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BURNING GRASS SEED FIELDS  
IN OREGON'S WILLAMETTE VALLEY

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THE SEARCH FOR SOLUTIONS

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EXTENSION MISCELLANEOUS 8397

JANUARY 1989

OREGON STATE UNIVERSITY EXTENSION SERVICE,  
OREGON AGRICULTURAL EXPERIMENT STATION,  
AND USDA-ARS COOPERATING

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## PREFACE

This publication is prepared as a public service by faculty members at Oregon State University in response to a perceived need for information on field burning. The report has been prepared as a reference and source document for 1989 legislative and agency deliberations on further adjustments in thermal sanitation of grass seed fields in the Willamette Valley of Oregon.

The legislative agenda may include a broader state-wide perspective than that presented here. To date, however, control of agricultural burning in Oregon has been confined to open-field burning of grass seed in the Valley. Consequently, adjustment and research activities have been confined to the Valley. The report addresses four major areas:

1. historical background of field burning and description of the industry;
2. compilation of research and development activities from 1968 to 1988 associated with the search for viable alternatives to field burning;
3. structural adjustments made to date and economic issues which will affect future adjustments; and
4. review of possible alternative policy choices for consideration by the 1989 Oregon Legislature.

This report is intended specifically for use by industry leaders, concerned citizens, agency administrators and legislators as a working document in legislative committee sessions throughout the 1989 legislative session. As the report was prepared on short notice, the background and research and development activities treated herein were compiled in part from selected key reports.

Those relied upon heavily included *Synopsis of Grass Straw Research in Oregon, 1968-1986* by Thomas R. Miles, Jr. and Thomas R. Miles, May 1987; *Final Report, Field Burning R&D Program Evaluation* by Nero and Associates, January 1987; and *DEQ Annual Reports on Field Burning*. Direct excerpts from those sources were taken in several instances. Use of these sources is gratefully acknowledged.

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## EXECUTIVE SUMMARY

### STATUS OF THE GRASS SEED INDUSTRY

Oregon is the world's major producer of cool-season forage and turf grass seed. The Willamette Valley is the national center of cool-season grass seed production with 330,000 acres harvested on 700 to 800 farms in 1988.

The farm gate value<sup>1</sup> of 1987 Willamette Valley production was \$140 million. Farm gate value of Oregon grass seed production was \$156 million, ranking grass seed the number one field crop by value in Oregon. Processing contributed an additional \$34 million. The total effect on the state's economy from sales, using a 2.0 business output multiplier<sup>2</sup>, is estimated at \$380 million. Farm gate value in 1988 in the Valley rose to \$190 million, while total Oregon farm gate value of grass seed production rose to \$211 million. Valley grass seed acreage has expanded by 95,000 acres (from 235,000 to 330,000 acres) during the past decade. The acreage and income increases are due largely to expanding consumer demand for turf-type perennial grasses, especially tall fescue and perennial ryegrasses.

Grass seed is grown on 32% of the total harvested cropland in the Willamette Valley. In the southern Valley where large tracts of poorly-drained soils have limited cropping alternatives, more than 56% of the total harvested cropland is in grass seed.

Overall, 75 to 80% of Oregon seed is sold domestically with the remaining 20 to 25% going into foreign markets which include the European Community, Japan, Canada, Korea, and Australia.

Markets for grass seed are distinguished by end use needs. They include lawn and turf use (fine fescues, bentgrass, turf-type tall fescue, turf-type perennial ryegrass, and Kentucky bluegrasses), cover-crop and pasture use (orchardgrass and tall fescue), and multi-purpose use (annual and perennial ryegrass).

Oregon grown seed represents two-thirds of all U.S. cool-season grass seed production with the other one-third coming from competing regions which include Washington, Idaho, and Missouri. Minor foreign competition in U.S. markets comes from Canada, New Zealand, The Netherlands, and Denmark. Oregon historically has had an economic advantage in domestic and foreign markets due largely to high mechanical and genetic quality of its grass seed.

### HISTORICAL DEVELOPMENT OF THE GRASS SEED INDUSTRY

Although climate in the Willamette Valley is ideal for grass seed production, disease problems limited the growth of the industry during its infancy in the 1930's. *Open-field burning* was developed as a *solution* to disease problems and permitted the fledgling grass seed industry to expand dramatically in the 1940's. Other benefits from open-field burning include effective weed control, stimulation of seed yield, partial control of several insect pests, recycling of nutrients, decreased initial nitrogen fertilizer demand for annual crops, easy and low cost stand establishment, higher quality seed, ability to meet strict certification standards, minimal need for pesticides and efficient and economical residue removal from fields that are not tilled annually because of perennial crop production.

The practice of field burning led to a new *problem* -- smoke as a by-product of grass seed production. This smoke is an air pollutant during the field burning season in the Willamette Valley.

### ATTEMPTS TO OVERCOME PROBLEMS ARISING FROM FIELD BURNING

The search for solutions to problems arising from field burning seeks to reduce or remove smoke problems while protecting the economic vitality of the grass seed industry, or identify an alternative industry. The new production practices sought must permit individual grass seed growers to produce an

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<sup>1</sup>Farm Gate Value is defined as the gross value of production for a given crop year; estimated as the average total annual production by growers x averaged annual price received by growers.

<sup>2</sup>The business output multiplier measures the total change in local sales generated by a one dollar increase in sales of the product outside the state. For the agricultural sector of Oregon the range in the business output multiplier is 1.4-2.7 with a mean of 2.2. The authors used a conservative value of 2.0 for the grass seed industry. Although most processing is done in state, its value added compared to final product is relatively small (Mandelbaum et al., 1984).

economically viable crop in the short run, and must not result in building up of disease, weed, and pest problems that could threaten the industry as a whole in the long run.

Given the current state of knowledge, all alternatives to open-field burning will represent increased costs and, other things being equal, decreased returns to growers. These alternatives are discussed below.

### **Smoke Management**

Smoke management was the first measure instituted to deal with the smoke produced by field burning. Initial measures were implemented during the late 1960's with growers, fire districts, and state authorities cooperating. At that time more than 300,000 acres of grass seed and small grain fields were open burned. In 1971, the State Legislature placed field burning under state regulatory powers of the DEQ (Department of Environmental Quality).

The DEQ has responsibility for regulating the amount of burning consistent with air quality considerations. The State Legislature instituted a system of grower fees to pay the administrative cost of the regulatory smoke management program and to establish a research and development (R&D) program to seek alternatives, study smoke management, and study health effects.

The system of grower fees continues in force and currently provides about \$550,000 annually for smoke management and \$250,000 to \$350,000 annually for R&D. The R&D activities during the past 17 years have totaled nearly \$7 million. Most of the R&D activities to date have come from the self-sustaining grower fee program rather than from public funds.

The maximum number of acres allowable for open burning was set at 250,000 acres by the State Legislature in 1978 and has continued to date. Actual acres burned under the DEQ managed smoke management program has continued at about 220,000 acres annually during the past decade except for 1988 when it declined to about 150,000 acres due to an 8-day temporary burning moratorium. The current DEQ smoke management program utilizes meteorological conditions to specify timing, method of field firing, and acreage levels to minimize smoke impacts upon the Valley population, particularly in urban centers.

Research and development activities have focused principally upon thermal sanitation alternatives, alternative crops, agronomic alternatives, uses for grass straw, and a preliminary examination of public health effects.

### **Thermal Sanitation Alternatives**

#### *Field sanitizers*

Thermal sanitation alternatives developed to date have been in the form of machine sanitizers. Several sanitizer designs were developed by OSU and private engineers starting in 1969 and field tested throughout the 1970's. These units used some or all of the straw residue as a fuel source to sanitize the fields under conditions that would complete the combustion process and minimize emissions. Although agronomic studies and field tests demonstrated that the units provided an effective technical substitute for open burning over a range of field conditions, difficulties with short machine life, high operating cost, high energy use, and slow operating speed made commercial sanitizer use an economically prohibitive option. By the late 1970's the emphasis was placed on smoke management and research shifted to alternative sanitation methods.

#### *Propane flaming*

Agronomic studies and field tests showed that thermal sanitation achieved by propane flaming could be similar to open burning without major seed yield loss, but only if most of the straw residue were removed prior to propane flaming. Higher residue levels left on the ground provided a greater combustible mass during dry weather thereby permitting faster field operation but generating greater emissions near ground level. Thus, residue removal, except for the stubble, and slow field operation are necessary for good results. This means that to be effective, the large volume of residue, some 2 to 4 tons per acre, has to be removed as a companion process to propane flaming, with subsequent use or disposal of the residue. The cost of the propane flaming ranges from \$8 to \$32 per acre depending upon level of residue and speed of operation. Residue removal represents an additional cost if a market is not found for the straw.

Propane flaming is being used by an increasing number of growers, especially in the North Valley. An estimated 56,000 acres were sanitized by propane flaming in 1988 (T.L. Cross, personal communication).

### **Non-Thermal Sanitation Alternatives in Perennial Grass Seed Production**

Grass seed production in the Valley is a diverse activity. It differs from many field crops in that two-thirds of the acreage is in perennial grass crops which have a productive life of four to eight years. The fields are not tilled during that time but require special field management instead. Following harvest the straw residue must be removed to assure a satisfactory crop in the following season. The remaining one-third of grass seed acreage is in annual ryegrass production which can be tilled each year. Grass seed farmers in the south Valley tend to be specialized in production of the ryegrasses while those in the north Valley are diversified with several grass seed species and other crops.

#### *Mechanical Straw Removal*

Baling was found to be the most economical removal option in situations where there is a market for the straw. Cost of baling and roadsiding approaches \$40 per acre. In the absence of a straw market, the lower cost choice of raking and use of stack wagons to position the straw at the side of the field for later burning is preferred. Burning of bales or loaves after placement at fieldside is used to dispose of unmarketable residue.

#### *Crew Cutting or Close Clip Stubble Removal*

In the absence of burning, the bulk of the straw must be removed mechanically, and followed by a "clean up" operation. The best non-thermal method of "clean up" is the clip and vacuum, or "crew cut" treatment, which involves special equipment not yet commercially available. The flail chop treatment is a chaff and stubble removal treatment using the best currently available equipment, a forage harvester. Both straw and stubble treatment methods involve significant labor and equipment costs as compared to open burning. The operations also generate considerable low level dust emissions.

#### *Less Than Annual Burning*

This practice includes alternating various combinations of burning and mechanical removal techniques over a period of several years. In perennial ryegrass, alternate year burning averaged 93% of annual burning yield over a five year period regardless of whether plots were crew cut or flail chopped during the non-burning year. No deleterious effects on seed yield were reported for fine fescue or bluegrass when averaged over four years.

#### *Chemical Treatment*

Chemical treatment with monocarbamide dihydrogensulfate (Enquik<sup>R</sup>), a urea-sulfuric acid reaction product, applied at 15 to 20 gallons of product per acre during mid-October has shown some potential for reducing fall germinating unwanted grass seedlings, controlling some weeds, increasing effectiveness of specific herbicides, and accelerating decomposition of old crown growth left at harvest. Results vary with grass species and weather, especially temperature and rainfall.

#### *Shorter Crop Rotation*

Perennial grass seed crops historically have produced for up to 10 to 12 years as a single stand without re-establishment. This has been reduced to about five years for proprietary varieties grown under contract. In the absence of annual open-field burning, further shortening of the rotation may be necessary to decrease the incidence of disease and pests. However, production costs increase significantly as establishment costs (including one season of lost income in several species) are amortized over fewer production years and thermal sanitation costs from propane flaming and residue removal are included.

#### *No Thermal Sanitation*

Seed production without field sanitation in the Willamette Valley has not been successfully demonstrated on a large scale. Several serious diseases of seed crops have been held in check with field sanitation.



tion but are still present at low levels. Diseases might increase quickly if thermal sanitation were discontinued entirely.

### **Non-Thermal Sanitation Alternatives In Annual Ryegrass Production**

Annual ryegrass represents one-third of total grass seed acreage in the Valley. Historically, it has been reseeded each fall in the ash of open-field burning. Some growers are shifting to less than annual burning. The cultural practice generally involves flail chopping of the straw residue and its incorporation into the soil by plow-down. In some instances, the straw is removed before plow-down. Growers feel that some, or all, of the straw must be removed as most annual ryegrass is grown on poorly drained clay soils in which incorporation of residue is difficult.

### **Control of Pests and Diseases**

While significant work has focused upon thermal and non-thermal sanitation, the collective or cumulative effect upon the seed industry of non-burning upon incidence of disease, insect, and other pests and their cost of control are unknown. Cultural, chemical, and field management measures for disease and weed control in grass seed crops in the absence of burning were initiated in the early 1980's and have had limited testing to date. Certain insects may be controlled by grazing or mechanical removal of crop residue while some may require thermal control methods. The extent to which thermal sanitation can be reduced as a cultural practice on a farm-by-farm and grass-seed-species basis without major consequences upon yield and seed quality due to disease, insect, weed, and other pest effects requires additional research.

### **ALTERNATIVE CROPS**

Alternative crops to grass seed production are influenced by technical and economic factors. In the north Valley where soil drainage is good, the profitability of grass seed types and their markets relative to other crop choices becomes the overriding factor. In the south Valley, poor soil drainage is a technical factor severely limiting crop choices as most crops will not survive soil moisture saturated winter conditions.

*Meadowfoam*, the only known winter annual crop that will tolerate such a condition, was identified as a potential crop with preliminary plot trials initiated in the mid-1970's. Since that time, studies of yield increase, seed dormancy, production, and economic feasibility and market development analyses have been done. Oil extracted from meadowfoam appears to have potential for industrial and cosmetic trade utilization. Two principle factors limit its use at this point. The first is low yield. A major effort is being made to improve seed yield and to reduce production costs enough to compete with oils currently used in the market. The second factor is that no industrial utilization research yet has been conducted to ascertain the qualities and properties of meadowfoam and hence potential role(s) in industrial and cosmetic markets. Research has been initiated in this area (C.D. Craig, personal communication). Potential technical viability of meadowfoam as an alternative crop for adoption is estimated to be 5 to 10 years away from consideration. Whether it will be an economically viable choice at that time is questionable. Its potential scope is unknown but appears to be limited. Currently, some 20 to 25 growers produce less than 200 acres annually with excess inventory of oil on hand.

### **STRAW UTILIZATION**

Straw removal and utilization or disposal have been essential companions to the viability of alternatives to open-field burning. Straw must be removed for mobile sanitizers, flammers, alternate year burning, and mechanical or chemical methods of disease, pest, and insect control to be effective.

From a technical standpoint, straw can be used as a raw material to make a wide range of products for fiber (paper, particleboard, fuel logs, hydromulch, composted fertilizer, etc.), chemical products (oil, gasoline, plastics, microbial protein, etc.), and livestock feed. Economically, it has been difficult for grass straw to compete in existing markets as a raw material source. Low bulk density of the straw which requires costly densification, high cost transportation, uncertainty of long-term supply, and low volume of supply in fiber markets have made straw non-competitive with other raw materials. The traditional base for making pulp and paper in the Pacific Northwest is wood chips which are cheap, adequate in continuing

supply and volume with manufacturing technology adapted to that source and require no storage from rainy weather. Converting to straw would involve major retooling in the wood fiber industry.

As a feedstuff for livestock, untreated straw is of poor quality because of low protein and high fiber content. With appropriate treatment, such as ammoniation, the digestibility and palatability of straw can be increased substantially making straw a potential component of maintenance diets for ruminant livestock. Costs of physical and chemical treatment have made the process marginal in an economic sense.

To date less than 20% of annual residue is being used in domestic and export markets as a supplemental livestock feed. During periods of short supply and/or excess demand for forages in U.S. markets, such as experienced during the major drought of 1988, a relatively small quantity of grass straw is marketed. Extended dry weather conditions in the Valley through October permitted more straw to be sold. Japan, the major current market, utilized an estimated 125,000 to 150,000 tons in 1988 for supplemental livestock feed.

## **THE PUBLIC CONCERN**

Research activities involving health, soiling, nuisance, hazards, and aesthetic influences from open-field burning in the Willamette Valley have been extremely limited. Nearly all of such activities have been financially supported by the DEQ Field Burning R&D Program.

Initial work in the early 1970's focused upon air quality and its measurement. From 1971 to 1977, limited surveys of respiratory patients in the Valley and respiratory patients statewide provided inconclusive results relative to health effects.

In 1977 health effects research was given top priority status in the Field Burning R&D Program. Funds were set aside for preliminary studies and for planning a major health effects research project. In doing so it became apparent that research on this issue would require multi-disciplinary research activities and be very costly, the magnitude could easily divert all R&D funds available annually for several years. Consequently, the Field Burning R&D Committee decided to:

1. support preliminary studies based on local data, if possible, to identify evidence that health impacts do indeed exist;
2. follow up such evidence with a planning effort to design a more extensive research effort; and
3. solicit the necessary funding for such an effort and contract the work.

Each of these activities were completed: physician visit and hospital admission surveys in 1980; a field burning health effects workshop in 1986; and a preliminary field burning health effects assessment in 1987. The health effects assessment, conducted to provide quantitative measures of exposures, health effects/risk, and related costs from field burning, slash burning, and residential wood burning, has not been released. A technical review of the assessment raised serious questions concerning the appropriateness of the methodology used and hence conclusions of the study for Willamette Valley conditions.

A 1986 DEQ contracted study provides an initial attempt to assess the importance of air quality through estimation of the amount the public would be willing to pay for improved visibility. No attempt was made to link the study to smoke impact.

In the case of the Willamette Valley grass seed industry, the desired level of environmental quality is made more complex in that a simple inverse trade-off between improved air quality and economic well-being of the industry does not exist. Although known for air pollution, the grass seed industry also provides positive environmental effects through low levels of soil erosion on hillside lands, low levels of dust emissions throughout the year which are more common with other crops and a buffer from urban/industrial development.

## **STRUCTURAL ADJUSTMENTS TO DATE**

Open-field burning has declined from a high of 315,000 acres in 1968 to about 220,000 acres annually during the 1980's. In 1988, 330,000 acres of grass seed were produced in the Valley of which 206,000 acres were thermally treated. An estimated 150,000 acres were field burned and 56,000 acres propane flamed. The remaining 124,000 acres employed other field cultural practices. In general, the net effect to the public has been reduced emissions by more than one-half from reduced acreage burned.

Less obvious grower adjustments have been made. They include changes in thermal sanitation practices to propane, changes in field cultivation practices which substitute for field burning, adjustment among the mix of grass seed species grown both at the farm and industry level, increased use of proprietary varieties, and adjustment to external market forces which have enhanced the industry in recent years.

With annual ryegrass, growers have reduced the acreage planted and made a shift to fall plow-down and reseeded to partially replace field burning. Some straw is removed from the field for disposal by stackburning as a companion practice. On the perennial grasses, especially those grown in the north Valley, a definite increase in straw removal followed by propane flaming has been observed. The volume of straw intended for sale has increased. Several storage units have been built and baling for commercial sale has become more common. During the early 1980's, a definite shift toward proprietary varieties under forward contracting was employed, largely as a mechanism for reducing the risk of low market prices. Some shifting away from this has occurred since 1985 as market prices improved significantly for grass seeds, especially for turf-type tall fescue and perennial ryegrasses resulting in a 23,000 acre increase from 1987 to 1988 for those two grass seed species.

#### **TECHNICAL AND ECONOMIC CONSIDERATIONS FOR FUTURE ADJUSTMENTS**

The Willamette Valley grass seed industry may be called upon to make further adjustments in response to the public desire to reduce smoke emissions from open-field burning. Understanding the past provides guidelines of issues to expect when one considers adjustment possibilities for the future.

Important technical and economic factors will influence the ability of the industry to make further adjustments. These include:

1. Ability of the industry to retain its relative economic advantage in the marketplace while responding to cost increasing alternatives to replace open-field burning is unknown. Positive market forces in the 1980's, which provided a measure of industry well being to offset cost increases, may not continue into the 1990's.
2. Incidence of future disease, insect, and weed pests without thermal sanitation is unknown.
3. The impact of straw removal, an important companion to propane flaming, comes at a high cost to growers if little of it is marketable.
4. The role of meadowfoam as a new crop is not expected to have strong economic potential for several years. Low yield and market potential persist as limiting factors.
5. Shifts by growers to crops previously grown are unlikely as their margin of return is very low.
6. Existence of public health effects from thermal sanitation has not been quantified.
7. Extent of public hazard, nuisance, soiling, and aesthetic effects from open burning has not been adequately measured.<sup>3</sup>
8. Ability to conduct required tests using *currently registered* pesticides for disease and weed control to remove EPA label restrictions on use of crop regrowth, straw, or seed screenings for livestock feeding or grazing is uncertain.
9. Ability to conduct necessary tests to obtain EPA registration of *new pesticides* is needed for seed production in the absence of field burning to permit legal access of straw residues to livestock feeding markets.

#### **A VIEW TOWARDS FURTHER ADJUSTMENTS**

In considering reduced open-field burning, it is important to examine what alternatives might be considered and what impacts such choices might have. One needs to consider the livelihood of the industry and its individual growers on the one hand, and the general public and its concern about the quality of air it breathes on the other.

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<sup>3</sup>Particulate emission (PM 10) quantities are estimable and available for different levels and sources of smoke. They serve largely as a limited proxy for estimating haze level. They should be used in conjunction with meteorological variables under actual conditions as air mixing is an important influencing factor.

Because little substantive research evidence is available to provide measurement estimates on the impacts of improved air quality to the public, currently it is not possible to make direct comparisons between economic losses to grass seed growers and air quality gains to the Oregon public from further reductions in open-field burning. Instead, what is done here is to provide a selected list of possible policy alternatives which simply are ranked in order of increasing improvement in air quality and decreasing economic well being to grass seed growers.

1. Maintain the current field burning program but impose further controls to minimize the risk hazard from open burning that may endanger human lives.
2. Implement negotiable burning rights to grass seed growers.
3. Use public funds for subsidies and expanded R&D on pollution abating technology.
4. Continue with the controlled open burning program but reduce the maximum burned acreage to some lower level with the actual number of acres burned determined by meteorological conditions.
5. Continue with the controlled open burning program but accomplish a reduction in the number of acres burned through an increased per acre burning fee which is of a magnitude large enough to serve as an economic disincentive.
6. Provide a phased reduction in open burned acreage over a set period of time until the practice is eliminated entirely.
7. Eliminate open burning for residue disposal purposes but permit thermal sanitation on a "prescription" basis for disease, weed, and insect control.
8. Eliminate open-field burning entirely.

As the emphasis shifts away from open burning toward greater reliance on propane flaming, production costs would increase accordingly. Increased costs would involve cost of propane flaming and cost for residue removal and disposal. An indirect effect would be reduction in grower fees available for needed smoke management and research and development activities unless alternative mechanisms for funding these activities are identified. Fees generated in policy choice 5 might be used, in part, for such activities.

The discussion of the net impact of further adjustments in grower production practices is complicated by the lack of reliable information on air quality associated with propane flaming and stack burning, practices developed as alternatives to open burning. Preliminary observations suggest that low level emissions from propane flaming may lead to widespread and persistent haze throughout the Valley if the practice gains greater use. Studies are underway to ascertain more precisely the air quality tradeoffs between open burning, propane flaming and stack burning. At issue for policy makers is the impact on air quality from further regulations of post-harvest management practices as they will not provide simple trade-offs in air quality changes.

## CHAPTER 1

### INTRODUCTION AND BACKGROUND

#### OREGON'S GRASS SEED INDUSTRY

Oregon is the world's major producer of cool-season forage and turf grass seed and a widely recognized center of expertise in seed production. Most of the acreage is located in the Willamette Valley, the "grass seed capital of the world." Farm gate value of the Valley's 1987 production was \$140 million (Miles, 1988). Preliminary data for 1988 show a substantial increase to \$190 million. Oregon growers produce essentially all of the U.S. production of annual ryegrass, perennial ryegrass, bentgrass, and fine fescue. Smaller but significant amounts of bluegrass, orchardgrass, and tall fescue are produced. Collectively, Oregon's Willamette Valley produces almost two-thirds of the total U.S. production of cool-season grasses.

Grass seed typically is produced on nearly 800 family farms, averaging 700 acres, with more than 60% of the total labor requirements provided by family members. Seed production of one or more seed species are the major enterprises, with growers using machine technology especially adapted to small seeds. Mild and moist winters with dry summers favoring seed maturation and harvest make the Valley an ideal place to produce high quality seed. Over 360 seed conditioning plants located in the Willamette Valley prepare the seed for market once the harvest operation is complete.

Linn County, with about 156,000 acres of grass seed production in 1987, is the leading grass seed producing county in the state. Linn County produces more than 40% of Oregon grass seed and 75% of the ryegrass produced in the U.S. (Miles, 1988).

Grass seed growers in Linn, Benton, and Lane counties, in the southern Willamette Valley, tend to specialize in grass seed crops because of the extensive area of poorly-drained soils in the region. Most other crops will not survive the winter flooding on these soils.

Grass seed crops are grown on more than 56% of the total harvested cropland in the southern Willamette Valley and 32% of all Willamette Valley counties (Table 1.1) (Miles, 1988).

Annual and perennial ryegrass are adapted to soils in the southern Willamette Valley, but have low net returns per acre. Although draining and supplemental summer irrigation of the soils is technically possible, market conditions and improvement costs generally preclude opportunities for improving soils and producing cereals or intensive fruit and vegetable crops. Availability of contracts for alternate crops is limited.

