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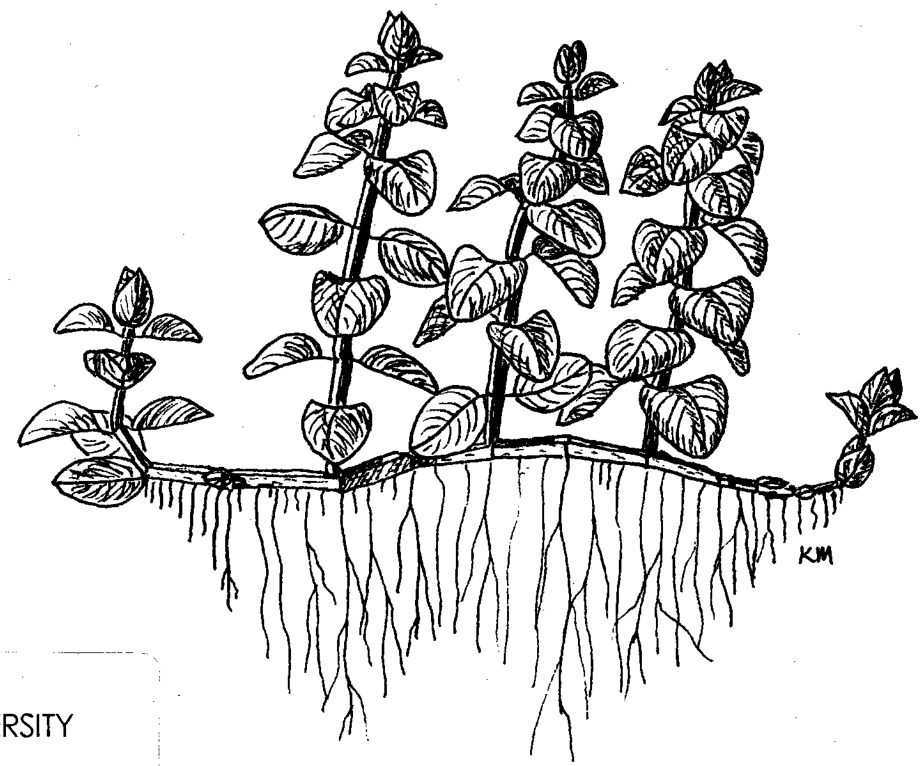
June 1993

Central Oregon Agricultural Research Center Annual Reports, 1990-1992



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Cover illustration: peppermint plant by Kathy Merrifield

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*Central Oregon Agricultural Research Center
in cooperation with
Crook and Jefferson Counties*

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Corvallis, Oregon

UPDATE, 1990-93

CENTRAL OREGON AGRICULTURAL RESEARCH CENTER

Fred Crowe, Superintendent

This is the first Central Oregon Crop Report published since Special Report 847, October, 1989. Since that time, the name of this branch station has been changed to the **Central Oregon Agricultural Research Center (COARC)**. This new name better reflects the work we do than did our older name (Central Oregon Experiment Station). The mission of the station remains to provide a local focus for both applied and basic research on crops, primarily irrigated crops, of the central Oregon region. As with other branch stations, the COARC functions administratively as a department within the Agricultural Experiment Station and within the College of Agricultural Sciences at Oregon State University.

In the 1989 report, it was indicated that the station planned to relocate its offices and laboratories from Redmond to Madras. The new research farm is on the corner of Dogwood Lane and Highway 26, three miles north of downtown Madras. This move was completed at the end of 1991. The Dogwood Lane farm replaces the old Mill St. farm near Madras. A long-term lease for this land was provided by Jefferson County and the City of Madras. The successful construction of buildings and roadways, and development of dry land into irrigated research farmland was made possible by extensive cooperation and contributions from several governmental agencies, OSU, several utilities, several commodity commissions, various agribusiness firms, and especially the planning time and voluntary efforts from many farmers and other business people who wished for this transition to occur.

The Station Development Committee included J.A. Macy & Mike Weber, chairpersons, Martin Zimmerman, secretary, and the following committee members: Judge Dan Ahern, Rick Allen, Rex Barber Jr., Paul Barnes, Michael Bauer, Bill Belamy, Don Boyle, Dean Brooks, Dave Campbell, John Campbell, Art Carlson, Floyd Carlson, Steve Carlson, Mike Cloud, Bob Crocker, Mayor Floyd Courtain, Leroy Elam, Ted Freeman, Wes Hagman, Gary Harris, Clint Jacks, Dale Killingsworth, Brad Klann, Ed Macy, Gregg Merritt, Ron Olson, Chuck Schonneker, Harold Siegenhagen, Fred Crowe (OSU-COARC) and Thayne Dutson (OSU-AES). JoAnne Sutherland, representing the City of Madras, was instrumental in getting the lease negotiated.

Several personnel changes have occurred since the last crop report. Dr. Alan Mitchell was hired in 1990 to conduct research on crop soil and water interactions. These topics were considered of highest priority for cropping systems nearly totally dependent on irrigation, and at a time when water usage and quality are being closely reviewed at all levels of society. Several split research and extension appointments were negotiated among Crook and Jefferson County extension staffs, the COARC and campus administrators. These split appointments are shown below. In the specialties indicated, those with split appointments have tri-county responsibilities.

State-supported staff as of April, 1993 include:

Dr. Fred Crowe, Superintendent, and Associate Professor of Botany & Plant Pathology

Dr. Alan Mitchell, Assistant Professor of Crop & Soil Science [75% research, 25% extension on soil and water issues]

Mylen Bohle, Assistant Professor, Crook County Extension [75% extension and 25% research on forages]

Marvin Butler, Assistant Professor, Jefferson County Extension/COARC [75% extension and 25% research on mint, grass seed and specialty crops]

Steve James, Senior Research Assistant [75% research, 25% extension on potatoes]

Dale Coats, Research Assistant

Pat Foltz, Bio-Science Research Superintendent

Sylvia McCallum, Bio-Science Research Technician

Peter Tomseth, Bio-Science Research Technician

Joan Starkel, Office Coordinator

Other staff were employed for significant periods during 1990-93, some of whom appear as authors on the enclosed research reports. Most of these were hired with the use of grant funds. One was a full time state-funded position that was eliminated due to state-mandated budget cutbacks. [Note, the office coordinator position was reduced to halftime for similar reasons].

Dr. Jeanne Debons, Research Associate

Tera B. Page, Research Assistant

Neysa Ferris, Research Assistant

Joy Light, Research Assistant

Brad T. Uhlig, Undergraduate Research Assistant

Karen Stevenson, Undergraduate Research Assistant

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Madras, Oregon, 1989

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
AIR TEMP. (°F)													
AVE. MAX. TEMP.	44	33	50	62	63	74	79	77	74	60	52	42	
AVE. MIN. TEMP.	29	16	32	40	40	48	50	50	45	37	33	25	
MEAN TEMP.	37	25	40	50	52	62	64	63	59	49	42	33	
AIR TEMPERATURE (No. of Days)													
MAX. 90 OR ABOVE	0	0	0	0	0	0	0	1	0	0	0	0	
MAX. 32 OR BELOW	2	11	2	0	0	0	0	0	0	0	0	5	
MIN. 32 OR BELOW	22	19	13	3	3	0	0	0	0	9	18	28	
MIN. 0 OR BELOW	0	8	0	0	0	0	0	0	0	0	0	0	
GROUND TEMP. (°F at 4")													
AVE. MAXIMUM	37	34	47	61	69	80	87	83	75	60	47	36	
AVE. MINIMUM	34	32	40	49	55	65	69	68	61	51	41	32	
GROUND TEMP. (°F AT 8")													
AVE. MAXIMUM	37	35	44	55	63	73	78	76	70	58	47	38	
AVE. MINIMUM	36	33	42	51	57	67	72	71	65	56	45	36	
PRECIPITATION (inches)													
MONTHLY TOTAL	1.52	0.53	2.55	2.40	1.21	0.27	0.26	0.60	0.25	0.42	0.31	0.31	10.63
EVAPOTRANSPIRATION (inches)													
AVE. PER DAY	0.03	0.03	0.08	0.14	0.16	0.23	0.25	0.21	0.18	0.09	0.05	0.02	
WINDAGE (miles)													
AVE. PER DAY	151	85	139	109	95	97	87	90	85	77	100	58	
SOLAR RADIATION (langleys)													
AVE. PER DAY	148	223	298	430	524	605	647	529	421	261	163	96	
HUMIDITY (percent relative humidity)													
AVE. PER DAY	76	81	77	70	69	61	63	65	58	69	75	84	

GROWING SEASON	**Last Date Before July 15**	**First Date After July 15**	**Total Number of Days Between Temp. Minimums**
AIR TEMP. MIN.			
32° or below	5/28	10/3	128
28° or below	3/26	10/15	203
24° or below	2/16	10/29	255

Madras, Oregon 1990

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
AIR TEMP. (°F)													
AVE. MAX. TEMP.	43	45	54	64	63	73	84	82	81	60	53	35	
AVE. MIN. TEMP.	31	27	32	39	40	48	56	55	50	38	35	18	
MEAN TEMP.	37	36	43	52	51	60	70	68	65	49	44	27	
AIR TEMPERATURE (No. of Days)													
MAX. 90 OR ABOVE	0	0	0	0	0	0	10	10	2	0	0	0	
MAX. 32 OR BELOW	2	2	0	0	0	0	0	0	0	0	0	10	
MIN. 32 OR BELOW	20	23	18	5	4	0	0	0	0	7	11	20	
MIN. 0 OR BELOW	0	0	0	0	0	0	0	0	0	0	0	7	
GROUND TEMP. (°F at 4")													
AVE. MAXIMUM	38	39	51	65	70	78	90	87	80	61	48	35	
AVE. MINIMUM	35	35	42	53	56	64	73	71	65	52	42	30	
GROUND TEMP. (°F at 8")													
AVE. MAXIMUM	38	38	47	60	64	71	81	79	73	59	48	37	
AVE. MINIMUM	37	36	44	56	59	66	75	74	69	56	46	34	
PRECIPITATION (inches)													
MONTHLY TOTAL	3.08	0.09	0.72	0.57	2.44	0.46	0.50	1.00	0.55	0.92	E	0.49	10.82+
EVAPOTRANSPIRATION (inches)													
AVE. PER DAY	0.04	0.06	0.10	0.16	0.19	0.25	0.33	0.28	0.25	0.11	0.07	0.03	
WINDAGE (miles)													
AVE. PER DAY	178	184	111	206	219	195	186	175	167	216	E	163	
SOLAR RADIATION (langleys)													
AVE. PER DAY	83	177	290	387	528	607	657	522	479	267	163	124	
HUMIDITY (percent relative humidity)													
AVE. PER DAY	78	70	66	62	69	66	58	63	60	69	72	72	

GROWING SEASON	**Last Date Before July 15**	**First Date After July 15**	**Total Number of Days Between Temp. Minimums**
AIR TEMP. MIN.			
32° or below	5/15	10/6	144
28° or below	5/8	10/7	152
24° or below	4/24	12/6	226

Madras, Oregon 1991

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
AIR TEMP. (°F)													
AVE. MAX. TEMP.	43	53	50	56	61	68	84	86	80	65	49	43	
AVE. MIN. TEMP.	26	35	31	35	40	46	54	56	46	36	35	31	
MEAN TEMP.	34	44	40	46	51	57	69	70	63	50	42	37	
AIR TEMPERATURE (No. of Days)													
MAX. 90 OR ABOVE	0	0	0	0	0	0	4	40	1	0	0	0	
MAX. 32 OR BELOW	5	0	0	0	0	0	0	0	0	0	0	3	
MIN. 32 OR BELOW	23	10	22	13	2	0	0	0	0	7	13	19	
MIN. 0 OR BELOW	0	0	0	0	0	0	0	0	0	0	0	0	
GROUND TEMP. (°F at 4")													
AVE. MAXIMUM	35	46	49	57	66	77	91	92	106	82	56	41	
AVE. MINIMUM	32	40	41	47	53	62	69	66	42	33	33	36	
GROUND TEMP. (°F at 8")													
AVE. MAXIMUM	36	44	46	53	60	70	80	85	104	79	54	40	
AVE. MINIMUM	34	41	43	49	56	64	72	68	42	32	32	34	
PRECIPITATION (inches)													
MONTHLY TOTAL	0.54	0.22	1.75	0.20	1.34	0.95	0.39	0.39	0.0	0.15	0.49	0.26	6.68
EVAPOTRANSPIRATION (inches)													
AVE. PER DAY	0.03	0.07	0.09	0.15	0.18	0.22	0.34	0.32	0.25	0.15	0.04	0.03	
WINDAGE (miles)													
AVE. PER DAY	152	158	161	301	186	196	181	171	124	121	132	112	
SOLAR RADIATION (langleys)													
AVE. PER DAY	137	194	314	442	524	587	703	592	482	283	130	105	
HUMIDITY (percent relative humidity)													
AVE. PER DAY	76	75	73	64	68	67	57	58	51	59	81	80	

GROWING SEASON	**Last Date Before July 15**	**First Date After July 15**	**Total Number of Days Between Temp. Minimums**
AIR TEMP. MIN.			
32° or below	5/9	9/21	135
28° or below	5/9	10/23	167
24° or below	3/11	10/29	232

Madras, Oregon 1992

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
AIR TEMP. (°F)													
AVE. MAX. TEMP.	46	50	59	61	75	80	83	85	74	64	47	37	
AVE. MIN. TEMP.	31	35	33	38	44	50	51	52	45	40	32	23	
MEAN TEMP.	39	41	45	50	59	66	67	69	59	51	39	30	
AIR TEMPERATURE (No. of Days)													
MAX. 90 OR ABOVE	0	0	0	0	1	5	10	11	0	0	0	0	
MAX. 32 OR BELOW	1	0	0	0	0	0	0	0	0	0	0	7	
MIN. 32 OR BELOW	21	14	17	9	3	0	0	0	1	3	17	26	
MIN. 0 OR BELOW	0	0	0	0	0	0	0	0	0	0	0	0	
GROUND TEMP. (°F at 4")													
AVE. MAXIMUM	40	45	52	60	69	73	74	74	64	55	44	37	
AVE. MINIMUM	39	42	47	51	55	59	63	63	57	50	42	36	
GROUND TEMP. (°F AT 8")													
AVE. MAXIMUM	40	46	56	59	65	68	70	70	62	53	44	38	
AVE. MINIMUM	37	40	43	51	58	64	65	66	59	55	45	38	
PRECIPITATION (inches)													
MONTHLY TOTAL	0.56	0.78	E	E	0.62	0.38	0.39	0.08	0.22	1.76	0.87	1.19	6.85+
EVAPOTRANSPIRATION (inches)													
AVE. PER DAY	0.04	0.05	0.11	0.14	0.24	0.28	0.28	0.29	0.20	0.11	0.04	0.03	
WINDAGE (miles)													
AVE. PER DAY	138	115	105	148	139	151	129	132	142	100	105	133	
SOLAR RADIATION (langleys)													
AVE. PER DAY	124	176	377	400	587	588	576	512	386	247	145	97	
HUMIDITY (percent relative humidity)													
AVE. PER DAY	75	82	71	69	57	56	58	50	60	70	82	81	

GROWING SEASON	**Last Date Before July 15**	**First Date After July 15**	**Total Number of Days Between Temp. Minimums**
AIR TEMP. MIN.			
32° or below	5/21	9/14	116
28° or below	4/23	10/14	174
24° or below	3/28	10/15	201

EVALUATION OF PEPPERMINT FIELD PERFORMANCE FROM PLANTS REGENERATED FROM MERISTEM TIP CULTURE

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Central Oregon Agricultural Research Center
Madras, OR

Abstract

Observations in Montana revealed that rooted cuttings produced from privately-produced meristemmed peppermint (cv 'Black Mitchum') grew more vigorously than the nonmeristemmed certified rooted cuttings from which they were taken. We (1) obtained greenhouse rooted cuttings from both sources for field evaluation in central Oregon, (2) conducted a literature review on the subject with respect to mint, and (3) initiated a meristem program at the Central Oregon Agricultural Research Center (COARC). The scientific literature indicated that peppermint has been successfully meristemmed in many laboratories, but there was no report of enhanced growth as a result of meristemming. Results of first-year growth of cuttings planted in test plots are presented: Rooted meristemmed cuttings arrived much larger and robust than the nonmeristemmed rooted cuttings, which could have been a result of differences in age and management of the sources of the cuttings as well as any effect of meristemming itself. In replicated field trials, differences in growth persisted for several weeks in the field, but over the course of the summer of 1992 growth differences diminished. By August 1992, no differences were noted between the two plantings. This suggested that earlier growth differences were most likely due to greenhouse handling rather than due to effects of meristemming, nor were they due to the small chance that a genetic change occurred during the meristemming and plant regeneration phase. These results do not explain the observed differences between meristemmed and nonmeristemmed peppermint plants in Montana, and do not eliminate some possible complex pathogenisis that could be different between Montana and central Oregon. The initial steps in the meristemming and plant regeneration process, which seemed relatively routine, were conducted at the COARC.

Introduction

Meristem tip culture has been widely used since the early 1960's, as a tool to eliminate viruses (and occasionally bacteria and other systemic pathogens) from vegetatively-propagated plants. In general, systemic pathogens lag behind the growing points of plants, primarily because they move most quickly in developed vascular tissues that are not developed in the very tip region of the growing points (the meristem area). Mint is not known to harbor viruses routinely in planting-stock, either greenhouse rooted cuttings or field stock however, viruses do exist in many vegetatively propagated species that may not manifest known symptoms. When these viruses are removed, the virus-free materials may grow dramatically different, or the response may be more subtle. Sometimes no obvious growth differences occur, but the virus-free material may be more hardy or able to resist stresses or other infections. It is rare that no effect is seen following removal of a virus from vegetatively-propagated stock. Sometimes, meristem tip culture has shown the prior presence of a virus that was previously unknown to be present. In general, reports of improvement in performance of a vegetatively-propagated plant following meristem tip culture suggest that a virus or other systemic pathogen may have been present previously. Other techniques can be employed to confirm this.

Mint has been meristemmed successfully in various laboratories (1,3,4) with no report of enhanced virus. A number of observers have witnessed remarkable growth of peppermint in Montana from plants that were regenerated from meristem tips of 'Black Mitchum' variety. To date, all such meristemmed plants have come from one commercial greenhouse, and we are aware of no direct comparison plantings of this material with nonmeristem plants. In response to a request by the Oregon Mint Commission, we obtained plants from the known commercial source of meristemed plants, and another commercial source of non-meristemed plants of the same variety. There potentially could have been a problem with receiving material with substantially distinct management histories in the rooted cutting and greenhouse production process (light, potting medium, fertility, etc.), which could influence plant behavior for some time after planting in the field. It was decided to proceed with what material could be obtained in 1992, irrespective of these problems.

In addition, we planned to develop our own meristemmed plants in our laboratory, so that these could be managed identically to the nonmeristemmed plants. Also, we could obtain information on the relative ease of meristemming various varieties.

Materials and Methods

A thousand rooted cuttings, each of meristemmed and nonmeristemmed peppermint (Black Mitchum' variety), were obtained from two different commercial sources for comparison of growth in the field in central Oregon. Ideally, nonmeristemmed plants would have been the mother source for meristemmed plants, and rooted cuttings from each would have been produced in the same greenhouse system to reduce variation in field performance due to genetic or management practices. However, this was not possible in 1992.

Plants were shipped and received at the same time and planted within two days into replicated field plots at the COARC, Madras field in early summer, 1992. Plants from each source were substantially different in size and development at time of arrival and planting. Meristemmed plants received from Starkle Farms Inc., Montana, were quite large (13-15 inch single stems, root system length 5-6 inches, 7-9 leaf nodes, 1-5 rhizomes plus stolons), and presumably had been allowed to develop in the commercial greenhouse prior to shipment. Nonmeristemmed plants received from Plant Technologies, Inc., Oregon, were from relatively recent cuttings and were smaller (3-4 inch single stems, 3-4 inch root system length, 6-7 leaf nodes, 0-1 rhizomes plus stolons). To sooner judge post-planting growth free of greenhouse management influences, the top growth of meristemmed plants was cut back to 4-5 inches in length just prior to planting. Two hundred and fifty plants were spaced one foot apart in rows 2 feet apart, in 10 rows per plot, on June 1, 1992. The field location had no prior mint production and was prefertilized. The systemic insecticide aldicarb was applied to all plots to inhibit spread of viruses in plots. Plantings were hand weeded for six weeks, and then treated with 0.75 lbs/a of Sinbar. Plantings were irrigated 2-3 times/wk for one month and 1-2 times/wk thereafter through October 1992 via overhead sprinklers.

Results and Discussion

All rooted cuttings suffered from heat stress and desiccation during the first several days and weeks of establishment during the very hot summer of 1992. There were more failures among meristemmed than among nonmeristemmed plants (3 vs. 1 percent). Growth among meristemmed plants was more vigorous early in establishment than among nonmeristemmed plants, but as plants developed between late June and late August, growth in all plots converged to the point that meristemmed plants could not be distinguished from nonmeristemmed plants. Continued growth and development (plant height, rhizome and stolon development, and overall appearance and vigor) seemed similar since late August. In all ways, mint growth in all plots seemed what we expected of rooted cuttings, and was similar in performance to 'Black Mitchum' elsewhere on the COARC Madras farm. Plots were not harvested.

No verticillium wilt symptoms were observed in any plots. A few plants within both meristemmed and nonmeristemmed plots (six plants total) declined rapidly as temperatures cooled during September and October, but did not manifest typical verticillium wilt symptoms. Each of these six plants tested positive for Tomato Spotted Wilt Virus-Impatiens Strain [TSWV-I], but symptomless plants from the same plots tested negative. The source of TSWV-I infection is not known, but the presence of this virus in this trial does **not** account for the general growth convergence and similarity among meristemmed and nonmeristemmed plants.

