the landscape of a home), then the probability of saving the tree may be worth the cost if the disease has not already progressed too far.

Prevention of DED by fungicide injection also must be evaluated on the basis of value, location, and disease incidence in the vicinity. If a high-value tree is in a strategic location and disease incidence is high, then the added protection from injection (in addition to methoxychlor spraying) may be worthwhile.

It is imperative that Lignasan® BLP be retained as a registered fungicide, at least until a definitive study comparing the efficacies of Lignasan® BLP and Arbotect® can be made.

Mangoes-Florida

Benomyl is used to control anthracnose on approximately 800 of the 1,600 acres of mangoes grown in Florida (186). Untreated groves result in 80 to 95 percent infection (59). Copper is the only registered alternative.

Copper is less effective (184) and it gradually builds up in the soil to levels that are toxic to the trees (88).

Seven applications of benomyl give better disease control than the 40 applications of copper used prior to benomyl registration (187).

In 1975, 325,000 bushels of mangoes were produced in Florida at an average bushel price of $8.75 (310).

Avocados-Florida

Benomyl is used to control three fungal diseases on approximately 310 acres of the 6,200 acres of avocados grown in Florida (186). Copper is the only registered alternative. The acreage treated with benomyl represents the Hale variety, which is extremely thin-skinned and cannot tolerate copper applications (187). The loss of benomyl would eliminate the production of this variety in Florida (187). Copper causes a skin roughness on all varieties; this does not lower the grade, but consumers will choose fruit without this blemish over blemished fruit (187).

During the 1975-76 season, a record 1,160,000 bushels of avocados were produced at a price of $10.00 a bushel (306).

Pineapple

Use of Benomyl to Control Seed-Piece Decay

Of the 43,000 acres of pineapple in Hawaii, about 10,000 acres are replanted each year. The fungus *Thielaviopsis paradoxa* (*Ceratocystis paradoxa*) occurs commonly in soils used for the culture of pineapple and may attack the stem, leaves, and fruit of the plant. This fungus may cause heavy crop losses by infecting and decaying the planting material (seed piece) in its early stages of development. The crown is the usual planting material in Hawaii today and is collected at the time the fruit is harvested. If the crown is planted without fungicide protection against *Thielaviopsis*, the entire planting can be lost. Treatment by dipping the crowns before planting in a suspension of 0.31 to 0.62 pound benomyl per 100 gallons of water makes the crowns virtually resistant to attack by *Thielaviopsis*. In addition, treated crowns usually form a more complete root system, and consequently develop more uniformly than untreated crowns.

Captan and captafol (Difolatan®) are also registered for control of Thielaviopsis rot on planting material. Captan is not dependable for control of this disease. Captafol causes allergic reactions in some workers and therefore is not suitable in a dip treatment for commercial planting material (117). A series of seven tests conducted by the Maui Pineapple Company showed that losses averaged 4.93 percent in planting material treated with captan, whereas the losses in benomyl-treated material averaged only 0.69 percent. This difference of 4.24 percent would result in 3 tons less fruit per cycle (plant crop + ratoon crop) per acre if captan were substituted for benomyl.

Use of Benomyl to Control Decay of Fresh Fruit During Marketing

Detached pineapple fruits are highly susceptible to infection and decay by Thielaviopsis paradoxa. The disease is promoted by warm and moist conditions, and although entry is usually through the stem end or through surface abrasions, these conditions are not essential for invasion if fruit is held under conditions ideal for the development of the fungus (272). Dipping the fruit after harvest in a suspension of 0.5 to 2.0 pounds benomyl per 100 gallons of water will assure protection against decay caused by Thielaviopsis paradoxa over the complete range of spore loads experienced in Hawaii (117). Benomyl may also be successfully incorporated in a wax treatment, which controls moisture loss during shipment. The control of postharvest disease has led to a major increase in fresh pineapple shipments from Hawaii to the United States mainland during the past 10 years.

Although Thielaviopsis sp. may be significantly reduced by shipping the fruit under refrigeration, the disease can only be controlled during exposure to ambient temperatures by postharvest treatment with fungicides. Sodium o-phenylphenate has been used successfully under conditions of low spore loads; however, it is not recommended when the fruit is exposed to heavy spore loads or environmental conditions that lead to a high disease pressure. Captan will reduce Thielaviopsis sp. infection in fresh fruit when it is applied at 10 times the rate of benomyl, but the performance is variable and undependable, particularly under conditions of high spore loads. Approximately 69,000 tons of pineapple were shipped fresh from Hawaii in 1976. One third of this fruit required treatment with benomyl to prevent losses due to Thielaviopsis rot. Under these conditions, fruit treated with sodium o-phenylphenate has an average 7 percent higher decay loss than benomyl-treated fruit. This would result in a minimum loss of 1,680 tons with a value of over $550,000. This is a direct loss of individual fruit; however, the impact of having diseased fruit scattered throughout shipments could result in a far greater economic loss.