Significant grass seed production also occurs in Lane, Benton, Polk, Yamhill and Marion counties. Small amounts are produced in Washington and Clackamas counties. Seed farms in Polk, Yamhill, Marion, Clackamas, and Washington counties are smaller and more diversified than those in the south Valley. Soils in these areas are more variable, providing opportunities for a variety of crop alternatives and rotations. Crop choices are definitely limited in the hilly areas where soil erosion can be a problem. Grasses are adapted and provide greater protection against soil erosion than annual cereals or row crops.

Outside the Willamette Valley, small amounts of grass seed are produced in Union, Jefferson, Jackson, Sherman, Malheur, Crook, Douglas, Morrow, and Baker counties.

Table 1.1 Grass seed crop acreage and total crop acreage in the Willamette Valley, 1987

District/County	Total Harvested Cropland	Grass Seed Crops Cropland	Percent of Total Harvested Cropland
	(acres)	(acres)	(percent)
<b>North Valley</b>			
Clackamas	77,805	7,900	10.2
Marion	176,285	49,700	28.2
Multnomah	13,047	90	.7
Polk	109,376	28,150	25.7
Washington	96,035	550	.6
Yamhill	112,900	9,500	8.4
Subtotal	585,448	95,890	16.4
<b>South Valley</b>			
Benton	67,084	28,400	42.3
Lane	83,250	24,880	29.9
Linn	220,593	156,450	70.9
Subtotal	370,927	209,730	56.5
<b>Valley Total</b>	<b>956,375</b>	<b>305,620</b>	<b>32.0</b>

Source: Miles, S.D. 1987 Oregon County and State Agricultural Estimates, Special Report 790, Revised January 1988, Oregon State University Extension Service.

### ECONOMIC TRENDS

The past decade has experienced a steadily expanding trend in Oregon's grass seed industry. The increase is attributed largely to an expansion of 95,000 acres (from 235,000 to 330,000 acres), greater use of proprietary varieties that provide market price stability through forward contracts in the U.S. markets and expanded domestic demand for turf-type perennial grasses, especially tall fescue and perennial ryegrass.

Farm gate value of grass seeds produced in Oregon totaled \$156 million in 1987, representing 11% of total field crop receipts in the state and 7% of the state's \$2 billion gross farm and ranch sales. This is an increase from 1980 when the \$81 million in cash farm receipts represented 7% of total field crop receipts and 4.6% of gross farm/ranch sales. Of this amount, \$140 million was generated by Valley growers. Cash farm receipts in 1987 from all grass seed production exceeded the value of Oregon's wheat crop which historically has been the number one field crop by value. The value added from processing grass seed is estimated at \$34 million. The total effect on the state's economy from sales, using a 2.0 multiplier, is estimated at \$364 million. Farm gate value of grass seed in 1988 rose to \$211 million, of which \$190 million was generated by Valley growers.

Across all grass species grass seed production has shown gains of 15 to 20% over the past decade. The most pronounced has been tall fescue with an increase of 60% largely from turf-type proprietary varieties. Growers have reduced acreage of annual ryegrass and expanded acreage of turf-type tall fescues and perennial ryegrass.

Prices have moved higher in nominal, and in some cases real, terms over the past decade. A major upsurge in prices, linked to the Conservation Reserve Program (CRP) provisions of the 1985 Food Security Act, continued from 1985 through 1987 for orchardgrass and tall fescue as pasture/cover crop grasses. Especially large price increases have occurred with turf-type proprietary tall fescue and perennial rye-

grasses in U.S. consumer markets due largely to genetic changes which have expanded the scope of their markets.

Value of production for all grass seed in the Willamette Valley has more than doubled during the past decade with major increases since 1985. However, individual grass seed crops have varied in response to the combined acreage, yield, and price trends. Tall fescue and orchardgrass increased in value throughout the decade. With exception of the 1982 to 1984 period, so did perennial ryegrass. Each of these three grass seed types were used for cover-crop and pasture grass uses. The other three grass seed types (used for lawn and turf purposes) suffered reductions in the value of production during the 1982 to 1984 period as a function of market price, but have since rebounded strongly. Value of production of annual ryegrass has been steady with improved prices offsetting a major decline in acreage.

Proprietary varieties<sup>4</sup> have become an important and dynamic factor in the industry, especially during the past decade. The 1970 Federal Plant Variety Protection Act provided proprietary protection by granting rights to private and public breeders for exclusive propagation and sale of grass seed under private varietal labels in both domestic and foreign markets. Certification records in Oregon indicate that in 1979, 10% of Willamette Valley grass seed acreage was planted to proprietary varieties. By 1987 the acreage had increased to 30%. Proprietary varieties of perennial ryegrass, Kentucky bluegrass, and turf type tall fescue account for 50 to 80% of total acreage of these grass seed types.

## MARKETS

Consumer markets for grass seed are specified by lawn and turf use (fine fescues, bentgrass, Kentucky bluegrasses, turf-type tall fescue, and turf-type perennial ryegrass), cover-crop and pasture use (orchardgrass and tall fescue), and multi-purpose use (annual and perennial ryegrass).

Most cool-season grass seed is marketed outside Oregon. Some 75 to 85% is sold in U.S. markets. Domestic markets for lawn and turf grasses are largely in the major urban areas of the U.S. including winter overseeding of lawns in the south. U.S. markets for pasture and cover-crop purposes are dispersed throughout agricultural producing areas and expanded under the 1985 Food Security Act.

Oregon competes with Idaho and Washington in Kentucky bluegrass production and Missouri in orchardgrass production. Field burning is used as a cultural practice in Washington and Idaho bluegrass stands.

Tall fescue is the only cool-season grass seed in which Oregon is not a dominant producer. Missouri produces about 70% of U.S. production of tall fescue, down from 80% in 1978 (F.S. Conklin, personal communication); Oregon captured the increase. Tall fescue and orchardgrass are grown in Missouri primarily for livestock pasture with seed production serving as a secondary enterprise and in which field burning is not employed as a cultural practice. However, Oregon is the largest producer of high-quality certified forage seed of these crops, and the primary producer of turf-type tall fescue.

In spite of expanded acreage and increased yields in Oregon of grass seeds over the past decade, Oregon production as a percentage of U.S. production declined from 73 to 64% (F.S. Conklin, personal communication). Increased U.S. production of tall fescue in Missouri and Kentucky bluegrass in Idaho and Washington outstripped overall Oregon increases in grass seed production through 1987. During this period, the decline in Oregon's annual ryegrass production, which historically accounted for more than one-half of total Oregon grass seed production, was a contributing factor. Since 1986, annual ryegrass acreage has remained relatively constant.

Competition from imports in the U.S. market historically has been very small, accounting for 2 to 3% of U.S. demand. From 1984 to 1987 imports increased from 10 to 40 million pounds due largely to expanded demand, triggered by the CRP program, which could not be met by immediate domestic production increases. Red fescue from Canada and perennial ryegrass from New Zealand accounted for most of

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<sup>4</sup>Proprietary varieties are propagated and released by plant breeders and their designees under an exclusive proprietary name. Such varieties are not available to the general public for propagation and release. This licensing arrangement permits holders of such rights to exclusive monopoly development, propagation and distribution rights to use the variety name. Public varieties may be propagated and released by anyone meeting the required certification standards.

the increase. Grass seed production in those areas is largely in conjunction with livestock grazing and/or short rotation with other crops in rotation in which field burning is not used as a cultural practice.

The export market, while somewhat important for all U.S. produced cool-season grass seed, is especially important for bentgrass. Essentially all U.S. produced bentgrass is exported, while 5 to 50% of the remaining cool-season grass species are exported. Principal export markets for lawn and turf grasses are the EEC (European Economic Community), Japan, and Canada. For cover-crop and pasture use grasses the EEC, Japan, Korea, and Argentina are major markets. For the multi-purpose ryegrasses, Japan, Italy, Netherlands, Australia, and Canada are major markets.

International competition in lawn and turf grasses comes from Denmark, West Germany, The Netherlands, and Canada, and in pasture and cover crop grasses from Denmark, Canada, New Zealand, and The Netherlands. Producer subsidies and non-tariff trade barriers in the EEC and Japan serve to restrict trade flow of U.S. grass seed to those markets with high flow years tending to coincide with low production in the EEC.



## CHAPTER 2

### FIELD BURNING

#### AN HISTORIC SOLUTION TO A PROBLEM

Open-field burning was introduced in Oregon as a solution for control of certain grass diseases during the mid-1940's (Hardison, 1948) which were threatening the fledgling grass seed industry. The practice was quickly adopted by all growers. In addition to disease control, burning of grass seed crop residue was found to have several other significant benefits which led to its general use in grass seed production in Oregon. The high seed yields and quality associated with a seed production program that included burning has made it possible for Oregon seed producers to compete effectively in national and international markets.

Several major advantages of field burning exist. They are stated succinctly in the next series of paragraphs. Later sections provide further elaboration.

**Disease control.** The primary reason for initiating field burning of grass seed fields was to control blind seed disease (*Gloeotinia temulenta*) and ergot (*Claviceps purpurea*) (Hardison, 1960). Several other plant diseases were found to be reduced or partially controlled by residue burning.

**Residue removal.** Grass residue must be removed from perennial grass fields because they are not plowed annually. After harvest, there is a straw volume of three to five tons per acre with a non-uniform distribution across the field. Left undisturbed, this quantity of residue shades developing grasses so severely they either die or grow with low vigor and loss of productivity. Burning is an effective and low cost method of removing grass residue from fields.

**Weed control.** Market standards allow very limited amounts of weed seed in commercial seed moving in trade. This requires a high level of weed control in seed fields. Weed control involves maintaining a low level of viable weed seeds on the soil surface and thorough removal of residue that can interfere with herbicide activity. Open burning performs both functions very effectively.

**Stimulation of seed yield.** Post harvest burning changes the plant and soil environment, promoting plant regrowth early in the autumn. Removal of older tillers and early vigorous new growth results in higher seed yields in the subsequent crop year.

**Insect control.** Field burning of crop residues destroys oviposition sites for some insect pests and controls certain insects such as plant bugs.

**Improved genetic purity.** Burning destroys shattered crop seed left in the field after harvest. When these seeds are allowed to grow, they represent a second generation and the crop cannot be certified for genetic purity, thus reducing the marketability of the seed.

**Nutrient recycling.** Ash deposited from burning residue recycles nutrients to the soil. Burning will recycle potassium, magnesium, calcium, and phosphorus. Removing post harvest residue will take these nutrients from the field and increase need for adding these nutrients to the crop as commercial fertilizer.

**Decreased nitrogen fertilizer requirement.** When annual grass seed straw is plowed down, nitrogen in the soil is immobilized by microbial activity during straw decomposition. Burning straw residue decreases the amount of organic material incorporated and thus the amount of nitrogen immobilized.

**Easier crop establishment.** Destroying weed seeds and residue on the soil surface eases establishment of the subsequent crop. With burning, annual ryegrass can be planted with little or no tillage, saving fuel and reducing costs. Establishing a small-seeded grass stand requires a good seedbed. The best seedbed can be prepared by disposing of straw prior to tillage.

#### CREATION OF A NEW PROBLEM

When field burning was started during the 1940's, few if any, public complaints were reported. But as the number of acres burned increased, and especially when fields with green regrowth were burned late in the season or when fields were burned under adverse atmospheric conditions, complaints about smoke increased.

## **Air Pollution: A Common Property Issue**

Smoke discharged into the air is an unwanted residual output from grass seed production. Air is a natural resource used as common property by society for a myriad of activities. Environmental pollution of air, water, and the landscape is largely a by-product of the industrial revolution of the U.S. which has continued for more than a century. The magnitude of its impact upon the public and its realization as a serious issue has emerged only in recent decades. While the environment has a natural capacity to assimilate and break-down some waste materials into desirable or inoffensive elements, a point can be reached at which wastes accumulate in a harmful and/or obnoxious form as population and the level of production increases without a corresponding increase in the effectiveness of the technology used for waste disposal.

Achieving a desired level of environmental quality is a complex problem since the costs, both measurable and unmeasurable, of pollution are borne externally. That is, the persons and firms whose decisions generate the externalities neither bear the costs of the pollution nor have to compensate those who do bear them. While a market economy is equipped to handle market transactions between buyers and sellers of commodities and services, it is not well suited to account for and measure the third party effects (diseconomies) from pollution, a by-product of market transactions.

Policy alternatives devised to control pollution include: direct regulation of input technology and pollution levels, effluent or emission fees to serve as economic disincentives to induce technological change, compensation to injured parties or use of compensation payments to seek alternate means to reduce emissions, and public subsidies of pollution abating technologies to encourage their use. Legislating and administering effective and flexible environmental controls, which are consistent with public desire on the one hand, while encouraging agricultural and industrial efficiency and market competition on the other, is a task of no small magnitude. Trade offs between economic efficiency, market concentration, employment, environmental quality, income distribution, and personal freedoms become the hard choices.

In the case of the Willamette Valley grass seed industry the desired level of environmental quality is made more complex in that a simple inverse trade-off between improved air quality and economic well-being of the industry does not exist. Although known for air pollution, the grass seed industry also provides positive environmental effects on water quality through low levels of soil erosion on hillside lands, lower levels of dust emissions throughout the year which are more common with other crops and a buffer from urban/industrial development.

## **Smoke Management**

Smoke management was the first tool applied to begin addressing the public problem of air pollution from field burning. No systematic effort to manage smoke existed before the 1960's. During the early 1960's, the U.S. Weather Bureau issued public advisories for agricultural burning. These advisories included the degree of atmospheric stability and the likelihood of good smoke dispersal. Farmers interpreted the advisories before arranging their burning programs. Post-harvest burning of grass seed straw was regulated only by local fire districts based on need for fire safety.

The 1967 Oregon Legislature gave the Oregon Sanitary Authority (now the Department of Environmental Quality) advisory power to recommend where field burning was to be done. The 1969 legislature granted the Sanitary Authority the power to limit the amount of field burning on marginal days.

In 1971 the legislature granted permanent authority to the DEQ to enforce and regulate a statewide environmental program, including control over field burning by limiting the amount of burning on marginal days. The Federal Environmental Protection Agency endorsed the Oregon control measures. Meteorological monitoring, daily acreage quotas, and an aerial observer were components of the initial DEQ program. The 1971 legislature also established June 1, 1975 as the date after which field burning would be prohibited. A burning permit system was established with a \$0.50 per acre fee assessed.

In the 1973 legislative session, the burning permit fee was increased to \$1.00 per acre with an equal amount matched from state funds to be used for research and development, after \$0.10 per acre was set aside for operation of the smoke management program. Experience and improved techniques of smoke management reduced the intrusion of smoke into major population centers in western Oregon.

The 1973 law established a five-member committee to direct the R&D program funded by the acreage burning fees. The program was focused primarily toward development of an acceptable mobile

field sanitizer. Secondary objectives included effective methods of straw removal from fields to be sanitized and research on uses for grass straw.

The 1975 legislature replaced the June 1, 1975 ban on field burning with a phase-down system scheduled to progressively reduce the allowed field burning from 285,000 acres burned under the 1974 regulation to 50,000 acres in 1978 and adopted a system of increased fees.

The 1977 legislature modified the 1975 phase-down to 195,000 acres and 180,000 acres respectively for maximum open burn limits for 1977 and 1978.

In 1979, the Legislature replaced the phase-down program with a 250,000-acre limitation with authority vested in the DEQ to set daily acreage quotas after 1978 in accordance with state and federal air quality standards. Burning of small grain straw and stubble in the Willamette Valley was prohibited except when a field was being prepared for establishment of a small seeded grass or legume crop. A \$3.50 per acre fee was established for burning. Funds were to be used for DEQ smoke management and to support a research program. An advisory committee was established to assist in developing a research program in smoke management, alternative forms of field sanitation, straw utilization, alternative crops, and health effects.

Throughout this period, the limitations on open burning applied only to field burning in the Willamette Valley counties. Areas of central and eastern Oregon were excluded. These areas adopted voluntary burning control programs designed to limit burning on days with atmospheric conditions that restricted smoke dispersal or affected populated areas.

From 1980 through 1987 the smoke management program was conducted by the DEQ and the Oregon Seed Council. The Council was responsible for grower training, radio communication, meteorological evaluation, and operation of the skywatch plane. Following a program review in 1987, most of the Seed Council technical functions in the program were transferred to the Oregon Department of Agriculture in 1988.

The Willamette Valley Field Burning Program provides for direct control of field burning according to prevailing weather conditions and existing air quality. Areas for burning are chosen primarily on the basis of wind direction and atmospheric dispersion or ventilation capacity with the objectives of avoiding direct smoke impact on highly populated areas while minimizing, to the extent possible, ground level concentrations of smoke in other areas. To reduce the possibility of residual smoke problems and nighttime drainage of smoke back into the Valley, significant levels of burning are contemplated only when favorable weather conditions are expected to be sustained.

On the basis of current and forecast weather conditions, the DEQ designates the times, amounts, and places of burning on a continuous basis each day so as to provide for a maximum amount of burning under optimum dispersion conditions. To facilitate geographical control of burning, the Valley is divided into approximately 60 control zones. Burning authorizations are made on a continuous basis to fire district permit agents over a radio network. These burning authorizations include the quantity of burning allowed in specific control zones for specific periods of time.

Continuous aerial and ground based observations of burning progress and smoke drift coupled with frequent updates of weather observations and forecasts are used to tailor burning activity to weather conditions and to avoid serious or prolonged smoke impacts on populated areas. In the event of unfavorable changes in weather or smoke behavior, directories are made by radio to fire district permit agents that may require them to cease or curtail permit issuance and also may require that growers discontinue the lighting of fields. Permit holders are required to monitor the field burning radio frequency at all times during the burning operation and must comply with all directives.

#### *Current Regulations for Field Burning*

Field burning regulations have been approved by the federal Environmental Protection Agency (EPA) as complying with federal Clean Air Act requirements. The following is a brief summary of the major regulatory provisions set forth by statute and administrative rule for the Willamette Valley:

1. A maximum of 250,000 acres may be open burned annually in accordance with daily smoke management restrictions. No more than 46,934 acres may be open burned in a single day in the south Valley counties of Linn, Lane, and Benton (under southerly winds).

2. Cereal grain acreage may be open burned only when preparing the field for planting a seed crop the following year.
3. No burning is allowed when the atmospheric mixing height is less than 2,000 feet and average winds are less than 5 knots. Burning also is prohibited in areas which might aggravate down-wind pollutant levels projected to exceed federal standards.
4. Burning is limited in any area when relative humidity exceeds 65% under southerly winds and 50% under northerly winds, except for test fires.
5. Burning is limited for up to four consecutive "drying" days following each 0.1 inch rainfall.
6. Burning of acreage in and around major cities, highways and airports is carefully managed to avoid direct intrusions.
7. A "performance standard" is in place for Eugene/Springfield area such that minimum ventilation criteria for burning become more stringent if and when the cumulative hours of smoke impact increase above an allowable level of 14 hours.
8. Civil penalties for illegal field burning generally range from minimum amounts of \$500 for burning without registration or permit, \$300 for burning at unauthorized times, and \$200 for burning without monitoring the field burning radio network. The maximum penalty for each violation is \$10,000.
9. Special provisions allow for experimental burning and emergency burning for reasons of economic hardship.
10. Tax credits are available for the use or installation of alternative field sanitation facilities such as propane flammes or equipment used to collect and process straw into marketable products.

#### *Visibility Protection Plan*

In 1980, the EPA established rules requiring states to protect visibility in Federal Class I areas. The rule requires states to "develop programs to assure reasonable progress toward meeting the national goal of preventing any future and remedying any existing impairment of visibility in mandatory Class I areas within which impairment results from man-made air pollution." Oregon has 12 Class I areas which consist of 11 wilderness areas (principally along the crest of the Cascades) and Crater Lake National Park.

Control strategies to remedy impairment from field and slash burning were adopted by Oregon's Environmental Control Commission (EQC) on October 24, 1986. With regard to field burning the new regulations took effect in 1987, prohibiting burning on weekends during the July 4 through Labor Day period upwind of the Class I areas. There is an exception for weekend days when there is already natural visibility impairment there such as clouds, fog, or rain. There is also an emergency clause which allows the Director of DEQ to modify the restrictions under unusual and severe hardship conditions. The rules adopted for slash burning are similar. Control strategies will be re-evaluated in 1989.

#### *Current Regulations for Propane Flaming*

DEQ regulations formally recognize propane flaming as an approved (less-polluting) alternative to open-field burning. Fields must be properly prepared (i.e., loose straw removed, stubble cut) before propane flaming, and the remaining material cannot sustain an open fire. But once these requirements are met, a grower may conduct propane flaming on any day, in any location, and on any number of acres, providing the DEQ does not prohibit it due to adverse atmospheric conditions or air quality. Propane flaming is exempt from all of the requirements related to registration, permits, and fees which apply to open-field burning. The limited controls on propane flaming, its effectiveness as a field sanitation method, and the increased demand for straw have helped to offset its somewhat higher costs and make it an attractive alternative for a substantial number of growers.

Current rules for propane flaming are as follows:

1. DEQ shall prohibit propane flaming under adverse meteorological or air quality conditions.
2. Propane flaming hours shall be 9 a.m. to one hour before sunset in July and August, and 9 a.m. to one-half hour before sunset in September.

3. Growers shall operate propane flammers in overlapping strips, crosswise to the prevailing wind, beginning along the downwind edge of the field.
4. Propane flammers must be designed such that a) flamer nozzles are no more than 15 inches apart, and b) a heat deflecting hood must extend a minimum of three feet beyond the last row of nozzles.
5. The loose straw must be removed from the field.
6. The remaining field stubble must be chopped or cut close to the ground and removed to the extent practicable.
7. The remaining field residue must not sustain an open fire.
8. A fire permit must be obtained from the fire district.

#### *Additional Restrictions in August 1988*

Following the tragic accident on I-5 south of Albany on August 3, 1988, the state imposed an eight day ban on field burning pending a program review. After the review, additional restrictions were placed on burning. One involved the addition of fire safety buffer zones surrounding I-5 and six additional designated major highways. The zones extend as a one-half mile corridor on each side of I-5 and one-quarter mile on each side of the other 6 highways. Within the buffer zones a one-fourth mile wide noncombustible ground surface zone between the field to be burned and the nearest right-of-way of I-5 is required for field burning to be allowed. The ground surface zone is one-eighth mile on the six designated major highways.

A further set of restrictions were implemented affecting all grass seed production in the Valley:

1. All burning in the Valley will be banned when two of the following three conditions exist: temperature of 95°F or above, relative humidity of 30% or below, and wind speed of 15 miles per hour or higher.
2. Twenty-foot noncombustible barriers around the field to be burned are required.
3. Two to four water tank vehicles with specified tank capacities, as pump capacity, and recharge capability determined by field size are required.
4. Radio communication between vehicles at the burn site and a manned station with telephone link to emergency response agencies is required.
5. Staffed fire safety watch at field perimeters prior to igniting and to continue one hour after open flame ceases is required.

Similar rules as listed above shall apply to propane flaming except that the noncombustible barrier around the field to be burned is a 10 foot strip and one or more water tank vehicles with a minimum total capacity of 500 gallons shall be on site.

## CHAPTER 3

### THE SEARCH FOR SOLUTIONS

The field burning permit fee system initiated in 1971 has continued to the present. The grower fee system has been used to pay the administrative cost of the regulatory smoke management program discussed in the previous chapter and to establish a research and development program to seek viable alternatives to open-field burning. All of the smoke management program and more than 75% of the research and development funds have come from the self-sustaining grower fee program. The smoke management program comprised of the field burning operation, fire district payments, smoke management support services, and lab operations for monitoring and regional enforcement have taken 50 to 60% of total grower fees. This has averaged about \$550,000 annually during the past decade.

The research and development expenditures over the past 17 years total nearly \$7 million. Current annual R&D activities average from \$250,000 to \$350,000. Use of those funds by project category are detailed chronologically in Appendix B. Overall dollar allocation was about \$1.9 million in search of alternative sanitation measures, \$1.5 million for straw utilization, \$1.3 million for alternative crops and \$300,000 on health effects. Private and public coordination of research and development (R&D) related to field burning has occurred since at least 1968.

From 1968 through 1970 management and R&D advisory was through an Oregon Seed Council Five-Member Research Committee. In 1971 program management and R&D advisory work were separated with hiring of a consulting engineer for program management. R&D management continued with this mode of operation through 1976 (Odell, 1974).

In 1977 the Legislature transferred responsibility for field burning to the DEQ and created a Five-Member Advisory Committee on Field Burning to aid DEQ in conducting the R&D portion of the program.

Three subcommittees were organized in 1977-78 to help the Advisory Committee and DEQ address air quality monitoring, health effects, and R&D planning. Subsequent reorganizations and consolidation of the subcommittees evolved into the single Five-Member Technical Subcommittee which currently serves the Advisory Committee.

The purpose of the DEQ Advisory Committee on Field Burning is to advise and assist the Department of Environmental Quality in the research, development, and application of feasible alternatives to the practice of open-field burning, including but not limited to the following areas (no order of preference):

1. Utilizing and marketing of crop residue.
2. Developing alternate crops.
3. Improving air quality and smoke management.
4. Alternative methods of field sanitization including the economic, agronomic and environmental effects of mobile burners and other methods.
5. Alternative weed, pest, and disease controls.
6. Health effects of open-field burning.

## CHAPTER 4

### RESEARCH ON ALTERNATIVES TO BURNING

#### THERMAL SANITATION ALTERNATIVES

Thermal sanitation alternatives to open-field burning developed to date have been in the form of machine sanitizers.