Plots will be maintained into 1993 for further observations, but based on growth in 1992 there seems to be little support for the hypothesis that the particular meristemmed plants received in 1992 might grow substantially better than nonmeristemmed plants perhaps this is due to some undetermined systemic pathogen (virus or bacteria). Reports of unexplained and exceedingly vigorous growth in Montana for meristemmed plants are not challenged by current results in this trial, but suggest that such growth may be due to other factors than a system pathogen that is eliminated by meristem tip culture. It would have been worthwhile to conduct this same trial in Montana at the same time to determine if there were growth differences there during 1992 between these two sources of rooted cuttings.

There is always the possibility that other sources of rooted cuttings may have performed differently than the ones evaluated in 1992. Various sources of 'Black', 'Todds', and redefined and old 'Murray' cuttings were collected from both central Oregon and the

Willamette Valley in the fall of 1992, both normally appearing sources and some which were thought to grow differently. These were to be meristemmed in the fall-winter of 1992-93, and rooted cuttings from nonmeristemmed and meristemmed sources of each were to be grown in the field in 1993 to determine whether growth differences may occur that might be attributed to an undetermined systemic pathogen. At this time, these plants will be held in isolation in small field plots until after spring growth is evaluated in the meristem/nonmeristemmed plots. If there seems little reason to proceed, these plants will be destroyed. One off-shoot of this program may be a determination of how easily various varieties may be meristem tip cultured. Preliminary results in our laboratory suggest that peppermint meristems respond quite well to standard methods of regeneration of plants (Murashige, I., and F. Skoog. 1962), as was suggested by the reported success of various laboratories around the world (Holm, Y., R. Holtunen, K. Jokinen, and T. Tormala., 1989, Repcakova, K., M. Rychlova, E. Cellarova, and R. Honcariv., 1986, Rodov, V.S., and O.A. Davidova., 1987).

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POST HARVEST GROUNDSEL CONTROL IN MINT

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OSU, Crop and Soil Science Department, Corvallis, OR
Jim Carroll
Full Circle, Madras, OR
Kurt X. Farris
Round Butte Seed Growers, Culver, OR

Abstract

Groundsel control is a major concern to mint growers in central Oregon. Herbicide trials were conducted at four locations, in both peppermint and spearmint, to evaluate four materials alone and in combination. Buctril at 1½ pts provided excellent control alone, as well as with 4 oz of Goal. Stinger at ½ pt was phytotoxic to peppermint, without providing adequate groundsel control. The Buctril treatments alone and in combination with Goal produced injury on spearmint, while Buctril at ½ pt with 1 qt of Basagran provided adequate control with minimal injury.

Introduction

Control of common groundsel (*Senecio vulgaris* L.) is a major concern to mint growers in central Oregon. Groundsel can germinate, flower, and produce seed nearly all year around. Properly applied post-harvest herbicide treatments are recommended for control of groundsel through the fall and winter months.

Materials and Methods

The objective of this research was to evaluate the efficacy and phytotoxicity of post-harvest treatments of four materials, alone and in combination, for control of groundsel in peppermint and spearmint. Materials shown in Table 1 were applied October 16 and 17, 1992, to two peppermint fields on the Agency Plains and one field near Culver. Application to a spearmint field in the Trail Crossing area was made on October 26, 1992. Materials were applied to 9 ft by 25 ft plots using a CO_2 pressurized boom sprayer at 40 psi and 20 gals/a. The peppermint plots were replicated four times and the spearmint plots replicated three times in a randomized complete block design.

Daytime temperatures just prior to applications on peppermint were in the 40-60°F, with lows around 25°F. The daily high temperatures following application to the peppermint were 60-70°F, with nights 30-50°F. Following application to the spearmint, daily temperatures had cooled to near 50°F with sub-freezing temperatures at night. Six-tenths of an inch of rain fell October 20 and 21, with another seven-tenths October 27 through 31.

When materials were applied at the Boyle location the groundsel was at two growth stages, the four to six leaf stage and 8-10 inches high with flowers. Groundsel at the Johnson location was at the six to eight leaf stage, and at the Macy location groundsel was 1-3 inches high with flower buds. At the High Country location groundsel was two to four leaves, and six to eight leaves when materials were applied.

Evaluation of peppermint plots were made November 11, 1992, using a visual rating of percent groundsel control, based on reduction in biomass. Evaluation of the spearmint plots on November 23 included a rating of percent injury to the crop.

Ten groundsel seed heads were collected from 8-10 inch plants in one replication at the Boyle location. These were used for germination testing to determine if seed viability was affected in herbicide treated plots.

Results and Discussion

In the peppermint plots, Buctril at 1½ pints provided the same control with and without Goal, which is not currently registered for post-harvest application. The control provided by Buctril at 1 pint was somewhat less, but acceptable. Buctril at ½ pint with 1 quart of Basagran provided inadequate control, as did Stinger, which damaged the peppermint by turning it reddish purple with light green tips. Control of the 8-10 inch plants at the Boyle location was only slightly less than for the 1-2 inch plants.

On spearmint, which is a more sensitive crop to herbicides, the plots with Buctril alone and Buctril with Goal provided excellent control of groundsel but resulted in approximately 40 percent injury to the crop. The Buctril and Basagran combination provided good control in these later plots, which experienced colder temperatures following application. Stinger continued to provide inadequate control, but was less phytotoxic at this location.

Although groundsel seed heads were collected from only one replication and therefore cannot be evaluated in the study statistically, seed viability did appear to be dramatically reduced as a result of herbicide application. Germination of groundsel seed in the untreated plot was 50 percent, 20 percent in the Stinger plots, and 4-10 percent for plots treated with Buctril alone or in combination with other herbicides. This would seem to indicate that although seed head development continues after application of a slow-acting contact herbicide like Buctril, seed viability is nevertheless affected.

Further research is necessary to confirm these results.

Table 1. Percent control of groundsel in peppermint with materials applied in central Oregon, October 16-17, 1992.

		Location			
		Boyle		Johnson	Macy
Treatments	Herbicide Rate	1-2"gr.	8-10"gr.	2-3"gr.	1-3"gr.
	product	----- percent control----			
Buctril	1 pt	96 a	91 a	100 a	86 ab
Buctril	1½ pts	100 a	99 a	100 a	98 a
Buctril +	½ pt				
Basagran	1 qt	86 b	74 b	65 b	73 b
Buctril +	1½ pts				
Goal	4 oz	99 a	97 a	100 a	100 a
Stinger	½ pt	79 c	63 c	60 b	45 c
Untreated	-	0 d	0 d	0 c	0 d

Percent control were statistically different with Duncan's Multiple Range test at P≤0.01

Table 2. Percent control of groundsel and percent crop injury with materials applied to spearmint in central Oregon, October 26, 1992.

		High Country Mint	
Herbicides	Rate	Control	Injury
	product	------ percent ------	
Buctril	1 pt	100 a	27 bc
Buctril	1½ pts	100 a	37 ab
Buctril +	½ pt		
Basagran	1 qt	98 a	7 d
Buctril +	1½ pts		
Goal	4 oz	100 a	42 a
Stinger	½ pt	28 b	20 c
Untreated	-	0 c	0 d

Percent control were statistically different with Duncan's Multiple Range test at P≤0.01

IRRIGATION AND NITROGEN FERTILITY OF PEPPERMINT IN CENTRAL OREGON*

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Abstract

A line-source sprinkler experiment on peppermint was used to test the effects of irrigation and nitrogen fertility at the Central Oregon Agricultural Research Center in Madras, OR. Dry matter and oil yield were greatly affected by irrigation level and N-fertilizer level. Oil quality was influenced by irrigation level, but not by N rate. The pressure chamber instrument sensed plant water stress over long periods, but daily data was less sensitive to stress. The infrared thermometer gave highly variable data for detecting plant stress. Measurements with a modified gypsum-block sensor (WATERMARK) compared well with water content measured with the neutron meter. Passive capillary samplers below the root zone indicated that there was no water leaching under this years' management system. Soil profile nitrate concentrations were measured to determine the loss of nitrate for each treatment.

Introduction

Irrigation management

It is conceivable that the optimal irrigation management of peppermint may include water stress to produce more oil yield. Knowledge of plant water stress and soil moisture is necessary for irrigation management, and plant stress instruments are being tested for their potential use in irrigation scheduling.

Many mint growers in the Northwest believe that a certain amount of water stress may improve mint oil yields (Weber, 1978). Loomis (1976) proposed a stress management theory to increase leaf retention. However, other scientists have found that mint produces optimum yield at highest levels of irrigation (Clark and Menary, 1980). Preliminary results of peppermint irrigation studies at Purdue University suggest that full irrigation is the optimal management practice (Simon and Joly, 1989). Scientists have also found that reducing irrigation early in the season did not seem to stress the mint plant (Clark and Menary, 1980).

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If the stress theory is true, it will be necessary to find an appropriate way to schedule irrigations. Scheduling for controlled stress will depend upon instruments that directly monitor crop stress such as pressure bombs, infrared temperature sensors, the neutron probe, or moisture blocks. Scheduling with these instruments requires field calibration for each specific crop. In addition to answering questions on the yield and quality of mint under water stress, our objectives were to find an instrument for irrigation scheduling that would be most appropriate for mint in this region.

Nitrate fertility and leaching

Nitrate is a potential contaminant of groundwater at levels above 10 ppm N. Non-point source nitrate originates in animal manures and commercial fertilizers, especially for high-valued crops where nitrogen is abundantly applied and the root zone is shallow. The fundamental question is how much nitrogen is required to produce optimum yields of peppermint, and how much nitrate is lost below the root zone.

With growing concern over environmental pollution, including agricultural contributions of nitrogen (N) in the form of nitrate to groundwater, it is imperative to know the N rates for optimum economic yield, as well as N rates for minimal groundwater contamination. These two rates are probably not the same, but research can indicate how close they are, and thus define the discrepancy between what is environmentally nonpolluting and what is economically beneficially to the grower. The present N-fertilization practice for central Oregon is to apply a total of 250-300 lbs of nitrogen to a peppermint crop divided into several applications. Although peppermint yields best under high N fertilization, the fact that multiple applications are practiced suggests that much of the N is lost. Only 150 lbs of N is accounted for by the above-ground plant (Hee, 1974). The remaining 100-150 lbs may be lost below the root zone due to excessive irrigation. The process of nitrification transforms fertilizer N to nitrate, a very soluble N form that is then susceptible to being carried below the root zone by excess applied water.

Fertilizers that release nitrate slowly have the promise of reducing nitrate leaching. Supplemental additions of N in the irrigation water have been found to increase oil yield under some situations (Heuttig, 1969). This is now a common practice among growers. The yield response to summer applied N may result from applying N as the plant requires it. This suggests that N may be washed out of the root zone by rainfall or excess irrigation. If excess irrigation is responsible for N loss, then the use of a slowly soluble N fertilizer should increase the amount of N available to the plant.

The questions of slow-release N fertilizer require knowledge of the quantity of water and N fertilizer needed for optimal oil yield. Tested together, irrigation and nitrogen factors will provide data on the amount of N lost below the root zone. The loss of N due to leaching beyond the root zone is a water management and fertilizer management problem. These two studies are being conducted together in order to study the interactions of irrigation and N.

The objectives of the study were to verify (or disprove) the theory that managing irrigation to induce a moderate, controlled level of water stress can improve oil yield and quality, and to determine the relationship between stress and oil production. Alternative techniques for irrigation scheduling for water stress were evaluated. The fertility objectives were to test various rates, and nitrification inhibitors, to increase peppermint oil yield.

Materials and Methods

The research was carried out at the new Central Oregon Agricultural Research Center (COARC) in Madras, Oregon on second-year peppermint, variety 'Murray'. The mint had been planted in March 1991, and tilled to enhance stand in February 1992. A line-source sprinkler system was set up to control applied water to the experimental plot. The line-source system is a low cost method for applying water at different rates to different sectors of the plot. The trial was replicated eight times, and nitrogen treatments were super-imposed on the irrigation treatment in the fashion of a factorial experiment. Plots were 25 ft x 8 ft with the longest side parallel to the sprinkler line.

Irrigation water was applied at five rates based on water loss from the fourth irrigation level, with I5 receiving full irrigation and the others the following amounts: I4 - 83 percent of I5, I3 - 67 percent, I2 - 52 percent, and I1 - 50 percent. Irrigation occurred twice weekly during June and July. Catch- cans were used to monitor the amounts of applied water, and soil water content was measured with WATERMARK sensors five days per week and with the neutron probe twice weekly. The WATERMARK sensors are described in the paper "Granular Matrix Sensors for Irrigation Management" in this annual report. Sensors were buried at three depths: 2-4 inches, 6-8 inches, and 20-22 inches. Ten sets of sensors were applied in two replications of the five irrigation levels. Neutron meter access tubes were installed in each of five irrigation levels of 12 N treatments. The meter measured soil water content in 6-inch increments; with the total depth varying from 2-7 ft depending on the strength of the hardpan layer at the 2-ft depth.

An infrared temperature sensor and a pressure chamber monitored plant stress for each irrigation treatment. The temperature sensor was used to measure plant temperature near midday throughout the summer. The temperature of the plant can be indexed with the relative humidity and air temperature to produce a crop water stress index (CWSI) (Gallardo, 1992). The CWSI was calculated in three ways: directly from the sensor, with a software program using theoretical values for aerodynamic resistance, and with a program using the empirical CWSI baseline calculated by Gallardo (1992).

The pressure chamber measures the water potential of an excised leaf by applying pressure to the leaves and recording the point at which the sap flows backwards down the stem. Gallardo (1992) observed that measurements taken before dawn had less day-to-day variability than at other times, and that the peak time for plant stress was in the afternoon. Thus, readings were taken midday, and before dawn on selected days. Four leaves per plot were taken directly from the field into the laboratory for pressure chamber measurements.

The N fertility and N loss experiment was established in conjunction with the peppermint irrigation experiment. Treatment fertilizers were applied in the spring. Additional differential rates were applied in summer (Table 1). The fertility treatments were tested across all five irrigation levels. For spring application, nitrogen was applied as urea (46-0-0) with a 3-ft wide fertilizer spreader that was calibrated to the listed rates. In the summer, Solution 32 was applied with a hand-held sprayer during summer irrigations to simulate irrigation-applied fertilizer. Soil N measurements were taken in March, throughout the summer, and after fall growth.

Table 1. Fertilizer trial rates, Madras, OR, 1992.

Fertilizer plot	Spring	Summer	Total
	lbs/acre		
N1	50	0	50
N2	150	0	150
N3	250	0	250
N4	250	100**	350
N5 PCU*	225	0	225
N6	150	100**	250

* polymer-coated urea
** split application of 50 lbs each

Passive capillary samplers (PCAPS), designed and built by Dr. John Selker, OSU Department of Bioresource Engineering, were installed April 23, 1992 in the peppermint plots. Twelve samplers (12.8 inches by 34.1 inches at the top by 20 inches deep) were buried with the top placed at the interface between the soil and the hard pan, which was 24-29 inches deep. PCAPS were placed in the I3, I4, and I5 levels of nitrogen plots N0, N2, N5, and N6.

The PCAPS, or wick lysimeters, were designed to collect the water that passes through the root zone into the vadose zone, which is the unsaturated soil that exists between the root zone and the ground water table. Wicks on the top face of a PCAPS extend to three collection jars located 18 inches below the top. This design provides for water collection with a small negative tension, or without requiring soil saturation, which is usually an unnatural condition in the field. Water was collected from four small tubes connected to three jars and an overflow, which were extended to a manifold at the edge of the field 50 feet away. A vacuum pump is used to collect the leachate, quantity is determined, and the leachate is analyzed for concentration of nitrate and ammonia.

Harvest was on July 29, which was approximately 10 days earlier that usual. Subsamples of the plot were 40 inches wide by 25 ft long, which produced enough mint forage to distill in potato sacks. Due to time and cost considerations, only three replications of the nitrogen experiment and three replications of the irrigation experiment were used for mint oil analysis. Sacked mint was quickly dried in the open air, and stored indoors until distillation. There was a delay in mint oil distilling until November due to lack of availability of the USDA facility in Corvallis. Oil quality analysis was performed by A.M. Todd, Kalamazoo, Michigan using a gas chromatograph.

Table 2. Irrigation level effects on dry matter and oil yield. Column means followed by a common letter are not significantly different at the 5% level.

Level	Dry Matter Yield	Oil Yield	Oil\Dry Matter Ratio
	lbs/acre	lbs/acre	percent
I1	793 a	24.2 a	3.05
I2	1098 b	28.9 a	2.63
I3	1362 bc	31.8 a	2.34
I4	2055 d	30.1 a	1.47
I5	2446 e	46.2 b	1.90

Table 3. Impact of Irrigation Level on Mint Oil Quality, Madras, OR, 1992.

Constituents	Signif.	Change	I1	I2	I3	I4	I5
			Irrigation Level %				
MENTHOL	*	-	40.95	40.12	39.23	39.54	39.77
MENTHONE	**	+	13.94	16.12	18.45	20.57	20.84
HEADS	**	-	13.34	12.68	12.37	11.63	11.04
CINEOLE	**	-	6.78	6.50	6.37	6.02	5.78
ESTER	**	-	7.02	5.77	5.18	4.74	4.38
MENTHOFURAN	**	?	2.64	3.76	3.77	3.10	3.45
NEOMENTHOL	**	-	4.38	4.02	3.70	3.53	3.39
D-ISOMENTHONE	**	+	2.60	2.69	2.78	2.89	2.80
GERMANCRENE-D	**	+	2.19	2.22	2.34	2.42	2.62
B-CARYOPHYLLENE	**	-	3.07	2.79	2.68	2.54	2.46
BETA PINENE	*	-	1.95	1.88	1.87	1.79	1.72
LIMONENE	**	-	2.20	2.13	1.97	1.70	1.56
ALPHA PINENE	*	-	0.95	0.91	0.92	0.88	0.84
PULEGONE	*	?	0.84	1.14	1.04	0.82	0.83
B-BOURBONENE	**	-	0.85	0.75	0.66	0.60	0.59
3-OCTANOL	**	+	0.18	0.19	0.20	0.24	0.26
MYRCENE	**	-	0.28	0.28	0.28	0.26	0.25
PARA CYMENE	**	-	0.21	0.18	0.12	0.14	0.10
			MEAN				
SABINENE HYDRATE	NS		2.18				
PIPERTONE	NS		0.42				
GAMMA TERPINENE	NS		0.25				
TERPINOL	NS		0.23				
ALPHA TERPINENE	NS		0.13				

* significant at the 5%, ** at the 1% level, NS not significantly different.
\+ or - is the increase/decrease in concentration with increasing irrigation.

Results

The yield data (Table 2) shows that the highest yield was achieved with the maximum irrigation rate (I5). Dry matter yield was better differentiated between treatments than oil yield. This is explained by the increase in oil/dry matter concentration. Such an increase in concentration is usually associated with maturity (Bullis et al., 1948; White et al., 1987), which could be induced by water stress.

Water stress affected 17 out of 23 oil constituents (Table 3), including the principal component of menthol, menthone, esters, and menthofuran. In its influence on oil quality constituents, stress appears to be related to maturity. During the period up to 50 percent bloom, the oil will increase in menthol, esters, and menthofuran (Bullis et al., 1948; White et al., 1987). These same constituents increase with water stress (Table 3). However, substantial water stress (50 percent of irrigation requirement) did not make oil quality undesirable. The nitrogen fertility treatments did not affect oil quality, although they had a positive effect on dry matter and oil yield.

Pressure Chamber

The 1991 data summarized by Gallardo (1992), indicated that the diurnal variability of leaf water potential makes its use as an stress-management technique difficult. His data did suggest that pre-dawn measurements were more stable and may be useful for irrigation scheduling. In 1992, we took pre-dawn and mid-day measurements. For pre-dawn readings we found that there was little difference between the higher irrigation levels for a single day (Fig. 1).

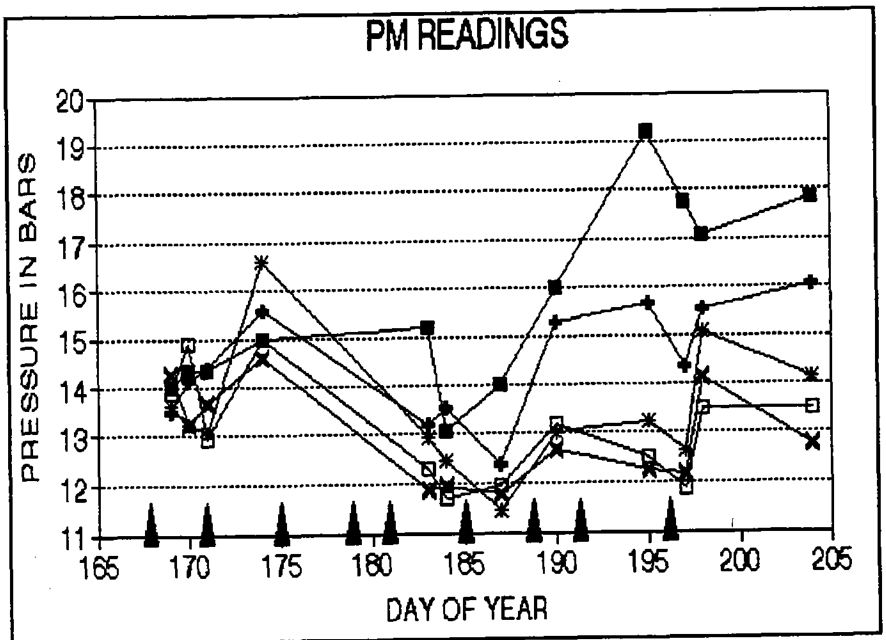

Figure 1. Pressure chamber afternoon readings, 1992.