Applicator and Farm Worker Exposure

Because of the questions raised concerning the problem of applicator exposure to benomyl and the Environmental Protection Agency's presumption that the risk index for teratogenicity has been exceeded, the assessment team members have included this section on applicator exposure to help answer potential questions concerning applicator risk.

Benomyl (methyl 1-(butylcarbam=oyl)-2-benzimidazolecarbamate) is commonly sold as Benlate®, a 50 percent wettable powder. It is packaged in 2-pound and 5-pound double-walled foil-lined paper bags. It is sold as Tersan® 1991 for turf application only, and is repackaged and sold as Greenlight Systemic Fungicide for homeowner use in the Southern States. MBC is also sold as Lignasan® BLP, a 0.7-percent solution of methyl 2-benzimidazolecarbamate phosphate and used as an injection treatment for Dutch elm disease. Approximately 3 million pounds of benomyl are sold in the United States annually.

Rice and Soybeans

During 1977, 1.06 million pounds of benomyl were used on rice and soybeans; this accounts for slightly more than one-third of the total benomyl use in the United States. Approximately 20 percent of this material was applied in Texas by 38 aerial applicators. Ground support personnel include an average of 3.8 flaggers and 2.5 mixers and loaders per applicator. Data for the U.S. totals were extrapolated from Texas data, and these should be representative of all aerial applicators. Applicators in Texas, Louisiana, Arkansas, Mississippi, and Missouri spray both rice and soybeans, but for the purpose of this report each crop will be treated on an individual basis.

Rice

Approximately 300,000 pounds of benomyl were applied on rice in the

United States in 1977. This material was applied by approximately 80 aerial applicators. Ground support personnel included 300 flaggers and 200 mixers and loaders. The average applicator applies some benomyl during approximately 30 working days and averages 6 working hours a day for a total of 180 working hours during the year. During working hours, pilots actually spend only 3 working hours per day applying pesticides. The remainder of the time is spent in transit and reloading. During the period that benomyl is being applied, other pesticides are also being applied, and it is impossible to determine exactly how much time is spent in spraying benomyl. Agricultural planes will spray a 42-foot swath at an average ground speed of 70 mi/h for an average of 6 acres per minute. If the total treated acreage is 422,000 acres, it would take 80 aerial applicators 30 working hours to treat this acreage twice. Each applicator normally has 2 or 3 flaggers working during his flying operations. Producers will often flag their own fields and exposure will be limited to that material being applied to their crop.

Most flaggers are normally equipped with a respirator, but they usually resist wearing any other protective equipment; however, pesticide exposure is not normally a hazard for flaggers because the flaggers set up the pilots for their passes and then move upwind before the airplanes reach them. The flaggers always move into the wind and should not be subjected to pesticide drift. Pilots also are not subject to drift as most are in enclosed air-conditioned cockpits and make each succeeding pass upwind. Mixers and loaders are most susceptible to exposure, as they come in direct contact with the pesticide being applied. Generally, mixers and loaders are well equipped with respirators and protective clothing inasmuch as they are accustomed to handling materials, such as parathion, that are highly toxic. Even though benomyl is relatively non-toxic, these ground support people are accustomed to wearing protective equipment and continue to wear it even when mixing benomyl.

Benomyl is used by commercial applicators as Benlate®, a 50 percent wettable powder. Most benomyl used is in 5-pound multi-walled paper bags with a foil inner lining. The benomyl is opened and dumped into a pre-mix or slurry tank. Once a slurry is obtained, it is then pumped into a mixing or holding tank. The pre-mix or slurry tank will vary from an open-top 55-gallon drum to an enclosed stainless steel tank. The potential applicator exposure in the application of benomyl involves only the mixers and loaders, and traditionally these people are well equipped with all of the necessary safety equipment.

At an average ground speed of 70 mi/h and a 42-foot swath width, a pilot will spray approximately 6 acres per minute (Note: 70 mi/h is the slowest they fly; most applicators are at an airspeed of >90 mi/h). If the efficiency of application and number of persons exposed to benomyl are considered, aerial application is the most effective and safest method of application.