##### Field sanitizers

Research funds were first directed toward development of a machine to burn residues in 1969. OSU agricultural engineers constructed several designs and ran extensive field tests in cooperation with the Department of Crop Science to evaluate the quality of the thermal treatment at the soil surface and to determine temperature limits so perennial grass crops would not be damaged.

During 1970, two stationary pilot test machines were built and tested. The initial concept was to use the machines for straw disposal as well as field sanitation. However, this approach was modified when tests showed that speed of operation was slowed because of the excessive heat produced by burning all of the straw. Youngberg, Chilcote, and Kirk (1975) found that removing all the straw and leaving only stubble provided enough fuel for field sanitation by machine burning. It was found that the sanitizer provided a more uniform heat treatment than open-field burn, with damage to the crop occurring only when extremely high temperatures were used.

Field experience in 1970, 1971, and 1972 demonstrated the need for a heat resistant firebox liner design. Various materials were tested with little success. Later models tested used a single wall construction, metal shingle design which provided unrestricted natural convective and radiation heat transfer. After more than 200 hours of field operation, inexpensive chromized mild steel and various grades of stainless steel showed little sign of deterioration.

Drawings, specifications, and performance data were supplied to three engineering consulting firms hired by the Field Burning Committee to refine the three basic machines in use in 1973, and to design an improved propane flaming device. Four machines were built by commercial shops incorporating a ceramic liner and single wall construction, with a forced vortex and regenerative burning concept. These were tested during the 1974 burning season.

In evaluating the field sanitizer, agronomists found the most effective burn treatments were made during the mid-summer season when the perennial plants are dormant. Sanitizer treatments late in the season (after the plant's regrowth had been initiated) increased plant mortality and reduced regrowth and seed production as did late open-field burning.

Overall, research indicated that the sanitizer was capable of thorough removal of residue around and on the plant crown over a moderate range of field conditions without serious injury to the plant. Temperatures of more than 1,000°F at the soil surface for short periods were recorded without seriously affecting plant survival and seed yield in the following year.

Sanitizer development was discontinued following a technical and economic evaluation of the machines by the Engineered Systems Division of FMC Corp (FMC Corporation, 1978). The report, commissioned by the DEQ, concluded that because of problems with short machine life, high operating cost, energy use, effective emission control, and slow operating speed, the field sanitizer was not an economical alternative to open-field burning.

##### Propane Flaming

Propane flammers built for use on mint fields were turned to for consideration in the mid-1970's. Propane flaming resulted in seed yields equal to open-field burning (Chilcote and Youngberg, 1975). Straw and stubble must be removed for this technique to be effective. No attempt was made to evaluate if the temperature developed by propane flaming was sufficient to destroy disease organisms under field conditions. However, studies in annual ryegrass showed that the temperature and duration of propane flaming was not able to destroy many of the weed seeds, whose survival was reflected by an increase in weed infestation.

Cost of propane flaming is influenced by speed of operation and has been shown to range between \$32.00 per acre at 1 mph and \$8.00 per acre at 4 mph (Youngberg *et al.*, 1984). Increasing the amount of residue allows for faster operating speeds but results in increased emissions. More complete stubble removal in advance of propane flaming requires slower operating speed to achieve good sanitation.

Propane flaming with residue removal as a companion practice is being used by an increasing number of growers, especially in the North Valley. An estimated 56,000 acres were sanitized by propane flaming in 1988 (T.L. Cross, personal communication).

## **SEED PRODUCTION WITHOUT THERMAL SANITATION**

Early studies of seed production without thermal sanitation focused on the effects of non-burning methods, and provided an explanation of the burning effect (Chilcote, *et al.*, 1980). Generally, mechanical removal of the straw reduced seed yield when compared with open burning. Also, weed problems were intensified in both perennial and annual grasses (Chilcote and Youngberg, 1975). However, the extent of loss depended on crop species, soil conditions, and age of stand.

### **Mechanical Straw Removal**

Several mechanical removal techniques have been studied:

1. Raking the straw (leaving remaining stubble intact).
2. Flail-chop removal of a major portion of the straw and stubble.
3. Close clip removal of most stubble and organic material on the soil surface.
4. Soil incorporation of the residue in annual ryegrass production.

An evaluation of six species showed that leaving all of the straw in the field lowered seed yield an average of 48%; raking was little better than no removal (Chilcote and Youngberg, 1975). Flail-chopping to remove additional stubble was somewhat better than raking, suggesting that the greater the degree of residue removal the higher seed yield in the subsequent harvest. The physiological response (plant growth and seed yield) to mechanical residue removal varied with the species, variety, and thoroughness of removal. Early studies showed Chewings fescue, red fescue, and Highland bentgrass usually showed greater need for burning than did bluegrass, perennial ryegrass, and orchardgrass. Researchers also observed that age of stand will influence response to non-burning treatment. In the absence of burning, the yield from older grass stands was reduced more than from young grass stands.

In annual ryegrass, seeding through straw and stubble using specialized drills was not successful. However, stands were established by drilling through stubble following mechanical removal of straw (Chilcote and Youngberg, 1975). Results from a subsequent study investigating residue management and seeding method over five years, found no significant yield difference between annual burning followed by sod seeding, and incorporation of straw residue into the soil prior to seeding (Young, *et al.*, 1984a).

When annual ryegrass fields are not burned, weed control problems increase. Non-selective pre-plant chemical weed control was partially successful in reducing weeds in annual ryegrass. This technique is not effective unless early fall rains occur because it relies on moisture to germinate weed seeds prior to seeding. A herbicide which selectively controls annual grass weeds in annual ryegrass is available but is effective only if crop residues are completely removed mechanically or are incorporated by tillage operations before application of the chemical.

### **Close-clip Stubble Removal**

Complete physical removal of crop residue by close clipping and sweeping was first evaluated in red fescue (Chilcote *et al.*, 1974). Seed yields of the close-clipped and burned treatments were significantly greater than less complete mechanical removal. These data support the hypothesis that the effect of burning on seed yield is due to the elimination of older, non-reproductive tillers and removal of residue, which allows for new tiller development at the soil surface.

Field testing of a prototype machine designed for close clipping and residue removal by vacuum (crew cutting) was shown to be an effective treatment for approximating the physiological response of burning (Youngberg, 1977). However, maintaining seed yield was only partially successful on some species. Stub-



ble and chaff were effectively removed from perennial ryegrass, tall fescue, and orchardgrass. In Kentucky bluegrass the chaff was removed, but some stubble remained. Fine fescues presented a special problem because the stubble left by the windrower lays flat and close to the soil, making it difficult to clean up around the plant crown.

Straw residue must first be removed from the field before close-clip machines can operate, and fields must be smooth and free of ridges to be satisfactorily treated. Rocks presented another serious problem as they were thrown a considerable distance when struck by the cutting knives. This operation causes air pollution with soil and chaff particles released in the air. The residue removed from the field represents a solid waste.

Evaluation of the close-clip technique in a four-year study comparing flail chopping and crew cutting in perennial ryegrass showed no clear advantage for the more complete stubble removal treatment. When compared with annual burning, the average seed yield of non-thermal treatments was 15% less over four years. Results of similar tests in fine fescue and Kentucky bluegrass found a slight advantage for crew cutting when compared to flail chopping. On these two species crew-cutting was capable of maintaining seed yield equal to burning through three years of testing. Thus, some perennial grasses are more tolerant in terms of subsequent seed yield to mechanical removal techniques than others (Young *et al.*, 1984b).

### **Chemical Treatments**

Chemical treatments have the decided disadvantage of requiring EPA registration and approval for use, a costly and time consuming process. Few chemicals currently are approved for use, especially when the straw residue is marketed for livestock feed. Concern about chemicals in groundwater and surface runoff also may restrict their use. An additional factor restricting the role of chemicals is that carbon ash associated with continuous open burning has been found to reduce the effectiveness of chemical pesticides, an issue which might disappear under a no burn regime.

Chemical treatments for pest and disease control were initiated in the early 1980s. Monocarbamide dihydrogensulfate (Enquik<sup>R</sup>), a urea-sulfuric acid reaction product applied at 12 to 15 gallons per acre during mid-October, has shown some potential for reducing fall germinating grass seedling (weeds), increased effectiveness of specific herbicides, and accelerating decomposition of old crown growth left at harvest. Results vary with grass species and weather conditions. Additional research is needed to define the role of this product as an alternative for thermal sanitation.

### **Shorter Crop Rotation**

The beneficial effects of burning on plant development and seed yield are greater on older fields than on younger stands. Therefore, a shorter perennial crop rotation may be necessary in perennial grass species if thermal sanitation is restricted. Perennial grass seeds historically have grown up to 10 to 12 years as a single stand without re-establishment. This has been reduced to about five years for proprietary varieties grown under contract. Shortening the rotation appears to decrease the known incidence of disease and pests.

Except for the ryegrasses, spring and late-fall planted grass species do not produce a seed crop during the establishment year. Loss of a year's income every time a new crop is established will become more critical as rotations become shorter. One possible solution is to establish grass seed crops with cereal or other companion crops during the establishment year. Studies with some grass species on well-drained soils have shown that the use of cereal companion crops will provide a cash income during the year of establishment (Appendix D). However, this system has not been evaluated on heavy, wet, clay soils.

### **Soil Incorporation of Straw in Annual Ryegrass**

In establishing annual ryegrass fields it is necessary to chop the straw from the previous crop before plowing it into the soil because whole straw decomposes very slowly. Agronomic trials in 1984 showed that seed yield from open burning and annual incorporation of straw were comparable when 80 pounds of nitrogen per acre was applied in the spring (Jackson and Christensen, 1985). However, the plow down treatment represents a definite increase in production cost. In addition, soil incorporation of weed seed in the residue intensifies weed management problems, increases cost for weed control, and increases the risk

of lower product quality in the marketplace. The extent to which diseases can be controlled through tillage is unknown.

### **ALTERNATING OPEN-FIELD BURNING WITH MECHANICAL REMOVAL**

In an attempt to combine the benefit of burning, but reduce the total amount of burning required, studies were conducted alternating one or two years of mechanical straw removal with one year of burning. A reduction in seed yield is realized compared to annual burning, but results were superior to continuous mechanical removal techniques (Chilcote and Youngberg, 1975).

Subsequently, less than annual burning studies investigated the possibility of alternating various combinations of burning and mechanical removal techniques over a period of several years. In perennial ryegrass, alternating burning with mechanical straw and stubble removal through four years produced seed yields averaging 93% of annual burning regardless of whether plots were crew cut or flail chopped during the non-burning year. No deleterious effects on seed yield were reported for fine fescue or bluegrass when averaged over three years (Young, *et al.*, 1984c).

### **CONTROL OF PESTS AND DISEASES**

Over 400 diseases in 63 host species in the United States have been listed for annual and perennial forage grasses and turfgrasses (U.S. Department of Agriculture, 1960). In most years, inocula for many of these pathogens are not present in sufficient amount, or environmental conditions limit disease development. Diseases that have caused frequent loss in Oregon and have been controlled by field burning are listed below.

#### **Disease Control**

##### *Blind Seed Disease (Gloeotinia temulenta)*

Blind seed was first reported in Oregon on perennial ryegrass and 15 other grass species in 1944 (Fischer, 1944). The disease was believed to have been introduced ca. 1940 in infected seed imported from New Zealand (Hardison, 1948) where the disease was well established (Hyde, 1938). By 1943, 25% of the total perennial ryegrass crop from the Willamette Valley had germination less than 85% as a result of a rapid, epidemic increase in blind seed disease (Hardison, 1948).

Comprehensive disease control studies were conducted in Oregon between 1943 and 1946 (Hardison, 1948). In 1944, a seed inspection and field recommendation program was established. Based on the level of disease determined from seed lot testing, the following controls were suggested for established fields: plow diseased fields; remove light seed from the fields during combining; open-burn as a temporary remedy; prevent heading of perennial ryegrass in pastures until after July; and destroy ryegrass screenings (Hardison, 1948, 1949). Recommendations for new seed fields were to use disease-free seed and to plant seed at least one-half inch deep. Additional recommendations were to plow, prepare good seed beds, and remove the crop after two seed crops.

The few fields that were burned merely for straw removal between 1943 and 1946 were studied; burning was found to provide excellent control of blind seed disease (Hardison, 1948). Following disease control recommendations in 1944 to 1947 reduced the incidence of blind seed in seed inspections. Failure to follow control recommendations in 1947 resulted in an increase in the number of severely diseased fields in 1948 (Hardison, 1949).

In 1948 a few of the perennial ryegrass fields were burned. The burning of perennial ryegrass fields was recommended as a general practice after the 1948 harvest. Blind seed control in 1949 was attributed to removal of light-weight seed and either plowing or burning diseased fields (Hardison, 1957). Burning tall fescue fields was recommended and adopted beginning in 1949.

Field observations (Hardison, 1948) suggested that disease control measures used between 1943 and 1949 were effective in reducing and controlling blind seed disease of perennial and annual ryegrass. Blind seed disease was not thought to be as serious a disease in orchardgrass, bluegrass, or bentgrass as it was in the ryegrasses (Hardison, 1962, 1976, 1980).

Recent studies of straw management practices (crew-cut, bale, and propane flaming) as alternatives to burning have not been evaluated for their effectiveness in managing the incidence of blind seed disease

in any grass species. Other methods of disease control such as chemicals have been ineffective in controlling blind seed in the field (Hardison, 1980). Urea-sulfuric acid reaction products (Enquik<sup>R</sup>) have been suggested for control (Hardison, 1987) but additional studies are necessary to evaluate the field efficacy of these materials.

#### *Ergot (Claviceps purpurea and Claviceps spp.)*

Ergot is one of the first plant diseases identified by humans. It occurs throughout temperate region countries and over 400 species of grasses are listed as susceptible to ergot (Bovine, 1970). All perennial grasses grown for seed in the Willamette Valley are susceptible to ergot (Hardison, 1962, 1980). Ergot is well recognized as a serious disease, capable of causing nearly total crop loss. Hardison (1980) described ergot as "probably the most serious of the grass seed diseases." The toxic properties of ergot have been known for centuries, and ergot poisoning of humans and animals has been documented in ancient and modern literature (Bovine, 1970).

A disease survey of the Willamette Valley during 1988 by the USDA (S.C. Alderman, personal communication) revealed ergot was widespread throughout the region on wild grasses surrounding seed production fields. These ergot-infected weed grasses are an important source of inoculum (Connors, 1953, 1956; Futrell and Webster, 1966; Harper and Seaman, 1980; Mantle and Shaw, 1977).

Grasses are susceptible to ergot infection only during the flowering period. Mowing or spraying grasses near production fields to prevent or delay development of ergot until after flowering in the seed crop has been cited as an important measure of disease control (Bretag and Merriman, 1981; Campbell and Freisen, 1959). Effective management of ergot also includes planting clean seed, deep planting of seed, rotating crops, and deep plowing (Bretag and Merriman, 1981; Weniger, 1924). Destroying infected fields by deep plowing is especially effective in lowering the effective or viable inoculum in infested fields (Bretag, 1985; Bretag and Merriman, 1981).

Several fungi have been documented as potential biological control agents (Cunfer, 1975; Gay and Shattock, 1980; Hornok and Walcz, 1983; Mower *et al.*, 1975). Conditions most favorable for the activity of hyperparasites are those most favorable for ergot development. However, toxicological and pathological tests need to be carried out before field application of the agents because the antagonists are known to produce chemicals toxic to mammals or to incite plant diseases in grasses or other crops (Mower *et al.*, 1975).

No effective fungicides are commercially available to economically control ergot (Cagas, 1986; Hardison, 1974, 1977a, 1977b). However, urea-sulfuric acid reaction products have been suggested as a means of ergot control (Hardison, 1987). Propane flaming may be inadequate for control of ergot (Hardison, unpublished).

#### *Seed Gall Nematode (Anguina agrostis)*

Seed gall nematode was believed to have been introduced into the Pacific Northwest before 1952 in imported seed (Courtney and Howell, 1952). The nematode has caused serious (total) losses of seed crops of creeping and colonial bentgrasses and of fine leaf fescues. Seed gall nematode was reported scattered throughout the Willamette Valley (Jensen, 1961).

Control of the seed gall nematode was evaluated in a comprehensive study by Courtney and Howell (1952). Bentgrasses were found to be especially susceptible to the nematode. They reported that the nematode from bentgrass did not increase on creeping timothy, Chewings fescue, creeping fescue, Kentucky bluegrass, annual bluegrass, velvet grass, and sweet vernal grass. However, Hardison (1946; 1980) and Jensen (1961) report Chewings fescue as very susceptible to seed gall nematode. Severe losses were observed in Chewings fescue seed crops in Clackamas County in the mid-1950's (R. Warren, personal communication).

Control measures for the seed gall nematode included planting nematode-free seed, rotating crops or practicing clean fallow, and preventing movement of galls from infected fields to clean fields. Courtney and Howell (1952) reported that the nematode cannot survive in moist soil for more than one year without a host plant. Apt *et al.* (1960) demonstrated that herbicides used to prevent flowering of bentgrass for one season were effective in breaking the life cycle of the nematode in that crop, but this would result in

loss of the seed crop. Burning was cited by Hardison (1980) as providing partial control of the nematode in colonial bentgrass and good control in Chewings and red fescue.

### *Foliar Diseases*

Foliar fungus diseases frequently found in fields include leafspots and stem blights caused by species of *Drechslera* in species of ryegrass (*Lolium* spp.), Kentucky bluegrass (*Poa* spp.), and fescue (*Festuca* spp.); *Rhynchosporium* which causes scald in species of orchardgrass (*Dactylis*), ryegrass and fescue; and *Septoria* which causes blight in species of bluegrass and fescue. The more important rust diseases include stem rust (*Puccinia graminis*) in perennial ryegrass, tall fescue, orchardgrass and Kentucky bluegrass (*P. pratensis*); stripe rust (*P. striiformis*) in Kentucky bluegrass and orchardgrass; crown rust (*P. coronata*) in tall fescue; and leaf rust (*P. recondita*) in perennial ryegrass and annual ryegrass, timothy and tall fescue. Although field burning destroys much of the current season inocula of these diseases, no quantitative data exist on the effect of burning on disease outbreaks in subsequent crops.

Fungicides have been studied continuously for major foliar disease control since 1944. Most serious foliar pathogens are controlled by fungicide application (Hardison, 1963, 1975; and Welty, 1986, 1987a, 1987b).

### **Insect Control**

Insect pests of grass seed crops can be divided into two groups based on their feeding habits: those that feed on the foliage and those that feed on the crown and roots.

#### *Insect Pest of the Foliage*

Aphids, thrips, leafhoppers, stem borers, plant bugs, and certain cutworms use the grass foliage as food or oviposition sites. Plant bugs, thrips, and stem borers feed on grass stems injuring the culm which in turn causes a partial or entirely white, sterile inflorescence. This condition is usually caused by plant bugs which lay their eggs in grass stems. Burning destroys the stems and thereby keeps the plant bug populations in check (Kamm, 1979). Plant bugs can also be controlled by grazing or mechanical removal of crop residue (Kamm, 1971; Kamm and Fuxa, 1977). However, several important insect pests require other control methods to reduce economic loss caused by insects feeding on the foliage.

#### *Insect Pests of the Crown and Roots*

Cutworms, billbugs, sod webworms, wireworms, March flies, and symphylans feed in the plant crown or on the roots. In general, crown or soil pests are not directly affected by the heat of field burning and are difficult to control with insecticides. Control of these insects requires multiple tactics in an integrated pest management program.

Billbug and sod webworm populations in orchardgrass seed fields were found to suffer no mortality during field burning (Kamm, unpublished). In 1987 growers reported an apparent failure of certain insecticides to control billbugs. Studies revealed the reduced efficacy was due to adsorption of the insecticide by carbon ash residue from field burning. Efficacy of the insecticide ranged from 95% on fields burned for three years to 15% on fields burned for 12 years. Subsequent tests indicated that activity of chlorpyrifos, diazinon, fonofos, dimethoate, and fenvalerate was significantly reduced by adsorption on carbon ash when compared with soil treatments without carbon.

Straw residue must be removed from the field for insect control because unburned straw residue remaining in the field harbors certain insects and reduces insecticide activity by intercepting sprays. On the other hand, straw residues might harbor beneficial insects for biological control of insect pests.

Field burning of crop residues destroys oviposition sites of some insects and controls foliar feeding insects such as plant bugs and stem borers. Alternative methods of control by straw removal or properly timed insecticide applications also have been shown to be effective in controlling some insects. Crown- or root-dwelling insects are not directly affected by field burning and ash residue often adsorbs and reduces insecticide efficacy. Multiple control and monitoring programs are necessary to control soil and crown-feeding insect pests.

## **Weed Control**

Weed control in grass seed fields is dependent upon reduction of the potential weed population (weed seeds) and creating the best condition for control of weed seedlings. Field burning affects weed control in grass seed fields primarily by physical destruction of weed seeds, and by changing herbicide behavior resulting from conversion of large quantities of crop residue into carbon ash.

Even a small amount of crop residue remaining after straw is removed has a significant impact on weed control. The effectiveness of propane flaming for weed control after mechanical straw removal has been found to vary greatly with speed of travel and amount of dry residue remaining. Weed seeds often survive propane flaming under conditions designed to minimize cost, time, and smoke production.

### *Negative Impact of Ash on Weed Control*

Herbicides will adsorb to both unburned crop residues on the soil surface and carbon residue left after field burning. In either case, the movement of the herbicide into the soil, where herbicidal activity occurs, is delayed or prevented.

Carbon and ash remaining on the soil surface after open-field burning has been shown to have a negative impact on the effectiveness of many herbicides (G.W. Mueller-Warrant, personal communication). Herbicide labels have generally recommended delay of application until rainfall has washed the carbon residue into the soil. Adsorptivity of the ash once in the soil has not been quantified, but anecdotal evidence suggests that the soil environment in older, annually-burned fields may impair herbicide performance.

### *Weed Control in the Absence of Burning*

When all the residue is left on the field, the straw creates a physical and chemical barrier to herbicides sprayed over the field. Therefore, some type of mechanical residue removal must be practiced for effective weed control.

Methods to control weeds in grass seed fields without open-field burning and after straw removal must be based on certain assumptions and conditions. The severity of both these problems is a function of the amount of residue remaining.

1. **The remaining stubble is burned with a propane flamer.** The ash residue following propane flaming is less than after an open burn of all straw. While the number of weed and crop seed surviving baling and propane flaming may be greater, improved herbicide performance brought about by reduced ash levels might offset the greater weed population. Under this condition, successful weed control may require little more than minor changes in herbicide practices. However, if propane flaming is not practiced, then weed control becomes a much more difficult problem.

2. **Complete absence of burning or propane flaming.** Without some burning or flaming, the residue remaining after mechanical straw removal causes two significant problems. First, it acts as a physical and chemical barrier to herbicides sprayed over the field, delays or completely prevents movement into the soil, thus reducing the effective concentration in the soil solution. Using herbicides with higher water solubility and lower affinity for organic matter to minimize the effect of the residue barrier might overcome the barrier effect. However, this action could increase the tendency to more rapidly leach the herbicide through the soil profile into the crop root zone and out of the zone of weed seed germination zone before the end of the growing season. This would also reduce weed control and increase risk of crop injury. Second, residues left on the soil surface create micro-environments favoring rapid weed seed germination. Weeds germinating under these conditions may achieve considerable size and an advanced development stage before herbicides finally reach them. Effectiveness of many herbicides is highly dependent on weed size at time of contact--smaller weeds are more susceptible. Herbicides used for grass seed weed control in western Oregon (atrazine, diuron, ethofumesate, and chlorpropham) require uptake at or before critical weed plant growth development stages.

Additional restriction or complete prohibition of burning or propane flaming reduces the means to control weeds and other pests and will necessitate additional use of pesticides and registration of new ones. The current system for pesticide registration is complex, slow, and expensive. This discourages labeling of chemicals for use on minor crops, such as grasses grown for seed. In order to obtain new regis-

trations to control pests in the absence of burning, funds must be made available to perform the pesticide residue analyses needed for minor crop registration and secure collaboration from the manufacturers.

Basic studies are needed compare the tendency to adsorb herbicides (or the ability to control weeds) between carbon ash left after field burning and various quantities of unburned residues left after mechanical removal of straw.

### **PLANT BREEDING AND FIELD BURNING**

New varieties of forage and turf grass, particularly proprietary varieties, have been released at a high rate during the 1980's (Barker and Kalton, 1988). New varieties have improved forage and turf quality and resistance to plant pests and diseases. However, varieties with high quality or resistance to plant pests have largely been developed in and for the geographic regions where they are used for forage or turf. Usually, diseases and pests in these regions are neither the same nor have the same effect as these problems in the Oregon seed production region. Thus, there is considerable susceptibility to attack by pathogens and insects when the seed crop faces longer exposure because they must remain in the field through physiological maturity.

There has been no forage or turf breeding for development of public varieties by OSU or the USDA-ARS scientists in Oregon in the past decade. Recently many private seed companies have developed active plant breeding programs in the Willamette Valley. Seed yield *per se* has become an important selection criterion resulting in release of varieties with higher seed production potential. This has been particularly pronounced with several turf-type tall fescue and perennial ryegrass varieties which had been adopted rapidly. However, the primary focus of current programs is still on evaluation of varieties and experimental lines developed in and for regions of use outside Oregon.