However, when the readings are added over time (Fig. 2), the differences become more manifest, except for I5 and I4. The pressure chamber could not detect the difference between I4 and I5, although the dry matter and oil yield differences were considerable.

For midday readings, a pressure chamber reading greater than 13 bars was an indicator of high stress. High readings generally occur later in the irrigation cycle. Again, there were only slight differences between I5 and I4.

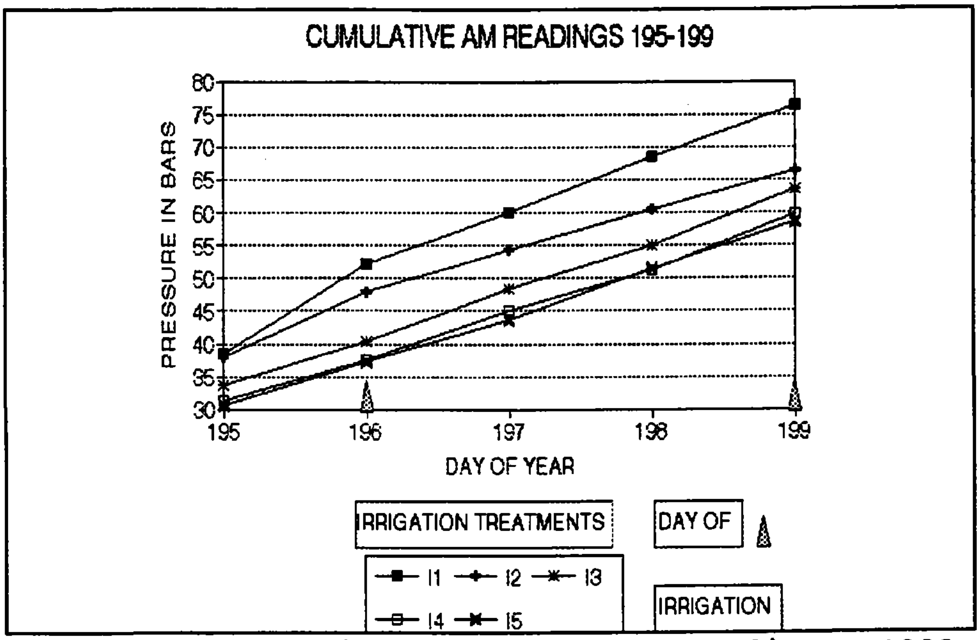

Figure 2. Cumulative pressure bomb readings, 1992.

Infrared thermometer

The 1991 study by Gallardo (1992) suggested that the infrared thermometer had potential for irrigation management by calculating the crop water stress index (CWSI) that is commonly used. In addition to the CWSI reading given by the thermometer, two other methods were used to calculate the CWSI: an empirical non-stressed baseline and a theoretical energy approach. Unfortunately, the 1992 readings were very unstable for all indices, as shown in Figure 3 for the thermometer's CWSI. The lack of a reasonable threshold value for water stress suggests that the method is not applicable to the peppermint stress in central Oregon. There may be several meteorological or physiological reasons for the poor performance, such as wind speed, clouds, plant temperature regulation, etc.

WATERMARK Soil Measurements

Soil water content was measured by the standard neutron meter system, and by WATERMARK sensors. The neutron meter was not effective in 1991 under sparsely planted, first-year peppermint, but in 1992 it proved effective at measuring water depletion under established peppermint. The agreement between the WATERMARK sensor, and percent water depleted is shown in Figure 5 for irrigation level I5. Note that the WATERMARK sensors were measured on a daily basis, in comparison to the neutron readings that were taken twice a week at considerable time expense. Sensors were read with a hand-held resistance meter, but have also been successfully measured with datalogger at set intervals.

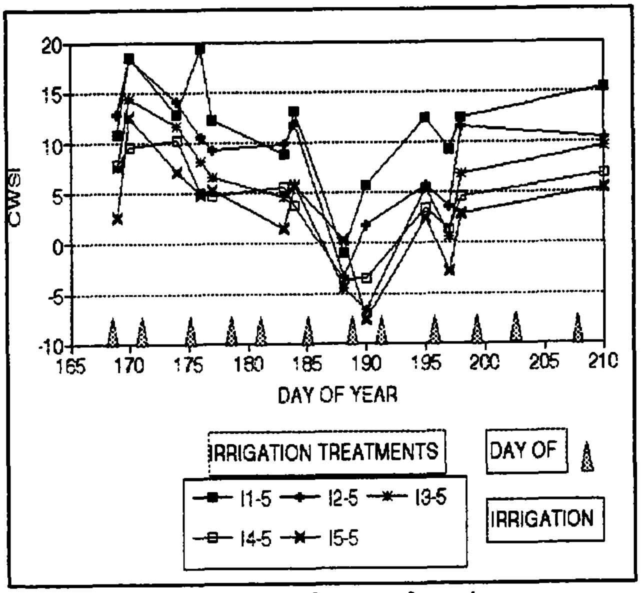

Figure 3. CWSI throughout season, Madras, OR, 1992.

Nitrate Fertility

Dry matter yield data are shown in Figure 1 for all six irrigation and nitrogen treatments. Supplemental summer nitrate application treatments (N4 and N6) were the top yielding treatments under high irrigation (I5). However, at low irrigation levels, low rates of N performed better than their counterparts, this is probably due to a salinity effect of the fertilizer that can depress yield. Dow et al. (1981) showed that peppermint is salt sensitive at soil salinities of 2 mmhos/cm, which may have occurred in areas of the root zone after the fertilizer was applied.

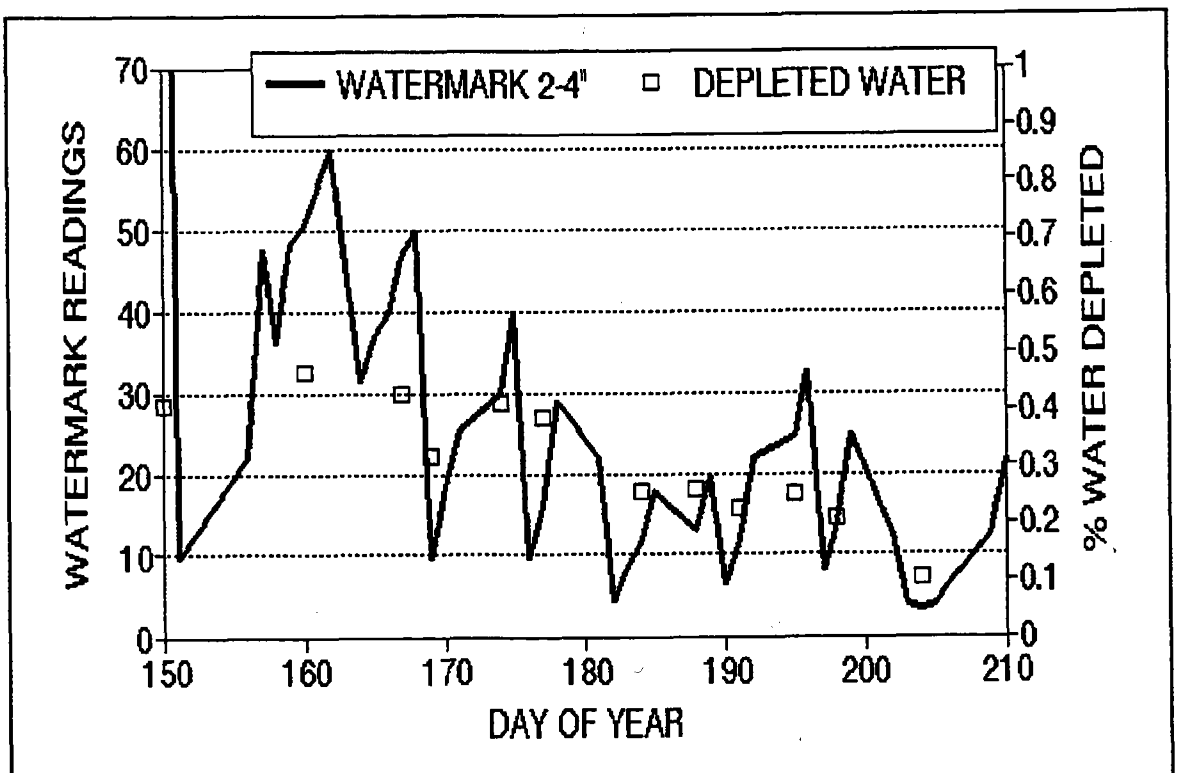

Figure 4. Soil water depletion and Watermark readings, Madras, OR, 1992.

Nitrate Leaching

In 1991 it appeared that nitrate leaching had occurred to a depth of 5 feet, in 1992 the PCAPS samplers did not intercept any water during the growing season. The neutron probe and WATERMARK data showed water contents were not at saturation near the PCAPS, which supports the conclusion of no leaching. It appears that first-year peppermint is more susceptible to leaching than established, second-year peppermint, which would be attributable to a stand that is less than fully established.

Conclusion

The line-source sprinkler experiment on a second year stand showed significant dry-matter and oil responses to irrigation rate and nitrogen fertility. Peppermint oil quality was also influenced by irrigation, although not by nitrogen level. High rates of nitrogen fertilizer produced a salinity effect at low irrigation rates. The 1992 results lacked an over-irrigated treatment that would indicate the point at which there is a lack of response to irrigation. Plant pressure chamber data showed that plants responded to stress according to irrigation level. Techniques for irrigation scheduling were evaluated, with the WATERMARK soil sensors preferable to the infrared thermometer and plant pressure chamber. The neutron probe was more effective on second-year than on first-year mint for measuring water content changes, but is more time-consuming than the WATERMARK sensors. We did not measure leaching under the plots this year, which may have been due to PCAPS malfunction.

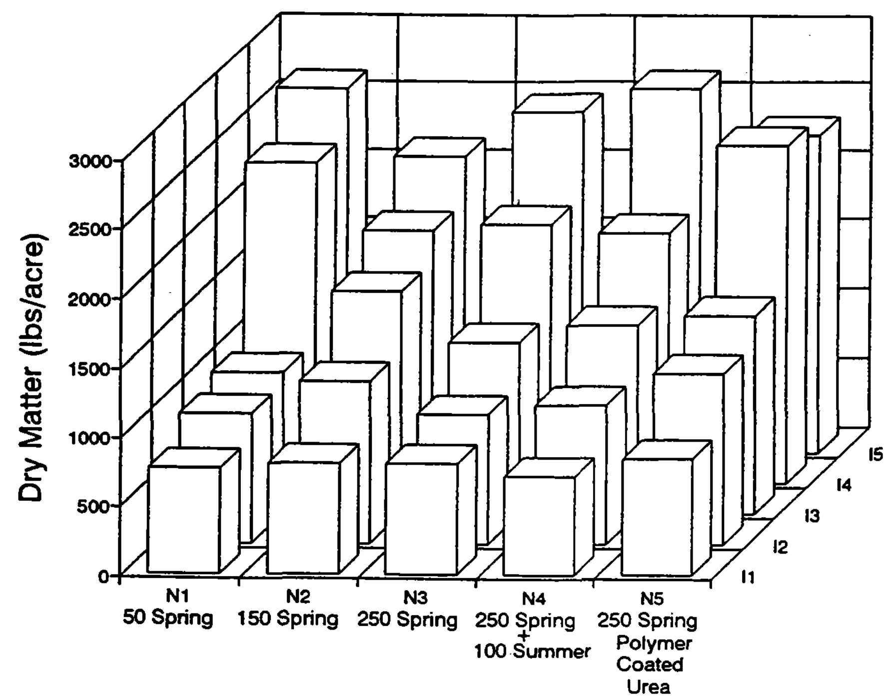

Figure 5. Dry matter yield for irrigation and nitrogen treatments, Madras, OR, 1992.

In the coming season, 1993, we will repeat the experiment with over-irrigation and continued measurements of nitrate leaching both with PCAPS samplers and soil samples. The focus will be on WATERMARK sensors for determining the level of water stress associated with optimal yield.

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NEW TOOLS FOR PLANT-RESPONSE NITROGEN TESTING OF PEPPERMINT*

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Abstract

Peppermint, a crop that requires high rates of water and nitrogen fertilizer, was the focus of a nitrate-nitrogen (NO_3-N) sensing study. A second-year stand of Murray Mitchum peppermint was evaluated using three methods: stem NO_3-N analysis, a CARDY ion meter that measures sap NO_3-N, and a SPAD chlorophyll meter. This study was designed to judge the accuracy of the two real-time sensors against the stem NO_3 content determined in the laboratory. The three methods were evaluated using data collected on soil NO_3-N, dry matter yield, and fertilizer rates. The stem dry matter NO_3-N was found to be correlated with the appropriate fertilizer rate. The CARDY meter was not correlated with the other methods or to the fertilizer rates, but the meter showed an inverse correlation with the dry matter yield. The SPAD meter showed correlation with the CARDY meter, but the results did not reflect the fertilizer rates. Water and salt stress occured in June, and although the plants showed good recovery, repercussion from the stress may have influenced our results. These results indicated that all plant-based measurements can be influenced by factors other than NO_3-N stress.

Introduction

With today's concern with ground water contamination, managing nitrate (NO_3) to prevent NO_3 leaching is important. Peppermint is a crop that has been shown to respond well to inputs of water and nitrogen (N) fertilizers (Clark and Menary, 1980), the high value of peppermint oil has provided an economic incentive for growers to make sure these inputs are not in deficit. High irrigation and fertilizer rates, along with a shallow root zone and permeable soils, make peppermint a target crop for NO_3 leaching. Timed NO_3 applications could improve N use efficiency. In this study, two real-time sensors will be compared to the traditional dry matter method of measuring stem NO_3, which involves a long turn-around time with an analysis laboratory.

Huettig (1969) and Brown (1982) have shown a relationship between final yield and NO_3-N concentrations in peppermint, and that stem NO_3-N concentrations were significantly increased with higher N rates. Using this information, Brown (1982) has calculated the critical stem NO_3-N level for maximum yield. The critical level falls during the season as the plant takes up NO_3.

*This research was supported by the Oregon Mint Commission and the Oregon Department of Agriculture.

Real-time analysis of N status of the crop would provide a tool for split N applications when they are needed most, not just in peppermint but also in other high-input, high-management crops (i.e. potato). Work with the CARDY NO_3 ion meter for measuring petiole sap NO_3 in potato has been successful (Wescott, 1992). Also, two years of field testing in Montana and Minnesota have confirmed that direct measures of potato petiole sap NO_3 are highly correlated (r=0.962**) with petiole dry matter NO_3.

The SPAD chlorophyll meter is a non-destructive sensor that measures leaf reflectance properties to determine leaf chlorophyll content (Yadava, 1986). Since leaf chlorophyll content is closely related to NO_3 in the plant, the chlorophyll meter readings have been related to leaf NO_3.

The objectives of the study were to calibrate new tools for plant response nitrogen testing of peppermint, i.e., the SPAD and CARDY meters.

Materials and Methods

This study was conducted at Oregon State University-Central Oregon Agricultural Research Center (OSU-COARC), Madras, Oregon, during the summer of 1992, on a second-year stand of Murray Mitchum Peppermint. The plots were set up using the line-source sprinkler system (Hanks, et al., 1976) to apply five different irrigation levels, of which only two were evaluated in this study: I4 was managed to replace 100 percent of the water deficit in the field, and I5 was 120 percent of I4. Six different rates of urea fertilizer were studied, ranging from 50 to 350 lb/a in a split application (Table 1). Polymer coated urea (250 lb/a) was also tested. Spring fertilization occurred on June 3-5, 1992. Later applications of the aqueous fertilizer, Solution 32, were applied to N4 and N6 treatments on July 10 and 17 at the rate of 50 lb/a. The plots were irrigated twice a week with amounts determined by weekly neutron probe readings.

Table 1. Fertilizer trial rates

Fertilizer plot	Spring	Summer**	Total
	------	lb N/a	------
N1	50	0	50
N2	150	0	150
N3	250	0	250
N4	250	100	350
N5 PCU*	225	0	225
N6	150	100	250

* polymer-coated urea
** split application of 50 lbs each

Twelve samples were taken, one from each of the two irrigation levels at the six fertilizer rates, to evaluate the three different NO_3 analysis techniques. The samples were composites of four stems taken in each of the eight replicated plots. Each stem consists of the top 6 inches of the plant minus the leaves and petioles. Before the leaves were stripped from the stem, the Minolta SPAD-502 chlorophyll meter was used. This meter was used on a leaf at the second or third node from the top to read the "greenness" of the leaves. The SPAD measures the "greenness" of the leaves by using the red and infrared energy bands to calculate an index, which is closely related to leaf chlorophyll content.

After the leaves were stripped, the stems were cut to 6-inch lengths from the top node down, and the ends clipped off to be put into a garlic press. The press was used to release sap onto the Horiba CARDY ion meter, distributed by Spectrum Technologies, Inc., Plainfield, IL 60544. The CARDY meter reads the ppm NO_3-N in the sap. The reading was later converted to a dry matter number for comparison, by using a ratio of the wet weight to dry weight of the stems.

The remaining portions of the stems were packaged and sent to a plant analysis laboratory (Agri-Check, Inc., Umatilla, OR 97882) for dry matter analysis for NO_3-N.

Peppermint was harvested on July 29 and 30 with a forage harvester taking a 40-inches-wide and 25-feet-long swath. Samples were taken to determine dry matter and oil yields.

Results and Discussion

The NO_3-N data from the stem-dry matter followed the pattern of development of Brown (1982), where NO_3-N concentrations decreased according to the fertilizer treatment, and as the season developed (Figure 1). It appeared that a salt or water-stress condition occurred in the early summer, which lowered the NO_3-N levels in the stems. On June 19 (day 171), there was no differentiation between fertilizer rates. By June 25 (day 177), some of the rates were differentiated according to their NO_3-N concentrations. Fertilizer plots N2 and N3 showed NO_3-N levels expected following spring fertilization in accordance with Brown (1982). At irrigation level I5, the N1 treatment showed low stem N due to lower applied N, while N4 exhibited lower stem N as an indication of a salt effect due to excess fertilizer. These results were not true at the lower irrigation level I4. N1 did not show any lowering of NO_3 concentration but was 875 ppm higher than N1 in irrigation I5. However, the salt damage in N4 showed more damage at I4 (data not shown). The stem NO_3-N concentrations at harvest were higher for the split-application treatments (N4 and N6) and the slow release urea (N5) than on early summer application. The measurements stayed above Brown's (1982) threshold of 8,000 ppm NO_3 except late in the season.

The results of all three methods indicated some type of stress condition early in June. The stem dry matter and soil NO3 concentrations indicated excess salt and low nitrogen. The SPAD meter showed possible water stress, followed by new growth and maturity. At irrigation level I5, recovery from these conditions was more complete than from I4, but the repercussion from the stresses influenced our results during the entire study. WATERMARK measurements of soil moisture indicated possible water stress from June 4 to June 25 (data not shown).

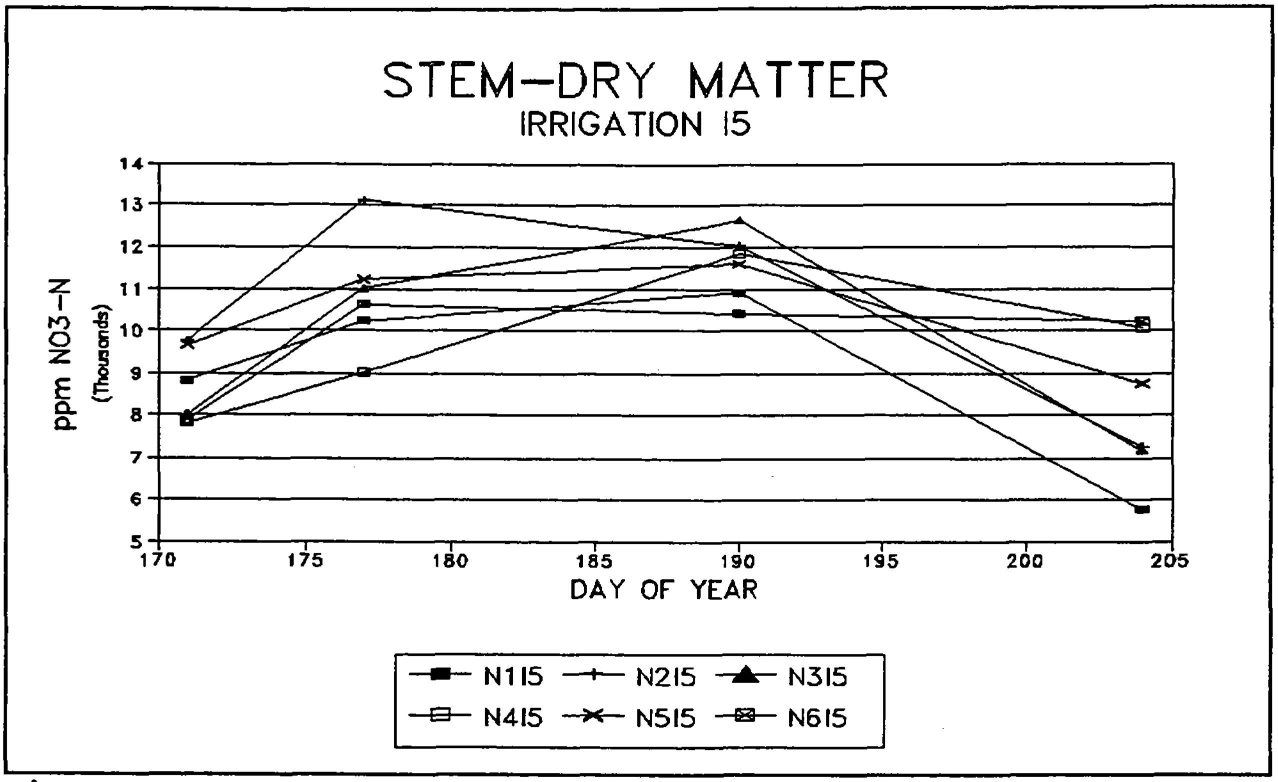

Figure 1. NO3-N Concentration in the stem-dry matter, Madras, OR, 1992.