All rice is harvested more than 30 days after the last application of benomyl, and since all harvesting, handling, and storage of rice is mechanical, there should be no exposure during the harvesting operations.

Soybeans

Approximately 760,000 pounds of benomyl were applied on soybeans in the United States in 1977. This material was applied on 1.5 million acres by approximately 200 aerial applicators. Ground support personnel included 700 flaggers and 500 mixers. The average applicator applies some benomyl during approximately 30 working days for a total of 180 working hours during the year. During working hours, pilots actually spend only 3 working hours per day applying pesticides. On a full day, the average pilot will treat slightly over 1,000 acres. The remainder of the time is spent in transit and reloading. During the time of year that benomyl is being applied, other pesticides are also being applied, and it is impossible to determine exactly how much time is spent in applying benomyl. Agricultural planes will spray an average of 6 acres per minute. It the total treated acres is 1.5 million acres, it would take 200 aerial applicators 41.6 working hours to treat this acreage twice. Each applicator normally has 2 or 3 flaggers working during his flying operations. Producers will often flag their own fields and exposure is limited to that material being applied to their crop.

Most flaggers are normally equipped with a respirator, but they usually resist wearing any other protective equipment; however, pesticide exposure is not normally a hazard for flaggers because the flaggers set up the pilots for their passes and then move upwind before the airplanes reach them. The flaggers always move into the wind and are not subjected to pesticide drift. Pilots also are not subjected to drift as most are in enclosed air-conditioned cockpits and make each succeeding pass upwind. Mixers and loaders are most susceptible to exposure, as they come in direct contact with the pesticide being applied. Generally, mixers and loaders are well equipped with respirators and protective clothing inasmuch as they are used to handling materials, such as parathion, that are highly toxic.

Benomyl is used by commercial applicators as Benlate®, a 50 percent wettable powder. Most benomyl used is in 5-pound multi-walled paper bags with a foil inner lining. The benomyl is opened and dumped into a pre-mix or slurry tank. Once a slurry is obtained, it is then pumped into a mixing or holding tank. The pre-mix or slurry tank will vary from an open-top 55-gallon drum to an enclosed stainless steel tank. The potential applicator exposure in the application of benomyl involves only the mixers and loaders, and traditionally these people are well equipped with all of the necessary safety equipment.

At an average ground speed of 70 mi/h and a 42-foot swath width, a pilot will spray approximately 6 acres per minute. If the efficiency of application and number of persons exposed to benomyl are considered, aerial application is the most effective and safest method of application.

All soybeans are harvested more than 30 days after the last application of benomyl, and since all harvesting, handling, and storage of soybeans is mechanical, there should be no exposure during the harvesting operations.

Fruit Crops

Stone Fruits

The use of benomyl on stone fruits accounts for approximately 10 percent of the total use in the United States; of this amount, California uses one-third. During 1977, California peach growers used 100,000 pounds of benomyl. Because of the unique pesticide laws in California, total use of benomyl can be fairly accurately assigned to commercial and noncommercial applicators. Commercial applicators applied 40 percent of the benomyl used on stone fruits in California. This figure can be broken down further into aerial applicators who applied 30 percent and commercial ground applicators who applied 10 percent. A total of 40 aerial applicators were involved, spraying benomyl an average of 40 days a year. The aerial applicator worked 6 hours a day, with less than 50 percent of that time involved with actual spraying operations. Each applicator required ground support of 2 flaggers and 2.5 mixers and loaders. Operation of mixing and handling as well as protective equipment is essentially the same as that described in the rice and soybean section.

Commercial ground applicators spray 10 percent of the California peach orchards. Twenty commercial applicators spray peach orchards 40 days a year and work 7 hours per day. Of the 7 hours per day worked, only half of the time involves actual spraying; the remainder of the time is used in mixing and loading operations. Commercial operators use high-volume air-blast sprayers, which travel at the rate of 3 miles per hour. An average applicator will spray from 30 to 40 acres of trees per day. About 30 gallons of water and 1/2 pound of benomyl are used per acre.

One thousand private applicators spray 60 percent of the total benomyl applied to California orchards. Each grower sprays benomyl an average of 6 days a year and works an average of 8 hours per day on his spraying operations. Again, only 50 percent of this time involves actual spraying operations. Private applicators use essentially the same type of equipment as commercial applicators. Young orchards are sprayed with a hand-held spray gun rather than an air-blast sprayer. The hand-held gun is used to conserve material. A private applicator will spray an average of about 30 acres per day.