Breeding of forage or turfgrasses for disease and plant pest resistance during seed production has not been given a high priority because most pests were adequately controlled by cultural practices (including burning and pesticides). Standard plant breeding practices, even in the regions of end-use, have used an annual clean up of residue in selection nurseries and evaluation plots. Selection pressure for low maintenance or no residue management has been used only to a limited extent. In turf species such as Kentucky bluegrass and hard fescue (*Festuca longifolia* Thuill.), selection under low maintenance has resulted in steminess and a decrease in leaves. These traits are opposite to those desired for high turf quality and would not be acceptable in commercial markets.

### **SEED CERTIFICATION AND FIELD BURNING**

Protecting the genetic purity and quality of Oregon grown grass seed of public and proprietary varieties is the purpose of the Oregon Seed Certification Program. Minimum standards for genetic quality in certified seed are established by Federal Seed Law. The number of volunteer plants surviving after harvest of a grass seed crop is a concern for plant breeders, seed contractors, and final consumer because if these plants survive, they alter the genetic purity of the seed harvested. Volunteer plants are eliminated or reduced in the stand by a number of chemical and cultural practices.

Seed producers have experienced problems with volunteer plants when they have not been able to burn after harvest. In annual ryegrass production, for example, volunteers are very common, and the Seed Certification Program has established a tolerance level for volunteers in a certified crop. This standard has been adopted to balance the need to avoid multiple generations in the certified stands against the practical concerns of field production. Burning has historically been the most effective practice used for volunteer control.

Other seed quality concerns associated with reduced field burning include failure to meet standards because of low germination (due to presence of blind seed disease) and higher weed content.

### **ALTERNATIVE CROPS**

Grass seed is grown throughout the Valley on a wide range of soils and topography. The crop alternatives vary with the soil type and topography. Farmers tend to produce higher income crops to the extent that soils, topography and markets allow. Where possible, crops with a higher value than grass seed are grown. Equipment used for seed crop production is used with many other field crops. The net return for grass seed crops relative to other field crops determines shifts among commodities.

### **Northern Willamette Valley Counties**

In the north Valley (Clackamas, Marion, Multnomah, Polk, Washington and Yamhill counties) there is a predominance of well-drained, high quality soil on which many different types of crops can be grown. Grass seed crops comprise only 16% of total harvested cropland in the north Valley. Most new or alternate crops being investigated in Oregon and/or adjoining states require moderate-to-well drained soils. These crops include rapeseed, lupine, fababean, triticale, Chinese milkvetch, and pyrethrum. Many field crops, such as wheat, barley, and oats are grown as government programs permit and prices are favorable.

### **Southern Willamette Valley Counties**

In the south Valley (Benton, Lane, and Linn counties), cropping alternatives are restricted severely by the predominance of poorly-drained Dayton type soils on the Valley floor. These soils have thin, light-colored top soil and a very slowly permeable clay layer at a depth of 16 to 24 inches. Water perched above this restricted layer creates a water table at or near the surface of the soil that may persist for 120 days from November to April. One effect of prolonged saturation is that manganese may be toxic for some agricultural crops. Another effect is that many plants simply cannot survive in the water-logged soils. A third effect is that tillage may be delayed in the spring. Fall harvest operations also can be hampered by poor drainage after an early fall rain.

Prior to the establishment and expansion of the grass seed industry, these poorly drained soils were used for very low return crops such as livestock pasture, spring-sown oats, alsike clover, and vetch. Drainage for these crops was provided by plowing surface furrows through the field.

Production of intensive crops such as tree fruits and nuts and perennial small fruits has been limited as development of irrigation and subsurface drainage systems is required to make them technically feasible. High capital investment for such activities and restricted potential for expansion of markets have historically limited these choices to a few growers.

Some limited tiling and irrigation has been done using federal ASCS (Agricultural Stabilization and Conservation Service) assistance. This has permitted some shifting from annual ryegrass to other grass species such as turf-type tall fescue which tolerates less flooding. The Oregon Legislature in 1983 passed a pollution control tax credit program. Drainage of wetland soils serves as a qualifying activity for the tax credit. Tiling as an Oregon tax credit has not been used by growers as it conflicts directly with the Wetland Conservation (Swamp Buster) provisions of the Food Security Act of 1985 (1985 Federal Farm Bill) in which growers would lose all USDA farm program benefits if sub-surface drainage were conducted on the Dayton type soils on the Valley floor (Appendix C).

Production of grass seed on these soils remains the most profitable and feasible use of this land. In the south Valley where Dayton soils predominate, the 210,000 acres of grass seed crops comprises more than 56% of total harvested cropland. By using surface drainage and species that are tolerant of winter flooding, continued grass seed cropping is possible.

### **Alternative crops for poorly drained land**

Currently, the only known winter annual crop that will tolerate unimproved Dayton-type soil condition is meadowfoam. This is a new crop that has been under investigation in Oregon for more than two decades. Full-scale commercial acreages have been grown, but expanded acreage awaits market improvement and/or development of higher yields.

#### ***Meadowfoam (Limnanthes alba Benth.)***

Meadowfoam is a winter annual plant native to southern Oregon and northern California, adapted to the poorly-drained soils and wet conditions typical of much of the Willamette Valley. As a winter annual, meadowfoam's growing season is slightly shorter than that of grass seed and wheat. Domestication has produced an upright plant with good seed retention and the planting, care, harvesting, and equipment requirements of meadowfoam are entirely compatible with those used to produce grass seed. The amount of leaf and stem material left after harvest is negligible, decays rapidly in the field, and does not require burning or present a residue disposal problem.

The product of the meadowfoam plant is seed containing 25 to 30% oil by weight. The chemical composition of the oil is unique, with high performance properties which may be suited to a variety of commercial and industrial uses. Experimental work on meadowfoam in Oregon was initiated in 1967.

A 1977 feasibility study commissioned by the Pacific Northwest Regional Commission (PNRC) identified oilseeds as promising crops for the region. OSU identified meadowfoam and rapeseed as the most promising oilseeds for the local soils. Bohemia Inc., OSU, and PNRC initiated market development studies in 1978, using oil extracted from 4,000 pounds of meadowfoam seed. DEQ funded 35 acres of meadowfoam plantings in 1979 and 14 acres in 1980 (Jolliff, 1981).

Production costs were found to be comparable to annual ryegrass in one or more studies, although such findings were based on critical assumptions and need further analysis. Production analysis, agronomic and economic feasibility studies were funded through 1982. The value of meadowfoam oil for industrial uses has been variously estimated at \$0.75 to \$1.00 per pound. Current cost estimates are about \$3.00 per pound.

OSU research has focused on understanding environmental factors which limit crop growth and seed yield, and the development of higher yielding cultivars. Agronomic studies on seed production management systems to increase seed yield have included weed and disease control, and soil fertility trials.

In 1984, OSU released the "Mermaid" cultivar of meadowfoam. Farm yields of oil from this variety have been 130 to 300 pounds per acre compared with research yields of 335 to 440 pounds per acre. A new meadowfoam variety selected in 1985 had a 45% higher average seed yield than Mermaid in 1986 to 1988. Its seed also contains approximately 10% more oil than Mermaid. Seed of this new material is being increased in 1988-89. Further advanced selections were made in 1986, 1987, and 1988. Early indications are that oil yield per acre has increased at the rate of 30 to 40 pounds per year. If these trends hold true, oil yields of 500 to 600 pounds per acre could be achieved on research plots by 1990 and available to farmers by approximately 1995 (G.D. Jolliff, personal communication).

In 1984 the Oregon Meadowfoam Growers Association consisting of 20 Willamette Valley grass seed growers was formed. Association growers produced 800 acres in 1985 and 900 acres in 1986. The group has retained a technical marketing consultant to promote the oil to the cosmetic industry, it has secured outside funding from the New Crops Development Board, and initiated a marketing program.

Market development and oil utilization promotion was first conducted through Bohemia Inc., and later through the Meadowfoam Growers Association. Oil samples have been provided to manufacturers and presentations made at trade shows. Cosmetic uses appear to be the most immediately accessible market.

During 1985, a Japanese cosmetic company purchased 10,000 pounds of crude oil and oil samples were sent to several companies in Japan, England, and in the United States for cosmetic research. Basic questions concerning oil processing and refining were studied including research into dehulling, seed pretreatment, mechanical expelling compared to solvent extraction, bleaching, and hydrogenation.

Several companies have explored various uses for the oil; some indicated serious interest, but the major obstacle is the cost of seed and oil production. Production costs are expected to decline with the introduction of improved varieties and development of better production practices.

There is currently a substantial inventory of refined oil and additional seed for planting or pressing to support those companies already interested in meadowfoam oil.

The U.S. Department of Agriculture currently considers meadowfoam one of the five most promising new crops but financial support for continued research is limited.

#### *Pyrethrum (Chrysanthemum cinerariaefolium)*

Pyrethrum, a perennial chrysanthemum, is native to areas with warm, dry summers and moderate to cool winters. It prefers deep, well-drained soils, but will respond well on heavier soils provided there is adequate drainage. Pyrethrum is a high input, relatively high return crop which may be adapted to portions of the Willamette Valley; however, because of the drainage requirement, it is not an alternative for the poorly-drained soils.

Pyrethrin is a potent natural insecticide contained in the daisy-like flowers of the pyrethrum plant. There is a well established market for pyrethrin, and the United States is the largest single consumer of



the world production. Currently nearly all production is in Kenya where political and agronomic instability have given pyrethrin the reputation of a commodity of unreliable supply.

Pyrethrum production and physiology studies were supported from 1984 to 1986 to examine the potential of growing this specialty crop (Ehrensing and Chilcote, 1985). Results of these studies were not sufficient to support funding of market analyses in 1986, although seed technology work was supported through 1987.

Demand for natural pyrethrin remains strong and preliminary commercial development is currently underway by a private firm.

## CHAPTER 5

### STRAW UTILIZATION AND MARKETING

Grass straw residue is a by-product of grass seed production. Annual straw production ranges from two to five tons per acre depending upon grass seed species and variety. In the Valley some 1 million tons of residue are produced annually. From a technical standpoint, straw can be used as a raw material to make a wide range of fiber products (paper, particleboard, fuel logs, hydromulch, composted fertilizer), chemical products (oil, gasoline, plastics, microbial protein) and livestock feed products. Economically, it has been difficult for grass straw to compete in existing markets as a raw material source. Low bulk density requiring costly densification, high cost transportation, uncertainty of long-term supply and low volume of supply relative to wood chips in fiber markets have made straw non-competitive with other raw materials. The traditional base for making pulp and paper in the Pacific Northwest is wood chips which are cheap and adequate in continuing supply and volume. Also, manufacturing technology is adapted to that source. Conversion to straw would involve major retooling in the wood fiber industry.

As a feedstuff for livestock, straw in untreated form is of poor quality because of low protein and high fiber content. With appropriate treatment, such as ammoniation, the digestibility and palatability of straw can be increased substantially, making straw a potential component of maintenance diets for ruminants. The costs of physical and chemical treatment historically have made the process marginal in an economic sense. The use of automation in straw handling and storage is increasing the possibility of providing chemical treatment with modest additional cost.

Some grass straw is currently being used in domestic and export markets as a supplemental livestock feed. During periods of short supply and/or excess demand for forages in U.S. markets, such as experienced during the major drought of 1988, some unspecified quantity of grass straw is marketed. The major current market is Japan which utilizes an estimated 125,000 to 150,000 tons annually for supplemental livestock feed.

Straw utilization or disposal has been an essential companion to the economic viability of alternatives to open-field burning. Straw must be removed in order for mobile sanitizers, propane flammers, or other alternate mechanical or chemical methods of disease and pest control to be effective.

Research since 1969 has included the development and demonstration methods of straw and chaff removal, surveys, economic and market studies to identify methods of straw removal and markets for straw, and produce and market development in the areas of feeds, fuels and chemical feedstocks, and fibers.

From 1972 to 1977 Oregon operated a unique *Straw Utilization Center* where prospective products and processes were carried from research level to pilot plant process tests and product preparation for field and market trials in feeds, fibers, and fuels. Straw processing prepared materials for feed trials, fermentation research, and fuel tests. Cubing and processing developments (1972 to 1976) led to Japanese feed contracts of 3,000 tons and 10,000 tons which set relationships for current sales with Japanese trading companies. Fiber processes led to construction of the Grassfiber Inc. hydromulch plant. Equipment and techniques contributed to construction of a straw particleboard plant operated by L. Opel and K. Gorzell.

### MARKET STUDIES AND PROMOTIONS

Market and economic studies have included straw removal alternatives (Conklin 1971, 1972; Anderson *et al.*, 1974), pulp and hardboard (Sandwell, 1975), feed exports to Japan (Inoue and Conklin, 1973; Porfily and Conklin, 1973), horse feed (Jacob, 1974), firelogs for fuel (Beelart 1975b; Wells *et al.*, 1979), field burners (Beelart, 1975b; FMC Corporation, 1978), straw uses for fiber (Miles, Jr., 1976b), straw market and technologies including feeds, fuels and fibers (Miles, 1974, 1976a; Miles, Jr., 1976c; Wells *et al.*, 1979), farm scale bale burners (MacKey, 1981), meadowfoam economic potential (Jolliff and Pearson, 1981), mulch (Agricultural Fiber Association, 1986a) and non-burning alternatives (Cornelius, 1983).

Export studies (1972 to 1973) helped describe the Japanese market which stimulated cubing development, but they did not include distribution channels which insulated producers from final consumers until 1980 when straw merchants began visiting Japan. Horse feed studies (Jacob, 1974) identified a potential market. Economic assessments helped detour research from product development in firelogs and also

verified engineering assumptions about the potential use of sanitizers. Economic analyses have helped select potential alternatives including straw utilization.

In 1978, the DEQ funded FMC Corporation to reassess the development of mobile field sanitizers and Battelle Pacific Northwest Laboratories to help determine the need for further research in straw markets and technologies (FMC Corporation, 1978; Wells *et al.*, 1979).

Market conditions and market potential for straw products have changed. The volume and accessibility of straw to fiber, feed, and fuel markets have declined. Hydromulch and possibly residential fuels represent the only markets where adequate margin is available for processing straw. Direct sale of bales to mushroom growers, export, mulch, and feed markets are surviving uses. A major consumer, the Salem Mushroom Plant, closed in 1987.

Information about market size, straw potential, sales, and product distribution should be included in more current utilization studies. New market studies could be used to verify current markets, market share, or impact for proposed new areas of research such as residential wood stoves.

Surveys have helped guide assumptions about current levels of straw removal, field treatments and markets (Mikesell, 1973; Miles, 1974; Miles, Jr., 1976a, 1976b, 1976c; Wilson *et al.*, 1983; DEQ, 1985).

Promotions used to communicate straw utilization alternatives and to market straw included OSU field days such as "Grassland 1971," and the Oregon Seed Council tours of Japan with the Governor in 1972 and the State Department of Agriculture in 1979 (Inoue and Conklin, 1973); assembly and demonstration of straw uses and methods at the World Straw Conference, Eugene, Oregon in 1975 (Miles, 1975); and the formation of trade associations such as the Agricultural Fiber Association (AFA) and Environmental Fiber Inc. in 1976. The direct promotion of straw by the Oregon Department of Agriculture (Kileen and Vanderplaat, 1976); cattlemans field day by Agricultural Fiber Association in 1977; and Christmas tree tours (Agricultural Fiber Association, 1986a, 1986b). Several of these promotions have led directly to straw contracts. Others have created temporary high demand for straw. Large plants and projects politically promoted from 1970 to 1980 (pulp, pyrolytic, oil, furfural, steam, fermentation, fuel pellets and insulating board) have not led to increased straw consumption.

Promotional literature or information sheets have been useful to straw and meadowfoam growers when available as circulars and fact sheets from the Oregon Seed Council, DEQ, OSU, or AFA.

## **STRAW REMOVAL AND HANDLING**

Costs and methods to remove straw were evaluated in early OSU research (Conklin, 1971; Anderson *et al.*, 1974). The need to remove straw was an important conclusion of mobile burner development from 1969 to 1971 (Kirk and Bonlie, 1973). A new emphasis was put on straw removal in 1974 when the mobile burner review showed that straw must be removed (Odell *et al.*, 1974). Further importance was given to straw removal during open burning acreage reductions of 1976 to 1977. Straw removal remains a significant cost for all alternatives to open-field burning (Miles, 1976; Cornelius, 1985; Smucker *et al.*, 1984). Rapid field removal of straw is important so that thermal sanitation can be started immediately after harvest when weather conditions are right and risk of straw deterioration from moisture is minimal.

The methods of straw handling and densification are determined by the end use. If no end use exists, the grower chooses the lowest cost option to remove the straw for field-side burning. Several methods to remove the straw from the field including baling, cubing, pelleting, and large stacks or "bread loaves" have been evaluated.

### **Baling**

Baling is done in the form of two-tie low density (80 pound), three-tie high density (100 pound), round (500 pound) and large bales (1,000 pound). Two- or three-tie baling is chosen if the straw will need to be transported and/or stored. The cost of baling ranges from \$20 to \$30 per ton at a rate of 8 to 10 tons per hour. Various handling and accumulating equipment has been developed to speed up the process of stacking bales, loading and unloading trucks and moving straw in and out of storage.

OSU (1969 to 1971) studied stationary and field densification to replace two-tie bales (6 pound per cubic foot) with cubes (20 pound per cubic foot) (Anderson *et al.*, 1974). By 1972 new commercial systems included three-tie high-tensile wire bales (100 pounds), eight-bale packages. Large round bales, stackwagons, bale stackers, and 56-bale squeeze systems appeared from 1971 to 1976. Three-tie high ten-

sile twine bales (100 pound), large square bales (1,200 pound), and individual compressed bales appeared by 1977.

Stack wagons and large round bales are the preferred grower choice for rapid, low cost field removal where the straw cannot be marketed.

### **Cubing**

Tests were run in 1970 to determine the adaptability of the John Deere hay cuber for cubing grass seed straw. The tests indicated a possibility that ryegrass straw could be cubed when lignin sulfonate or sodium hydroxide is used as a binder. Later, tests were run in a cubing plant set up to do stationary commercial cubing of alfalfa hay and grass seed straw. Although straw was first exported as cubes, current markets are supplied with compressed bales. Cubing and compressing costs are similar (\$25 to \$55 per ton) with no clear advantage in the market over bales.

### **Bale Compressor**

Several bales were densified and strapped together by Hastrol West with 6,000 tons exported from 1972 to 1974. The 1,200-pound bales were strapped with steel and difficult to handle.

Steffen Systems built one of the first single bale compressors for straw export in 1979. Six bale compressors operated in the Willamette Valley in 1986. The largest compresses eight bales at a time into 800 pound bales, which are resawn into individual 70 pound bales.

The most common form of densification now in use is the bale compressor, which compresses a single square bale or a package into about one-third its original size. The need for compressing is generally for transportation cost reduction for straw going into the export market. The compressors are used with large-scale operations in the 7,000 to 10,000 ton size and cost approximately \$150,000.

### **Pelletizing**

Some uses or markets for straw require further densification. Pelletizing is one form that has advantages in that it produces a flowable material with high bulk density that has good characteristics for use in livestock rations or as a fuel. The drawback is that pelletizing is expensive and grass straw is particularly hard on equipment and requires a binder of some type to hold the pellet together.

### **Storage**

Historically, a limiting factor in the handling of straw has been storage. Oregon's rainfall pattern means that about 75% of the straw handled for off-farm end use during a year must be put into storage for later delivery. Some straw can be delivered or shipped directly out of fields and some can be stored under tarps or plastic; the rest must go into permanent storage when delivered for a year-round supply. The usual form of storage is a pole-barn type with metal roof and siding on at least two sides. The cost of such a building is approximately \$45,000 for 1,500 ton capacity. Storing straw also increases the cost of delivered straw to \$45 to \$50 per ton because of the additional handling and storage costs such as insurance.

Recently there has been an increase in construction of on-farm straw storage due largely to expanding markets for straw. Some 20 on-farm storage sheds have been built since 1986, aided by the Oregon Pollution Control Tax Credit initiated by the 1983 Oregon Legislature. Storage sheds qualify for the 25-50% state income tax write-off.

## **STRAW USES**

### **Animal feed**

Feed uses for straw have included feeding trials for beef, dairy cows, lambs and horses; nutritive value surveys; feed processing trials and product development including grinding, defibration, densification, chemical treatment, and fermentation.

Feed trials for winter maintenance from 1967 to 1976 included rations for range cattle (Macy, 1973; Vavra *et al.*, 1973; Phillips *et al.*, 1975; Bedell, 1976; Isley, 1976; Anderson, 1977; Kellums, 1983, 1985; Kellums *et al.*, 1984; Pirelli *et al.*, 1985), and dairy cows (Adams, 1977) in feed market areas of Union, Squaw

Butte, Lakeview, and the Willamette Valley. Straw treatment for livestock maintenance rations included lick tank, a bale supplement injector, and ammoniation. Liquid and dry supplements including alfalfa were used. The DEQ supported reconstruction and testing of a prototype bale supplement injector (Agricultural Fiber Association, 1982) which led to the design and construction of a commercial scale system (Agricultural Fiber Association, 1983a). From 1983 through 1984 straw markets for beef maintenance have been negligible. The 1988 drought saw renewed interest in straw with an unspecified volume shipped to the inter-mountain area for livestock feed.

Beef production trials between 1973 and 1977 were carried out on heifers, calves and steers (Ralston *et al.*, 1966; Ralston and Anderson, 1970; Anderson *et al.*, 1974; Shultz and Ralston, 1973, 1974; Shultz *et al.*, 1984; Church, 1975; Church and Kennick, 1977a, 1977b, 1977c). At the Straw Utilization Center straw was pelleted or cubed or ground as meal and combined with other feedstuffs. These products were ensiled, or treated with alkali such as NaOH or KOH. Straw levels of up to 33 to 37% in mixed rations were determined to maintain adequate production levels (3.1 pound per day) without loss in body condition.

Producing dairy products with straw and seed screenings was investigated at OSU in 1975 using Holstein cows (Adams, 1977). Compared with hay, straw depressed fat and fluid milk production. Depressed fat production also was found when pelleted grass seed screenings made up 50% of a cow's diet (Anderson *et al.*, 1974).

Western Oregon feeder lambs were used to evaluate the metabolism of alkali (NaOH) straw pellets. Carcass weight and feed conversion were measured. Feed conversion of 6 to 20 pound feed per pound gained were obtained when 50 to 65% of the ratio was treated (Anderson and Ralston, 1973; Church and Kennick, 1977a, 1977b, 1977c). A preliminary digestion trial was performed with lambs (Church, 1976). Intake and conversion of ryegrass pellets was sufficient to recommend moderate levels (20 to 30%) of ryegrass straw. Digestion of NaOH-treated straw was better than untreated straw. Cubes were too large and had to be reground to be fed as meal. Eastern Washington trials contributed information about bluegrass straws (Early and Anderson, 1976).

Straw pellets, cubes, and briquettes were fed in horse maintenance trials (Pulse, 1973; Shurg and Pulse, 1974). Digestibility was followed by a horse maintenance trial with cubed rations (Shurg *et al.*, 1978). Horses adapted to up to 50% straw in their rations. All horses showed normal health, no disturbance and trimmer appearance, with a slight gain of body weight. Cubes were range fed to stabled horses for half of their daily diet (Miles, 1976a).

#### *Nutritive value research*

Studies between 1971 and 1976 established the quality of grass straw relative to other straws, hays and feedstuffs. Several assay methods included *in vitro* and *in vivo* digestibility, acid detergent fiber, *in vitro* dry matter disappearance (IVDMD) and TSAE (16 hour enzyme) digestibility. A special effort in 1976 led to a comparative study which is the basis for most of the published information (Guggolz *et al.*, 1971; Anderson and Ralston, 1973b; Han *et al.*, 1975; Youngberg and Vough, 1977).

Pesticide residues on straws have received little attention. Restrictions for feeding straw containing pesticide residues have been published (Terriere and Kiigemangi, 1973; Youngberg *et al.*, 1988).

#### *Feed processing*

Straw processing by grinding or milling (Groner, 1974a, 1974b), cryogenic grinding (Humphrey, 1975); densification by pelleting, briquetting, and cubing; treatment with alkali (NaOH, KOH) and acids (sulphuric, phosphoric); defibrizing; and semi-solid fermentation have been reported.

Experience at OSU, Brennen Industries, and the Straw Center showed that field cubing was unworkable. Bulk densities of stationary cubes were 16 to 22 pounds per cubic foot. Miles used the Osborn Gear cuber with alkali treatment (NaOH) to densify straw to 40 pounds per cubic foot. The cube had sufficient density, enhanced nutrition and storability for export (Miles, 1976).

Alkali treatments used to increase digestibility of energy in straw included sodium hydroxide, ammonia, and combination of chemical treatment with several reactors (Miles, 1976; Han *et al.*, 1976; Kellums *et al.*, 1984). To increase digestibility, four percent or 80 pounds of alkali are required per ton of straw. Alkali was used to lubricate and bind straw for cubing while preserving fiber length. Ammonia gas (NH<sub>3</sub>) enhanced non-protein nitrogen and digestibility at about the same cost as liquid supplement.

Fermentation of straw included the use of straw to absorb runoff from corn silage (Ralston and Anderson, 1970; Keck and McCarthy, 1976), and cultivation of mushrooms and torula yeasts through semi-solid fermentation (Frey, 1973; Anderson, 1974; Han and Anderson, 1975; Han *et al.*, 1976). From 150 to 200 pound of yeast were cultivated, dried and harvested in 30 hours for each ton of straw that was extensively milled and acid hydrolyzed. However, animals rejected most semi-solid fermented products and the cost of fermentation was prohibitive.