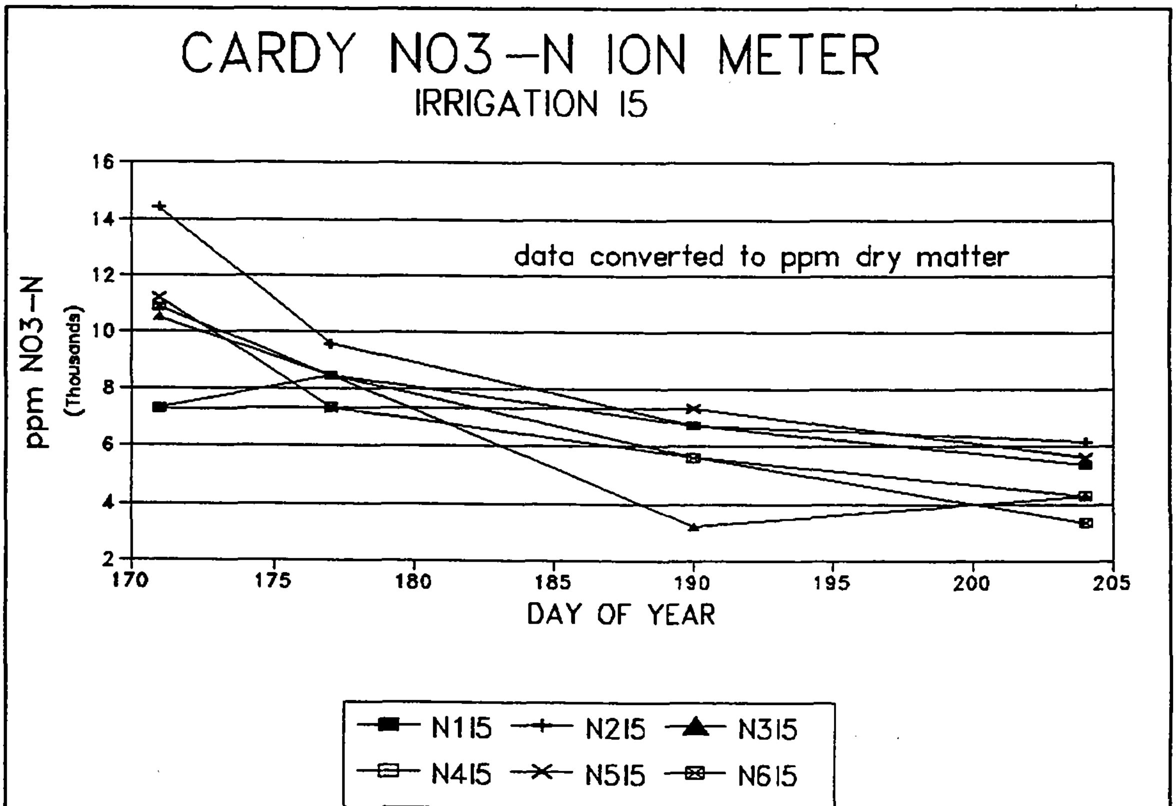

Figure 2. NO3-N concentration in the peppermint stem sap (dry-matter conversion), Madras, OR, 1992.

The CARDY meter did not show any correlation with the other methods or to fertilizer rate (Figure 2). Correlation with the stem-dry matter becomes smaller as the season progresses. Interestingly, the final CARDY meter measurements and the dry matter yield were *inversely* correlated, high final NO_3-N concentrations produced low dry matter yield.

Table 2. Correlation coeffcients of N sensing methods, Madras, OR, 1992.

	CARDY (DM)	SPAD	YIELD (DM)	SOIL
STEM	0.029	0.076	0.545	0.261
CARDY (DM)	----	0.478**	-0.657*	0.176
SPAD	----	----	-0.363	0.416*
YIELD (DM)	----	----	----	-0.079

**, * Significant at the 0.01 and 0.05 probability levels, respectively.

The SPAD meter, like the CARDY meter, showed mixed results (Figure 3). There was more correlation (0.478) between the SPAD and the CARDY meters (Table 2) than any other comparison. The results from both methods seem to show a period of water stress on June 25 (day 177), but then the SPAD readings indicated possible improvement to a level of maturity by July 22 (day 204). The poor results may be due to how the plant partitions N. Nitrogen translocates upward, taking N from the mature leaves when it is not available in the soil to supply the leaves with the highest growth rate. Recalling that the SPAD measurements were taken on the leaves at the third node, it is possible that the SPAD measurements may not have been representative of the entire plant.

The NO_3-N analysis of the soil gave results that reflected the fertilizer rates (Figure 4). At Irrigation level I5, N1 had 49 ppm NO_3-N on June 19 (day 171), and by July 22 (day 204) the NO_3-N level had rapidly dropped to 10.5 ppm, this did not seem to make any difference on the dry matter yield results N1-I5 and N1-I4 yielded 333 and 527 lb/a, respectively, better than the lowest yields. N3 and N4 showed very different concentrations in the beginning, 81 and 53 ppm respectively, despite the same spring fertilizer rates. This could be due to the remaining NO_3-N in the soil from 1991 when they had different rates: N3=200 lb/a and N4=150 lb/a plus 5 percent DCD. By the end of the experiment N3 dropped off sharply to end at 28 ppm NO_3-N and N4 gradually decreased until an additional 100 lbs of fertilizer were applied in July when the NO_3-N concentration increased 8 ppm. N5, slow-released urea, showed a release of N after June 25 (day 177). At I4, the NO_3-N concentration stayed fairly steady, I5 followed the same pattern but much more dramatically, increasing sharply to a peak on July 8 (day 190), and then dropping off.

The correlation between stem-dry matter and the soil was not significant (r=0.261), but the correlations between yield and stem NO_3-N for individual sampling dates increased as the sampling approached harvest. For example, N2I5 had both a low soil and stem-dry matter NO_3-N concentration, 16.5 and 7,250 ppm respectively, and the lowest treatment yield at 2,579 lb hay/a. N4I5 had a soil concentration of 45 ppm and a stem-dry matter of 10,075 ppm, and yielded 3,054 lb hay/a. A possible stress threshold was found to be between 20 and 30 ppm NO_3-N in the soil.

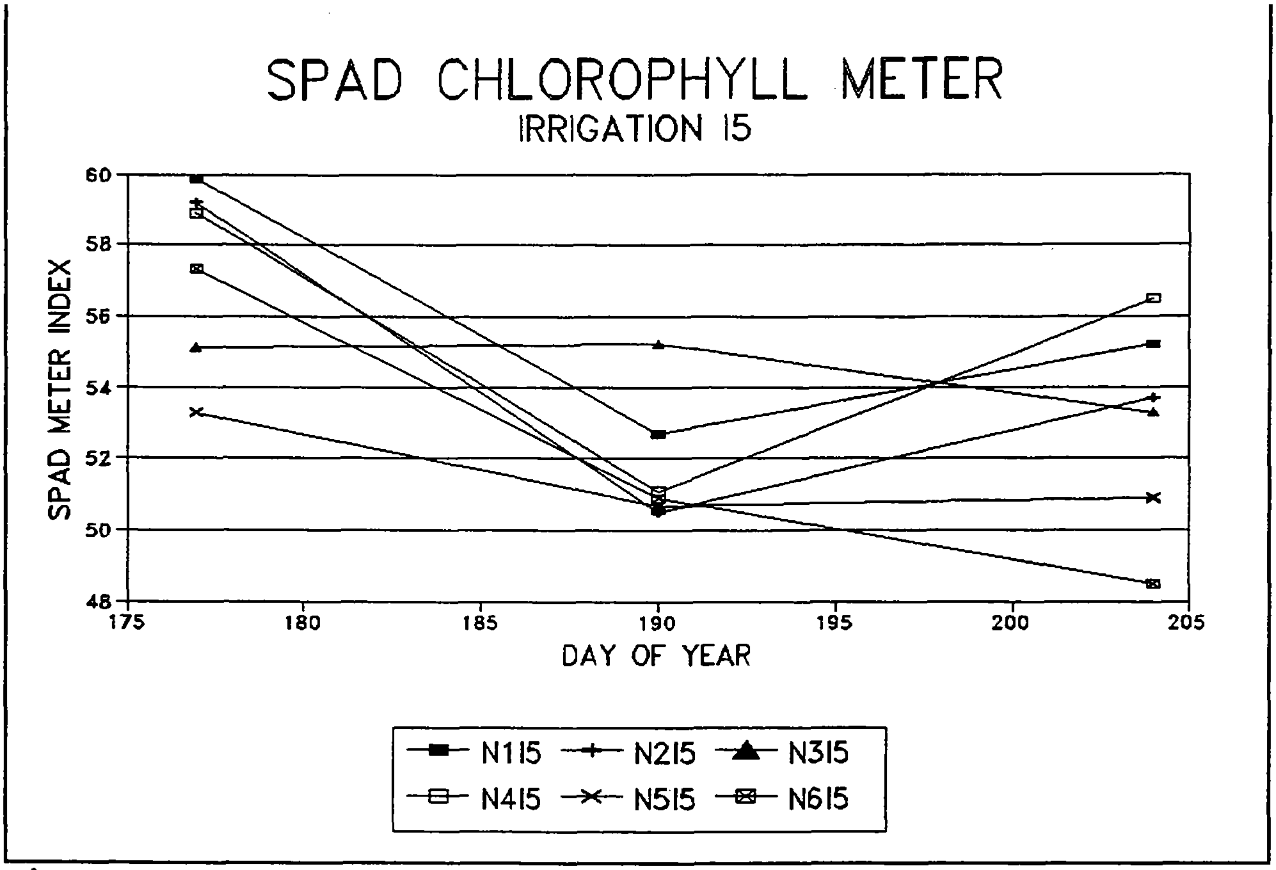

Figure 3. SPAD meter results throughout the season, Madras, OR, 1992.

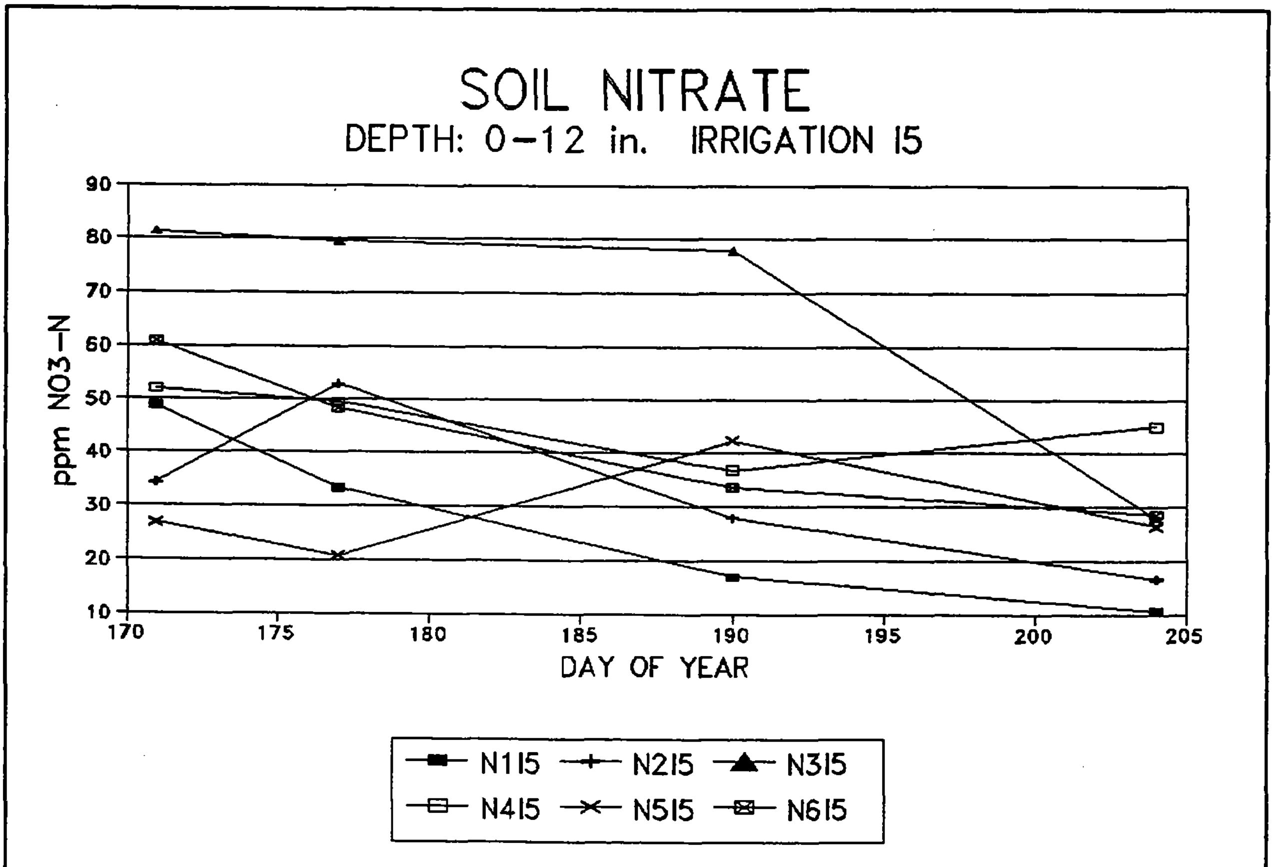

Figure 4. Soil nitrate levels throughout the season, Madras, OR, 1992.

CONCLUSION

Of the methods analyzed in this report the traditional stem analysis appeared to be the most accurate. The CARDY and SPAD meters showed correlation with each other but not with stem NO_3-N. This may be the result of water or salt stress in June, but it points out that all plant-based measurements can be influenced by factors other than NO_3-N stress. The stress factors were not excessive (no plants died), which indicates the limitation of the plant stress monitoring. The stem NO_3 measurements were above the 8,000 ppm level until late in the season. A possible soil NO_3-N threshold is the 20-30 ppm level.

Similar studies being conducted by Dr. Malvern Wescott, Montana State University, Western Agricultural Research Station, show correlation between the three methods. These studies were conducted on Black Mitchum peppermint. Next year, with funding from the Oregon Department of Agriculture Ground Water Research and Development Grants, studies in Madras will be conducted on both Murray and Black Mitchum peppermint with water stress kept at a minimum.

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ALTERNATE AND ALTERNATING FURROW IRRIGATION OF PEPPERMINT TO MINIMIZE NITRATE LEACHING*

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Abstract

Furrow irrigation practices to alleviate nitrogen leaching and conserve water may have advantages over sprinkler irrigation for some crop and soil situations. Two *alternate-furrow* practices were compared on peppermint (*Mentha piperita*, L.) against a furrow-irrigated control, namely: an *alternate-furrow* scheme where odd furrows are never irrigated, and an *alternating-furrow* scheme where the every-other furrow scheme is shifted by one furrow every irrigation so that all furrows are irrigated over the course of two irrigations. Dry matter yield was significantly higher for the *alternating-furrow* treatment. Oil yield was not significantly different among treatments. The interactions between treatment and field location were significant for dry matter yield. Nitrate leaching is not yet determined. Nine stations were set up for monitoring soil water content and nitrate movement, and corresponded to the three treatments times three locations in the furrow run, i.e. north, middle, and south. Soil was sampled for nitrate, and ammonia before, during, and after flood irrigations.

Introduction

High nitrate levels in groundwater have been attributed to irrigated agriculture. Surface irrigation systems (e.g. furrow, basin, border-strip) are especially suspect as nitrate con tributors if practiced on highly permeable soils. Flood irrigation may lead to high leaching rates at the top of the furrows, and still cause a water deficit at the lower ends of the runs. Flood irrigation systems generally have low efficiency in terms of crop-water requirement as a percent of water delivered. This inefficiency is partly the result of high water runoff rates from the end of the field, which are caused by large water application over the distance of irrigation run. Many of the proposed irrigation system upgrades to alleviate nitrate leaching (e.g. sprinkler, or drip irrigation) require large capital expenditures when converting from furrow irrigation. In addition, the energy costs of pumping for new irrigation systems may require new sources of electrical power.

There exists a need to improve management techniques for furrow irrigation in order to conserve water, and reduce groundwater contamination from nitrate. *Alternate-furrow* irrigation has been reported as a method to reduce nitrate leaching on corn grown in

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Southern Idaho (Lehrsch et al., 1992). This report evaluates water and nitrate in the furrow irrigation system under *alternate-* and *alternating-furrow* irrigation strategies for their potential to reduce nitrate leaching.

Alternate-furrow irrigation consists of irrigating every other furrow of a field while leaving the off furrow dry. Several investigators studied *alternate-furrow* irrigation in the 1960s and early 1970s with much the same results: water was saved as compared to *every-furrow* irrigation and yield was usually, but not always, unaffected. The research was over a wide variety of crops: Fishbach and Mulliner (1972) on corn, Grimes et al. (1968) on cotton, New (1971) on grain sorghum, Box (1973) on potatoes, and Musick and Dusek (1974) on potatoes, sugarbeets, and grain sorghum. Musick and Dusek (1974) cautioned that the practice could have a deleterious effect on water infiltration and yield of sugarbeets and grain sorghum in the lower one-fourth to one-half of the field, although potatoes showed no yield decrease. They recommended not using the practice for slowly permeable soils or wide furrow spacings. Crabtree et al. (1985) also found yield decreases for soybean under the alternate-furrow system, but found the water savings (50 percent less irrigation) to be an acceptable trade-off.

The *alternating-furrow* irrigation scheme consists of irrigating every odd furrow (1, 3, 5, etc.) during an irrigation event, then, during the following irrigation, irrigating even furrows (2, 4, 6, etc.). The overall benefits are first, that the amount of applied water is reduced, and second, the water flow in the furrow should have a larger lateral flow component. Because nitrate is very mobile in water, this would tend to increase the horizontal component of nitrate and water flow, and keep nitrate in the root zone, rather than have it leach downward. Water stress may be reduced in spite of an uneven water distribution because water transfer can occur within the root system, as shown by Baker and van Bavel (1988).

The objective of this study was to test *alternate-furrow, alternating-furrow*, and *every-furrow* irrigation practices for yield, water savings, and nitrate leaching. Peppermint (*Mentha piperita*, L.), which is grown under high irrigation and N fertilizer conditions (Clark and Menary, 1980), is subject to leaf damage by sprinkler irrigation that may cause 20 percent loss of marketable oil yield (Croteau, 1977), which makes furrow irrigation desirable.

Materials and Methods

Field Description

The experiment was conducted in a field of 3.21 acres, with 2.0 acres of peppermint surrounded by a rye border crop. The soil was Madras loam (fine-loamy, mixed mesic, Xerolic Duragrid). The field had a slope of 2.0 percent with a 560 ft irrigation run.

In March of 1992, the field was prepared for planting and fertilized with 64 lbs of 16-20-0-14 per acre. The peppermint rhizomes were then planted on March 16 and 18. On June 22, the field was again fertilized with an additional 184 lb N/a as urea. The furrows were dug using a rotary corrugator, which covers the bed with a mulch and buries the urea. The furrows were 4.5 inches deep and 24 inches apart.

Granular matrix sensors (GMS) were installed the following day. A total of 144 GMS were installed at nine different locations in the field (see "Granular Matrix Sensors" in this issue). The first furrow irrigation occurred on July 16. At this time the stand was approximately 8 inches tall and not at full canopy. Subsequent furrow irrigations occurred on July 17, 24, 31, and August 7, 12, 14, 18, and 21.

The mint was harvested on August 26-27. The peppermint was swathed in 12-ft windrows. At each tier (north, middle, south), three 10-ft windrow samples were taken for fresh matter yield. These samples were weighed and subsamples of 9-11 lbs were taken for oil yield analysis. Subsamples were processed at a research distillery at Oregon State University on November 13.

Plot Design

The experiment was a random block design with four replications. Each treatment consisted of six furrows. Treatments A, B, and C correspond to the *alternate-furrow, alternating-furrow*, and the *every-furrow* control. The field was irrigated using a gated pipe system flowing out of a pressure reduction tank. The gated pipe was 5 feet from the edge of the field in a border of rye and was set on cinder blocks, 3-4 inches above the ground. The gates were set and monitored to deliver 12 liters a minute per row. The gates were set using a stop watch and a 5 liter pitcher.

Sampling of N

Nitrogen movement was monitored in two ways-in a sampling grid throughout the bed, and at the end of the season, beneath the bed and furrow. The grid sampling was done at the nine different GMS locations within the first replication. Grid soil samples were taken at three times during the season-first on June 29, before the first furrow irrigation, but after several sprinkler irrigations. The second sample was taken on July 21, after three more sprinkler irrigations and one furrow irrigation (July 16). The third sampling was on September 1, after harvest. The grid soil samples were taken several feet south of the GMS locations in the first replication only. Sixteen total samples were taken in four layers, each 5 inches deep to a depth of 20 inches and 6 inches wide for the 24-inch width of the bed.

The total field was soil sampled in the last week of September and the first week of October with a hydraulic soil sampler mounted on a tractor (The Giddings Machine Company, Fort Collins, CO 80522). Three cores were taken and made in to a composite for the sample. Samples were taken in the same three tiers as before, but this time all replications were sampled. Samples were taken on the beds and in the furrows. In treatment A (*alternate-furrow*), the furrow samples were taken for both the irrigated and dry furrows.