Protective equipment is worn by all applicators because benomyl is generally applied in a tank mix with highly toxic insecticides. Equipment worn by applicators includes rain wear (jacket and pants) with a full hood, goggles, respirator, rubber boots, and gloves. Benomyl may be sprayed up to harvest for aid in certain postharvest diseases.

Grapes

Approximately 50 percent of the benomyl used on grapes in the United States is used in California. Sixty percent of all grapes grown in California are sprayed by 20 private applicators (growers). Each grower sprays benomyl an average of 15 days per year and is actually involved in spraying operations an average of 4 hours per day. Commercial ground applicators spray 38 percent of the grapes. Commercial applicators number 30 and are involved in benomyl application 20 days per year an average of 3 hours of actual spraying time per day. Both commercial and noncommercial growers use air-blast sprayers and most applicators use the same type of protective equipment as described under peaches. Four aerial applicators spray 2 percent of the benomyl used on California grapes. Each applicator sprays benomyl an average of 5 days a year and is involved in actual spray applications 3 hours per day. Generally, there are 4 flaggers and 6 mixers and loaders who serve as ground support personnel.

Strawberries, Blueberries, and Raspberries

Twenty-five percent of the benomyl applied to strawberries, blueberries, and raspberries is applied by 15 aerial applicators. Each applicator sprays benomyl an average of 22 days a year and works 2.5 hours a day. Ground support personnel include 20 mixers and loaders, and flagmen when necessary; however, with most blueberries and raspberries the fields are preflagged. Thirteen commercial applicators treat 50 percent of the strawberry acreage; these applicators apply benomyl 196 days a year and spray about 3 hours a day. Fifteen custom applicators treat approximately 20 percent of the blueberry and raspberry acreage. Blueberries and raspberries are sprayed only 1 to 4 times a year.

Sixty private applicators (growers) treat the remaining 26 percent of the strawberry acreage and 250 private applicators treat the blueberry and raspberry acreage.

Fruit Crops - East of the Mississippi

Benomyl is applied to fruit crops almost exclusively by private applicators (farm workers). There are approximately 13,000 farms on which tree fruits are grown and 4,500 commercial vineyards in the Eastern States. The size of farms and vineyards and the number of applicators vary considerably, but an estimated 35,000 workers are directly involved with pesticide applications. Benomyl is used on a minimum of 60 percent of the farms; thus, 21,000 private applicators apply benomyl to commercial fruit crops. There are a few aerial applicators (10 to 20) who would be classified as custom or commercial applicators. Benomyl is not used commonly by home fruit growers because it is not readily available in small packages.

Benomyl is seldom used alone on fruit crops. Handling procedures for benomyl are similar to other pesticides, which involve adding the contents of the package directly to the sprayer tank or to a filler unit (pre-mixer). Commercial fruit growers customarily use protective clothing, such as coveralls, rubber gloves, and a hat. When using organic phosphates or filling the tank, the operator wears a canister-type respirator approved for pesticide use. Respirators are not always worn during the spraying operation unless adverse wind conditions or high concentrate mixtures are involved. A general summary of benomyl use on fruit crops east of the Mississippi is given in table 63.

Fruit - Postharvest

Benomyl is applied postharvest to fruits as a spray, drench, or wax additive. Benomyl is suspended in wax at the rate of 0.1091 oz (ai) to 0.1353 oz (ai) per gallon of wax. One gallon of wax is then used to treat 5 to 6 tons of apples or 6 to 7 tons of pears. Only one treatment is used before the fruit is packed. The applicator applies the wax at the rate of 0.6 to 1.0 gal/hour. One person is usually in charge of the wax applicator on the packing line. He or she is responsible for monitoring the applicator and adding fungicide to the wax. Protective clothing worn by the person in charge includes impermeable overgarment, mask, and gloves.

When benomyl is used as a line spray or drench, it is used at the rate of 4 oz ai/100 gal of water per 25 to 30 tons of fruit. The mixture is applied as an overline spray from a pressurized tank or as a drench from a dump tank. One postharvest application is used. Approximately 5 to 7 tons of fruit are treated per hour. One person is usually in charge of monitoring the equipment and mixing the fungicide. This person is usually protected by an impermeable overgarment, spray mask, and rubber gloves.