Pretreatments for fermentation included hydrolysis with acids, such as sulfuric, phosphoric (Frey, 1973; Grant *et al.*, 1977) and enzymes (Mandels and Gaden, 1976). Changes in nutritive value, digestibility, and composition were documented (Han and Anderson, 1975; Han *et al.*, 1975; Han *et al.*, 1976; Han *et al.*, 1978). Pretreatment by defibrizing straw with a disc refiner showed significant sugar release (Han *et al.*, 1978).

Other hydrolysis and chemical investigations included enzymatic hydrolysis for the production of glucose syrup (Andren *et al.*, 1975), Quaker Oats search for raw material for furfural (1974 to 1975), sugar extraction (Brady, 1976) and xylitol sugar substitute (Brady, 1976). Straw was too expensive for furfural production. Xylitol was abandoned when linked to cancer.

### *Livestock feed markets*

As with other raw materials, the issue of price of straw relative to other livestock feeds is the overriding consideration. The largest market to date is the export market to Japan. Straw is used primarily as a roughage source for the Japanese dairy industry, where the Japanese find themselves with an abundance of protein sources, (soybean and fish wastes), but little low quality roughage. The market in Japan has grown steadily over the past 10 years with a rapid increase during the past two years when growth from 30,000 tons to 120,000 tons annually occurred. Straw for export is baled, compressed, loaded in containers, and then shipped on deepwater freighters to Japan.

Livestock feed markets exist in the U.S. for straw but primarily as a maintenance feed for dry, non-pregnant cows. Supplemental protein and energy is required for all rations. The more common source is liquid molasses with urea or fish meal as the protein source, but protein blocks also are used. Other straw treatments used to improve digestibility include sodium hydroxide, liquid anhydrous ammonia, and hydrogen peroxide but their expense has prohibited large scale operations.

Pesticide registration for grass seed crops that includes use of straw for livestock feed and in straw aftermath for grazing may become an issue of concern. Testing for pesticide residue may be an important part of the registration process and is expensive. Additional funds from industry or public sources will be needed to complete this process.

### **Fuels**

Fuel research from 1969 to 1986 has been extensive. It has included industrial user trials; product development including grinding, cubing, firelogs, and pelleting; process trials in combustion, pyrolysis, and gasification; market studies; and burner development.

Industrial and institutional burner trials were carried out with major hog fuel consumers including Weyerhaeuser, Georgia Pacific, Eugene Water and Electric Board (EWEB), University of Oregon, Bohemia and Willamette Industries (Meland, 1973b; Oregon Seed Council 1973; Odell and Miles, 1974; Miles, 1975). Burner manufacturers cooperated in straw fuel tests, including Applied Combustion (Meland, 1973b), Energex, Coen (Odell and Miles, 1974), Turco Industrial Combustion and others (Hughes, 1976; Miles, 1975, 1976a, 1977a, 1977b).

Straw was supplied as pellets, bales, strawdust (less than 1/4 inch diameter) and cubes. Chopped straw was tested as a dryer fuel at Bohemia (Miles, 1975), and as a boiler fuel at several locations, including Withycombe Hall at Oregon State University (Meland, 1973b; Hughes, 1976). The largest test was 2,000 tons of straw supplied by Van Leeuwen Farms to Willamette Industries for boiler fuel in 1980.

Straw requires some special equipment for handling and pollution control. It is more expensive than hogged wood fuel (Miles, 1976a, 1976b, 1978; Miles and Miles, 1979; Wells *et al.*, 1979). In tests to determine the safety of milled straw for fuel the OSU Department of Mechanical Engineering found that ground straw tends to burn in closed containers rather than explode (Hughes, 1976; Miles, 1977b).

Residential straw fuels tested included Weyerhaeuser Presto logs, Agnew Firelogs, Chip and Saw firelogs and straw pellets (Oregon Seed Council, 1973; Meland, 1973b; Miles, 1976a; Irwin, 1984; Cade, 1986; Traeger, 1986). Firelogs from grass seed straw do not burn well. Growers that produce their own pellets like Venell or Kizer Farms have built their own pellet burners. Traeger Industries has made a commercial furnace available for straw or straw-wood pellets. Fuel cost and smell are major concerns. Straw-fired stove tests have not determined combustion efficiencies or appliance emissions.

Farm scale burner development included a series of furnace designs for bales and chopped straw tested at the Utilization Center (Hughes, 1976; Hughes and Welty, 1976). Bale burners included the adaptation of the rotary path field burner design for stationary farm use (Miles, 1977). Emissions were tested by Rossman (1981). Use of this principle with other crop residues evolved into commercial designs that can be used for straw (Miles, 1979; Sukup, 1982; Ebling *et al.*, 1982; Huffman and L'Ecuyer, 1985; Canadian Resourcecon and Miles, 1985). Hughes developed an opposed bale furnace design that became an OSU prototype (Page, 1979). Market studies for DEQ led to development of a water jacket style bale burner which is still in use at the Fraser home near Monmouth (MacKey, 1980; Kirk, 1982, 1984, 1985). Farm scale furnaces for heating or drying have not found a strong demand on grass seed farms.

Oil from straw was investigated in pyrolysis trials by Garret Research (Willard, 1975). Gasification trials included cubes and straw for direct gas conversion in prototype gasifiers by EWEB and others (Miles, 1976; Wilkinson, 1976).

Conversion to synthesis gas for ammonia, urea, or methanol was tested by Battelle (Rohrmann, 1974; Miles, 1976). The feasibility of a commercial straw/refuse-fired ammonia or urea plant was reviewed in 1976 by an interdisciplinary group composed of refuse haulers, seed growers, synthesis gas scientists, consulting engineers, and chemical producers. The group included Battelle Pacific Northwest Laboratories, British Petroleum, W.R. Grace, and Reichhold Chemicals (Miles, 1976). Straw could not compete with imported products.

OSU researchers found that straw added to high protein manures increases biogas production through fermentation (Miles, 1976). Other potential chemical uses of straw were researched and reported by OSU (Oregon State University, 1969; Groner, 1971a; Anderson, *et al.*, 1974).

Fuel markets have been monitored and reviewed since 1969 (Miles and Miles, 1979; Wells *et al.*, 1979). Straw quoted at a price of \$27.50 per ton in 1975 had about the same fuel cost (\$2.00 per MMBtu) as oil, but still more than hog fuel or natural gas. Hog fuel in this period rose from \$16 per unit (\$1.00 per MMBtu) to a peak of \$40 per unit (\$2.50 per MMBtu) in 1981, equivalent to \$37.50 per ton straw.

Hog fuel has returned to a price equal to \$15 per ton of straw. This is too low for industrial contracts where straw costs \$30 to \$45 per ton delivered. Homeowners may be willing to pay \$80 to \$100 per ton for straw-based pellets or firelogs, if an acceptable product can be produced. But they may not be interested in paying \$1,500 for a straw pellet fired furnace. Unless straw as a new product is subsidized to the point of use or energy costs of other products (i.e., electrical and natural gas rates) rise dramatically, straw as a fuel will not be economically feasible.

## Fiber

Fiber investigations have included market studies, pilot plant production, and field and market testing of paper, linerboard, particleboard, hardboard and insulating board products, hydromulch and straw mulch, and potting media.

Paper and paperboard market studies were carried out for kraft and fiber processes in general (Sandwell, 1975; Miles, Jr., 1976b, 1976c; Wells *et al.*, 1979). Private companies including Crown Zellerbach, Weyerhaeuser, and Reichhold carried out independent market analyses.

Laboratory pulp and paper studies by OSU (Bublitz, 1974) were followed by pilot plant production at Crown Zellerbach. Product yields, costs and pollution control limited access to paper markets.

Corrugating medium appeared to offer the best potential use for straw fiber compared to fine paper and newsprint. However, the questionable stability of the supply of raw material and relative prices of raw materials favoring wood fibers require considerable changes in technology and relative market prices before straw can become a strong economic contender against wood as a fiber source in pulp, paper, and fiberboard production in the Pacific Northwest where the timber industry provides the existing fiber source.

Nonwoody plant materials such as grass straw and bagasse from sugar cane were the first sources of fiber for paper. They still constitute an important fiber source in parts of the world where woody plants (trees) are not readily available. In the U.S., and the Pacific Northwest in particular, the overriding reason for use of woody plants is economics.

Yields of usable fiber from cereal plants, canes and grasses tend to be much lower than those from wood. Typical straw yields would be 25 to 35% as compared to 48 to 50% from wood. Thus proportionately more straw than wood would have to be collected and transported to the pulp mill to make a ton of fiber.

Straws are generally lower in density than wood, resulting in demand for larger shipping trucks or railcars, larger storage space, and decreased pulping efficiency. Pulping digesters have a fixed volume, and the higher the density of the raw material being used, the greater tonnage output per day, with proportionately lower pulping cost per ton of fiber produced. Low-density raw material costs extra money in every operation, a case for raising straw density. Unfortunately, straw densification itself is costly compared with wood chips which have no such need.

Straw fibers tend to be shorter than woody fibers, thus making weaker paper. Many straws contain bast fiber that is unsuitable for paper making and must be removed. Straw generally contains a higher percentage of inorganic materials (ash) including silica that tend to contaminate process equipment and lower paper quality.

The logistics of straw procurement are unfavorable as compared with those of wood. Straws are available for harvest in a relatively short period of time. Wood can be cut nearly any time in the year if the forests are accessible. A year's supply of straw for a mill would have to be harvested, densified, transported, and put into storage in a month or two, requiring heavy investment in equipment that might lie idle for 10 to 11 months of the year and requiring investment in storage facilities. Wood, by contrast, can be stored in the forests or at mill sites as the occasion demands, and processing machinery can be designed to operate year round. Straw must be dry when densified or putrefaction will quickly set in. It must be stored under shelter from rain for the same reason. Wood is far less susceptible to decay, and it can be stored unprotected for years, if necessary, in either log or chip form with reasonable chance of preservation.

Straws do have some advantages over wood. They contain less lignin (the undesirable portion of wood that must be destroyed to obtain fibers) requiring less drastic and sophisticated pulping methods and can be more readily bleached by simple methods.

Particleboard research at OSU recognized that isocyanate resins made it possible to make a decorative board from straw (Groner, 1971a, 1971b; Groner and Barbour, 1971, 1972a, 1972b; Groner, 1975). Sample boards were sold by the Women for Agriculture. A laboratory press loaned from the Straw Center led to construction of the Meadowood plant in 1976. Expansion attempts beyond 500 tons per year (1980 to 1983) were unsuccessful (Wilson *et al.*, 1983).

Acoustic and insulation board produced from straw in Europe as "Stramit" was studied and promoted by seed growers until 1973 (Meland, 1970; Jacob, 1973). The Stramit plant in Canada closed. K.H. Industries, the successful producer in Australia, has not been able to establish a market for its "Speedboard," made in Yuba City, California.

Fiber mats were produced for a board overlay product in cooperation with Reichhold Chemical, which supported pilot plant work (Miles, 1976; Razali, 1976; Ayres, 1977). The mats were overlaid and pressed with plywood veneer to make a straw hardboard-plywood structural building panel. Panels made at the Straw Center were weather tested against building standards at Reichhold. The product was ready for the market during a building slump and was abandoned.

Hydromulch was made from straw beginning at OSU in 1974 (Wells *et al.*, 1979). A commercial defibration process was developed and demonstrated at the Straw Utilization Center (1976 to 1977), where 1.5 tons of straw was used for fuel and fiber to produce 1 ton of dry bagged hydromulch for erosion control (Miles, 1976). The product was tested on roadside jobs with commercial contractors (Anderson *et al.*, 1975) and by field and pilot laboratories (Miles, 1976; Kay, 1979, 1983). Pilot plant equipment from the Straw Center was used to start production at Grassfiber Inc., Eugene in 1978. DEQ supported studies to improve product preservation in 1979 (Anderson and Israilides, 1979). Currently, grass fiber straw hy-



dromulch is sold for erosion control to a very limited market of less than 2,000 tons per year at a price of about \$125 per ton.

Fiber from hydromulch produced at the Straw Center was tested in molded pulp products such as flower pots (Oregon Seed Council, 1973), as hydromulch (Miles, 1976), as potting media (Brady, 1976; Ticknor, 1977) and as a substrate for yeast fermentation (Han *et al.*, 1978). Grass fiber straw mulch was later used as a specialty mushroom compost at a commercial plant in Salem, and as a horticultural mulch (Agricultural Fibers Association, 1986a).

Straw mulch for erosion control was used by the BLM, Forest Service and Highway Departments between 1973 and 1977. Energy prices depressed road and reclamation programs, which depressed markets for mulch. Straw mulch was tested on Christmas tree farms and hillside crops in 1984 through 1986 (Agricultural Fibers Association, 1986a, 1986b).

Straw bales were tested for direct market vegetable production of lettuce and tomatoes (Mansour, 1984, 1985). The technique is of interest to direct, U-pick, and organic markets.

Potting media trials were carried out with finely-ground strawdust and refined hydromulch fiber in screening tests at the OSU North Willamette Experiment Station (Ticknor, 1977) and in parallel germination trials at the Straw Center (Brady, 1976). Plants such as ivy and azalea responded well to both fiber and finely-ground straw. Quality control in refining eliminated need for herbicides to control volunteer grass seed germination. These results, combined with the need for sawdust mulch substitutes, stimulated the use of straw as mulch for blueberries (Agricultural Fibers Association, 1986b).

Teuffel Industries tested grass straw for their urea formaldehyde resin treated "Strawdust Mix"™ (Ticknor, 1982, 1983). Problems with volunteer grass seed terminated research.

#### *Fiber markets*

Straw is not an economically viable source in most U.S. markets. Technical limitations that translate directly into economic disadvantages relative to wood as a fiber source is the major factor. Technology exists to overcome these technical limitations, but at a price that makes straw unattractive. Little information is available today on the pulping characteristics of straws from grasses other than annual and perennial ryegrass. In the long-range view, world-wide demand for fiber in the paper industry may outstrip the supply of wood in the next 50 to 100 years. However, this offers little immediate promise of a market for straws from grasses in the Willamette Valley.

#### **Chemical Extraction**

The components of grass straw include cellulose, lignins, pentosans, waxes, oils, and ash. These components can be separated by solvent extraction, oxidation, pyrolysis, and other chemical treatments to produce cellulose acetate, cellulose nitrate and other useful derivatives. Waxes and lignins extracted from straw are similar to those being used industrially. High pressure hydrogenation and destructive distillation of straw yield a combustible gas, an oily liquid, and a carbon residue. Straw is not being used as a commercial source of those products for economic reasons, largely due to the high cost of extraction and low yield relative to other sources.

## **CHAPTER 6**

### **HEALTH: THE PUBLIC CONCERN**

Pollution of the environment emerged as a public concern during the 1960's in the United States. This coincided with public concern in Oregon over smoke emissions from field burning, particularly as it may affect public health. Concerns have come largely from residents of communities which experience smoke intrusions.

The scientific literature offers little definitive information on acute effects or chronic effects from long-term exposure to field burning. Reasons for this include:

1. most of the limited literature on air pollution health effects addresses severe urban pollution events from industrial and automotive emission sources;
2. the relatively temporary and transient nature of field burning smoke intrusions, largely particulate, are not readily comparable to monitoring data for particulate pollutants which are typically present year around at relatively constant levels in large urban and industrial areas;
3. little has been known about how the physical and chemical composition of field burning smoke compares to other sources including vehicles, wood stoves and slash burning emissions; and
4. methods for quantitative exposure and health risk assessment have been slow to develop, and often lack critical information such as dose-response relationships for specific smoke constituents.

R&D activities on health effects provided through the Field Burning Program paid by grower fees has been small. Less than \$300,000 have been spent over the past two decades with more than half of it devoted to air quality research from 1969 to 1973. The remaining health effects studies are discussed in this chapter.

#### **REPORT ON RESPIRATORY PATIENTS**

Initial health work came from a Eugene physician who reported to the 1971 Legislature on a survey of 10 physicians who saw 201 respiratory patients between July 9 and August 29, 1969. Of these patients, 167 (83%) had a prior respiratory condition and 92 had been seen on more than one occasion for a total of 293 visits. Of these, 152 patients had symptoms of acute coughing, 199 had tightness of the chest, and 84 experienced wheezing and labored breathing. The report stated that 95 patients found it necessary to leave the Valley for relief. It was necessary for 173 patients to purchase medicine and 131 work days were lost. Whether field burning smoke aggravated these pre-existing conditions and to what degree was not determined.

#### **BREATHMOBILE STUDY OF PULMONARY LUNG FUNCTION**

From 1972 to 1977 the Oregon Lung Association sponsored lung function tests as part of its five-year Christmas Seal Breathmobile Program. The Breathmobile toured the state offering free spirometric tests to the public. In 1978 the OSU Survey Research Center was funded to conduct a retrospective analysis of this statewide pulmonary lung function data base to detect any glaring dissimilarities in respiratory health between residents of different regions.

For purposes of this study, seven different regions of the state were delineated on a geographical/airshed basis. Included were the southern portion of the Willamette Valley representing a smoke impacted area, the west side of the Valley which is usually free from smoke, Portland, the coastal area, and the regions of central, eastern, and southern Oregon. The following pulmonary functions were evaluated: one second forced expiratory volume; percent of the forced vital capacity expired in the first second; and forced expiratory flow 25 to 75 percent.

As would be expected, respiratory function generally declined with age and increased smoking intensity. For non-smokers, however, there were significant differences between regions. Adjusting for

age, sex, and height, residents of the south Willamette Valley, the area representing smoke exposure, had the *highest* average one second forced expiratory values of all the regions, and the difference was statistically significant in every case. The south Valley region also had higher forced expiratory flow values which were statistically better than values for residents of central Oregon, southern Oregon, and the west side of the Willamette Valley. There were no significant differences in the first second forced expiratory values.

Definitive conclusions could not be drawn from this cursory review. Questions regarding the comparability of the test groups, and the effects of regional differences in climatology on respiratory performance could not be addressed. Still no obvious effect on public health could be detected. In fact, residents of the area (south Valley) most frequently exposed to field burning smoke performed better (and presumably had better respiratory health) than residents from all other areas tested.

In 1977 health effects research was given top priority status in the Field Burning R&D Program. Funds were set aside for preliminary studies and for planning a major health effects research project. In so doing it became apparent that research on this issue would require a major and complex undertaking of a multi-disciplinary research nature and be very costly. It could easily divert all of the available R&D funds from other topics. Accordingly, it was decided to:

1. support preliminary studies based on local data if possible, to identify evidence that health impacts do indeed exist;
2. follow up such evidence with a planning effort (i.e., a workshop with selected experts) to design a more extensive research effort, and
3. to solicit the necessary funding for such an effort and contract the work.

The discussion which follows reports on those activities which have been completed.

#### **1980 PHYSICIAN VISIT SURVEY**

Questionnaires were made available to patients visiting health clinics in Lebanon (an area affected by smoke) and Corvallis (an area relatively free of smoke). The questionnaires were offered to people seeking medical assistance for any type of respiratory ailment. The questionnaires asked for the following information: date of visit, age, sex, zip code, nature of symptoms, date symptoms began, number of work loss (WLD) days, health status, and exposure to cigarette smoke or other air contaminants.

A total of 164 questionnaires were returned, 137 of these from the Lebanon Clinic. Of the respondents, 59% were women, 21% were smokers, and 45% had been diagnosed as having a chronic respiratory disease or condition. There was fairly even age distribution with regard to symptoms with 80% reporting some upper respiratory symptoms. Symptoms specifically identified were as follows: cough (38%), headache (38%), eye irritation (37%), breathing difficulty (36%), sore throat (34%) congestion (32%), wheezing (23%), sneezing (23%), other (20%), and phlegm (15%).

The survey was intended as a "blind" or objective way to gather local health information, unprejudiced by the participants' personal opinions about field burning. The returned questionnaires, however, contained numerous comments and complaints specifically directed to field burning, suggesting the potential for subjective bias. Therefore, a detailed dose-response analysis or correlation with ambient smoke levels was never performed and no definitive conclusions were attempted.

#### **1980 HOSPITAL ADMISSIONS STUDY**

The OSU Survey Research Center conducted a retrospective analysis to determine relationship between smoke "dose" and public health "response" in an area affected by field burning smoke. Admissions into Lebanon Community Hospital during the 1978 and 1979 summer burning seasons, for both respiratory and non-respiratory type ailments were reviewed and compared with smoke data for that area.

Primary and secondary diagnosis codes were selected on the basis of prior studies. In-patient admissions data also included sex, age, and admission and discharge dates. Information on patient smoking status was incomplete and not included in the data base.

Aerometric data considered in this study included continuous nephelometer measurements summarized for each day as 1-hour maximum, 3-hour maximum (average of the highest consecutive three hours),

and 24-hour mean. Other data included maximum, minimum, and average daily temperatures and average daytime relative humidity, as recorded at Eugene 30 miles away.

Results of the study indicated no statistical evidence of an effect. No significant differences were observed between respiratory and non-respiratory admissions. There was also no discernible lag effect or delay between a smoke intrusion and a measured response.

#### **1986 FIELD BURNING HEALTH EFFECTS WORKSHOP**

A Field Burning Health Effects Workshop sponsored by DEQ and the Advisory Committee on Field Burning was held at Oregon State University to consider alternative approaches to quantitative assessment of the health effects of exposure to field burning smoke.

The difficulties facing health effects studies related to field burning were summarized and discussed. Different approaches to quantitative assessment of health risks related to exposures to particulate air pollution were discussed. One approach utilized correlations between ambient particulate levels and adverse health effects represented by work loss days (WLD) and leisure time reduced activity days (RAD).

Preliminary results suggested the possibility that short term, fine particulate concentrations effects as occur with field burning might be correlated with respiratory related RADs (RRAD). Such morbidity effects have been determined by EPA to be costly to undertake, much more costly than mortality effects associated with cancer incidence and particulate ambient air quality levels. Applying such an approach to the Willamette Valley left several major unanswered issues:

1. whether fine particulate and/or nephelometer data from DEQ field burning or other Willamette Valley monitoring sites could be positively correlated with RRAD from the same area(s), and
2. whether such correlations would remain robust for the brief duration (episodes of a few hours), and seasonal average concentrations which correspond to the principal exposures attributable to field burning.

Another approach suggested the use of prior relevant studies, mathematical models, dose-response, and health-related information to provide for a more thorough and diagnostic approach to the research. Such analysis would need to collect clinical data on health effects, consider lifestyle habits and economic costs to the community as well.

#### **1987 PRELIMINARY FIELD BURNING HEALTH EFFECTS ASSESSMENT**

Results of the 1986 Workshop led to initiation of a Preliminary Field Burning Health Effects Assessment in 1987. DEQ contracted an environmental firm to conduct a quantitative assessment of exposures, health effects/risks, and related costs, under typical and worst case conditions, related to field burning, slash burning, and residential wood burning. The study was completed in 1987 and submitted for technical review in 1987. The study has not been released. A technical review of the assessment raised serious questions concerning the appropriateness of the methodology used and conclusions of the study for Willamette Valley conditions.

In summary, to date there is insufficient evidence to ascertain whether or not controlled open-field burning in the Valley has direct and/or indirect health effects.

## CHAPTER 7

### STRUCTURAL ADJUSTMENTS: ECONOMIC REFLECTIONS AND FUTURE CONSIDERATIONS

#### DYNAMIC NATURE OF THE VALLEY'S GRASS SEED INDUSTRY

The Willamette Valley grass seed industry has been under pressure for the past 20 years to resolve its field burning problem, a fact well known to Oregonians. Less well known is the dynamic character of that industry, particularly its growers, in adjusting to the need for change. This industry, like many others in the U.S., has had to adjust to reduced pollution levels of concern to a broader public. Some industries in the quest for solutions have simply absorbed the additional costs for pollution control and passed them on to consumers in the form of higher prices. This scenario is not characteristic of agriculture in general nor grass seed production in particular, both of which are perfectly competitive in nature. This means they are price takers in the marketplace with no direct ability to pass on increased costs of pollution control to consumers of grass seed in the form of higher grass seed prices, as the monopolistically competitive firms are able to do. An exception is if the Valley grass seed growers face cost increases collectively and the industry has an adequate comparative economic advantage with competing regions in the marketplace to pass on the cost increases. This issue is unknown. Thus a major concern has prevailed over time concerning the extent to which growers can adjust further to reduced field burning through selection of higher cost alternatives which reduce smoke emissions *and* retain viability as an industry.

A review of the past two decades, and in particular the past decade, reveals an industry which has made considerable adjustments. Open-field burning has declined from 315,000 acres in 1968 to about 220,000 acres annually during the 1980's. In 1988, 330,000 acres of grass seed were produced in the Valley of which 206,000 acres were thermally treated. An estimated 150,000 acres were field burned and 56,000 acres propane flamed. The remaining 124,000 acres were not burned, employing other field cultural practices. In general, the net effect to the public has been reduced emissions by one-half from reduced acreage burned.

Under the current smoke management program, about 75% of total acres burned has occurred within 13 burning days. Total hours of heavy smoke intrusions in metropolitan areas have been reduced from 166 hours in 1981 to 73 hours in 1987 for the entire Valley (1987 DEQ Annual Report on Field Burning). Complaints from individuals citing eye irritation and aggravation of asthma and other illnesses range from 500 to 1,500 per year. A higher proportion of complaints come from urban areas with high populations. Complaint levels correlate poorly with intrusion levels.

The internal adjustments made by growers which have made reduced burning possible while retaining the economic viability of the industry are less obvious. The adjustments have included changes in field cultural practices, changes in thermal sanitation practices, adjustment among the mix of grass seed species grown both at the farm and industry level, and increase in use of proprietary varieties.