The samples were air dried and ground if needed. Twenty grams of soil was mixed with 75 ml of KCl extractant for an hour and filtered. The filtrate was then analyzed for ammonia with an ammonia analyzer, (Wescan Model 360. Alltech Associates, Inc, Deerfield, IL 60015). A reduction cartridge was used to reduce nitrate and nitrite ions to ammonium, allowing measurement of the total inorganic nitrogen concentration. Nitrate was determined by subtracting ammonia from total inorganic N, assuming nitrite concentration to be negligible for the high pH (>7 pH) soil.

RESULTS

Yield

The dry matter yield showed significant differences for treatment ($p=.07$), location in field ($p=.04$), and the treatment-by-location interaction ($p=.04$). The alternating furrow irrigation (treatment B) had significantly greater dry matter yield, and it was greater for each location in the field (Fig. 1).

The peppermint oil yield statistics showed no significant treatment or location tests. The oil yield field average was 43.1 lb/a. It is not unusual to have such results for peppermint, where oil yield can be affected by other factors, such as maturity, which increases oil (Bullis et al., 1948), and insect damage, which decreases it. We noticed spider mite infestation at harvest, as well as differences in maturity (blooms) at harvest.

Nitrate Movement

The grid soil samples give us a moment in time picture of water movement under the furrow irrigation system. Figure 2 shows the nitrate concentrations of the control (*every-furrow*) before the first furrow irrigation, after first irrigation, and after harvest. After one irrigation, the water has moved the nitrate down and to the middle of the bed. Note that after harvest, the largest nitrate concentration is at the bottom of the profile.

Contrast this with the *alternate-furrow* data of Figure 3. After one irrigation, the nitrate is concentrated away from one furrow and toward the other. The highest N concentration after harvest is located at the top of the bed, not at the bottom of the profile.

Nitrate Leaching

Due to limited availablity of the data, this topic will be discussed in a future report.

Conclusions

Alternating-furrow irrigation yielded higher than the *alternate-furrow method* and *every-furrow* control treatment in dry matter. In oil yield there were no significant differences. This suggests that *alternating-furrow* irrigation may not be detrimental to yield and gross income. It is possible, but not yet proven, that nitrate leaching may be minimized under *alternate-furrow* irrigation. The work of Lehrsch et al. (1992) supports this conclusion. Water savings, although not studied here, may also result from the practice. *Alternating-furrow* irrigation of peppermint appears to be a viable practice for limiting leaching and saving water, without a yield decrease. The extrapolation of these results to other crop and soil situations should be done cautiously. For example, a field with furrow lengths longer than the 560 ft of this study may produce different results.

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Figure 1. Peppermint dry matter yield by treatment and location in the field, Madras, OR, 1992.

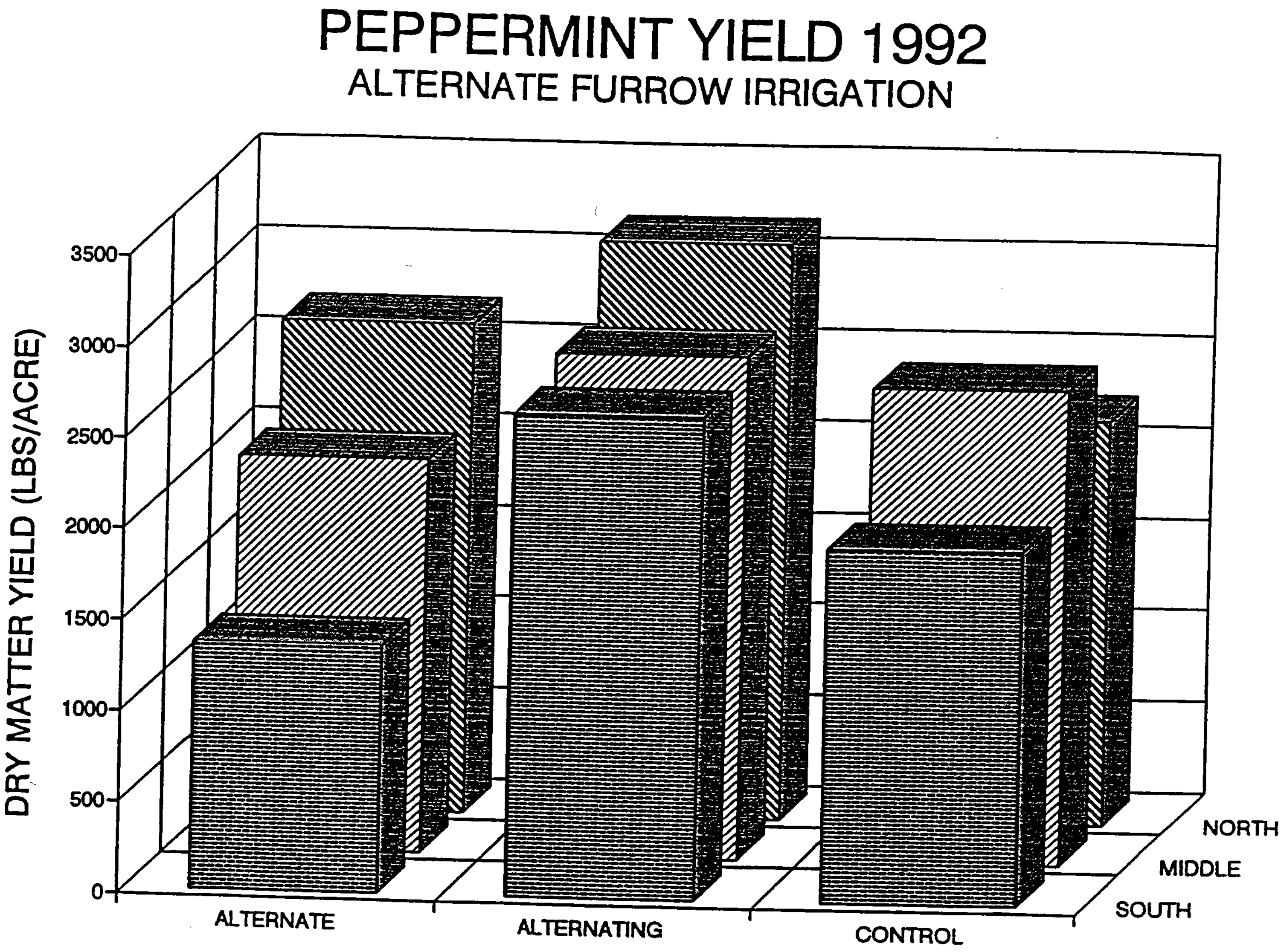


Figure 2. Nitrate concentration in furrow bed of *alternate-furrow* treatment at three times during growing season, Madras, OR, 1992.

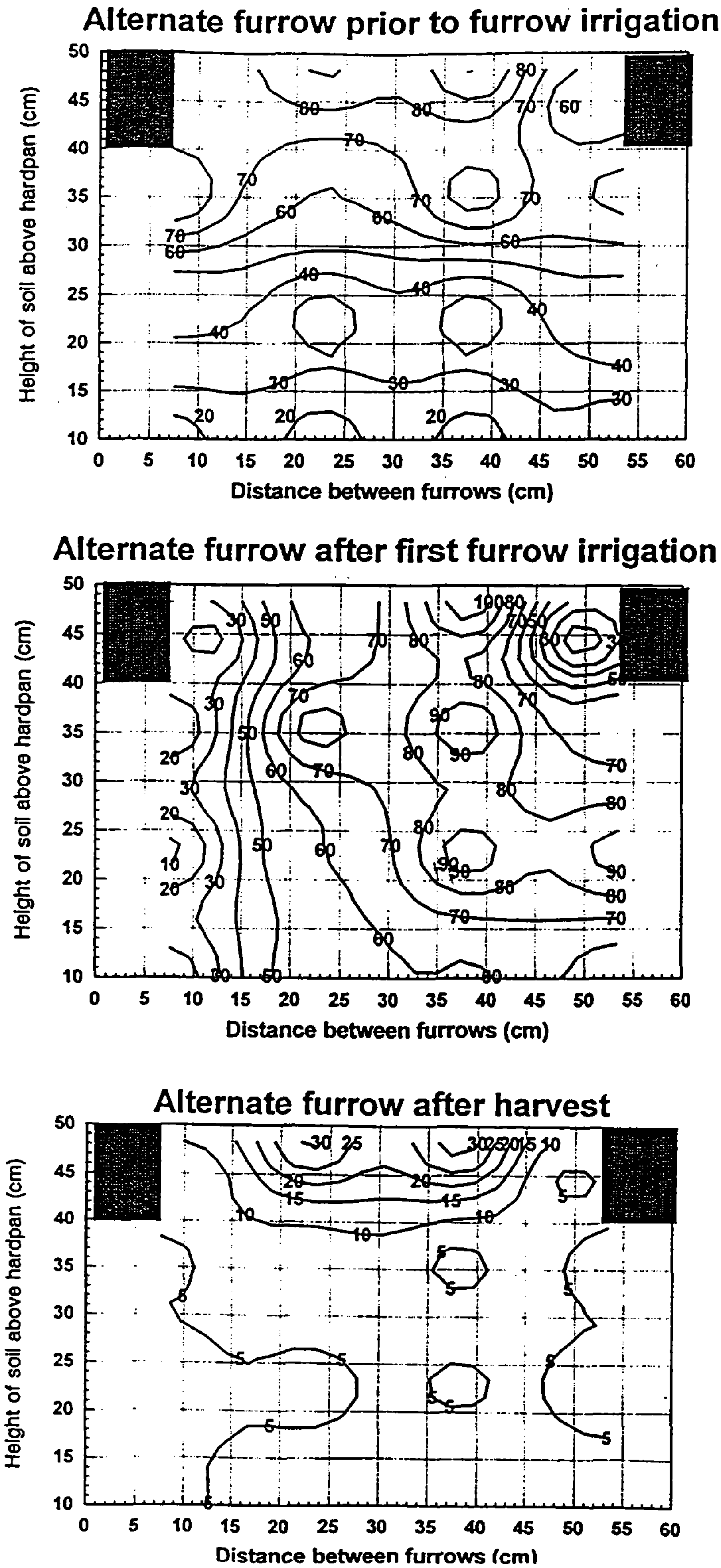
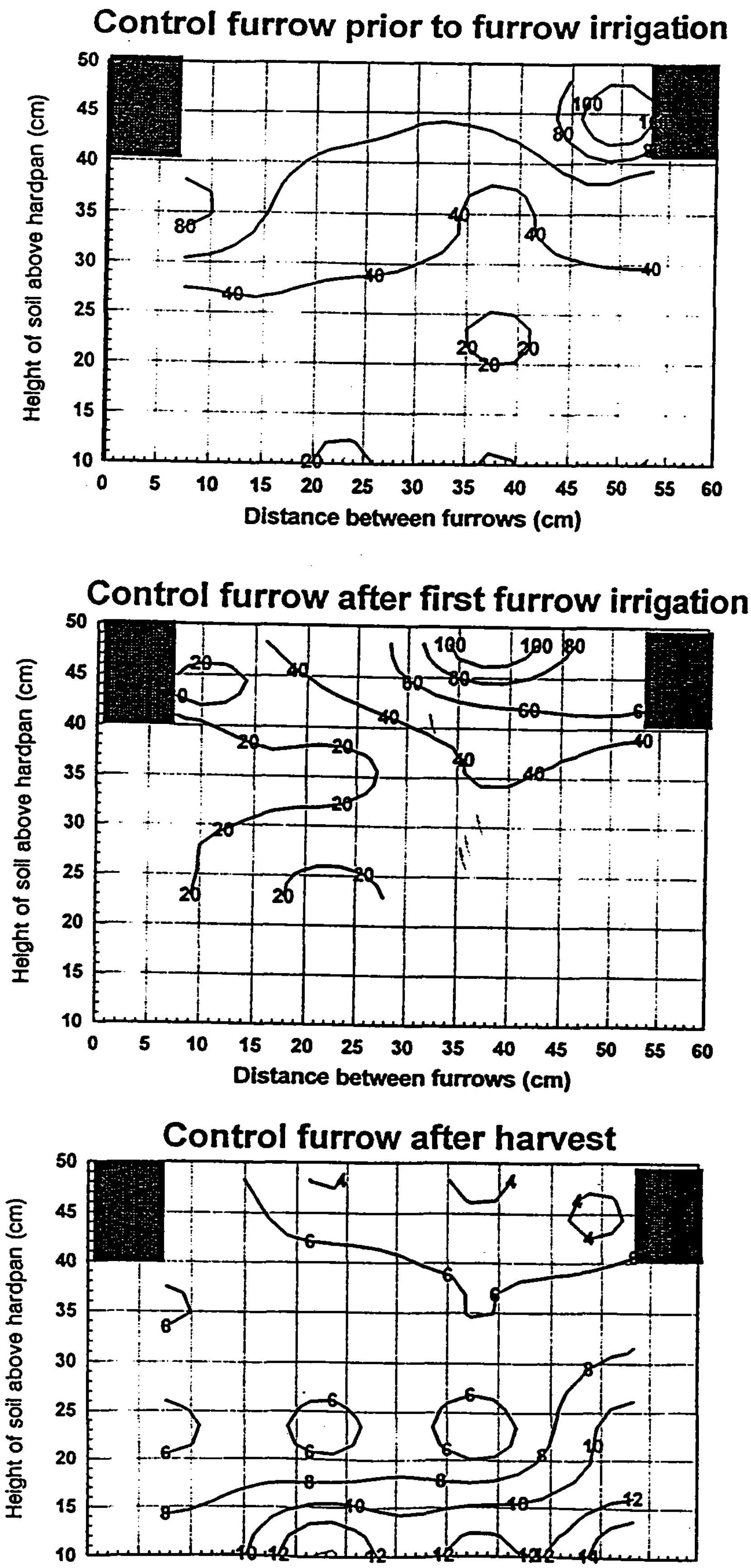


Figure 3. Nitrate concentration in furrow bed of *every-furrow* (control) treatment at three times during growing season, Madras, OR, 1992.



GRANULAR MATRIX SENSORS FOR IRRIGATION MANAGEMENT*

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Abstract

The goal of this study was to develop an automated and multiplexed measurement system using granular matrix sensors (GMS). The system included 144 sensors connected to three multiplexers and eight temperature probes connected to a single multiplexer. Calibration of the GMS were performed in the laboratory to determine the relationship between resistance and percent mass water content for a Madras loam soil. Sensor curves were plotted to determine the occurrence and location of wetting fronts in the field. An automated and multiplexed GMS system accurately predicted changes in soil water content and the occurrence of wetting fronts. The system described should be useful for field research on many subjects, including investigating plant-soil systems and validation of water-flow models. Without automation, the GMS can be used by irrigators to determine when and how much water to apply.

Introduction

A granular matrix sensor (GMS) has been developed for electronically measuring soil moisture (Larson, 1985). The GMS operates on the same electrical principle as the gypsum block and contains a reservoir of gypsum imbedded in the granular matrix, which minimizes the effect of soil salinity on the resistance measurement. The objective of this study was to determine if an automated, multiplexed GMS system could accurately measure soil water status at several locations, thus providing a profile of soil water content. This was accomplished by calibrating the GMS to soil water content for a specific soil, measuring GMS response to wetting fronts, and by testing the appropriate instruments in the field.

Materials and Methods

Calibration of Granular Matrix Sensors

The calibration was done in a soil material from the A horizon of a Madras loam (fine-loamy, mixed, mesic, Xerollic Durargid). The sensors were planted wet in 8L containers, each containing soil with a different water content percentage, ranging from completely saturated to completely dry. Each container was covered with plastic wrap to reduce loss of moisture due to evaporation. Measurements were then taken everyday for six days until there was no change in the readings.

*This research was funded in part by the USDA-CSRS 1991 Special Water Quality Research Program.

Initially, 24 stainless steel GMS Model 200-SS were immersed in 21°C (70°F) water overnight. The sensors were then allowed to dry for one day after soaking. The soak-dry cycle was repeated two more times to improve sensor response. Before installing the sensors in the soil, one more soaking cycle was performed in which the 24 sensors were immersed for three hours. Soil moisture readings were then taken using the WATERMARK Soil Moisture Meter (Irrometer Company, Inc.). The temperature setting was fixed to the appropriate temperature (21°C). The WATERMARK Soil Moisture Meter converts the electrical resistance reading of the sensor to an estimate of centibars of soil tension. The digital readout meter gives a range of -4 to 200 centibars (C), with -4 being completely saturated. This equates to 0 to 27 kΩ electrical resistance (R) according to the following formula,

$$\Omega = 0.726 + 0.143(C) \qquad [1]$$

The sensors were removed from the soil, and soil samples (approximately 150 cm^3) were taken from each of the three areas in each bucket where the sensors were located. Mass water content was determined gravimetrically. The final readings were used for calibration purposes.

Instrumentation and Installation

The initial system consisted of 144 sensors and eight Model 107 Temperature Probes wired to four AM416 Relay Multiplexers. The multiplexers were then controlled using a CR10 Datalogger. All of the above equipment was obtained from Campbell Scientific Inc., Logan, UT. Each of three multiplexers were wired to 48 separate sensors. The fourth multiplexer was wired to eight separate temperature probes. Using coaxial cable, each of the four multiplexers were then wired to a single CR10 datalogger, which took resistance readings (Ohms/10) from the sensors and Celsius readings from the temperature probes. Measurements were taken using the AC half bridge instructions in the CR10 manual with ±2.5 V excitation.

The system was installed in June 1992 in a furrow-irrigated peppermint (*Mentha piperita* L.) field at the Central Oregon Agricultural Research Center at Madras, OR. The sensors were buried in nine different locations in the field. Each location, labeled R-Z, contained one set of 16 sensors. Individual sensors were wired to one of three multiplexers, resulting in 48 sensors per multiplexer. The eight temperature probes were buried at a single location in the field to monitor soil temperature at the relative depths of the sensors. The sensors were buried 152 mm apart, starting in the furrow, and at varying depths, depending upon location in the bed/furrow (Fig. 1). Holes were dug at various depths using an Oakfield soil probe. To insure proper contact, a mud slurry was poured into the hole before burying the sensor. The sensor was then inserted into the narrow hole and more slurry inserted. The hole was then backfilled with soil.

The CR10 Datalogger took resistance and temperature readings every five minutes during irrigation, and once-a-day (at 6:00 a.m.) between irrigations. Once the data had been transferred to the computer, the SPLIT (Campbell Scientific, Logan, UT) software application was used to retrieve the data into ASCII files. These files were later imported into spreadsheet files for analysis.

Results and Discussion

Calibration

The calibration of the sensors yielded a high correlation between resistance and percent mass water content, for a value of $r^2=0.965$. The best-fitting curve was an exponential (decay) curve represented by the following:

$$\Theta = a(b)^R, \qquad R>.5k\Omega \qquad [2]$$

as shown in Figure 2. When using the WATERMARK soil moisture meter, R should be substituted with the following:

$$\Theta = a(b)^{0.143(C)+0.726} \qquad [3]$$

where C=Centibars measured by the WATERMARK meter. For most practical applications, the *a* coefficient (27.1 percent) approximates the maximum water content measurable by the GMS. The equation is also easily manipulated into volumetric water content by multiplying the *a* coefficient by the soil bulk density and specific volume of water. The *a* coefficient may be given in percent, or as a ratio, without changing the other coefficients of the equation.

Contrary to Spaans and Baker (1992), our data indicates that a common calibration can be used for all sensor blocks. In agreement with Eldredge et al. (1993), the good fit of the model and the strong correlation indicate that the GMS can be used to measure soil water content.

For field readings, a temperature correction factor was determined using the initial temperature setting of the calibrated sensors. Spaans and Baker (1992) showed that the resulting equation for a temperature correction factor was:

$$R_r=R_m[1+k^*(T_m-T_r)] \qquad [4]$$

where R_r= reference resistance in Ohms, R_m= measured block resistance in Ohms, T_m= temperature (°C) at measured resistance (R_m), and T_r= reference temperature. The manufacturer of the GMS reported k=0.018 at T_r=18.3°C. Spaans and Baker (1992) reported k=0.024 with T_r=25°C. Thomson and Armstrong's (1987) findings are numerically similar, although the mathematical expression is somewhat different. Substituting R_r of equation 4 for R in equation 2, water content can then be calculated more accurately.

Field Data

The reference resistance, measured resistance, and temperature were plotted against time to examine changes in soil water content. At low resistance (high water content), the temperature correction becomes less critical. The fluctuation in diurnal temperature and water content are out of phase, resulting in a dampening in the fluctuation of the resistance curve due to the temperature. As noted by Jackson (1973), the amplitude of the diurnal water content change decreases with depth (Figure 3).

The infiltration and redistribution process are shown in Figure 4 for a period of three days, with a shallow GMS responding quickly to infiltration and drying, and the deeper GMS responding more slowly. A sharp drop in resistance occurs in the sensors near the surface during irrigation, while a gradual decrease in R occurs in the sensors located deeper in the soil. This can be explained if one considers how soil water content changes during the infiltration process. At the beginning of infiltration, the infiltration rate is high, which results in relatively fast soil water content changes at a point behind the wetting front. As time increases, the water becomes transmitted through a wet zone that is continuously increasing in length. This is accompanied by an increase in the resistance to flow and a decrease in the infiltration rate. As the infiltration rate drops in time, the wetting front decreases in velocity and the changes in soil water content immediately behind the wetting front more time.

Conclusion

WATERMARK sensors allow for multiplexed, automated, *in situ* measurements for determining changes in soil water content and the onset of wetting fronts when such occur abruptly in the field. The system described here proved reliable, effective, and cost efficient, exhibiting only minor problems. The GMS have advantages of low unit cost and ease of installation and automation. Once installed, data acquisition can be remote from the measurement site. The main disadvantage of this type of system is poor calibration of the sensors near saturation (low end of the scale), which may not be critical for field studies or for practical applications such as irrigation scheduling. Occasionally, malfunctions occur due to poor electrical conductivity or bad connections to the multiplexer. Currently, this type of system is being used in furrow irrigation research at Central Oregon Agricultural Research Center, and Malheur Experiment Station.