Table 63.--Benlate® 50W usage on fruit crops east of the Mississippi

Crop	Amount (oz per 100 gal)	Total (ai) per acre	Number of applications	Method	Application equipment (ground)	Season	Minutes per acre (ground application)
Apples	1.0-1.5	3.0-4.0	1-12	Ground and air.	Airblast	Spring and summer.	7-8
Blueberries	---	8.0	4	Ground	High pressure	Spring	10
Brambles	---	6.0	2-5	Ground	High pressure	Spring	10
Grapes	---	8.0-12.0	1-5	Ground	Airblast and high pressure.	Spring and summer.	10
Pears	2.0-3.0	4.0-10.0	2-7	Ground and air.	Airblast	Spring and summer.	7-8
Stone fruits.	---	6.0-16.0	2-7	Ground and air.	Airblast	Spring and summer.	9-10
Strawberries.	---	8.0	1	Ground	High pressure boom.	Spring	10
Postharvest (fruit).		4.0	2-5	Dip	Dip or spray	Autumn	---

Citrus - Preharvest: Florida

Benomyl is applied preharvest to citrus in Florida at the rate of 0.5 lb/500 gallons of water. Generally, 1,000 gallons of spray mixture are applied per acre with an air-blast sprayer. Owing to the extremely dense foliage on citrus, the sprayer is operated at 1.5 mi/h and all citrus is treated by ground application. There are approximately 714 commercial applicators and farm workers involved in treating Florida citrus. Protective equipment usually consists of a long-sleeved shirt, hat, and in some instances a respirator and goggles.

Citrus - Postharvest

In California, citrus fruits are treated with benomyl only postharvest. Generally, technical benomyl (95 pct) is purchased by formulators (FMC Corp., Pennwalt Corp., and Brogdex Co.) who formulate the benomyl in their wax formulations at the rate of 500 to 3,000 p/m. Application of the wax to the fruit is carried out in a tunnel and supervised by the personnel of the formulator. The benomyl spray does not escape from the tunnel. Workers in packinghouses are not contacted by the benomyl. Graders who handle treated fruit wear gloves.

Pineapple

Pineapple fruits are treated postharvest by dipping the fruit in a suspension of 0.5 to 2.0 pounds of benomyl per 100 gallons of water. Because of the extremely rough texture and the fact that the fruit is wet, persons handling the fruit wear rubber gloves.

Pineapple planting material is dipped in a suspension of 0.31 to 0.62 pound of benomyl per 100 gallons of water. Worker contact is negligible. Dr. Tony Hepton of the Pineapple Growers Association stated that only three persons were involved in the pineapple seed-piece treating operation.

Sugarcane

Benomyl is used on sugarcane in Hawaii only as a seed-piece treatment. Cane pieces in large baskets are dipped in a suspension of 1/8 pound of benomyl per 100 gallons of water. The entire operation is mechanized. No one comes in contact with the solution or the treated seed pieces.

Mushrooms - Applicator Exposure

Although specific information is lacking on applicator exposure to benomyl in mushroom production practices, there is little reason to expect that mushroom house employees would be exposed to hazardous quantities of benomyl during application to mushroom beds. Benomyl is applied as a drench or as a gentle spray using a rose face nozzle. Prior to a spray with benomyl, the pressure is adjusted to between 30 and 40 lb/in^2 so that a gentle spray will fall in an arc onto the surface of the casing soil approximately 1.5 feet from the rose face. About 3 to 3.25 gallons are applied each minute. A gentle spray minimizes destruction of soil structure, thereby preventing crusting and sealing over the production beds. It also eliminates the production of aerosol droplets during spraying.

It takes an applicator about 1.5 hours to treat a standard double mushroom house (8,000 ft^2). An applicator can treat up to three doubles a day (24,000 ft^2) for a maximum exposure time of 4.5 hours; however, since the average U.S. mushroom facility has only about 32,000 ft^2 in production at any given time, and since benomyl is applied an average of only three times per crop with three crops per year, an applicator would rarely be exposed to benomyl for the maximum daily time of 4.5 hours. Furthermore, considering that these applications are made inside the mushroom-growing facility, there is very little reason to expect any drift whatsoever during and immediately following drenching or spraying of the beds.

Any exposure to benomyl via dermal contact or through inhalation that occurs during mixing, application, and cleanup can be avoided completely with the use of proper clothing and protective equipment. There is no applicator exposure to benomyl during treatment of mushroom beds considering the method (drench or gentle spray) and location (inside mushroom houses) of application.