Growers have reduced the acres of annual ryegrass produced and have gone, on a portion of the acres remaining, to a fall plow-down and reseedling to replace field burning. Some straw is roadsided as a companion practice. On the perennial grasses, especially those grown in the north Valley, a definite increase in roadsiding the straw followed by propane flaming is observed. An increased volume of straw appears to be intended for sale. Some 20 storage units have been built since 1986. A state pollution control tax credit serves as an incentive for storage construction. Baling for commercial sale is relatively common. During the early 1980's, a definite shift toward proprietary varieties with forward contracting was employed, largely as a mechanism for reducing market price risk. Some shifting away from this has occurred since 1985 as market prices improved significantly and have stayed favorable since then.

#### HETEROGENEITY OF THE VALLEY'S GRASS SEED INDUSTRY

In discussing internal adjustments it is important to recognize that the industry of some 800 growers is not homogeneous nor is the ability to adjust equal among growers.

Soil conditions and topography vary widely across the Valley and have a major influence upon the nature of grass seed production. Farmers in the southern Willamette Valley (Linn, Benton and Lane

counties) tend to specialize in grass seed crops with emphasis upon annual and perennial ryegrass because of the extensive area of poorly-drained soils in which most crops will not survive the winter flooding. Grass seed farmers in Polk, Yamhill, Marion, Clackamas and Washington counties have smaller farm units and are more diversified. Soils are variable, providing opportunities for a variety of crop alternatives and rotations. In the hilly areas where soil erosion is a problem, such as the Silverton Hills, crop choices are more restricted. In those areas farmers specialize in bentgrass and fine fescues, grasses well adapted for erosion control.

Geography is a factor. Grass seed farm location relative to urban population concentrations, major traffic flows, and prevailing winds during the burning season strongly influence whether and when open burning is allowable. The net effect is a wide variation in terms of adjustment alternatives and ability to absorb cost increases associated with those adjustments.

Each grass seed species faces a different market (ranging from export only for bentgrass, to U.S. only for orchardgrass), and serves different market roles ranging from lawn and turf use, pasture and cover-crop use, and multi-purpose use for seed mix blending. Domestic and foreign prices differ markedly among species at a moment in time and over time. Thus relative profitability among species can and does change over time. In general, annual ryegrass has been historically the species with the lowest profit margin. In the marketplace it is most used for winter overseeding of lawns and pastures in the south, and as a filler in grass seed mixes.

## **ADJUSTMENTS IN CULTURAL PRACTICES INVOLVING THERMAL SANITATION**

Some growers are choosing forms of low cost residue removal practices combined with propane flaming for thermal sanitation as a substitute for open-field burning (Appendix D). While this mix of choices is more expensive than open-field burning, it is less costly than other choices or mix of choices. While agronomic research currently is focusing upon non-thermal cropping practices and farming systems, such a focus was begun only since 1980. Some form of thermal sanitation continues as an important cultural practice to dispose of an unmarketable residue and control insect, disease, and weed pests inexpensively.

## **TECHNICAL AND ECONOMIC CONSIDERATIONS FOR FUTURE ADJUSTMENTS**

### **Competitive and Risky Nature of the Industry**

Production of grass seed in the Willamette Valley, like U.S. agriculture generally, is conducted under a perfectly competitive environment in which individual producers are price takers in the marketplace. Market demand is dictated by forces beyond the control of producers. Consumer demand for lawn and turf grasses, especially turf-type proprietary varieties of tall fescue and perennial ryegrass have increased markedly in the 1980's, especially the past five years. This has come largely through the development and release of proprietary varieties which are capturing cool-season turf markets and some warm season grasses markets as well. Additionally, these new turf-type varieties of tall fescue and perennial ryegrass provide significantly and consistently higher yields of 200 to 300 pounds per acres than their traditional counterpart. The combined higher market price and higher yields have led to phenomenal growth of these species in the Valley. Grass seed producers have shifted away from annual ryegrass and expanded total acreage of grass seed. Supply continues to lag behind demand in this market, a condition which may prevail for another year or two.

The pasture grass market for tall fescue and orchardgrass softened greatly in 1988 with high inventories in the seed trade as the government CRP program comes to an end.

The boom years since 1985 for the industry can be expected to taper off as lagged supply increases catch up with demand. An overshooting of this situation would send market prices tumbling accompanied by major economic stress as occurred in the early 1980's. Slow adjustment by growers to lower prices through downward acreage adjustment would further aggravate the situation.

### **Unknown Ability of Industry to Absorb Further Cost Increases**

Structural adjustments within the Willamette Valley grass seed industry to date have been absorbed almost totally by individual growers through higher production costs. Production costs are an extremely

important element in maintaining production efficiency. Increased unit production costs have occurred as growers have shifted from low cost open burning to higher cost alternatives. Improved markets since the mid-1980's have helped offset the increased production costs through higher market prices. Whether further increases in production costs can be absorbed by the industry, without offsetting higher market prices, is unknown.

Historically, the industry has had an economic advantage in the marketplace relative to competing production regions through quality, yield, and cost efficiency advantages. Grass seed contractors, skittish about the future of the Valley's grass seed industry, are searching for alternative producing areas in the U.S. and overseas. Whether such a quest will be successful is unknown. Most other producing regions treat grass seed production as a complementary crop to pasture production for livestock. No analysis of these regions have been made to determine production costs/returns from grass seed/forage production, profitability of grass seed production relative to alternative crop and livestock enterprises in those regions, certification requirements, and seed yields. All of these factors influence the extent to which regions compete with one another in the various grass seed markets.

### **Physiological Response Differences Among Species to Thermal and Non-Thermal Management**

The physiological response of each grass seed species differs widely both under thermal sanitation and non-thermal management alternatives. In other words, the need for burning differs across species and possibly even varieties. Very limited information is currently available in regard to how species might be ranked or given priority for burning. Additional considerations include the thoroughness of mechanical residue removal that is possible on a given field site, and the age of stand. Comparisons between burned and unburned management through previous research have been very limited and under optimal control conditions.

Susceptibility to disease may also determine the necessity of burning on a species by species basis. Ergot is potentially the most serious of the grass seed diseases as all grasses grown for seed are susceptible, and it is widespread throughout the region on wild grasses, which are an important source of inoculum. In perennial ryegrass blind seed disease is the most serious problem; it is also a threat in annual ryegrass, and has been identified in several tall fescue fields. Seed gall nematode has previously caused serious yield loss in seed crops of bentgrass and fine-leaf fescue.

Similar variation by species to affliction from insect pests has also been observed. However, monitoring systems capable of identifying economic levels of impairment from disease or insect scourge have not been developed. Before considering post harvest residue management to be differentiated by particular species, research should evaluate the long term implications of physiological and pest issues.

### **Unknown Impact of Future Disease, Insect, and Weed Pests Without Thermal Sanitation**

Open-field burning as a single operation has played a number of important roles in the production of grass seed. One of them involves pests. The cumulative effect upon seed quality, germination, and yield of reducing thermal sanitation and shifting to less than annual burning and non-thermal practices is unknown. Further, the potential impact of eliminating thermal sanitation entirely in the Valley upon the incidence of pests that affect yield and quality is unknown. Research is now underway to assess these issues. However, short of an outright ban on thermal sanitation, there is no effective way to research the aggregate or industry effect of pests when large acreages of grass seed are not burned. Research on non-thermal sanitation alternatives was initiated in the 1980's when it became apparent that mobile field sanitizers were not an economically viable alternative.

The availability of pesticides for control is very limited and will continue to be further restricted. Concern over pesticide residue in grass straw for livestock and ground water may further limit their use.

### **Straw Utilization: A Marginal Activity**

A very limited market has been found to date for straw residue. Straw must go through costly field removal, transportation, and transformation processes to be used successfully in livestock feed, fiber, fuel, and chemical extraction markets. This makes straw noncompetitive with existing raw materials in those markets, an issue amply tested by R&D activities on straw utilization. At this point perhaps 20% of all straw removed is marketed, mostly in Japan, with some limited U.S. markets during periods of short sup-

ply of usual livestock forages. An important implication here is that any additional unburned acres will have little or no potential for straw utilization thus further increasing straw disposal costs for those acres.

#### **Alternative Crops**

Crops which are economically superior to grass seed production continue to be elusive. Meadow-foam, a new crop with oil potential in the industrial market, is a prospect but several years away, if ever, from being economically viable in such a market. Potential market size appears to be small, so an unlikely potential crop for the entire Valley.

A number of crops have been grown on grass seed lands. They include small grains, grass pasture for livestock, alsike clover, and vetch. Each of these crops are less intensive in nature and hence less profitable than grass seed.

#### **The Quest for a Solution: To Date Largely a Private Sector Endeavor**

Grass seed producers in the Willamette Valley have been the dominant actors in finding economically viable alternatives to open-field burning. Their action has come through use of grower burning fees to fund research and development activities over the past two decades and strong cooperation in making the smoke management program effective. Very limited public funds have been devoted to such activities. The major focus in use of R&D funds has been upon alternative means of thermal sanitation, improved smoke management, crop residue utilization, alternatives to thermal sanitation, and alternative crops. Limited research activity has focused upon public health effects, either through public or Field Burning R&D Program funds.

Public funds have been used for the Pollution Control Tax Credit program initiated by the 1983 Oregon Legislature. Some 20 to 40 grass seed growers have used the tax credit in construction and/or purchase of storage sheds, propane flamers, stack wagons, and associated equipment. The program has provided a 25 to 50% state income tax write-off of capital investment items used in environmental pollution control. The program is being phased down with termination at the end of 1990.

#### **Adverse Public Health Effects Largely Unmeasured**

To date, little research has been undertaken to determine the existence of adverse health effects of smoke from field burning under the current smoke management program. This is unfortunate as it is public outcry which has expressed concern over health effects from field burning. Research has not been undertaken to measure the nature and magnitude of such health effects. The transitory nature of field burning, while highly visible during the short burning periods during the summer, is elusive to detection and measurement of incremental health effects. The smoke management program currently in place has contributed to moving smoke to the upper atmosphere and away from urban areas as evidenced by DEQ nephelometer readings and reduced smoke impact hour reportings. As a consequence, it is still unknown whether field burning is or is not the source of substantive health effects. Further, it is unknown whether the full set of smoke emissions in the Valley which includes slash burning, residential wood burning, and open-field burning collectively create a substantive health hazard and the role of field burning as a component.

#### **Public Hazard, Nuisance, and Aesthetic Effects Observed but Largely Unmeasured**

It is apparent that field burning can create hazards as evidenced by the August 1988 accident on I-5 near Albany with resulting loss of human lives. Addition of fire safety buffer zones along major Valley highways and strengthening of current smoke management rules were implemented to reduce risk of such a hazard. The extent to which even more stringent rules can serve to minimize or eliminate such hazard is unknown. Some minimal level of fire hazard likely will persist on highway rights-of-way during hot and dry summers as they are grass covered.

A further issue not treated involves nuisance, soiling, and aesthetic effects from field burning. Negative effects upon Oregon's tourist industry, which have been mentioned in public debate, have been limited to a single study contracted by DEQ in 1986. The study provides an initial attempt to estimate the amount Oregonians would be willing to pay for improved visibility. No attempt was made to directly link that to smoke from specific sources (Crocker, 1986).



## **Research Needs**

Significant progress has been made identifying individual factors relating to the complex issue of finding alternatives to open burning. However, many problems remain to be resolved and cannot be resolved without additional resources.

Several methods have been proposed for removing straw residue from perennial grass seed fields and have been tested in experimental trials. Tests have not been conducted under field conditions regarding the effectiveness of these practices to control grass seed diseases or control weeds in the absence of field burning and field flaming.

An integrated research approach is needed to provide definite guidelines for a seed production system for each of the major grass species under Willamette Valley conditions when straw is not burned. Straw handling methods, tillage systems, species, fertilization, disease, insect, weed, and pest variables should be compared. These practices should be molded into competitive production systems.

A study of the seed industry and its ability to compete with other producing regions is needed.

A program for improvement of seed yield in meadowfoam in conjunction with federal resources should be supported. A marketing program for meadowfoam oil should be initiated.

Support is needed to develop an integrated pest management program for grass seed. Such a program would provide both research and extension support for implementation of new technology of pest management to provide long term solutions for pest control.

Support should be provided for registration of pesticides essential for grass seed production to permit livestock feeding.

Support is needed to coordinate on-farm research and conduct an aggressive demonstration trial education program on non-burning alternatives.

## CHAPTER 8

### A VIEW TOWARDS FURTHER ADJUSTMENTS

Although significant reductions in open-field burning have been realized in the last two decades, public concerns with the hazard effect of field burning resurfaced with the unfortunate series of accidents and subsequent deaths on I-5 near Albany on August 3, 1988. The debate over broader public welfare effects of field burning has also intensified. As a consequence, there is renewed interest in developing grass seed production techniques which are compatible with the welfare of the broader community.

The initial step in addressing this debate is the outlining of a range of policies which may be considered. Next, the implications each choice might have upon all of the relevant groups should be detailed. At stake are the expected benefits and losses resulting from each alternative policy for the grass seed industry and its individual growers on the one hand and the general public concerned with air quality on the other. To date, little substantive research evidence has been provided that quantifies the health impacts from burning. Similarly, while public hazard, nuisance, soiling, and aesthetic effects have been confirmed by observation, their importance has not been measured. It is therefore not possible to quantify the extent that public air quality will be affected by further reductions in open burning.

The discussion of the net impact of further adjustments in grower production practices is complicated by the lack of reliable information on the smoke emissions associated with propane flaming, a practice developed as an alternative to open burning. Preliminary observations suggest that low level emissions from propane flaming may lead to widespread and persistent haze throughout the valley if this practice gains greater use. Studies are underway to ascertain more precisely the air quality tradeoffs between propane flaming and open burning. The treatment of propane flaming within the context of changes in the regulation of thermal sanitation practices remains unclear.

It is unfortunate but true that, given our current state of knowledge, there will be a direct tradeoff between reductions in smoke impact levels and reductions in the profitability of grass seed production, all else equal. At one extreme, unrestricted burning would permit growers to minimize their costs of production and maximize profits but would result in reduced levels of air quality. At the other extreme, the elimination of all thermal sanitation practices would improve air quality levels but would have significant short and long run impacts on the profitability of the industry. In a broader sense the inverse relationship between air quality and the profitability of grass seed production may be an over simplification as current grass seed production practices have favorable environmental impacts when compared to alternatives in areas such as erosion control, levels of dust in the atmosphere, and urban/industrial development.

The current situation which requires growers to register acreage and open burn under the DEQ controlled Smoke Management Program represents an initial effort to weigh the tradeoffs between the conflicting objectives outlined above. In the light of recent events, it is likely that the status quo with regard to burning will be viewed as being at one end of the spectrum of choices with the other alternatives that will receive serious consideration being more restrictive. A selected list of possible alternatives to be considered are listed and briefly discussed below. Increased restrictions on propane flaming may or may not be included for each of these alternatives.

**1. Maintain the current field burning program but impose further controls to further reduce the hazard from open burning which may endanger human lives.** This policy choice is intended to solely address and reduce the risk of life-threatening accidents. The impact on growers would be geographically focused and limited to those located adjacent to the highways and urban centers. As compared to the current situation, the smoke management program would become more expensive and affected farmers would face increased production costs.

**2. Implement negotiable burning rights for grass seed growers.** This policy choice involves use or access rights which can be bought and sold in the marketplace among growers. The rights would permit the marketplace to be used to determine the economic importance of open-field burning relative to other choices. Where bans or severe restrictions are placed on burning, the growers can sell their rights or portions thereof, using the proceeds to invest in alternative measures. The current Smoke Management program would not be affected.

**3. Use public funds for subsidies and expanded research and development on pollution abating technology and adjustment options.** The intent of this policy choice is to expedite the transition toward fewer air polluting activities by seed growers through increased support and assistance from the public sector.

**4. Continue with the restricted open burning program but reduce the maximum burned acreage to some lower level with the actual number of acres burned determined by meteorological conditions.** Growers in 1988 demonstrated the ability to adjust to a lower level of burning through an increased reliance upon straw removal (often followed by propane flaming), plow-down of residue of annual ryegrass, and other techniques. As the maximum acreage limit is reduced, grower adjustments will become more difficult and costly to accomplish.

**5. Continue with the restricted open burning program but accomplish a reduction in the number of acres burned by increasing the per acre fee for burning.** The current burning fee of \$3.50 does not come close to offsetting the economic advantage to the grower of open burning. Increasing the fee to a level great enough to serve as a disincentive to open burn and shift to other alternatives would simultaneously reduce the number of acres burned and increase or maintain the money generated by the DEQ for research on alternatives to burning. However, availability of effective and economical alternatives is a critical requirement. Several years may be required to construct and field-test equipment.

**6. Provide a phased reduction in open burned acreage over a set period of time until the practice is eliminated entirely.** The advantage of the deliberate phase-down approach to farmers is that it would provide them with a learning period to incorporate new production technologies. The public, in turn, would realize a gradual reduction in smoke emissions. Adequate time should be allowed for growers to meet contract agreements of two to four year duration.

**7. Eliminate open-field burning for residue removal (i.e. for short term economic reasons) but permit the use of thermal sanitation on a "prescriptive" basis in order to control disease, weed, and insect problems.** This approach would safeguard the long term productivity of the grass seed industry but would ignore potentially significant short term economic impacts. The key unknowns are cost and effectiveness of the monitoring system, the number of acres burned, and alternative means for residue disposal.

**8. Eliminate open-field burning entirely.** This approach would be at the extreme end of the spectrum and would provide an abrupt and immediate transition towards the minimization of smoke impacts while simultaneously maximizing the short and long term economic costs and viability risks faced by the industry.

As the emphasis shifts away from open burning toward greater reliance upon mechanical propane flaming and stack burning, production costs would increase accordingly (Appendix D). Increased costs would include propane flaming and residue removal and disposal. An indirect effect would involve reduced grower fees available for needed smoke management and research and development activities unless alternative mechanisms for funding these activities are established as suggested in one of the policy alternatives named above. The air quality effects of propane flaming and stack burning, while unknown, are being researched.

## **APPENDICES**

## APPENDIX A

### LITERATURE CITED

- Adams, H., 1977. "Complete dairy rations using straw." Feeding trial report to Oregon Field Sanitation Committee by OSU Extension Service, Corvallis. March 15, 1977.
- Agricultural Fiber Association, 1982. "The straw bale injector project (Single bale injector)." Report to Oregon DEQ Advisory Committee by AFA, Dallas, OR on March 8, 1982. DEQ vol. 27A.
- Agricultural Fiber Association, 1983a. "A bale injector? The AFA has it!" Brochure by AFA, Dallas, OR. April 1983. DEQ vol. 27.
- Agricultural Fiber Association, 1983b. "Feeding grass straw." Brochure by AFA, Dallas, OR. April 1983. DEQ vol. 7.
- Agricultural Fiber Association, 1983c. "Design, construction, testing and use of straw bale nutrient injector." Report to DEQ Advisory Committee by AFA, Dallas, OR, on March 8, 1982. DEQ vol. 27.
- Agricultural Fiber Association, Inc. 1986a. "Straw mulch demonstration and testing (1984-1986)." Report to DEQ Advisory Committee for AFA by T.R. Miles, Consulting Engineer, Portland, OR, April 11, 1986. DEQ vol 36.
- Agricultural Fiber Association, Inc. 1986b. "Use of straw to control erosion." Fact sheet by Agricultural Fiber Association, Dallas, OR, April 1986. DEQ vol 36.
- Agricultural Fiber Association, 1986c. "Use straw to control erosion." Fact sheet, Dallas, OR. DEQ vol. 36.
- Anderson, A.W., E.M. Bates, W.J. Bublitz, D.O. Chilcote, D.C. Church, D. Claypool, F.S. Conklin, V. Freed, J.R. Hardison, J.A. Kamm, D.E. Kirk, W.O. Lee, G. Page, R.E. Pulse, A.T. Ralston, W.A. Schurg, H. Youngberg, 1974. *Oregon State University Research on Field Burning*. OSU Agricultural Experiment Station Circular of Information 647, Corvallis. December 1974.
- Anderson, A.W., and C.J. Israilides, 1979. "Mold inhibition on hydromulch." Report to DEQ Advisory Committee by OSU Department of Microbiology, Corvallis, on May 9, 1979. DEQ vol. 15.
- Anderson, D.C., 1977. "Cow wintering programs and the use of low quality roughages." In *Cattleman's Handbook for Cattle Conferences*. OSU Extension Service, Corvallis.
- Anderson, D.C., and A.T. Ralston, 1973a. "Chemical treatment of ryegrass straw: In vitro dry matter digestibility and compositional changes." *J. of Animal Science*, 37(1), 148-152 (1973).
- Anderson, D.C., and A.T. Ralston, 1973b. "Ryegrass utilization by sheep." *Proceedings of the Western Section*, American Society of Animal Science, vol. 24.
- Andren, R.K., M.H. Mandels, and J.E. Madeiros, 1975. "Production of sugars from waste cellulose by enzymatic hydrolysis. Part I: Preliminary evaluation of substrates." Presented at 8th Cellulose Conference. SUNY, Syracuse, NY., on May 19-23, 1975.
- Apt, W.J., H.M. Autenson, and W.D. Courtney, 1960. "Use of herbicides to break the life cycle of the bentgrass nematode, *Anguina agrostis* (Steinbuck 1799, Filipjev 1936)." *Plant Dis. Reprtr.* 44:524-526.
- Ayres, G.D., 1977. "Effect of four variables on grass-straw fiber overlaid plywood panels." Master's thesis presented to Department of Forest Resources, University of Washington, Seattle, WA, February 1977.
- Barker, R.E., and R.R. Kalton, 1988. "Cool-season forage grass breeding: Progress, potentials, and benefits." In D. A. Sleper and K. H. Asay (eds). *Contributions from breeding forage and turf grasses. Crop Science Society of America*, Madison, WI. (In press)
- Bedell, T.E., 1976. "Liquid protein supplementation of pregnant beef cows." Feeding trial report prepared for Oregon Field Sanitation Committee, December 1976.
- Beelart, J.H., Jr., 1975a. "Field burning machine demand in the Willamette Valley." Survey report to Oregon Field Sanitation Committee.
- Beelart, J.H., Jr., 1975b. "Market feasibility of straw based firelogs." Report to Oregon Field Sanitation Committee, August 12, 1975.
- Boubel, R., 1976. "Particulate emissions from a straw-fired boiler." In A.D. Hughes. *Strawdust as a boiler fuel*, test report prepared for Oregon Field Sanitation Committee. February 18, 1976.

- Bovine, F.J., 1970. "The story of ergot." S. Karger. Publ., New York. 297 pp.
- Brady, B., 1976. "Disc defibration of Oregon grass straws." Prepared for T. R. Miles and Oregon Field Sanitation Committee, September 1976.
- Brede, A.D., T.M. Harris, and P.L. Sanders, 1987. "Control of ergot in Kentucky bluegrass seed production. Fungicide and nematicide tests." *Amer. Phytopath. Society Press*. St. Paul, MN.
- Bretag, T.W., 1981. "Epidemiology and cross-infection of *Claviceps purpurea*." *Trans. Br. Mycol. Soc.* 77:211-213.
- Bretag, T.W., 1985. "Control of ergot by selective herbicide and stubble burning." *Trans. Br. Mycol. Soc.* 85:341-343.
- Bretag, T.W., and P.R. Merriman, 1981. "Effect of burial on survival of sclerotia and production of stromata by *Claviceps purpurea*." *Trans. Br. Mycol. Soc.* 77:658-660.
- Bublitz, W.J., 1974. *Pulping characteristics of Willamette Valley grass straws*. OSU Agricultural Experiment Station Station Bulletin 617, Corvallis. November 1974.
- Cade, K., and R. Hadley, 1986. "Straw pelletizer 1986 (Pelco, Inc.)." Report to DEQ Advisory Committee, December 17, 1985. DEQ vol. 40.
- Cagas, B., 1986. "Effectiveness of selected fungicides against the ergot (*Claviceps purpurea*) in grasses." *Sbor. UVTIZ - Ochr. Rostl.* 22:199-205. (English summary).
- Campbell, W.P., and H.A. Freisen, 1959. "The control of ergot in cereal crops." *Plant Dis. Repr.* 12:1266-1267.
- Canadian Resourcecon Limited and T.R. Miles, 1985. "Development and evaluation: Concentric vortex chaff furnace phase I." Report to ERDAF Program No. 01SG.01916-3-ER37, Agriculture Canada, Swift Current, SASK.
- Chilcote, D.O., P.C. Stanwood, and S. Kim, 1974. "The nature of post-harvest residue burning effect on perennial grass seed yield." In *Proceedings of the 34th Annual Meeting of the Oregon Seed Growers League*, Eugene, OR, pp. 15-19.
- Chilcote, D.O., and H.W. Youngberg, 1975. "Propane flamer burning of grass seed stubble." *Progress Report EXT/ACS 8*, OSU Agricultural Experiment Station, Corvallis.
- Chilcote, D.O., and H.W. Youngberg, 1975. "Non-burning techniques of grass seed residue removal." *Progress Report EXT/ACS 9*, OSU Agricultural Experiment Station, Corvallis.
- Chilcote, D.O., H.W. Youngberg, P.C. Stanwood, and S. Kim, 1980. "Post-harvest residue burning effects of perennial grass development and seed yield." In P. D. Hebblethwaite (ed.) *Seed Production*. pp. 91-103. Butterworths, London.
- Church, D.C., 1975. A "preliminary report on digestibility trials with ryegrass straw." Prepared for the Oregon Field Sanitation Committee by OSU Department of Animal Science, Corvallis.
- Church, D.C., and W.H. Kennick, 1977a. *Grass straw in finishing rations for lambs and cattle. 1977 Sheep and Wool Day, OSU Agricultural Experiment Station Special Report 482, Corvallis. April 1977.*
- Church, D.C., and W.H. Kennick, 1977b. *Grass straw in finishing rations for cattle. 18th Annual Beef Cattle Day, OSU Agricultural Experiment Station Special Report 486, Corvallis. May 14, 1977.*
- Church, D.C., and W.H. Kennick, 1977c. *Grass straw in finishing rations for cattle and sheep. OSU Agricultural Experiment Station Technical Bulletin 140, Corvallis. November 1977.*
- Conklin, F.S., 1971. "Farmer alternatives to open field burning: An economic appraisal." OSU Agricultural Experiment Station Special Report 336, Corvallis.
- Conklin, F.S., 1972. "Research by OSU associated with issues of open field burning: 1965-1972." Memo from OSU Department of Agricultural Economics, Corvallis.
- Connors, I.L., 1953. "Ergot in cereals in Western Canada in 1953." *Canadian Plant Dis. Survey* 33:23-28.
- Connors, I.L., 1956. "Ergot in cereals in Western Canada in 1955." *Canadian Plant Dis. Survey* 35:29-31.
- Connors, I.L., 1967. "An annotated index of plant diseases in Canada and fungi recorded on plants in Alaska, Canada, and Greenland." *Canadian Dept. Agr. Public.* No. 1251. Queen's Printer, Ottawa. 381 pp.
- Cornelius, J.E., 1985. "Economic analysis of non-yearly burning alternatives in Willamette Valley grass seed production." Report to DEQ Advisory Committee from OSU Department of Agricultural and Resource Economics, Corvallis, July 10, 1985. DEQ vol 17F.