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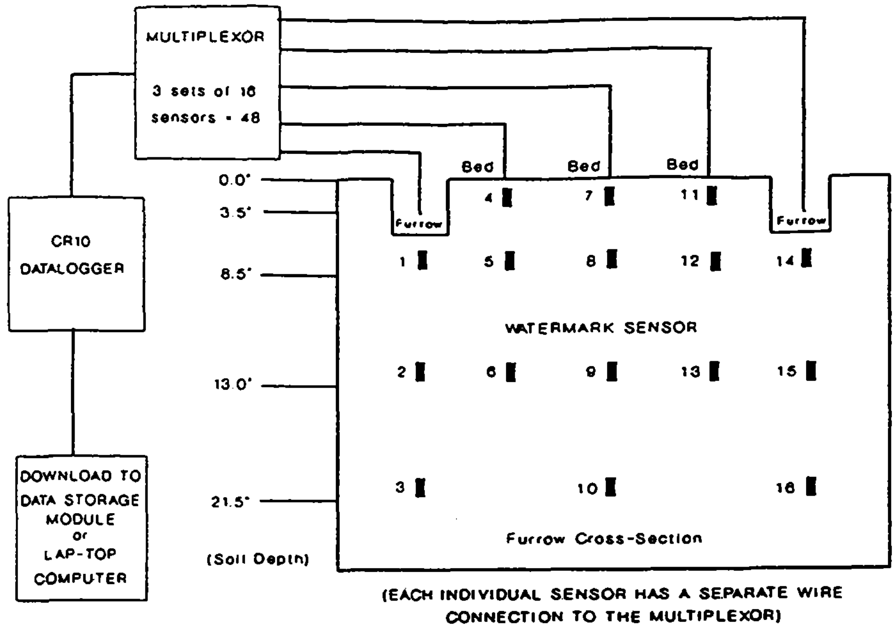

Figure 1. Diagram of individual WATERMARK sensor set, Madras, OR 1992.

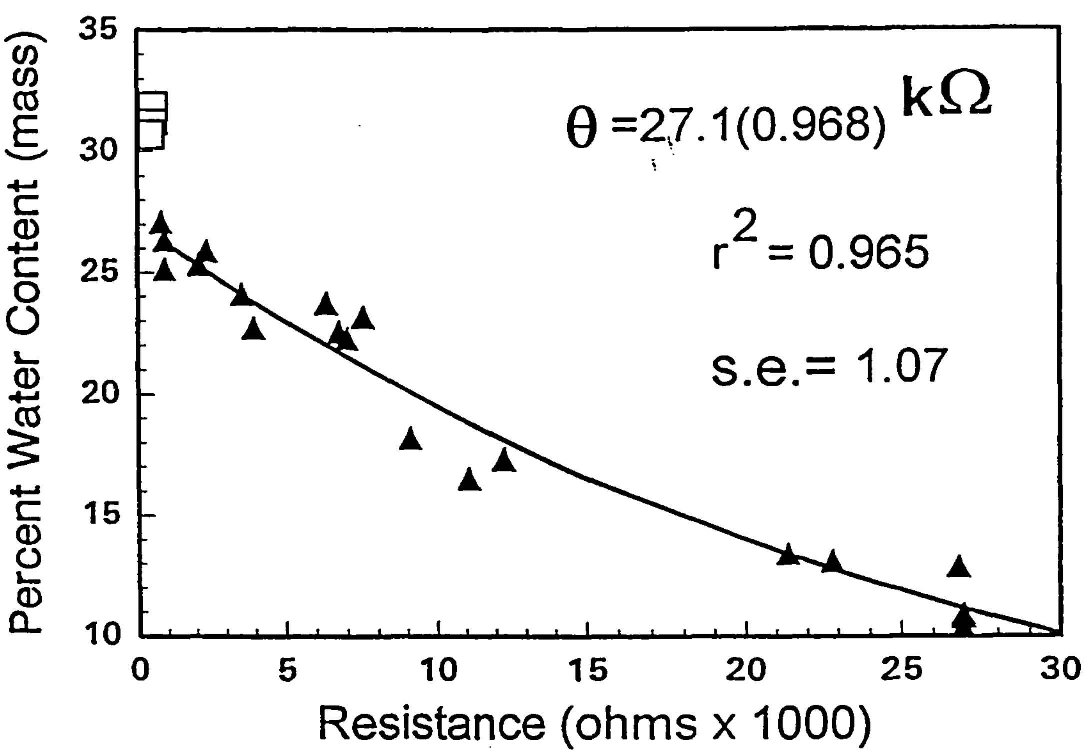

Figure 2. GMS calibration for water content of Madras loam. Open squares represent data not included in the regression, Madras, OR 1992.

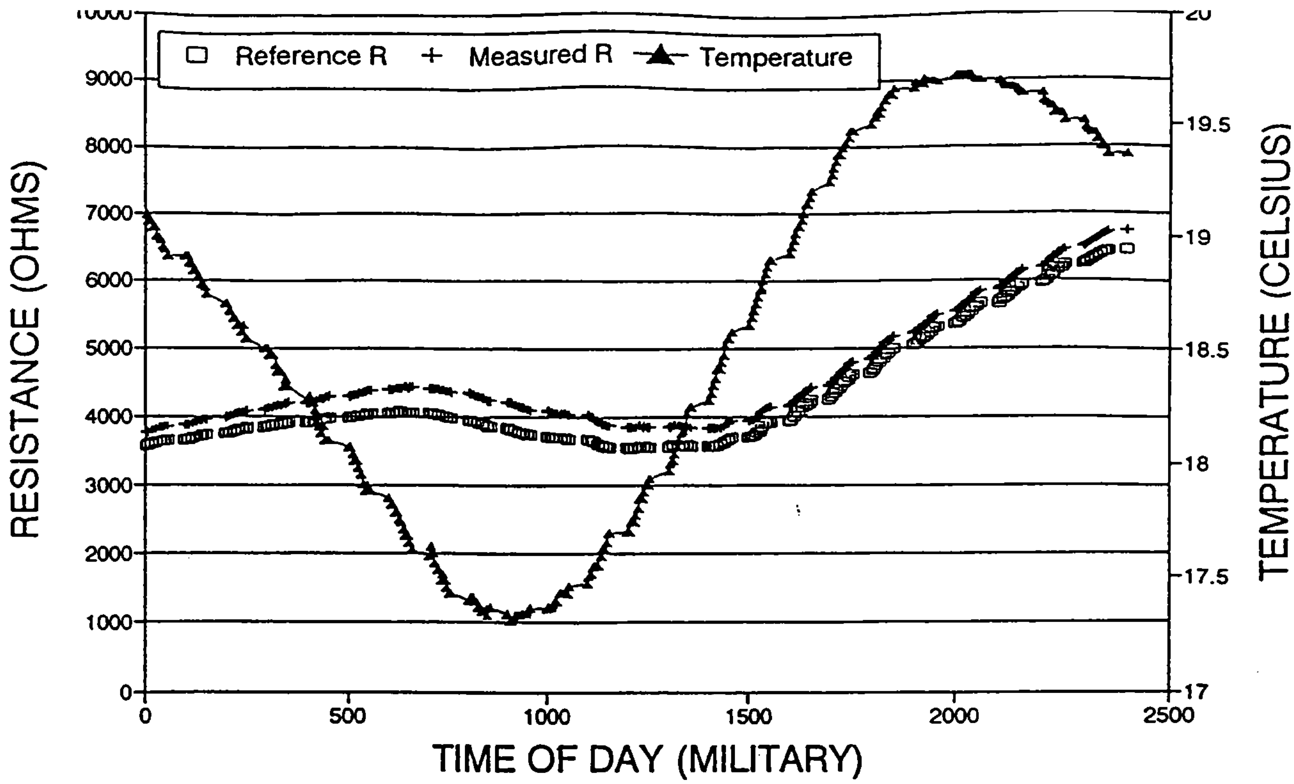

Figure 3. Temperature and Resistance, Madras, OR 1992.

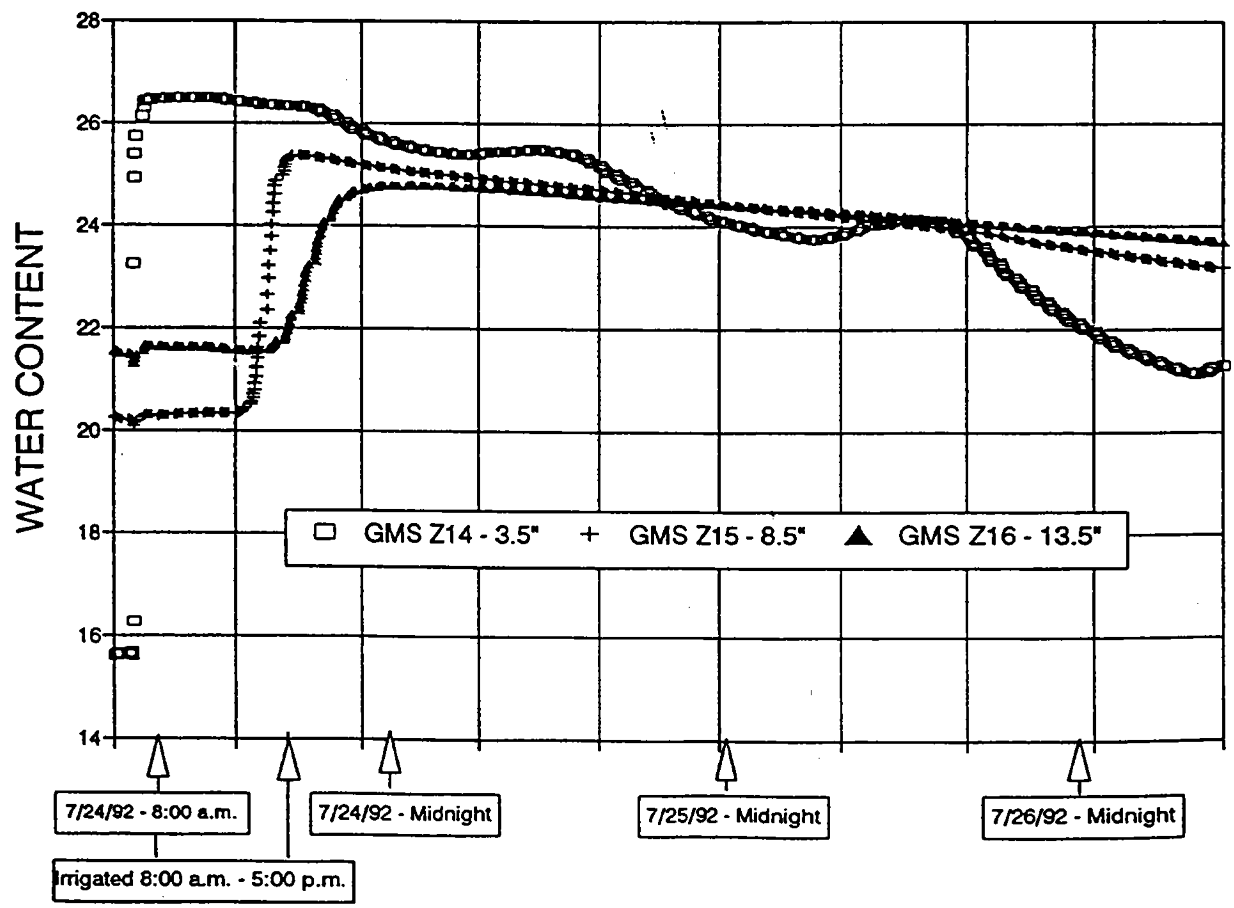

Figure 4. Infiltration and Redistribution, Madras, OR 1992.

STRAW MULCH APPLICATION TO FURROW IRRIGATED CARROTS
Analysis of irrigation stream advance, soil wetting front and sediment in runoff water.

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Abstract

A 20-acre carrot field was used to test straw-mulching of irrigation furrows to control erosion. Straw mulch was applied at a rate of 960 lb/acre, with the exception of a small control section. The first furrow irrigation lasted for 24 hours with an inflow rate of 7.3 gal/min per furrow. The average water advancement for the control and mulched sections was 3.65 ft/min and 1.32 ft/min, respectively. The water advance time dictated the infiltration rate and therefore the time needed for the complete water saturation of the furrow. The advance of the wetting front was considered complete when the soil became saturated at a depth of 12 inches. Complete saturation took place within 4 hours after initial wetting while the control furrows took more than 8 hours to completely saturate. Erosion was greatly reduced by the mulched treatment. Soil loss dropped from 10.3 g/L (12.7 tons soil/acre ft water) in the control plot to 0.365 g/L (0.45 tons/acre ft) in the mulched plot. Therefore, the application of straw mulch in this furrow irrigation system greatly increased the rate of water infiltration and dramatically reduced the amount of soil loss due to erosion. Yield of carrot seed was unaffected by straw mulching. Straw-mulching may require the irrigator to manage differently, and several suggestions are given that may prove helpful.

Introduction

In this age of environmental consciousness, many aspects of today's modern farming practices are being reviewed and improved. Furrow irrigation, which may waste water, and contribute to downstream pollution by adding soil sediment and chemicals, is the focus of this study. Furrow irrigation on moderate to severe slopes can dramatically increase soil erosion and decrease water use efficiency. One technique that has been shown to improve these factors is the application of straw mulch to the irrigation furrows. Miller and Arstand (1983) at Prosser, Washington, showed that the application of small amounts of plant residue in irrigation furrows reduced erosion and lowered the turbidity of the runoff water. Berg (1984) also showed that application of small amounts of straw into irrigation furrows could increase water infiltration and decrease soil erosion on furrow-irrigated land near Kimberly, Idaho. Straw-mulching of furrows, is gaining widespread acceptance in Malheur County, Oregon, where tests have shown its effectiveness at reducing erosion.

The objective of this study was to test the effectiveness of straw mulching to reduce erosion and increase water infiltration in central Oregon. Irrigation stream advance and soil sediment in runoff water were tested, along with the wetting front of the soil water into the bed. An experiment was designed to determine the effects of a wheat straw mulch application on soil erosion, water infiltration, water runoff rate, and yield.

Materials and Methods

The study was conducted on the Jack Ickler farm located just outside Culver, Oregon. The soil consisted of a Cullius loam with a 2.05 percent slope. The soil is shallow, 10 to 20 inches to bedrock, and is well drained. The available water capacity is about 2 inches.

A 20-acre field was bedded and planted with carrots for a seed crop. In May, wheat straw was applied to the whole field at a rate of 960 lb/a, with the exception of a small control plot that received no straw. The control plot was 24 ft wide (eight rows) and 1,200 ft long. Straw was applied with a commercially-available, straw-mulching machine that takes bales of wheat straw and applies them to furrows. The carrot crop was sprinkler irrigated until the height of the plants, about 1 foot, made this practice no longer feasible. Sprinkler irrigation was then replaced by furrow irrigation, which was used until seed harvest. Measurements of irrigation were taken during the first furrow irrigation.

Prior to the first furrow irrigation, markers were placed at 50 foot intervals to assist in measuring the water advance rate. Furrow dams were placed at the end of the furrows to measure the water outflow rate. WATERMARK soil moisture sensors (Model 200) were placed 50 feet from the head of the field in both control and mulched sections at depths of 3, 6, 9 inches, below the furrow bottom, and 3, 6, 9, and 12 inches in the beds. The WATERMARK sensors were used to determine the location of the wetting front in time of both treatments. Soil erosion was determined by collecting several water samples and correlating the results with runoff rates.

Yield of carrot seed was determined on the control plot and two mulched plots on each side of the control. No statistics were calculated because the study was unreplicated.

Results and Discussion

Irrigation stream advance

After a few minutes of irrigation, several differences between the mulched and control sections could be observed. The first obvious difference between the two sections was the rate of water advancement in the furrows (Fig. 1). Irrigation in the control plot reached the end of the field (1,300 ft) in less than 6 hours. Irrigation in the mulched plot took more than 12 hours to reach the end.

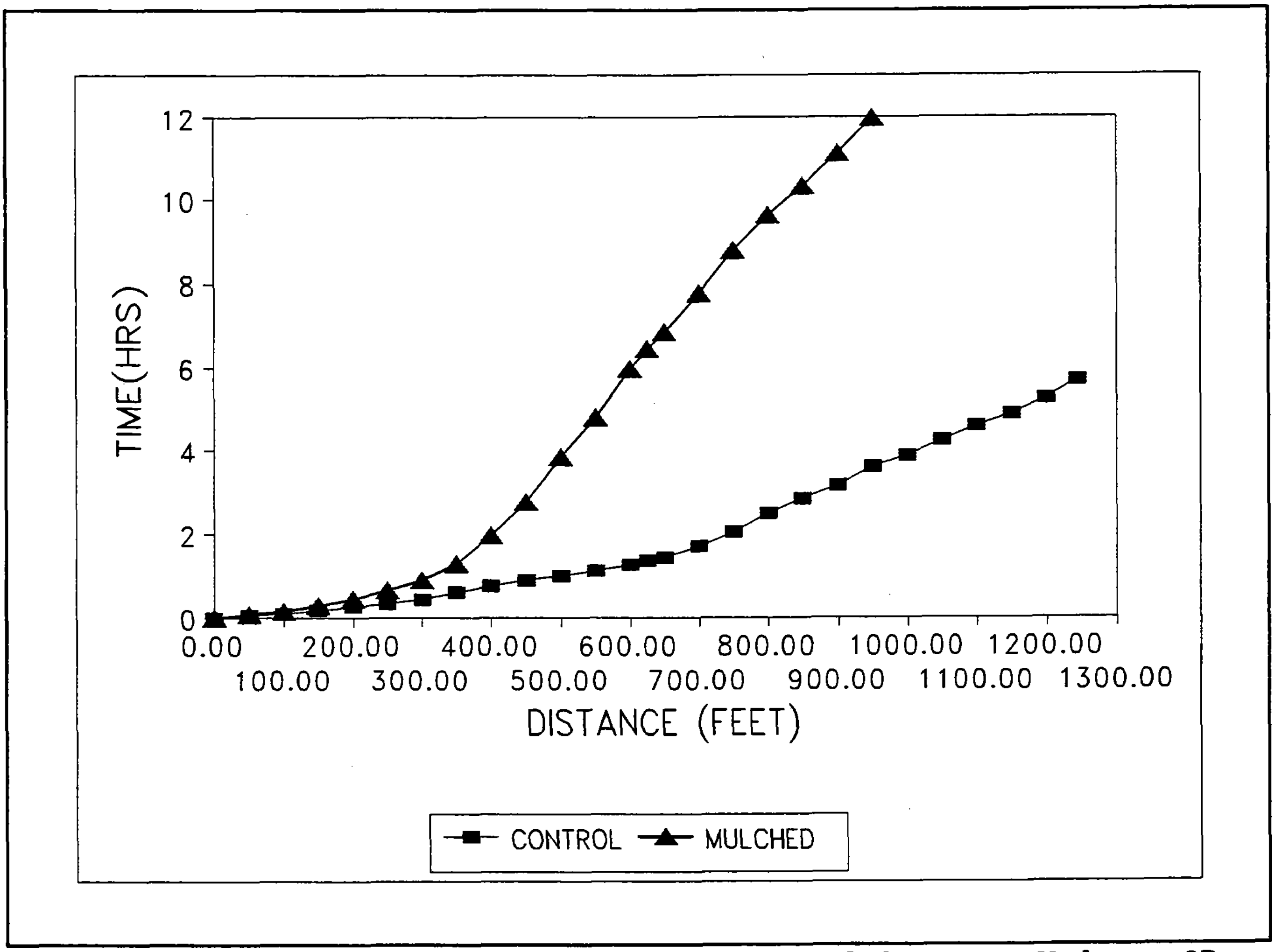

Figure 1. Water advance for control and mulched furrows, Madras, OR,

Christiansen et al. (1966) pointed out the relationship the water stream advance and the infiltration rate (all other factors being equal), and developed equations to relate the two. DeTar's (1989) modification of the Christiansen method of determining average infiltration rates, uses the stream advance function in surface-irrigated plots to obtain the infiltration function. Using the DeTar modification, the infiltration equations were

$$I=0.058T^{0.614} \tag{1}$$

and

$$I=0.026T^{0.975} \tag{2}$$

for the control and mulched sections respectively. Using these infiltration functions, one is able to obtain an average of depth infiltrated over time. The amount of water that infiltrates into the mulched treatment after 4 hours is twice the amount of the nonmulched treatment. Longer infiltration times result in greater differences in water intake between the treatments.

The intake equation (2) for the mulched furrow is approximately linear, since the exponent $0.975 \approx 1$. Theory of soil water infiltration, which is beyond the scope of this report, suggests that the intake rate may drop sharply after the soil is entirely wet. This would imply that water is not being applied in excess in the mulched treatment. Additional research should address the question of the whether excess irrigation water is, in fact, being applied to the mulched treatment.

Wetting front advance

As we have seen, the infiltration rate of the mulched furrow was greater than that of the control furrow. This information means that less irrigation time is needed for complete saturation of the furrow slice. This fact can be seen in the soil saturation data measured by the WATERMARK sensors. Complete saturation of the mulched furrow took place within 4 hours after initial irrigation, whereas the nonmulched furrow needed more than 8 hours for full saturation.