Exposure of Pickers and Other Mushroom House Workers to Benomyl

Mushroom house workers have very little direct contact with the growing mushroom crop following treatment with benomyl, except when the crop is picked and during cleanup of beds and trays. Residues of benomyl and its metabolites are well below the tolerance limit of 10 p/m when benomyl is applied at least 2 days prior to harvest at the recommended rate of 1 lb/100 gallons of water (12.5 gal/1,000 ft^2 of bed) (tables 64 and 65).

Picker exposure to benomyl residues is, at most, very slight considering that benomyl is applied after casing and at pinning and then, if needed, between breaks in the crop. There should be very little residue on the surface of the mature mushroom. Strict observance of the recommended application procedures should all but eliminate, or minimize, benomyl residues on the mushroom crop at harvest.

Persons involved with cleanup and general maintenance of the beds and trays, and with removal of the spent compost, can eliminate any direct contact with benomyl residues in the compost by simply using waterproof gloves and wearing protective clothing.

Table 64.--Benomyl residue data

Source: Butler County Mushroom Farm, Inc., Worthington, Pa.

Sample: Mushrooms from Butler Co. Mushroom Farm

Analyses by: Schiller Laboratory, Ingomar, Pa.

Method: J. Agric. Food Chem. 17:267-270; 1969.

Samples submitted were:

(1) Mushrooms grown in the research pilot plant without application of benomyl or any other pesticide.

(2) Mushrooms grown in the research pilot plant without application of benomyl but with application of zineb.

(3) Commercial mushrooms from packinghouse.

(4) Commercial mushrooms from packinghouse.

(5) Commercial mushrooms from packinghouse.

(6) Commercial mushrooms from grocery shelf.

Results:

Sample number	Benomyl residues[1/] (p/m)
(1)	0.53
(2)	.57
(3)	.72
(4)	.76
(5)	.77
(6)	.68

1/ 78 percent sample recovery.

Table 65.--Benomyl residue analyses

Source: Castle and Cooke Foods, Mainland Products Division, Salem, Oregon

Sample: Mushrooms from Soquel Farm

Analyses by: Soil Control Laboratory, 1234 Highway 1, Watsonville, California

Method: J. Agric. Food Chem. 17:267-270; 1969.

Mushrooms sampled from Soquel Farm production, harvested in usual manner, and analyzed as fresh commodity.

Sampling date	Benomyl residues (p/m)	Sampling date	Benomyl residues (p/m)
12/10/73	<0.1	4/16/76	<0.05
1/31/74	<0.1	5/28/76	<0.1
4/5/74	1/ND	7/9/76	ND
6/11/74	0.1	9/13/76	ND
8/15/74	ND	10/5/76	ND
8/30/74	ND	11/5/76	ND
10/10/74	0.3	12/27/76	ND
12/11/74	0.3	2/11/77	ND
12/23/74	ND	3/8/77	ND
2/3/75	0.2	4/25/77	ND
2/27/75	ND	6/8/77	ND
4/7/75	ND	7/12/77	ND
6/23/75	ND	8/30/77	ND
8/19/75	ND	9/30/77	<0.1
10/17/75	ND	11/8/77	0.2
12/2/75	<0.1	12/12/77	<0.01
2/4/76	<0.05		

1/ ND = None detectable.

Based on all information currently available, benomyl does not present a hazard to persons working in mushroom production facilities or packinghouses when used according to the instructions on the product label. No epidemiological information is known that would implicate benomyl as a hazard to workers (tables 64 and 65).

Wheat

Custom applicators treat 95 percent of the wheat sprayed with benomyl. Eighty percent of the acreage is treated by air and 20 percent by ground application. Ten commercial applicators and 15 farm workers are involved in treating this area. Only one application is made during either March or April. Safety equipment consists of rubber gloves, dust masks, and coveralls.

Peanuts

Application of benomyl to peanuts is made by both air and ground applicators. Because of the large number of farms and their distribution throughout the Southern States, it is impossible to estimate the number of applicators involved. More than 50 percent of the acreage is treated by ground application and involves private applicators. Four to five applications are made during the year. Applicators generally use 6-row or 8-row sprayers and spray at the rate of 3.5 mi/h. Benomyl is used at the rate of 0.125 lb per acre and sprayed at the rate of 25 gallons of water per acre. Applicators usually wear protective clothing consisting of coveralls. When mixing, a dust mask is generally worn.