- Courtney, W.D., and H.B. Howell, 1952. "Investigations on the bentgrass nematode *Anguina agrostis* (Steinbuck 1799, Filipejev 1936)." *Plant Dis. Repr.* 36:75-83.
- Cunfer, B. M., 1975. "Colonization of ergot honeydew by *Fusarium heterosporum*." *Phytopathology* 65:1372-1374.
- Early, R.J., and D.C. Anderson, 1976. "Bluegrass straw composition and utilization." *Proceedings Western Section American Society of Animal Science*, vol. 27.
- Ebling, J.M., M.L. Stone, and G.A. Kranzler, 1982. "A direct combustion biomass furnace for hop residue." *American Society of Agricultural Engineers*, Paper PNR 82-302, St. Joseph, MO, September 15, 1982.
- Ehrensing, D.T., and D.O. Chilcote, 1985. "Production physiology of pyrethrum." Department of Environmental Quality Field Burning Report, vol. 39A.
- Fickeisen, D.H., D.A. Neitzel, and D.D. Dauble, 1984. "White sturgeon research needs, workshops results." PNL-4950. Prepared by Battelle Pacific Northwest Laboratories for Bonneville Power Administration, February 1984.
- Fischer, G.W., 1944. "The blind seed disease of ryegrass (*Lolium* spp.) in Oregon." *Phytopathology* 34:934-935.
- FMC Corporation, 1978. "System engineering study of technical and economic evaluation of grass field sanitizing machines," Vol.I Tech. Report. Engineering Systems Division, Santa Clara, CA. ESD Project 656.
- Frey, K.L., 1973. "Hydrolyses of rye grass straw for propagation of *Candida utilis*." Master's thesis presented to OSU Department of Microbiology, Corvallis. June 1973.
- Frischknecht, W.D., H.P. Adams, and L.R. Vough, 1977. "Feeding beef cattle during periods of feed shortages." OSU Extension Service Extension Circular 934, Corvallis. June 1977.
- Futrell, M.C., and O.J. Webster, 1966. "Host range and epidemiology of the sorghum ergot organism." *Plant Dis. Repr.* 11:828-831.
- Gamroth, M., and G. Pirelli, 1988. *Feeding grass straws to cattle and horses*. OSU Extension Service Fact Sheet 234, Corvallis. October 1988.
- Gay, C.N., and R.C. Shattock, 1980. "*Fusarium heterosporum* and *Claviceps purpurea* on *Lolium perenne*." *Trans. Br. Mycol. Society* 74:537-542.
- Grant, G.A., Y.A. Han, A.W. Anderson, and K.L. Frey, 1977. "Kinetics of straw hydrolysis." *Developments in Industrial Microbiology*, Chapter 50, Society of Industrial Microbiologists.
- Groner, R.R., 1971a. "Straw composition and utilization: A literature survey." Prepared by OSU Department of Agricultural Chemistry, Corvallis. November 1971.
- Groner, R.R., 1971b. "Industrial Utilization of Straw: Review of international publications." Prepared by OSU Department of Agricultural Chemistry, Corvallis. November 1971.
- Groner, R.R., 1974a. "Classification of hammermilled annual ryegrass straw." Prepared for T. R. Miles, consulting engineer, by OSU Department of Agricultural Chemistry, Corvallis. July 17, 1974.
- Groner, R.R., 1974b. "Reduction of straw particle size by milling." Prepared for T. R. Miles, consulting engineer, by OSU Department of Agricultural Chemistry, Corvallis. July 1974.
- Groner, R.R., 1975. "Proposal for a small scale commercial straw particleboard plant." Prepared by OSU Department of Agricultural Chemistry, Corvallis. 1975.
- Groner, R.R., and J.F. Barbour, 1971. "Straw particleboard: An engineering and economic analysis." Prepared for HEW Bureau of Solid Waste Management by OSU Department of Agricultural Chemistry, Corvallis. 1971.
- Groner, R.R., and J.F. Barbour, 1972a. "Effect of wax removal on straw particleboard physical properties." Prepared by OSU Department of Agricultural Chemistry, Corvallis. March 1972.
- Groner, R.R., and J.F. Barbour, 1972b. "Particleboard made from straw/wood blends." Prepared by OSU Department of Agricultural Chemistry, Corvallis. March 1972.
- Guggolz, J., G.O. Kohler, and T.J. Klopfenstein, 1971. "Composition and improvement of grass straw for ruminant Nutrition." *Journal of Animal Science*, 33 (1), 151-156, January 1971.
- Hagemann, J.W., J.A. Rothfus, and M.A. Taylor, 1981. "Comparison of sperm whale oil with three potential replacements on a mini four-ball wear tester." *Lubr. Eng.* 37:145-152.

- Han, Y.W., and A.W. Anderson, 1975. "Semi-solid fermentation of ryegrass straw." *Journal of Applied Microbiology*, 30:930-934.
- Han, Y.W., W.P. Chen, and T.R. Miles, 1978. "Effect of refiner defibrizing on the fermentability of ryegrass straw." *Biotechnology and Bioengineering*, vol. XX:567-575.
- Han, Y.W., G.A. Grant, A.W. Anderson, and P.L. Yu, 1976. "Fermented straw for animal feed." *Feed-stuffs* 48:17-20.
- Han, Y.W., J.S. Lee, and A.W. Anderson, 1975. "Chemical composition and digestibility of ryegrass straw." *Agric. and Food Chemistry* 23:928.
- Hardison, J.R., 1946. "Preliminary suggestions for control of the grass seed nematode." *Proceedings 6th Annual Meeting*, Oregon Seed Growers League, pp. 69-74.
- Hardison, J.R., 1948. "Field control of blind seed disease of perennial ryegrass in Oregon." *Phytopathology* 38:404-419.
- Hardison, J.R., 1949. "Blind seed disease of perennial ryegrass." OSU Agricultural Experiment Station Circular of Information 177. 11pp.
- Hardison, J.R., 1957. "Record of blind seed disease control in Oregon." *Plant Dis. Repr.* 41:34-41.
- Hardison, J.R., 1960. "Disease control in forage seed production." In *Advances in Agronomy* Vol. XII. Academic Press, Inc. pp. 96-106.
- Hardison, J.R., 1962. "Susceptibility of Gramineae to *Gloeotinia temulenta*." *Mycologia* 54:
- Hardison, J.R., 1963. "Commercial control of *Puccinia striiformis* and other rusts in seed crops of *Poa pratensis* by nickel fungicides." *Phytopathology* 53:209-216.
- Hardison, J.R., 1972. "Prevention of apothecial formation in *Gloeotinia temulenta* by systemic and protectant fungicides." *Phytopathology* 62:605-609.
- Hardison, J.R., 1974. "Disease problems without burning." *Proceedings 34th Annual Meeting*, Oregon Seed Growers League. pp. 9-11.
- Hardison, J.R., 1975. "Control of *Puccinia striiformis* by two new systemic fungicides. BAY MEB 6447 and BAS 31702F." *Plant Dis. Repr.* 59:652-655.
- Hardison, J.R., 1976. "Fire and flame for plant disease control." *Ann. Rev. Phytopathol.* 14:355-379.
- Hardison, J.R., 1977a. "Chemical suppression of *Gloeotinia temulenta* apothecia in field plots of *Lolium perenne*." *Phytopathology* 68:513-516.
- Hardison, J.R., 1977b. "Chemical control of ergot in field plots of *Lolium perenne*." *Plant Dis. Repr.* 61:845-848.
- Hardison, J.R., 1980. "Role of fire for disease control in grass seed production." *Plant Dis. Repr.* 64:641-645.
- Hardison, J.R., 1987. "Biological control of ergot and blind seed disease by microbial decomposition of sclerotia stimulated by treatment with monocarbamide dihydrogen sulfate." *Phytopathology* 77:1239.
- Harper, F.R., and W.L. Seaman, 1980. "Ergot of rye in Alberta: Distribution and severity 1972-1976." *Canadian Journal Plant Path.* 2:227-231.
- Hornok, L., and I. Walcz, 1983. "*Fusarium heterosporum*. A highly specialized hyperparasite of *Claviceps purpurea*." *Trans. Br. Mycol. Society* 80:377-380.
- Huffman, D.E., and A. L'Ecuyer, 1985. "Testing and assessment of the Sukup Biomaster Crop Residue System." Report to ERDAF Program No. 34sz.01843-1-ER07, *Agriculture Canada*, Ottawa, ONT, January 23, 1985.
- Hughes, A.D., 1976. "Strawdust as a boiler fuel." Test report to Oregon Field Sanitation Committee. February 18, 1976.
- Hughes, A.D., and J. Welty, 1976. "Explosibility of strawdust." Reported In T.R. Miles. The combustion of straw: Mobile and stationary. Presented to Spring Meeting, Western States Section, The Combustion Institute, WSC/CI Paper 77-15. April 18, 1977.
- Humphrey, A., 1975. "Tests for T.R. Miles at College of Engineering and Applied Science." University of Pennsylvania. Philadelphia, PA, 1975.
- Hyde, E.O.C. 1938. "Detecting *Pullaria* infection in ryegrass seed crops." *New Zealand Journal of Agriculture* 57:301-302.



- Inoue, M.S., and F.S. Conklin, 1973. "Japanese market potential for grass straw." Presentation to Oregon Seed Growers League, 33rd Annual Meeting, Eugene, OR, December 10-12, 1973.
- Irwin, T.C., III, 1984. "Grass straw as a viable source of home heating fuel." Report to Oregon Department of Energy No. C 50046, Irwin & Sons Agricultural Supply, Inc., Cheshire, OR. August 14 1984.
- Isley, A., 1976. "Lake County feeding trial (Straw and supplement)." In T. R. Miles. Consulting Engineers Report to the Oregon Field Sanitation Committee for the Years 1975, 1976. Portland, OR. December 1976.
- Jackson, T.L., and N.W. Christensen, 1985. "Nitrogen fertilizer effects on straw decomposition." Report to the Field Burning Committee by OSU Department of Soil Science, Corvallis. October 1985.
- Jacob, I.H., 1973. "Building materials made from grass straw ("Stramit")." Brochure prepared by Normarc, Inc., Tangent, OR. June 27, 1973.
- Jacob, I.H., 1974. "Market feasibility of maintenance ration for horses using grass straw." Master's thesis presented to OSU Department of Agricultural Economics, Corvallis. April 29, 1974.
- Jensen, J., 1961. *Nematodes affecting Oregon agriculture*. OSU Agricultural Experiment Station Bulletin 579. 34 pp.
- Jolliff, G.D., and C.H. Pearson, 1981. "Analysis of the agronomic and Economic feasibility of meadowfoam 1979-1980." Report to the DEQ Advisory Committee by OSU Department of Crop Science, Corvallis, OR.
- Jolliff, G.D., I.J. Tinsley, W. Calhoun, and J.M. Crane, 1981. *Meadowfoam (Limnanthes alba): its research and development as a potential new oilseed crop for the Willamette Valley of Oregon*. OSU Agricultural Experiment Station Bulletin 648.
- Kamm, J.A., 1971. "Silvertop of bluegrass and bentgrass produced by *Anaphothrip obscurus*." *Journal Econ. Entomol.* 64:1385-1387.
- Kamm, J.A., 1979. "Plant bugs: Effects of feeding on grass seed development; and cultural control." *Environ. Ent.* 8:73-76.
- Kamm, J.A., and J.R. Fuxa, 1977. "Management practices to manipulate populations of the plant bug *Labops hesperius* Uhler." *Journal Range Management* 30:385-387.
- Kamm, J.A., and M.L. Montgomery, 1988. "Reduction of insecticide activity by carbon ash produced by post-harvest burning of grass seed fields." *Journal Econom. Entomol.* (in press).
- Kay, B.L., 1979. "Hydromulching fiber - What's new?" *Agronomy Progress Rept.* No. 98, University of California Agricultural Experiment Station, Davis, CA. August 1983.
- Kay, B.L., 1983. "Straw as an erosion control mulch." *Agronomy Progress Rept.* No. 140, University of California, Agricultural Experiment Station, Davis, CA. August 1983.
- Keck, S., and J. McCarthy, 1976. "Battelle process: hydrolysis and fermentation." Farm Ecology Management Ltd., Seattle, WA. 1976.
- Kellums, R.O., 1983. "Upgrading low quality forages." Presented to Pacific Northwest Animal Nutrition Conference.
- Kellums, R.O., 1985. "Beef cattle ryegrass straw feeding trials 1983-84." Report to DEQ Advisory Committee by OSU Department of Animal Science, Corvallis. January, 1985. DEQ vol. 27C.
- Kellums, R.O., R. Miller, and D.W. Weber, 1984. "Comparative supplementation methods (Liquid, injector, ammonia) of ryegrass straw for wintering beef brood cows." *Proceedings Western Section, American Society of Animal Science*, vol. 35, 1984.
- Kellums, R.O., and D.W. Weber, 1984. "Beef cattle ryegrass straw feeding trials 1982-84." Report to DEQ Advisory Committee by OSU Department of Animal Science, Corvallis. February 1984. DEQ vol. 27B.
- Kileen, J., and A. Vanderplaat, 1976. "Willamette Valley grass seed straw." Brochure prepared for the Oregon Department of Agriculture and the Oregon Field Sanitation Committee.
- Kirk, D.E., 1982. "Straw bale burner development phase I: Literature review, model testing." Report to DEQ Advisory Committee by OSU Department of Agricultural Engineering, Corvallis. July 15, 1982. DEQ vol. 24B.

- Kirk, D.E., 1984. "Straw bale burner development phase II: Construction and testing." Report to DEQ Advisory Committee by OSU Department of Agricultural Engineering, Corvallis. March 15, 1984. DEQ vol. 24C.
- Kirk, D.E., 1985. "Furnace system for burning baled straw for domestic heating." Report to DEQ by OSU Department of Agricultural Engineering, Corvallis. May 1985. DEQ vol. 24.
- Kirk, D.E., and R.W. Bonlie, 1973. "Development and testing on a mobile field sanitizer." OSU Agricultural Experiment Station, Corvallis. May 1, 1973.
- Labruyere, R.E., 1978. "Fungal disease of grasses grown for seed." In *Seed Production*. P.D. Hebblethwaite (ed.). Butterworths, London. pp. 173-187.
- Lekprayoon, C., 1973. "Production of *Candida utilis* from annual ryegrass straw hydrolyzate." Master's thesis in OSU Department of Microbiology, Oregon State University, Corvallis. June 1973.
- MacKey, R.B., 1981. "Biomass bale burner: Preliminary feasibility study." Report to DEQ Advisory Committee by AREA Consultants, Corvallis. July 31, 1981. DEQ vol. 24A.
- Macy, G., 1973. "Feeding grass straws to livestock." Presentation to Oregon Seed Growers League, Eugene, OR. December 10-12, 1973.
- Mandelbaum, T.B., S.B. Wood, and B.A. Weber, 1984. *Sectoral output multipliers for rural counties: Lessons from Oregon's input-output studies*. OSU Extension Service, Extension Circular 1166, Corvallis.
- Mandels, M., and E. Gaden, 1976. "Enzymatic conversion of grass straw to glucose for fermentation." Tests for T.R. Miles, Consulting Engineer, Portland, OR.
- Mansour, N.S., 1984. "Straw bale vegetable production." Report to DEQ Advisory Committee by OSU Extension Service, Corvallis. November 29, 1984. DEQ vol. 37A.
- Mansour, N.S., 1985. "Vegetable production on straw bales." Report to DEQ Advisory Committee by OSU Extension Service, Corvallis. October 20, 1985. DEQ vol. 37B.
- Mantle, P.G., and S. Shaw, 1977. "Role of weed grasses in the etiology of ergot disease in wheat." *Ann. Appl. Biol.* 86:339-351.
- Meyer, W.A., 1982. "Breeding disease-resistant cool-season turfgrass cultivars for the United States." *Plant Dis. Reprtr.* 66:341-344.
- Meland, B.R., 1970. "Straw utilization technology in Canada and Northern Europe." OSU Department of Agronomic Crop Science, Corvallis.
- Meland, B.R., 1973a. "Costs for sanitizer, straw utilization and alternate smoke management techniques for 1969-1973." Memo by R&D Coordinator on Field Burning to Oregon Seed Council and Five-Member Committee.
- Meland, B.R., 1973b. "Report on alternatives to open field burning for Oregon Seed Council and Five-Member Committee." Monthly reports from R&D Coordinator, No 1-11. July 31, 1972 to May 7, 1973.
- Mikesell, O.E., 1973. "Seed grower survey." Prepared for T.R. Miles and the Oregon Seed Council by OSU Extension Service, Corvallis. 1973.
- Miles, T.R., 1974. "Straw removal and equipment survey." Prepared with OSU Extension Service for the Oregon Field Burning Committee, by T.R. Miles, consulting engineer, Portland, OR.
- Miles, T.R., 1975. "Report of the First World Straw Conference." Eugene, OR. May 1975. Proceedings prepared by T.R. Miles, consulting engineer, Portland, OR.
- Miles, T.R., 1976a. "Consulting engineers report to the Oregon Field Sanitation Committee, Report for the Years 1975, 1976." T.R. Miles, consulting engineer, Portland, OR. December 1976.
- Miles, T.R., 1976b. "Third quarter report to the Oregon Legislative Committee on Trade and Economic Development." Prepared for the Oregon Field Sanitation Committee. September 28, 1976.
- Miles, T.R., 1977a. "Straw uses as feed, fibre and fuel in Oregon." Presented to the Straw Utilization Conference, Oxford, England MAFF/ADAS Oxford, England. February 1977.
- Miles, T.R., 1977b. "Combustion of straw: Mobile and stationary." WSC/CI Paper 77-15, presented to Spring Meeting, Western States Section, The Combustion Institute. April 18, 1977.
- Miles, T.R., 1978. "BTU's by the bale." Presented to the Pacific Northwest Bioconversion Workshop, U.S. Department of Energy, Region X, Portland, OR. October 24, 1978.

- Miles, T.R., 1979. "Concentric vortex cornstalk burner, design and report." For Department of Agricultural Engineering, Iowa State University by T.R. Miles, consulting engineer, Portland, OR. July 27, 1979.
- Miles, T.R., 1985. "Development and evaluation: Concentric vortex chaff furnace phase I." Report to ERDAF Program No. 01SG.01916-3-ER37, *Agriculture Canada*, Swift Current, SASK. June 1985.
- Miles, T.R., and T.R. Miles, Jr., 1977. "Logistics of energy resources and residues." In Tillman, D.A., K.V. Sarkanen and L.L. Anderson (ed.). *Fuels and Energy From Renewable Resources*. Academic Press Inc., New York, NY.
- Miles, T.R., and T.R. Miles, Jr., 1980. "Densification systems for agricultural residues." In Jones, J.L. and S.B. Radding (ed.). *Thermal Conversion of Solid Wastes and Biomass*. American Chemical Society, Symposium Series 130, Washington, D.C.
- Miles, T.R., Jr., 1976a. "1975 straw survey." Report to the Oregon Field Sanitation Committee for T.R. Miles, consulting engineer, Portland, OR. February 1976.
- Miles, T.R., Jr., 1976b. "Economics of grass straw as a fibrous raw material." Report to the Oregon Field Sanitation Committee. T.R. Miles, consulting engineer Portland, OR. August 1976.
- Miles, T.R., Jr., 1976c. "Selling straw and straw products." Report to the Oregon Field Sanitation Committee for T.R. Miles, consulting engineer, Portland, OR. January 1976.
- Miles, T.R., Jr., 1986. "Straw mulch demonstration and testing (1984-1986)." Report to DEQ Advisory Committee for Agricultural Fiber Association by consulting engineer in Portland, OR. DEQ vol. 36. April 11, 1986
- Miles, S.D., 1987. *Oregon county and state agricultural estimates for 1986*. OSU Extension Service Special Report 790, Corvallis. 12 pp.
- Miles, S.D., 1988. *1987 Oregon county and state agricultural estimates*. OSU Extension Service Special Report 790, Corvallis. 13 pp.
- Miwa, T.K., and I.A. Wolff, 1962. "Fatty acids, fatty alcohols, and wax esters from *Limnanthes douglasii* (meadowfoam) seed oil." *Journal Am. Oil Chem. Society* 39:320-322.
- Mower, R.L., W.C. Snyder, and J.G. Hancock, 1975. "Biological control of ergot by *Fusarium*." *Phytopathology* 65:5-10.
- Odell, F.G., 1974. "Straw utilization by pelleting: A cost and feasibility test." Report to Oregon State Field Burning Committee by F. Glen Odell, consulting engineers, Portland, OR. October 1974.
- Odell, F.G., and T.R. Miles, 1974. "Consulting engineers' report to the Oregon field burning committee, report for 1974." T.R. Miles, consulting engineer, Portland, OR.
- Odell, F.G., T.R. Miles, J.A. Talbott, and Camran Corp., 1974. "Interim report: Mobile field sanitizer design review study." Prepared for the Oregon Field Burning Committee, February 6, 1974.
- Oregon Seed Council, 1972. "One million tons of grass straw annually: How can it be used." Brochure prepared by the Oregon Seed Council, Salem, OR.
- Oregon Seed Council. 1973. "Synopsis: Oregon Seed Council history of field burning since 1969." Mimeo from Oregon Seed Council, Salem, OR.
- Oregon State University, 1969. *Progress Report: Chemical utilization of straw and cellulose plastics*. Prepared by OSU Environment Health Sciences Center, Corvallis. September 9, 1969.
- Oregon State University, 1975. *Rye grass straw utilization in paper and fiberboard products*. OSU Agricultural Experiment Station, Circular of Information 648, Corvallis. January 1975.
- Oregon State University, 1977. *Field burning in Oregon*. OSU Special Report 476, Corvallis. January 1977.
- Phillips, R.L., M. Vavra, and R.J. Raleigh, 1975. "Wintering cattle on grass straw." Presentation to the Pacific Northwest Animal Nutrition Conference, Portland, OR. November 12-13, 1975.
- Pirelli, G.J., R.O. Kellums, and J. Crocker, 1985. "Cooperative straw feeding trials 1984-85." Report to DEQ Advisory Committee by OSU Department of Animal Science, Corvallis. June 30, 1985. DEQ vol. 27D.
- Pollard, M.R., and P.K. Stumpf, 1980. "Biosynthesis of C<sub>20</sub> and C<sub>22</sub> fatty acids by developing seeds of *Limnanthes alba*." *Plant Physiol.* 66:649-655.