A possible reason for the rapid saturation of the 9 and 12 inch sensors is a duripan layer at the 10 to 12 inch depth that would direct water flow horizontally after it reached the pan. Water flowing laterally from the furrow stream would also tend to quickly saturate the deeper sensors. Still, with this in mind, saturation of the mulched furrow mound (MM) happened at a much faster rate than the control mound (CM). A lower saturation time was dictated by the increased infiltration rate resulting from the mulch application.

Sediment in runoff water

Water samples taken during the first irrigation showed an average sediment concentration of 10.3 g soil/L water for the non-mulched control plot, and 0.365 g soil/L for the mulched treatment, which was less than 4 percent of the control. The results were startling to the farmer, who had to clean his tail ditch only in the area where he had not mulched.

Yield

Yield statistics are shown in Table 1. The straw-mulch treatment had 3.2 percent greater yield than the control, which is not large enough to suggest that there was any yield benefit. The germination percentages were essentially equal for both treatments.

Table 1. Yield data, Ickler Farm, Culver, OR, 1991

	Straw Mulch	Control
	--lb/a--	--lb/a--
Yield uncleaned	1937	2007
Yield cleaned	585	567
Germination percentage	--%--	--%--
Large seeds	95	95
Medium seeds	98	97
Small seeds	95	95

Implications for irrigation management

If switching to a straw-mulched furrow, the irrigations will need to be managed differently than before. The greater infiltration rate of the mulched furrows means that the irrigation can be stopped soon after water reaches the end of the field, thereby reducing runoff. Due to the high intake rate, it is possible that the soil at the head end may receive excess water that could leach nitrate from the soil. If that is the case, further management improvements could combat the leaching, e.g. irrigating alternate furrows, or reducing the amount of straw in the head end of the field to speed the furrow advance in that area. Surge irrigation could also be used in conjunction with straw-mulching to reduce infiltration rate and leaching while controlling erosion. Field research could test the ability of these methods to modify infiltration under the straw-mulching system, but the irrigator will need to observe intake rates as they occur in the field and adjust his management accordingly.

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RUSSET BURBANK VINE DESICCATION WITH DIQUAT*

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Abstract

An experiment to examine the efficacy of Diquat on stem and leaf desiccation, tuber maturity, yield, grade, specific gravity, and stem end discoloration of Russet Burbank potatoes was established during 1989 at the Powell Butte site of Central Oregon Agricultural Research Center. Although the initial two pint Diquat rate was quicker acting than the one pint rate, after seven to 10 days both initial Diquat rates were equal in leaf and stem desiccation. The second application of Diquat produced no statistically significant increase in stem or leaf desiccation under the conditions prevalent in this trial. The application of Diquat hastened tuber maturity as compared with untreated plots, but tuber skinning remained unacceptably high 14 days after treatment. Tuber bulking in Diquat treated plots continued for approximately one week after application. Specific gravity of the untreated plots was significantly higher than the specific gravity of Diquat-treated plots seven, 14, and 27 days after the initial Diquat treatment. Tubers that had a higher percentage of skinning suffered a higher percentage of weight loss in storage than tubers that had less skinning. There were no significant differences in stem end discoloration among treatments.

Introduction

Killing potato vines prior to harvest is a common practice in most of the major potato producing areas in Oregon. Various top-kill methods are employed, but all serve to mature tuber skins, control tuber size, reduce potential bruise susceptibility, and reduce disease and dehydration in storage.

Diquat has been widely used by potato growers in Oregon since the U.S. Environmental Protection Agency (EPA) ban on dinoseb imposed in 1987. In fact, Diquat is the most commonly used chemical desiccant on potatoes in Oregon. Although Diquat has been available for many years, growers did not utilize it until dinoseb was banned because it was more expensive than dinoseb and growers were largely unfamiliar with it.

A number of field trials have been conducted in major potato growing areas with Diquat. Application rates, leaf and stem kill efficacy, the time of day it is applied, and the effect on

*This study was supported in part by a grant from Valent, U.S.A. Corporation.

tuber stem end discoloration have all been thoroughly researched. However, little information is available for Diquat's effect on yield, grade, specific gravity, and tuber maturity. This study was initiated to provide information in those areas.

Materials and Methods

An experiment to examine the efficacy of Diquat on stem and leaf desiccation, tuber maturity, yield, grade, specific gravity, and stem end discoloration of 'Russet Burbank' (Solanum tuberosum L.) potatoes was established during 1989 at the Powell Butte site of Central Oregon Agricultural Research Center. Five treatments were arranged in a randomized block experimental design with four replications. Individual plots were 10 rows wide (30 ft) by 50 feet in length. Rows were planted 36 inches apart and plants were spaced at 9 inches apart in the rows. The trial area was sprinkler irrigated throughout the growing season and a final irrigation was applied two days prior to the first application of Diquat. The field in which the trial was located was fertilized and managed by practices common in central Oregon.

The experimental treatments, application rates, and application dates are shown in Table 1. Treatment application rates were chosen to provide data for EPA registration and labelling. The plots were green with no natural vine senescence on September 1, 1989, when the first Diquat treatments were applied. The following summarizes the weather data and application procedures for each spray date:

	September 1, 1989	September 6, 1989
Air Temperature:	72°F	66°F
Soil Temperature-4":	51°F	49°F
Soil Moisture:	Moist	Moist
Wind:	West 3-5 mph	West 5-8 mph
Sky:	Partly cloudy	Clear
Time of Day:	10:30 am	10:45 am
Sprayer:	Tractor Mount	Tractor Mount
Nozzles:	Flat fan	Flat fan
Spray Pressure:	32 PSI	32 PSI
Spray Gallonage:	33 gal/acre	33 gal/acre

Stem and leaf desiccation were visually rated prior to the initial spray treatment and twice weekly thereafter for three weeks.

On August 31, 1989, two rows were harvested from each plot. The vines from each harvest row were eliminated with a flail mower and the tubers were lifted with a level bed digger and hand- bagged to minimize harvest injury. A similar procedure was followed for each of the four subsequent harvest dates (September 5, September 8, September 15, September 28).

Plots were graded into six size and grade categories immediately after harvest for each of the five harvest dates. A sample of 20, 6-12 ounce tubers was taken from each plot to determine specific gravity and skin set. Specific gravity was calculated using the air-water method. The 20 tubers were then air-dried and subjected to skinning in the Valent potato skinning apparatus, which simulated harvest on harvesters with a coated digger chain. Each of the 20 tubers were rated for percent skinning based on the Barrat and Horsfall surface defect rating scale. After skinning measurements were taken, the tubers were placed in poly-mesh bags and placed in storage until January 10, 1990, when all samples were removed and weighed to determine tuber weight loss (shrinkage). The storage temperature was gradually lowered from 55°F to 38°F over a period of several weeks and relative humidity was maintained at 92 percent. The tuber samples from the September 28, 1989 harvest date were also evaluated for stem end discoloration. The tubers were sliced longitudinally and scored for depth of discoloration.

Results

The effects of Diquat on the leaf and stem desiccation of Russet Burbank potatoes are shown in Tables 2 and 3. Three days after the initial Diquat application, the two treatments that initially received two pints of Diquat had significantly greater stem and leaf desiccation than the two treatments that initially received one pint of Diquat. However, after seven days and the second Diquat application, there were no differences in leaf desiccation among the Diquat treatments. Ten days after the initial Diquat treatment there were no significant differences in stem desiccation among the Diquat treatments. The stem and leaf desiccation that occurred in the untreated control was caused by light frosts on September 3 and 10, 1989 and a severe killing frost on September 18, 1989. The data suggests that there is little benefit in applying more than one pint of Diquat on the initial application. Although the initial two pint rate was quicker acting than the one pint rate, after seven to ten days both initial Diquat rates were equal in leaf and stem desiccation. The second application of Diquat produced no statistically significant increase in stem or leaf desiccation under the conditions prevalent in this trial.

Tuber maturity results are tabulated in Table 4. The application of Diquat decreased tuber skinning at seven and 14 days after the initial Diquat application as compared with the untreated control treatment. Although the application of Diquat hastened tuber maturity, tuber skinning remained unacceptably high 14 days after treatment. A similar study (Central Oregon Crop Research 1987-1988, Special Report 847, pages 119-126) conducted in 1988 at Powell Butte, OR also suggested that harvest of Russet Burbank potatoes should be delayed for 18-21 days after the initial Diquat treatment.

The effect of Diquat on the yield of Russet Burbank potatoes is summarized in Table 5. No statistically significant differences in yield were noted until the last two harvest dates. Total yields from the untreated treatment were significantly greater than the Diquat treatments when harvested 14 days after the initial Diquat treatment. A similar trend was noted for the last harvest date. U.S. number one yields observed for the untreated plots also trended higher than number one yields of Diquat treated plots at the last two harvest dates. Tuber bulking in Diquat-treated plots continued for approximately one week after application.

Specific gravity of the untreated plots was significantly higher than Diquat-treated plots seven, 14, and 27 days after the initial Diquat treatment (Table 5). When vines are killed rapidly, either by chemical desiccants, severe frosts, or mechanical means, there is less opportunity for the transfer of carbohydrates from plant tops to the tubers. As a result, the tubers are lower in dry matter.

There were no differences in tuber weight shrinkage among all treatments within each harvest date (Table 4). However, tuber shrinkage and skinning were directly related. Tubers that had a higher percentage of skinning suffered a higher percentage of weight loss in storage than tubers that had less skinning. Maturing tubers after desiccation served to minimize tuber skin defects and reduce weight loss in storage.

There were no significant differences in stem end discoloration among treatments.

Table 1. Diquat application rates and dates, Powell Butte, OR, 1989.

Treatment	Application Rate and Date September 1	September 6	Total Application Rate
Diquat	1 pt[1]	1 pt	2 pt
Diquat	1 pt	2 pt	3 pt
Diquat	2 pt		2 pt
Diquat	2 pt	1 pt	3 pt
Untreated	----	----	0 pt

1 - 1 pt=0.25 lbs a.i. of Diquat H/A

Table 2. Effect of Diquat on leaf desiccation of Russet Burbank potatoes, Powell Butte, OR, 1989.

		Leaf Desiccation--Days After First Application						
Treatment	Rate	0	3	7	10	14	17	21
					---%---			
Diquat	1 pt + 1 pt	0	48	91	96	100	100	100
Diquat	1 pt + 2 pt	0	53	94	100	100	100	100
Diquat	2 pt	0	73	95	99	100	100	100
Diquat	2 pt + 1 pt	0	69	96	100	100	100	100
Untreated		0	5	25	58	83	100	100
LSD 5%		NS	10	6	9	3	NS	NS

Table 3. Effect of Diquat on stem desiccation of Russet Burbank potatoes, Powell Butte, OR, 1989.

		Stem Desiccation--Days After First Application						
Treatment	Rate	0	3	7	10	14	17	21
					---%---			
Diquat	1 pt + 1 pt	0	13	66	91	99	100	100
Diquat	1 pt + 2 pt	0	14	70	93	100	100	100
Diquat	2 pt	0	18	79	94	100	100	100
Diquat	2 pt + 1 pt	0	19	76	95	100	100	100
Untreated		0	0	6	36	60	81	100
LSD 5%		NS	4	9	6	6	6	NS

Table 4. Tuber skinning and shrinkage of Russet Burbank potatoes at five harvest dates after vine desiccation with Diquat, Powell Butte, OR, 1989.

Harvest Date	Treatment	Rate	Tuber Skinning	Tuber Shrinkage[1]
DAT[2]			%	%
0	Diquat	1 pt + 1 pt	41	12
0	Diquat	1 pt + 2 pt	45	12
0	Diquat	2 pt	52	13
0	Diquat	2 pt + 1 pt	49	12
0	Untreated		44	12
	LSD 5%		NS	NS
4	Diquat	1 pt + 1 pt	51	11
4	Diquat	1 pt + 2 pt	42	11
4	Diquat	2 pt	49	11
4	Diquat	2 pt + 1 pt	42	11
4	Untreated		45	10
	LSD 5%		NS	NS
7	Diquat	1 pt + 1 pt	33	9
7	Diquat	1 pt + 2 pt	37	10
7	Diquat	2 pt	36	11
7	Diquat	2 pt + 1 pt	39	12
7	Untreated		42	10
	LSD 5%		NS	NS
14	Diquat	1 pt + 1 pt	16	7
14	Diquat	1 pt + 2 pt	15	7
14	Diquat	2 pt	15	7
14	Diquat	2 pt + 1 pt	14	7
14	Untreated		25	7
	LSD 5%		7	NS
27	Diquat	1 pt + 1 pt	1	4
27	Diquat	1 pt + 2 pt	1	3
27	Diquat	2 pt	1	3
27	Diquat	2 pt + 1 pt	1	3
27	Untreated		1	3
	LSD 5%		NS	NS

1 - Tuber shrinkage=(harvest weight-weight on Jan. 10, 1990)/harvest weight x 100

2 - Days after the initial Diquat treatment.

Table 5. Yield and specific gravity of Russet Burbank potatoes at five harvest dates after vine desiccation with Diquat, Powell Butte, OR, 1989.

Harvest Date	Treatment	Rate	Yield < 4 oz	Yield No. 1	Yield Total	Specific Gravity
DAT[1]			cwt/A	cwt/A	cwt/A	
0	Diquat	1 pt + 1 pt	73	325	445	1.083
0	Diquat	1 pt + 2 pt	72	321	477	1.082
0	Diquat	2 pt	69	324	435	1.083
0	Diquat	2 pt + 1 pt	71	318	445	1.083
0	Untreated		75	300	435	1.083
	LSD 5%		NS	NS	NS	NS
4	Diquat	1 pt + 1 pt	100	350	509	1.085
4	Diquat	1 pt + 2 pt	81	335	475	1.085
4	Diquat	2 pt	86	341	480	1.084
4	Diquat	2 pt + 1 pt	88	365	499	1.086
4	Untreated		87	343	492	1.087
	LSD 5%		NS	NS	NS	NS
7	Diquat	1 pt + 1 pt	94	326	475	1.084
7	Diquat	1 pt + 2 pt	73	341	480	1.083
7	Diquat	2 pt	86	306	461	1.083
7	Diquat	2 pt + 1 pt	81	326	466	1.083
7	Untreated		68	329	457	1.088
	LSD 5%		NS	NS	NS	0.003
14	Diquat	1 pt + 1 pt	92	351	503	1.082
14	Diquat	1 pt + 2 pt	77	326	484	1.083
14	Diquat	2 pt	74	312	454	1.082
14	Diquat	2 pt + 1 pt	91	322	472	1.083
14	Untreated		82	355	491	1.088
	LSD 5%		NS	NS	31	0.002
27	Diquat	1 pt + 1 pt	120	308	478	1.084
27	Diquat	1 pt + 2 pt	85	324	471	1.085
27	Diquat	2 pt	88	307	474	1.085
27	Diquat	2 pt + 1 pt	94	333	499	1.085
27	Untreated		106	347	513	1.090
	LSD 5%		18	NS	NS	0.002

1 - Days after the initial Diquat treatment.

EFFECT OF DIQUAT ON DESICCATION AND TUBER MATURITY OF TEN POTATO CULTIVARS*

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Abstract

An experiment was established at the Powell Butte site of Central Oregon Agricultural Research Center in 1991 to examine the effects of Diquat on stem and leaf desiccation and tuber maturity of 10 potato cultivars. The vines of the early maturing cultivars Norgold, Norkotah, and Frontier were completely desiccated within two weeks. The stems of cultivars Century, Shepody, Ranger, and A74212-1E were not 100 percent desiccated after 21 days. For most of the cultivars tested, harvest should be delayed for 21 days after vine kill until tuber skinning drops below 5 percent. Of the ten cultivars tested, only the cultivars Norkotah, Norchip, and Shepody were ready to harvest 14 days after topkill. For all cultivars, tuber shrinkage (water loss) was positively correlated (R^2=0.84) with percent tuber skinning. Percent vine kill was not a good indicator of tuber maturity for cultivars Russet Burbank and Shepody.

Introduction

The number of acres planted to 'Russet Burbank' (*Solanum tuberosum* L.) is declining in the Pacific Northwest. As recently as 1988, 97 percent of Idaho's potato crop was planted to Russet Burbank, but two years later this proportion was only 92 percent. During the same period Washington's Russet Burbank acreage decreased from 79 to 73 percent, and Oregon's shrank from 83 to 74 percent (Fraser's Newsletter, 1990). New cultivars such as Shepody, Frontier, Ranger Russet, Norkotah, Century Russet, and others are finding specialized niches in western potato production.

Potato growers have experienced various production problems with new cultivars, including vine desiccation. To address this emerging problem, an experiment was established at the Powell Butte site, Central Oregon Agricultural Research Center in 1991 to examine the effects of Diquat on stem and leaf desiccation, and tuber maturity of 10 potato cultivars. The effect of Diquat on the cultivar Russet Burbank has been researched extensively since the US Environmental Protection Agency's ban on dinoseb, but little information is available for other potato cultivars.

*This study was supported in part by a grant from Valent, U.S.A. Corporation.

Materials and Methods

Ten potato cultivars were chosen for the study. They included two chipping cultivars, Atlantic and Norchip; four early maturing fresh market cultivars, Norkotah, Frontier, Norgold, and Shepody; and four main season cultivars, Russet Burbank, Ranger, Century, and A74212-1E. Each of the 10 cultivars were planted in 350 foot single row plots on June 4, 1991 at Powell Butte, Oregon. The plots were managed with cultural methods commonly used in Central Oregon. A mixture of one pint of Diquat H/A plus 16 ounces per acre of X-77 surfactant and 30 gallons of water was applied to all cultivars at 10:00 am on September 9, 1991. Another identical application of the Diquat mixture was applied to all plots on September 13, 1991.

All cultivars were visually evaluated for the percentage of leaf and stem desiccation prior to the first Diquat application and every three or four days thereafter for 21 days.

A random sample of ten 8-12 ounce tubers was obtained from each plot prior to the initial Diquat application. Additional samples were obtained from each plot 7, 14, and 21 days after the first Diquat application. After each of the four harvests, tubers from each plot were washed, air dried, and subjected to skinning in the Valent skinning apparatus, which simulated harvest on harvesters a with coated digger chain. Each of the 10 tubers were rated for percent skinning based on the Barratt and Horsfall surface defect rating scale (Barratt and Horsfall, 1942). After skinning measurements were taken, the tubers were weighed and placed in 50°F storage at 70 percent humidity. Tuber samples were then weighed weekly for four weeks to determine tuber shrinkage.

Results

The effects of Diquat on leaf and stem desiccation of each cultivar are shown in Tables 1 and 2. As expected, the vines of the early maturing cultivars Norgold, Norkotah, and Frontier were completely desiccated within two weeks. The stems of cultivars Century, Shepody, Ranger, and A74212-1E were not 100 percent desiccated after 21 days. Of the chipping cultivars, the vines of Norchip were fully desiccated one week prior to the vines of Atlantic.

Percent tuber skinning decreased the longer harvest was delayed after the initial Diquat application (Table 3). The data suggests that, for most cultivars, harvest should be delayed for 21 days after vine kill until tuber skinning drops below five percent. Of the 10 cultivars tested, only the cultivars Norkotah, Norchip, and Shepody were ready to harvest 14 days after topkill.

Although 100 percent stem desiccation was not achieved with the cultivar Shepody after 21 days, tuber skinning was minimal after 14 days. Shepody tubers appeared to mature rapidly even though the vines were not fully desiccated. The percent tuber skinning for A74212-1E and Century remained unacceptably high until 21 days after harvest.

The vines of Russet Burbank were 100 percent desiccated 15 days after the first Diquat application. However, tubers did not mature at the same rate vine desiccation progressed. Percent tuber skinning remained unacceptably high until 21 days after treatment with Diquat. The data suggests that vine desiccation is not a good indicator of tuber maturity for the cultivar Russet Burbank.

For all cultivars, tuber shrinkage was positively correlated (R^2=0.84) with percent tuber skinning (Table 3). In general, over one-half of the skrinkage occurred within the first week after harvest for all harvest dates. Tuber skinning and shrinkage were markedly reduced when tubers were allowed to mature before harvest.

Summary

As new potato varieties are released, desiccation profiles need to be developed. Rates and practices effective for Russet Burbank will not necessarily produce optimum results for all cultivars. Vine rolling, nitrogen management, desiccant compounds, desiccant application rates, and other cultural factors need to be determined for each new cultivar as it is released to insure effective vine desiccation.

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Table 1. Effect of Diquat on the leaf desiccation of 10 potato cultivars, Powell Butte, OR, 1991.

Cultivar	Leaf Desiccation					
	0 DAT[1]	3 DAT	7 DAT	10 DAT	15 DAT	21 DAT
			---%---			
Norgold	10	70	100	100	100	100
Norkotah	30	80	95	100	100	100
Frontier	0	50	85	100	100	100
Shepody	0	30	70	80	100	100
Atlantic	0	40	80	90	100	100
Norchip	0	40	90	95	100	100
Russet Burbank	0	30	80	85	100	100
A74212-1E	0	40	70	85	100	100
Century	0	30	60	70	100	100
Ranger	0	30	70	80	100	100

1 - DAT=Days after the initial Diquat treatment

Table 2. Effect of Diquat on the stem desiccation of 10 potato cultivars, Powell Butte, OR, 1991.

Cultivar	Stem Desiccation					
	0 DAT[1]	3 DAT	7 DAT	10 DAT	15 DAT	21 DAT
			---%---			
Norgold	0	30	90	95	100	100
Norkotah	0	50	80	95	100	100
Frontier	0	40	70	80	100	100
Shepody	0	5	40	60	90	95
Atlantic	0	10	30	70	90	100
Norchip	0	10	50	80	100	100
Russet Burbank	0	10	40	60	100	100
A74212-1E	0	20	40	70	90	95
Century	0	5	10	50	70	70
Ranger	0	10	30	50	80	90

1 - DAT=Days after the initial Diquat treatment

Table 3. Tuber skinning and shrinkage for 10 potato cultivars at four harvest dates, Powell Butte, OR, 1991.