Turf

Benomyl is applied to turf as Tersan® 1991, a 50 percent wettable powder, and Proturf Fertilizer + DSB Fungicide, a 2 percent granular material. Equipment used varies from 50-gallon to 200-gallon ground sprayers to hose-on applicators. The material is sprayed by custom lawn care applicators, golf course workers, and homeowners. Approximately 85 percent of the benomyl used on turf in the United States is applied on golf courses. Ten percent is applied to home lawns by commercial applicators, and 5 percent is applied to home lawns by homeowners. Spraying is accomplished primarily by hand using a spray gun. Coverage is achieved at the rate of 1,000 ft^2 per minute. Most homeowners' lawns average 500 ft^2 and spraying operations will be completed in less than 30 minutes. In fact, in a recent informal test conducted at Texas A&M University, it took 12.5 minutes to spray 5,000 ft^2 of turf using the recommended rate of benomyl. In these tests an Ortho® Lawn and Garden Sprayer Model 100-1 was used. This is a typical hose-on type sprayer that would normally be used by a homeowner. The weighing and mixing took 1 minute and 15 seconds. This operation had to be performed twice. It took 30 seconds to rinse the sprayer at the completion of the operation. Total exposure time during the whole operation was 15 minutes and 30 seconds. A maximum of four sprays is applied per year. Protective clothing for homeowners varies from general clothing to what is at hand. Custom applicators generally wear required protective clothing such as coveralls, rubber boots, rubber gloves, face mask, and goggles.

Ornamentals

Approximately 125,000 pounds of benomyl are used yearly on ornamentals in the United States. Of this amount, 25,000 pounds are used in nurseries and 100,000 pounds are used by homeowners. Benomyl is generally applied to nursery crops in combination with insecticides. Applicators are equipped with respirators, goggles, and protectant outerwear--that is, rubber gloves, rubber boots, rubber suit. Applicator exposure should not be a problem on commercial nursery crops because of general experience in pesticide handling. The greatest concern is with homeowners who have little to no experience with pesticide application. Equipment used by, and generally available to, homeowners includes hose-on type sprayers and 1- to 3-gallon Hudson-type sprayers. Tests were conducted at Texas A&M University to determine the average time required to treat specific areas. By using a Model 100-1 Ortho® Lawn and Garden Sprayer, it took 0.8 minute to spray one gallon of spray solution. Several types of landscape arrangements were sprayed, including roses, cut flower beds, and perennial plants. All plants were sprayed to the drip point with Benlate® used at the rate of one tablespoon (4.64 g) per 2 gallons of water. Average times included 1.2 minutes to treat 12 average-sized (2 ft) rose bushes. One and 1/4 minutes were required to measure and pre-mix benomyl. Most homeowner situations would include less than 500 ft^2 of cut flower beds and less than two dozen roses. Total time required to treat a maximum area of 500 ft^2 of cut flowers and two dozen rose bushes would be less than 10 minutes. An average homeowner would apply a maximum of five applications with less than one hour of exposure per year. Benlate® is available to homeowners in 2-oz, 6-oz, and 2-lb packages. Using the hose-on sprayer and figuring the maximum spraying time of 1 hour per year, a homeowner would apply 75 gallons of spray solution per year. If the recommended rate is one tablespoon (4.64 g) per 2 gallons of water, then the homeowner would use 174 grams or 6.14 ounces of benomyl per year. Theoretically, if all homeowners who used benomyl purchased it in 6-oz containers, then approximately 534,000 homeowners would be involved in total homeowner use; however, some purchases would involve 2-pound bags and some would involve the 2-oz package, so the total number of homeowners is strictly theoretical. Most homeowners use no protective equipment when applying pesticides other than normal clothing.

Vegetables

Benomyl is used on all vegetables as a wettable powder containing 50 percent active ingredient. It is commonly applied in 25 to 50 gallons of water per acre if applied by commercial hydraulic sprayer and in 7 to 10 gallons of water per acre if applied by airplane.

Commercial ground application equipment consists of hydraulic sprayers utilizing 20 to 100 gallons of water per acre at 25 to 200 lb/in^2 and applied through a boom, and mistblowers, which utilize a large volume of air to apply the benomyl. Commercial application is also done by airplane, which uses less than 10 gallons of water per acre and is also applied through a boom. Homeowners use either Hudson-type sprayers of 3-gallon capacity in which the benomyl is applied at 30 lb/in^2 through a handwand with a single nozzle, or a metering system attached to a garden hose that utilizes 15 lb/in^2.