- Porfily, L., and F.S. Conklin, 1973. "Technical and economic considerations in shipping grass seed residue to Japan." OSU Agricultural Experiment Station Circular of Information 638, Corvallis. February 1973.
- Pulse, R.E., 1973. "Ration alternatives for horses." Presented to the Pacific Northwest Animal Nutrition Conference, Portland, OR.
- Ralston, A.T., and D.C. Anderson, 1970. "Utilization of grass straw." Presented to the Fifth Annual Pacific Northwest Animal Nutrition Conference, Richland, WA. November 12-13, 1970.
- Ralston, A.T., W.H. Kennick, and T.P. Davidson, 1966. "Effect of prefinishing treatment on finishing performance and carcass characteristics of beef cattle." *Journal of Animal Science*, 25, 1, 29-33. January 1966.
- Razali, A., 1976. "Pretreatment of grass straw fiber with sodium pentachlorophenate." Prepared at the Department of Forest Resources, University of Washington, Seattle, WA.
- Rice Research Board, 1985. "Sixteenth annual report to the California Rice Growers: Sixteen years of research progress (1969-1984)." Rice Research Board, P.O. Box 507, Yuba City, CA. March 1985.
- Rohrmann, C.A., 1974. "Energy and fixed nitrogen from agricultural residues." Summary of gasification tests BNWL-SA5070 by Batelle Pacific Northwest Laboratories, Richland, WA. July 1974.
- Rossman, D.R., 1981. "Particulate and NOx emissions from Miles Conentric Vortex Furnace." Test report to T.R. Miles, consulting engineer by D.R. Rossman, Consulting Engineers, Corbett, OR. April 7, 1981.
- Sandwell, Inc. 1975. "Rye grass straw utilization in paper and fiberboard products." OSU Agricultural Experiment Station Circular of Information 648, Corvallis.
- Shultz, T.A., and A.T. Ralston, 1973. "Effects of chopping, pelletizing, hydroxide treatment and NPN sources on ryegrass straw utilization by heifers." *Proceedings of the Western Section, American Society of Animal Science*, 24.
- Shultz, T.A., and A.T. Ralston, 1974. "Effects of additives on nutritive value of ryegrass silage. II: Animal metabolism and performance observations." *Journal of Animal Science*, 39, 5, 926-930.
- Shultz, T.A., A.T. Ralston, and E. Shultz, 1974. "Effects of additives on nutritive value of ryegrass straw silage: I. laboratory silo and in vitro DM digestion." *Journal of Animal Science*, 39, 5.
- Shurg, W.A., and R.E. Pulse, 1974. "Grass straw: An alternative roughage for horses." *Proceedings of the Western Section, American Society of Animal Science*, 25.
- Shurg, W.A., R.E. Pulse, D.W. Holton, and J.E. Oldfield, 1978. "Use of various quantities and forms of ryegrass straw in horse diets." *Journal of Animal Science* 47(6):1287-1291.
- Smith, C.R., Jr., M.O. Bagby, T.K. Miwa, R.L. Lohmar, and I.A. Wolff, 1960. "Unique fatty acids from *Limnanthes douglasii* seed oil: the C<sub>20</sub> and C<sub>22</sub> monoenes." *Journal Org. Chem* 25:1770-1774.
- Smucker, W., H. Youngberg, C.C. Moon, and D.T. Ehrensing, 1984. "Construction and evaluation of an improved propane flamer for grass seed field sanitation." Report to DEQ Advisory Committee by Willard Smucker and OSU Agricultural Experiment Station, Corvallis, January 15, 1984. DEQ vol 32.
- Sprague, R., 1950. "Diseases of cereals and grasses in North America." The Ronald Press Co., New York. 538 pp.
- Steusloff, C., 1975. "Solons look at straw cuber." Capital Press, Salem, OR. September 26, 1975.
- Sukup, C.E., 1982. "Performance of a biomass furnace for grain drying." Paper No. 82-3524 presented to the 1982 Winter Meeting, American Society of Agricultural Engineers, St. Joseph, MI. December 14-17, 1982.
- Terriere, L.C., and U. Kiigemangi, 1973. "Pesticide residues in grass straw." Analysis of orchardgrass, bluegrass and ryegrass straws for B. Meland, R&D Coordinator, Oregon Field Burning Committee.
- Throckmorton, J.C., P.R. Cheeke, D.C. Church, D.W. Holtan, and G.D. Jolliff, 1982. "Evaluation of meadowfoam (*Limnanthes alba*) meals as a feedstuff for sheep." *Canadian Journal Animal Science* 62:513-520.
- Throckmorton, J.C., P.R. Cheeke, N.M. Patton, G.H. Arscott, and G.D. Jolliff, 1981. "Evaluation of meadowfoam (*Limnanthes alba*) meal as a feedstuff for broiler chicks and weaning rabbits." *Canadian Journal Animal Science* 61:745-742.

- Ticknor, R.L., 1977. "Results of straw potting media trials March-July 1977." Report to T.R. Miles, consulting engineer from OSU North Willamette Experiment Station, Aurora, OR. March-July 1977.
- Ticknor, R.L., 1982. "Strawdust<sup>(R)</sup> growth trial 1981-82." For Teuffel Industries by OSU North Willamette Experiment Station. Aurora, OR.
- Ticknor, R.L., 1983. "Growth of English ivy-hedera helix-in urea formaldehyde straw mixes." For Teuffel Industries by OSU North Willamette Experiment Station, Aurora, OR. June 29, 1983.
- Traeger Industries, Inc., 1986. "Grass straw pellet heaters - Progress report." Presented to the Oregon Seed Growers League, Portland, OR, December 1986. DEQ project 41.
- U.S. Department of Agriculture, 1960. *Index of plant diseases in the United States*. Agricultural Research Service. Agriculture Handbook 165. Washington, D.C. 531 pp.
- Vavra, M., J.A.B. McArthur, and M. Wing, 1973. "Feeding grass straw to wintering beef cows." 15th Annual Beef Cattle Day, OSU Agricultural Experiment Station, Special Report 384, Corvallis. May 19, 1973.
- Vough, L.R., H.P. Adams, and H.W. Youngberg, 1976. "Feeding grass straws to cattle and horses." OSU Extension Service Fact Sheet 234, Corvallis. August 1976.
- Wells, K.D., J.K. Currie, R.P. Mazzuchi, and D.E. Eakin, 1979. "A market analysis of grass straw commercial use potential." Report to Oregon Department of Environmental Quality by Battelle Pacific Northwest Laboratories, Richland, WA. May 18, 1979. DEQ vol. 14.
- Welty, R.E., 1986. "Response to applications of fungicides to control leaf diseases (orchardgrass, perennial ryegrass, and tall fescue)." In Seed Production Research at Oregon State University, USDA ARS Cooperating, Crop Science Extension No. 68. pp. 32-36. H.W. Youngberg (ed.).
- Welty R.E., 1987a. "Control of three leafspot diseases in orchardgrass grown for seed by fungicides." *Phytopathology* 77:1749.
- Welty, R.E., 1987b. "Disease control research." In Seed Production Research at Oregon State University, USDA ARS Cooperating, Crop Science Extension No. 70. p. 3. H.W. Youngberg (ed.).
- Weniger, W., 1924. "Ergot and its control." North Dakota Agricultural Experiment SB 176. 23 pp.
- Wilkinson, L.E., 1976. "Straw pyrolysis tests using modified New Mexico retort." Report to Oregon Field Sanitation Committee by Cascade Recovery Systems, Inc. Salem, OR. March 8, 1976.
- Willard, H.K., 1975. "Flash pyrolysis disposal of straw, EPA-GRD Cooperative Project Summary." EPA S-801202 Garrett Research and Development Company, La Verne, CA. May 9, 1975.
- Wilson, A., R.B. Mackey, and T.R. Miles, Jr., 1983. "Outline of the straw industry and its potential." Report to the DEQ Technical Advisory Committee by Agricultural Fiber Association, Dallas, OR. November 28, 1983. DEQ vol. 33.
- Young, W.C. III., H.W. Youngberg, and D.O. Chilcote, 1984a. "Agronomic and economic effects of non-yearly burning in Willamette Valley seed production." Department of Environmental Quality Field Burning Report, vol. 17E.
- Young, W.C. III., H.W. Youngberg, and D.O. Chilcote, 1984b. "Post-harvest residue management effects on seed yield in perennial grass seed production. I. The long-term effect from non-burning techniques of grass seed residue removal." *Journal Applied Seed Production*. 2:36-40.
- Young, W.C. III., H.W. Youngberg, and D.O. Chilcote, 1984c. "Post-harvest residue management effects on seed yield in perennial grass seed production. II. The effect of less than annual burning when alternated with mechanical residue removal." *Journal Applied Seed Production*. 2:41-44.
- Youngberg, H.W., 1977. "Evaluation of the close stubble-cut technique of residue removal as an alternative to field burning." Progress Report EXT/ACS 28, OSU Agricultural Experiment Station Oregon State University.
- Youngberg, H.W., D.O. Chilcote, and D.E. Kirk, 1975. "Evaluation of a field sanitizer for controlled burning of grass seed fields." Progress Report EXT/ACS 10, OSU Agricultural Experiment Station, Corvallis.
- Youngberg, H.W. and D. Grabe, 1975. "Evaluation of an alternative grass seed harvest system to facilitate residue handling." Crop Science Report EXT/ACS 15, Oregon State University, Corvallis. September 1975.

- Youngberg, H.W., C.C. Moon, and D.T. Ehrensing, 1984. "Construction and evaluation of modified propane flamer for grass seed field sanitation, Part II." EWQ Field Burning Report, vol. 32.
- Youngberg, H.W., and L. Vough, 1977. "A study of the nutritive value of Oregon grass straws." OSU Extension Service Special Report 473, Corvallis. January 1977.
- Youngberg, H.W., L. Burrill, G. Fisher, and P. Koepsell, 1988. "Feeding restrictions on pesticides used in grass seed production in Oregon." Crop Science Report EXT/CRS 27R, Oregon State University, Corvallis. Revised September 1988.

APPENDIX B  
RESEARCH AND DEVELOPMENT PROJECTS ON FIELD BURNING, WILLAMETTE VALLEY, OREGON, 1968-1988

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1969</u>					
Mobile Field Sanitizer Prototype			Emissions from Burning Stubble/Straw	Air Quality Survey of 200 Respiratory Patients	
Alternate Year Burn					
Crew-Cutting					
Residue Incorporation and Stubble Seeding					
\$40,000			\$130,000	\$45,000	\$215,000
<u>1970</u>					
Mobile Field Sanitizer Prototype	Initiate Straw Use Program		Meteorological Conditions	Air Quality	
Alternate Year Burn			Smoke Management Approaches		
Crew-Cutting					
Residue Incorporation and Stubble Seeding					
\$60,000	\$30,000		\$130,000	\$45,000	\$265,000
<u>1971</u>					
Field Sanitizer - Testing	Particle Board - Lab Testing and Pilot Trials	Economic Analysis of Grass Seed Industry/ Alternative Crops	Smoke Management Approaches	Air Quality	
Alternate Year Burn	Livestock Digestibility				
Crew-Cutting	Hydrolysis/ Fermentation				
Residue Incorporation and Stubble Seeding	Chemical Feedstock - Pyrolysis				
Disease/Insect Control	Hydromulch				
	Straw Removal Alternatives - Economics				
	Field and Stationary Cubing and Use of Binders				
	Pelleting				

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1971 (continued)</u>					
	Baling				
	Bale and Breadloaf Stacking				
	Residue Densification				
\$90,000	\$234,000	\$40,000	\$130,000	\$45,000	\$539,000
<u>1972</u>					
Field Sanitizer - Testing - Manufacturing and Use	Pulp, Paper, Hardboard and Linerboard Potential	Meadowfoam Plot Trials	Climatological Variables	Air Quality	
Crew-Cutting	Japan Market Potential				
Residue/Incorporation and Stubble Seeding	Residue Densification (cubes, superbales, stacking)				
Stack Burning					
Disease/Insect Control	Beef Maintenance Feeding Trials				
	Digestibility, Pellets, Silage, Alkali Treatment				
	Trials with Sheep and Cattle				
	Hydrolysis/Fermentation				
	Pellets for Fuel				
	Pyrolysis				
	Furfural				
	Particle Board Pilot Trials				
	Bales for Mulch				
\$226,000	\$175,000	\$10,000	\$130,000	\$45,000	\$586,000
<u>1973</u>					
Field Sanitizer - Manufacturing and Testing	Densification Cubing/Binders	Meadowfoam Plot Trials	Climatological Variables	Air Quality	
Crew Cutting	Feed Processing/Extrusion NaOH				



Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1973 (continued)</u>					
Residue Incorporation and Stubble Seeding	Briquettes				
	Pellets and Cubes to Japan				
Stack Burning	Beef Maintenance Feeding Trials (pellets, meal, cubes, NaOH, KOH)				
Disease/Insect Control	Horse Maintenance-Pellets, Briquettes				
	Hydrolysis/Fermentation Pilot Plant				
	Firelogs				
	Pyrolysis				
	Gasification				
	Furfural				
	Bales for Mulch				
\$137,000	\$153,000	\$10,000	\$155,000	\$40,000	\$495,000
<u>1974</u>					
Field Sanitizer - Manufacturing and Testing	Densification (bales, chopped, cubed, briquettes, pellets)	Meadowfoam Plot Trials	Smoke Management Research		
Crew-Cutting					
Total Harvest	Feed Markets - Cattle/Horses - US and Japan				
Residue Incorporation and Stubble Seeding	Superbale Export to Japan				
Stack Burning	Hydrolysis/Fermentation				
Propane Flaming	Firelogs				
Disease/Insect Control	Gasification				
	Bales for Mulch				
\$337,000	\$354,000	\$10,000	\$90,000		\$791,000
<u>1975</u>					
Field Sanitizer - Field Use	Densification (bales, chop, strawdust, cube)	Meadowfoam Plot Trials			

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1975</u> (continued)					
Crew-Cutting - Evaluation	Bale Stacking				
Total Harvest - Evaluation	Firelog Market				
Stack Burning	Feed Pellets				
Spray Steam/ Sulfuric Acid After Straw Removal	Feeding Trials/ Supplements/ Dairy Use				
	Feed Processing (NaOH)				
	Hydrolysis/ Fermentation				
	Industrial Burner Trials (ground straw, bales)				
	Furfural				
	Gasification				
	Hydromulch - Pilot Process				
	Bales for Mulch				
		\$10,000			NA
<u>1976</u>					
Field Sanitizer - Field Use	Densification (bales, stackers, crewcut, strawdust, cubes)	Meadowfoam Plot Trials			
Stack Burning					
Crew-Cutting	Economics of Fiber Use				
	Feeding Trials (of hydrolyzed straw, pellets, meal, cubes) to Beef, Lambs, Horses				
	Strawdust for Bedding				
	Feed Processing				
	Industrial Burner Trials				
	Gasification				
	Hydrolysis - Sugar Extraction				
	Particle Board - Test and Production				

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1976 (continued)</u>					
	Potting Media				
	Bales for Mulch				
		\$10,000			NA
<u>1977</u>					
	Particle Board				
	Digestibility				
	Comparative Analysis of Feeding				
	Strawdust for Bedding				
					(Combined with 1978)
<u>1978</u>					
Field Sanitizer - Evaluation	Particle Board	Meadowfoam Seed Trials	Air Quality Surveillance	Health Effects of Burning	
Agronomic Effects of Non-Burn	Hydromulch - Market Analysis		Smoke Management R&D		
	Crew-Cutting		Emission Testing		
	Straw Utilization				
\$168,000	\$268,500	\$14,000	\$387,000	\$23,000	\$860,500
<u>1979</u>					
Sanitizer Evaluation	Battelle Straw Market Analysis	Meadowfoam Seed Production, 35 Acres	Air Quality Impact Studies	Breathmobile Study	
Crew-Cutting/ Less-than-Annual Burning	Mold Inhibition on Hydromulch		Emissions Testing		
			Plume Studies		
Crewcutter Dust Emissions Tests			Application Rapid Ignition		
			Fireline Strip-lighting Method		
			LIRAO Verification		
\$37,000	\$37,000		\$191,000	\$7,000	\$272,000
<u>1980</u>					
Crew-Cutting/ Less-than-Annual Burning	AREA's Biomass Burner Feasibility	Meadowfoam Seed Yield Studies	Acreage Validation	Hospital Admissions Study	

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1980 (continued)</u>					
		Meadowfoam Seed Production, 14 Acres	Plume and Fuel Studies		
		Meadowfoam Meal Fermentation	FB Emission Factor Review		
\$74,000	\$4,000	\$20,000	\$88,000	\$5,000	\$191,000
<u>1981</u>					
Crew-Cutting/ Less-than- Annual Burning	Bale Injector  Bale Burner, Phase I	Meadowfoam Yield Studies - Water stress, fertility, self- pollination	Meteorological Forecasting Study  Acreage Validation Study	Diary Study Respiratory Patients	
\$76,000	\$13,500	\$24,000	\$50,000	\$9,000	\$172,500
<u>1982</u>					
Less-than- Annual Burning/ Growth Retardants	Bale Injector  Straw Feeding Trials	Meadowfoam Agronomic Studies - Selection, fertility, fertilization process, photosynthesis			
Chemical Disease Controls	Bale Burner, Phase II	- 34 acre production			
Urea-Sulfuric		Meadowfoam Oil Utilization - Market development - Oil processing			
\$186,000	\$62,000	\$236,000			\$484,000
<u>1983</u>					
Growth Retardants	Straw Market Survey	Meadowfoam Agronomic - Nutrients, environmental factors, selection and crossing			
Urea-Sulfuric Tests	Straw Feeding Trials				
Propane Flamer	Straw Mulch Tests				
	Straw Bale Vegetable Production	Meadowfoam Field Trials and Seed Production			
		Meadowfoam Seed Dormancy			
\$128,000	\$34,500	\$192,500			\$355,000

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1984</u>					
Control Ergot/ Blind Seed Diseases	Cooperative Straw Feeding Trials	Meadowfoam Seed Yield Increase - Temperature, fertility, pollination	(Experimental Evening Burning Tested)		\$355,000
Minimum Till/ Non-Burning Rotation System	Straw Bale Burner Monitoring		(Grower Survey)		
Economic Analysis Less- than-Annual Burning	Straw Bale Vegetable Production	Meadowfoam Field Trials  Meadowfoam Seed Dormancy			
Urea-Sulfuric Tests		Meadowfoam Market Development  Pyrethrum Production and Physiology			
\$47,000	\$20,000	\$163,000			\$230,000
<u>1985</u>					
Control Ergot/ Blind Seed Diseases	Grass Pellet Heaters	Meadowfoam Yield Increase - Temperature, pollination, yield trials, selection	(Experimental Evening Burning Employed)		
Minimum Till/ Non-Burning Rotation System	Straw Pelletizer				
Urea-Sulfuric Tests		Meadowfoam Field Trials  Meadowfoam Seed Technology  Pyrethrum Production and Physiology			
\$50,000	\$35,000	\$136,000			\$221,000
<u>1986</u>					
Minimum Till/ Non-Burning Rotation System	Straw Pelletizing Evaluation	Meadowfoam Yield Increase	Emissions Sampling of Propane Flaming and Stack Burning	Health Effects Study	
Decomposition of Crown Growth and Straw		Meadowfoam Market Development			
Alternate Control of Ergot/Blind Seed Diseases		Meadowfoam Oil Composition and Stability  Meadowfoam Seed Technology  Pyrethrum Seed Technology		Evaluation of Field Burning R&D Program	

Appendix B, Page 8, Research and Development Projects on Field Burning, Willamette Valley, Oregon, 1968-1988 (continued)

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1986 (continued)</u>					
\$39,940	\$13,900	\$192,521	\$39,146	\$15,000	\$300,500
<u>1987</u>					
Minimum Till/ Non-Burning Rotation System	Straw Decomposition	Meadowfoam Market Development		Health Effects Peer Review	
Alternate Control of Ergot/Blind Seed Diseases	Tissue and Soil Nutrient Survey	Meadowfoam Oil/Seed Yield Increase			
\$39,489	\$46,067	\$154,110		\$14,825	\$255,000
<u>1988</u>					
Minimum Till and Non-Burning System	Ryegrass in Pulp and Paper	Meadowfoam Oil/Seed Yield Increase			
Effect of Soil pH on P Availability and Herbicide Efficacy	Product Research/ Nonreturnable Strawboard Pallets	Meadowfoam Market Development			
Distribution/ Severity of Ergot and Blind Seed Disease in Willamette Valley	Straw Decomposition Study				
Development of Farming Systems under Non- Burning Management					
Survey of Propane Flaming					
Assessment- Impacts of Propane Flaming and Stack Burning					
Field Burning Training Video					
\$134,776	\$62,154	\$120,600			\$317,500
<u>Grand Total</u>					
\$1,870,205	\$1,542,621	\$1,342,731	\$1,520,146	\$293,825	\$6,550,000

Source: Oregon Department of Environmental Quality Annual Field Burning Report, 1986 Evaluation of Field Burning R&D Program, Nero and Associates, Inc., and Oregon State University Agricultural Experiment Station files.

## APPENDIX C

### IMPLICATIONS TO WILLAMETTE VALLEY GRASS SEED PRODUCERS OF THE FOOD SECURITY ACT OF 1985

The Food Security Act of 1985 (1985 Farm Bill) contains two sections which can directly influence a grower's cropping decisions in western Oregon. These sections are entitled Wetland Conservation (Swamp Buster) and Conservation Compliance.

Under the Wetland Conservation provision, soils that are classified as hydric may not be drained (or have drainage improved) in order to allow for annual crop production. Drainage would result in immediate loss of all USDA program benefits such as price and income support programs, federal crop insurance, FmHA loans, CCC storage payment and CRP payments. Annual crops can be grown if no drainage improvements are made.

Under this provision, most grass seed fields on Dayton-type soils in the southern Willamette Valley would be classified as prior converted farmed wetlands. These are wetlands where simple drainage improvements, such as, surface drainage, have made cropping possible. Maintenance of existing drainage systems is allowed under the Food Security Act. Further drainage improvement of such soils would not be allowed and would be considered to be conversion, unless drainage improvement was initiated prior to December 23, 1985. The sub-surface drainage required to raise winter annual crops other than the grass seeds and meadowfoam could not be put in unless the grower was prepared to lose USDA farm program benefits on his/her farm as a whole. Additionally, cost-sharing with the Soil Conservation Service for soil drainage is no longer allowed. The full cost of drainage systems would be borne by the individual grower. Therefore, improvement of Dayton-type soils through drainage would carry a substantial penalty for many growers.

The other provision of the Food Security Act that has potential impact on Willamette Valley growers is the Conservation Compliance Provision. Under this provision, growers with highly erodible soils must develop a conservation plan that is acceptable to the Soil Conservation Service. This plan is to be developed by January 1, 1990 and implemented by January 1, 1995. In many parts of the central Willamette Valley (Silverton Hills, foothill areas, etc.), perennial grass seed crops are included as a part of the conservation plan. Perennial grass seed crops, are a valuable part of conservation plans since soil disturbance is minimized over extended periods of time. The presence of a three to four year stand grass seed crop allows growers to raise other crops such as grains and clovers since average soil erosion over a five to ten year period is below allowed levels. The removal of grass seed crops from rotations or the shortening of crop stand life would negatively impact a grower's ability to comply with soil loss requirements. Non-compliance results in immediate loss of all USDA farm program benefits.

## APPENDIX D

### FIELD MANAGEMENT OPTIONS FOR PERENNIAL GRASS SEED FIELD

Figure 1. Straw management options in the absence of annual burning for production of perennial ryegrass (forage type) seed crop in the Willamette Valley.

			Post harvest management cost per acre	
			<u>Full cost</u>	<u>Straw re-removed at no cost</u>
WINDROW				
↓				
COMBINE				
→	SPREAD STRAW	OPEN BURN (4 t/a)	Labor & fee	<u>\$8.90</u>
			Total	\$8.90
→	REMOVE ALL STRAW (3 t/a)			
→	PROPANE FLAME (1 t/a)	Propane	\$32.00	\$32.00
		Straw removal	\$37.50	\$ 0.00
		Stack burn	<u>\$ 0.50</u>	<u>\$ 0.00</u>
		Total	\$70.00	\$32.00
→	FLAIL CHOP (Stack hand) (1/2 t/a)	Straw removal	\$37.50	0.00
		Flail chop	27.55	27.55
		Stack burn	<u>0.50</u>	<u>0.00</u>
		Total	\$65.55	\$27.55
→	CREW CUT (1 t/a)	Straw removal	\$37.50	\$ 0.00
		Cut and Vacuum	\$36.00	\$36.00
		Stack burn	<u>\$ 0.50</u>	<u>\$ 0.00</u>
		Total	\$74.00	\$36.00
→	CHEMICAL TREATMENT	Enquik (mat. & applic.)	\$33.00	\$33.00
		Straw removal	\$37.50	\$ 0.00
		Stack burn	<u>\$ 0.50</u>	<u>\$ 0.00</u>
		Total	\$71.00	\$33.00

Source: Miles, 1977; Cornelius, 1985, Youngberg, *et al.*, 1984.

Notes: 1) Estimated yearly crop production cost - \$350 per acre; 2) Costs of less than annual burning will be increased as listed above, depending on the treatment method used.



Figure 2. Costs associated with shorter rotation seed production of perennial ryegrass in the Willamette Valley.

		Post harvest management cost per acre	
		<u>Full cost</u>	<u>Straw re-removed at no cost</u>
SHORT ROTATION (2 yr.)	Incr. amortized establishment <sup>1</sup>	\$30.00	\$30.00
	Straw removal	\$37.50	\$ 0.00
	Stack burn	\$ 0.50	\$ 0.00
	Reduced seed yield <sup>2</sup>	<u>\$68.00</u>	<u>\$68.00</u>
	Total	\$136.00	\$98.00

<sup>1</sup> Based on \$53.30 per year for 4 years = \$213.19 (\$161.90 + int @ 12%)

<sup>2</sup> Based on 15% yield reduction, 900 pound per a average yield, and price of \$0.50 per pound

Figure 3. Straw management options in the absence of annual burning for production of annual ryegrass seed crop in the Willamette Valley.

		Post harvest management cost per acre	
WINDROW			
↓			
COMBINE			
→	SPREAD STRAW	OPEN BURN (4- 6 t/a)	Labor & fee Total
			<u>\$8.90</u> \$8.90
→	REMOVE STRAW (2 - 4 t/a)	CHOP & PLOW IN (2 t/a)	Straw removal Chop Stubble Herbicide Annual Tillage Total
			\$24.00 10.00 30.00 <u>35.00</u> \$99.00

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