Geographically, benomyl can be used throughout the calendar year in the Southern States and from May through September in the Northern States. The time of year that applications are made is determined by the time of the year that the target organism is apt to be troublesome. This time frame is different for each vegetable disease complex in each geographical region of the Nation. On snap beans and dry beans, benomyl is applied two times--at the start of the bloom period and again at full bloom. On celery, benomyl is applied 10 times--from the seedbed until harvest. On cucumbers, cantaloups, squash, watermelons, and field tomatoes, four applications are made--beginning when specific diseases appear. On greenhouse tomatoes, seven applications are made--beginning with first disease appearance. On cabbage seed crops, five applications are made--beginning with first flowering of the crops.

Most commercial vegetable ground application equipment treats one acre every 10 minutes, and most aerial equipment treats 6 acres per minutes. Homeowners can generally treat 100 ft^2 in 5 minutes.

The actual number of benomyl applicators cannot be determined. Types of vegetable applicators are custom, farmworker, farmowner, and homeowner.

There is a lack of information on percentage of vegetable acreage treated by custom applicators. If a crop season is marked by frequent or heavy rainfall, more vegetable acreage is treated by custom aerial application and the percentage of acreage treated by custom applicators would increase. The reverse is true in dry weather, and in several vegetable production areas not a single acre would be treated by custom application under these conditions.

Most commercial vegetable ground applicators pre-mix benomyl in 3 to 5 gallons of water and then pour the resultant mixture, or slurry, into the actual sprayer tank. Generally, this is done by the operator of the spray equipment. In California, where custom application is big business, custom applicators do all of their pesticide mixing and transferring in closed systems. In aerial application, benomyl spray is prepared the same way as in ground application except for a ground assistant doing the mixing while the pilot of the aircraft does the application. Homeowners generally put benomyl directly into their sprayer, add water, shake or stir, and then apply.

Commercial ground applicators of benomyl wear a hardhat and coveralls. Pilots wear no special clothing, but their ground assistants wear the same protective clothing as commercial ground applicators. Homeowners generally wear coveralls and boots.

Lignasan - BLP

MBC is supplied as 0.7 percent active ingredient (methyl 2-benzimida= zolecarbamate phosphate). This 0.7 percent solution is diluted (1 quart with 8 gallons of water for preventive treatment; 1 quart with 4 gallons of water for therapeutic treatment). One-half gallon of either of the dilutions is injected into trees for each inch of diameter or for each 3 inches of circumference measured at breast height.

Application is by low-pressure injection (10 to 30 lb/in^2) directly into the tree being treated.

Application equipment varies but is generally composed of a regulated pressure source (usually air) coupled to a container for the diluted fungicide. This fungicide container is coupled to injectors that are either tapped, screwed, or nailed into holes that are drilled about 6 inches apart around the tree.

Application can be made any time the fungicide solution does not freeze. In the spring before the leaves expand, injection is slow. Usually one preventive application is made during a year, but sometimes repeated therapeutic applications are made if symptom development is not arrested. Most trees are treated preventively so the average number of annual applications is slightly over one.

The time required to treat an elm will vary depending on time of day, time of year, whether the tree has Dutch elm disease (and how far advanced the disease is), amount of liquid that is injected, the pressure used for injection, the size of the tree, and the number of injection sites. Limited data indicate that it may require an estimated 1.5 hours (average time of healthy and Dutch elm-diseased trees) to inject the required volume of diluted Lignasan® BLP. About 20 additional minutes are required for the combined preparation and dismantling operation.

Lignasan® BLP is packaged in 5-gallon or 2 1/2-gallon flexible polyethylene bottles encased in hard cardboard boxes for support, protection, and ease of handling.

There are three types of applicators: Homeowner, commercial arborist, and municipal arborist.

An estimated 0.3 percent of all municipal elms were treated in 1977. Over half of these were treated by commercial arborists (0.2 percent or about 66,000 elms).

No uniform mixing or loading procedure is known. Generally, however, since very small amounts are handled at any time, the prescribed amount of Lignasan® BLP is measured and added to the prescribed amount of water (that is already in the injector liquid-holding tank) and this is mixed by stirring. Then the liquid tank is pressurized and the injection started. Once the liquid tank is filled and closed, the system is closed, with virtually no possible contact with the applicator.

No special protective clothing is generally worn; however, many applicators do wear gloves and some form of eye protection while handling the fungicide. Applicators have water available for flushing chemical from the skin in case of contact.

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