Cultivar	Harvest Date[1]	Tuber Skinning	Tuber Shrinkage			
			7 DAH[2]	15 DAH	21 DAH	28 DAH
		---%---	---%---			
R. Burbank	0	40	9.7	13.1	14.9	16.4
	7	45	9.1	11.4	13.6	14.5
	14	18	7.4	10.2	11.6	12.6
	21	4	3.9	5.0	5.7	6.1
Norgold	0	48	6.9	10.7	12.8	14.1
	7	22	5.8	7.7	9.5	10.2
	14	9	3.9	5.9	6.5	7.2
	21	4	3.9	5.0	5.7	6.1
Norkotah	0	45	7.7	12.3	14.2	15.7
	7	18	5.9	7.9	9.5	10.7
	14	5	3.1	4.5	5.2	5.7
	21	2	2.3	3.1	3.4	3.8
A74212-1E	0	53	8.0	11.3	13.1	14.5
	7	48	9.1	11.0	13.0	14.0
	14	26	5.3	7.8	8.9	9.6
	21	4	4.0	5.0	5.7	6.0
Century	0	63	7.2	11.0	13.1	14.3
	7	54	9.8	13.0	15.4	16.9
	14	28	4.7	7.7	9.0	9.8
	21	7	4.3	5.4	6.2	6.6
Atlantic	0	28	8.6	11.7	13.2	14.2
	7	27	7.1	9.4	10.6	11.4
	14	9	4.3	5.7	6.6	7.4
	21	5	3.0	4.0	4.4	4.9
Norchip	0	24	5.5	7.3	8.4	9.1
	7	25	6.0	7.5	8.7	9.4
	14	4	3.3	4.5	5.3	5.8
	21	1	2.0	2.8	3.2	3.4
Frontier	0	51	9.8	13.6	15.3	17.7
	7	23	6.0	7.8	9.5	10.2
	14	13	3.9	6.6	7.0	8.3
	21	3	3.0	3.7	4.7	4.9
Shepody	0	46	8.2	11.2	12.6	13.9
	7	29	4.9	6.2	7.6	8.0
	14	4	2.3	3.3	3.6	4.3
	21	0	1.0	1.7	2.0	2.1
Ranger	0	53	9.6	12.9	14.6	16.4
	7	40	10.6	13.8	17.1	18.7
	14	13	5.4	7.8	8.8	9.5
	21	3	2.9	3.9	4.5	5.0

1 - Days after the initial Diquat treatment
2 - DAH=Days after harvest

EFFECTS OF POST-HARVEST RESIDUE MANAGEMENT ON KENTUCKY BLUEGRASS SEED YIELD AND SEED QUALITY IN CENTRAL OREGON

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Abstract

A study was conducted over three years to evaluate alternatives to open-field burning of post-harvest residue on crop growth, development, and seed yield of Kentucky bluegrass (*Poa pratensis* L.). The least intensive residue treatment was baling the straw after combining and leaving a large portion of the stubble remaining. All other treatments were in addition to baling. The most intensive residue removal was standard open-field burning. Averaged over all testing sites, seed yield was the highest with open-field burning. Seed yield was intermediate when residue was removed with a vacuum-sweep plus propane treatment or with a vacuum-sweep treatment alone. Flail-only and bale-only treatments resulted in the lowest seed yields. Averaged seed yields were progressively lower for second, third, and fourth-year stands, with non-aggressive varieties out-yielding aggressive varieties. Fertile tiller numbers were least in plots receiving the bale-only or flail-only treatments, and were greatest with the open-field burn. The vacuum-sweep plus propane treatment, and the vacuum-sweep treatment alone were intermediate with respect to fertile tiller numbers. Thousand seed weight and seed germination percentages were comparable among all treatments.

Introduction

Burning of post-harvest residue in seed production of Kentucky bluegrass (*Poa pratensis* L.) in the Pacific Northwest was originally started in the early 1950s to control disease. Until recently, burning of residue was universal in this region for the many species of cool-season grasses grown for seed. In Kentucky bluegrass, seed is harvested from the same stand for several years and the stand is generally not "plowed out" until it becomes unproductive. The residue cannot be incorporated into the soil after each harvest as it can be for annual crops. If the residue is not burned *in situ* after production of each seed crop, the only known feasible alternative is mechanical removal.

In the intermountain areas of the Pacific Northwest research comparing burning with mechanical removal of residue has given variable results. Seed yields of Kentucky bluegrass using mechanical removal methods have ranged from 70 to 120 percent of yields with burning in several experiments involving different cultivars, years, location, and methods of residue removal under both dry land and irrigated conditions (Canode and Law, 1977; Young, et al., 1984). No difference in yield between burning and mechanical removal of residue was reported in two dry land experiments (Pumphrey, 1965), and one irrigated experiment (Evans et al., 1980). In the high rainfall areas of western Oregon, where diseases of grasses are more numerous and more severe, research comparing burning to mechanical removal of residue has resulted in less variable results with open-field burning out-performing any mechanical removal techniques thus far.

With the increased awareness for air quality, reduction or elimination of smoke from open-field burning of grass seed fields has become a concern. Our research was designed to: 1) determine crop growth and development of Kentucky bluegrass with reduced smoke impact management treatments; 2) demonstrate different mechanical residue management practices; and 3) compare the mechanical treatments to open-field burning for seed yield and seed quality.

Methods and Materials

Studies were initiated in central Oregon in the fall of 1989 on 14 existing commercial Kentucky bluegrass fields. Commercial grass seed fields are relatively flat. Many are furrow irrigated, and growth and production is quite uniform. All fields were row planted with spacing range from 7-14 inches. Before our study, post-harvest residue management on older stands was by open-field burning.

Varieties were classed into two groups, aggressive and non-aggressive. The aggressive varieties are highly rhizominous cultivars. When planted in rows, the rows become obscured within a year or two. Non-aggressive varieties are less rhizominous and do not spread to form a turf mat as quickly. Each of these variety types are managed somewhat differently. Three stand ages were utilized during the course of this study, second, third, and fourth-year harvest. The second year (1990-1991 crop year) of the study involved three of the original 14 sites, all non-aggressive varieties, and the third and final year involved one of the original 14 sites for an assessment of the treatments over time.

For the 1991-1992 crop year, new equipment used for the new study included a wheel rake that has stiff tines to scratch the residue, dethatch, and remove debris from around the crowns, and a Grass Vac, both developed by Rear's Manufacturing in Eugene, Oregon. The Grass Vac machine enabled us to clip and vacuum remove the stubble to a 1 inch height. With the wheel rake, the bulk of the residue is moved to a windrowed strip, which is then baled or otherwise disposed of. Other equipment utilized include a propane flamer with conventional nozzle spacing at 40 psi. Propane flaming after vacuum-sweep results in relatively little smoke.

Commercial grass seed fields normally have a large portion of the crop residue removed as baled straw, followed by open-burning of stubble, propane burning or both. Thus, the primary focus of this research was to compare this "field treatment" with several alternative methods of stubble management. Treatments included 1) field treatment; 2) bale-only (no subsequent stubble management); 3) flail chop (flailing all the stubble back on the ground); 4) rake (wheel rake); 5) vacuum-sweep (mechanical removal of stubble after baling with a Grass Vac); and 6) vacuum-sweep plus propane. The treatment plot size was 200 x 18 ft in selected areas of each field. For vacuum-sweep plus propaning, the Grass Vac was used followed by propane flaming of the plot area.

Data were collected for vegetative tiller development, fertile tiller development, seed yield, and seed quality. All other management practices such as fertilizing, irrigating, and pest control were done as the normal grower practices for the individual fields. Four randomly selected 60-square-foot areas were harvested from each plot by hand after the field was swathed. Bundles were placed in a cloth bag to prevent shattering, then air dried for threshing in a Wintersteiger plot combine. Seed was cleaned and weight of pure seed was determined.

Results and Discussion

Significant differences in seed yield resulted from the various management treatments. Seed yields are reported as lb/a of clean seed. Figure 1 shows the mean of 14 sites in the 1989-1990 crop year. Figures 2 and 3 show the mean seed yield over three crop years of one site 1989-1990 thru 1991-1992. The highest yields consistently were produced where the residue was removed completely either by mechanical means or by burning. Averaging the seed yields from all testing sites showed the field treatment had the greatest yield. Vacuum-sweep plus propane, vacuum-sweep, and bale-only treatments yielded 93, 84, and 50 percent of the field treatment, respectively. This average included 18 sites of three stand ages (second, third, and fourth), and different variety types over three crop years (1989-1990 thru 1991-1992). In the later two years a flail chop treatment was added and in the last year, the wheel rake treatment was added. Flail chop treatment was intermediate in seed yield between the vacuum-sweep and the bale-only treatments. The wheel rake was obtained late in the season and used for residue removal after the crop began to grow. Therefore, the wheel rake results will be skewed because the treatment was not applied at the appropriate time. Analysis of these data of age of stand and variety type is presented below.

<u>Age of Stand</u>: A decrease in seed yield was observed as the stand aged (Figures 5 and 6). Young et al., 1984, and Canode and Law, 1976, found that after the first and second harvest yields decrease as much as 25 percent to 50 percent.

For the 1989-90 crop year, seed yield of second-year stands showed only 3 percent variation among the vacuum-sweep, vacuum-sweep plus propane, and field treatment. The bale-only treatment, however, yielded 63 percent of the field treatment. For third-year stands, the vacuum-sweep plus propane and bale-only treatments differed little in seed yield (77 percent of field treatment), and fell between seed yield with the vacuum-sweep (54 percent of field treatment), and field treatment (Figure 5).

For the 1990-1991 crop year, third-year stand seed yield for vacuum-sweep plus propane, vacuum-sweep, flail, and bale-only treatments were 122, 106, 95, and 84 percent, respectively of the field treatment in the same crop year. Seed yield from fourth-year stands for flail-chop and vacuum-sweep plus propane treatments were both 89 percent of field treatment seed yield. Yield for the vacuum-sweep and the bale-only treatments was 77 percent and 52 percent of field treatment, respectively (Figure 6).

For 1991-1992 crop year, one site (cv. 'Kelly') of the original 14 sites, was harvested to observe residue management treatments over three years. Seed yield in 1992 for vacuum-sweep plus propane, vacuum-sweep, and bale-only were 69, 64, and 57 percent, respectively, of field treatment. Averaged over three years of continuous treatments, vacuum-sweep and vacuum-sweep plus propane were 91 and 90 percent of field treatment. Bale-only averaged over three years is 70 percent of the field treatment (Figure 3).

Variety type: Differences in seed yield by variety type were observed in our study and are a well-known aspect of Kentucky bluegrass seed production (Canode and Law, 1977). The aggressive varieties showed a significant need for a more complete residue removal in the early years of the stand. In the 1990 harvest we measured an average of 52 percent decrease in yield from the more aggressive varieties compared to the non-aggressive types. In 1990, both aggressive and non-aggressive varieties performed similarly with respect to residue management. In descending order of seed yield, open-field burning yielded the best, followed by vacuum-sweep plus propane, vacuum-sweep, and then bale-only (Figure 4).

Tiller development: The general trend of fertile tiller numbers was the same as the trend for seed yield. Fall and spring vegetative tiller development showed no differences among treatments with the exception that plants in the bale-only treatment had fewer tillers.

Seed quality: Seed quality was determined by observing germination percentage and by measuring 1,000 seed weight. Seed quality was not affected by different residue management treatments (data not shown).

Conclusion

Our results support general grower experiences with respect to open-field burning vs. bale-only treatment. Field burning encourages higher fertile tiller numbers and yield. This increase was true for the older stands, but was even more pronounced on younger stands. In general, mechanical removal performed much better in our studies compared to bale-only treatment. However, compared to open-field burning, removal of residue with vacuum-sweep, or vacuum-sweep followed by propane flaming were not quite as reliable. In general, our data requires economical analysis for final evaluation. It is likely that mechanical means of straw removal will elevate the cost of production over the cost of open-field burning, both by requiring additional equipment purchase and usage, and by depressing yield. For non-aggressive varieties, these mechanical means of residue removal may prove adequate. The rake treatment showed good promise in the first year of use as a cheaper more efficient mechanical stubble removal technique.

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Figure 1. 1990 Kentucky Bluegrass Seed Yield Summary (avg. of 14 sites), Madras

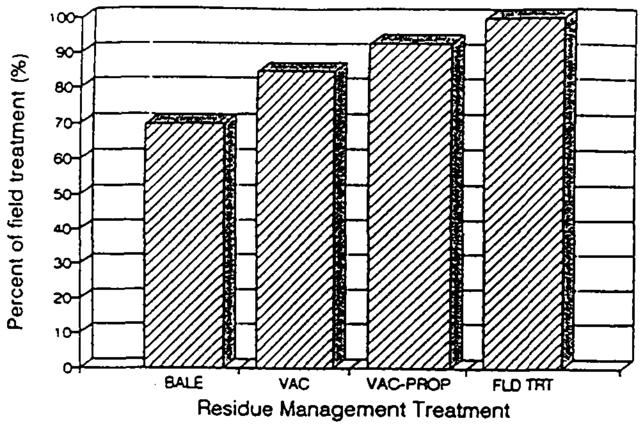


Figure 2. Kelly Kentucky Bluegrass-H&T Farms 3-Year (1990-1992) Average Seed Yields

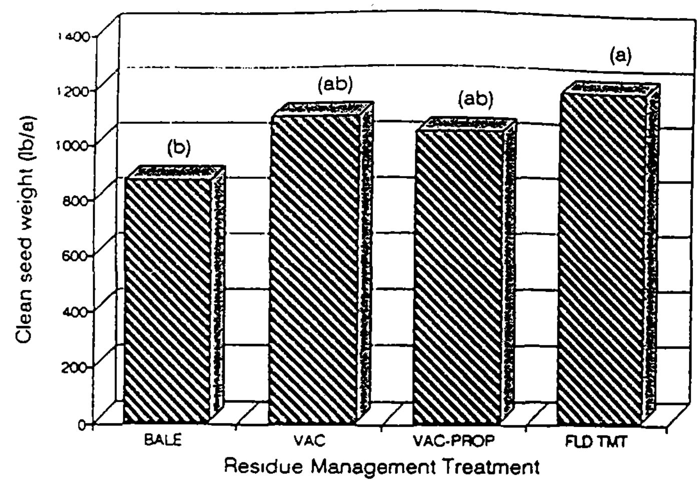


Figure 3. Kelly Kentucky Bluegrass- H&T Farms 1990, 1991 & 1992 Seed Yields

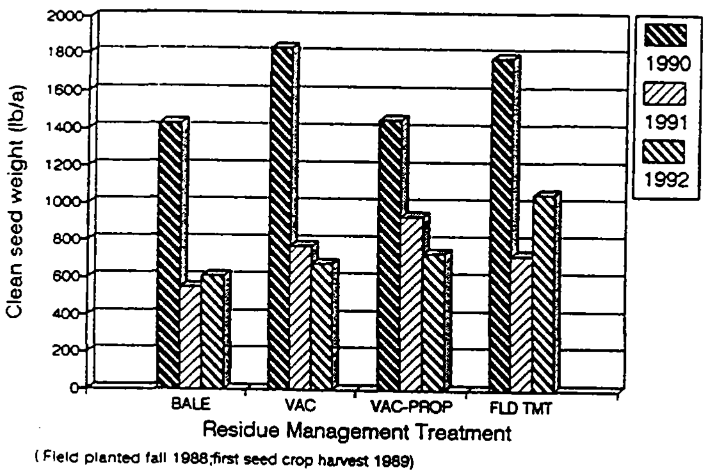


Figure 4. Influence of Variety Type on Kentucky Bluegrass Seed Yields, 1990 Harvest

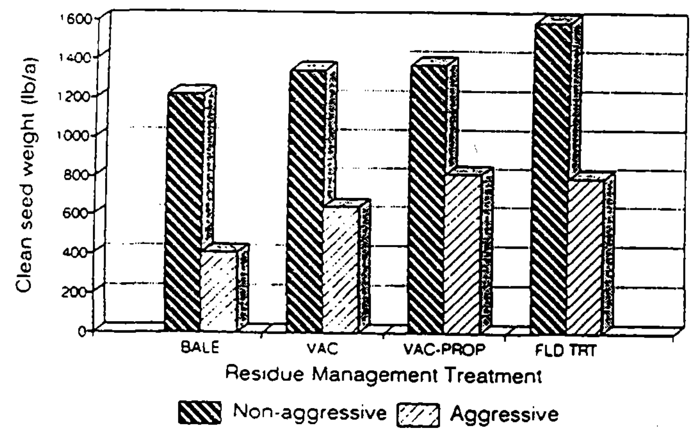


Figure 5. Influence of Stand Age on Kentucky Bluegrass Seed Yields, 1990 Harvest

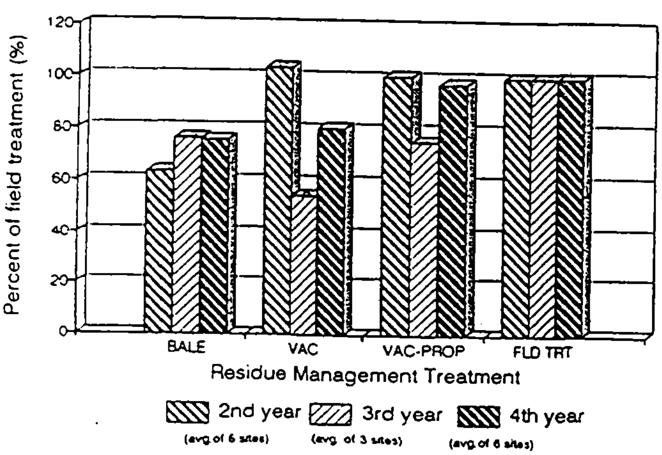
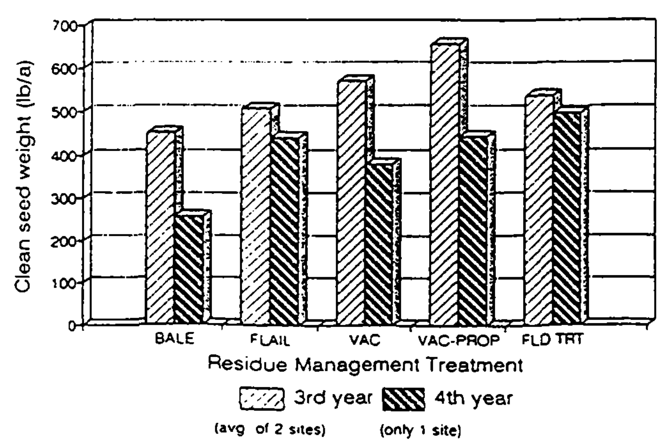


Figure 6. Influence of Stand Age on Kentucky Bluegrass Seed Yields, 1991 Harvest



DISTRIBUTION OF ERGOT *(Claviceps purpurea)* AMONG KENTUCKY BLUEGRASS GROWN FOR SEED.*

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Abstract

Ergot *(Claviceps purpurea)* is an important-flower infecting fungus that reduces seed yield in Kentucky bluegrass *(Poa pratensis* L.*)* by replacing the seed with a fungal sclerotium (ergot). Distribution, incidence, and severity of ergot on Kentucky bluegrass were evaluated in 1991 and 1992 in central and eastern Oregon. Samples (454 g) of both combine-run and clean seed were obtained from 160 fields. Ergot was detected in 23 out of 160 fields sampled in 1991, all but three of which were in the southern portion of the grass seed growing region. In eastern Oregon the disease occurred throughout the region. Ergot was found in 8 of 30 varieties surveyed. Germination for small (approximately the size of Kentucky bluegrass seed), medium, and large (four times the size of Kentucky bluegrass and larger) sclerotia was 23, 58, and 89 percent, respectfully. Ergot in weed grasses was assessed in central Oregon by sampling 127 sites selected at random in the region. Grass species and number of ergot sclerotia of each grass were determined. Weed grasses supporting ergot included brome (*Bromus spp.*), cereal rye *(Secale cereale)*, tall fescue (*Festuca arundinacea*) and Kentucky bluegrass. Infected weed grasses were also located in the southern area of the region.

Introduction

Ergot *(Claviceps purpurea)*, is an important pathogen of Kentucky bluegrass grown for seed in central Oregon. The disease can reduce yield through seed replacement by sclerotia, reduce the value of seed cleanings as feed, decrease harvest efficiency due to honeydew, and induce animal illness through alkaloids present in the ergot. In spite of frequent losses to ergot, the disease is believed to be suppressed by post-harvest open field burning (Hardison, 1980). With the increased awareness of air quality, post-harvest open field burning may be decreased or eliminated. Understanding the occurrence, distribution, and intensity of ergot in a period before the anticipated decrease in field burning could be helpful in comparing any subsequent changes in incidence after open field burning is curtailed, and for evaluation of future alternative control measures.

*This research was funded by the Oregon Department of Agriculture.

In a survey conducted in central Oregon in 1989 ergot was detected in 7 percent of the fields (Alderman, 1989). This survey was part of a one year study that also included the Willamette Valley. Blind seed disease and seed gall nematode were also assessed, and none were observed in central Oregon. Alderman's survey is the only reported assessment of incidence and severity of these diseases in the central Oregon area.

Incidence levels of ergot can range from little to high, depending on the year and associated climatic variability. Factors affecting yearly variations of ergot are not well understood, although rainy conditions at the time of flowering are believed to promote ascospore production and subsequent infection (Calvert and Muskett, 1945; Harper and Seaman, 1980; Johnston et al., 1964; Mantle and Shaw, 1976). The objectives of the study were to: (1) determine the distribution, incidence, and severity of ergot in central Oregon; (2) determine distribution of infected weed grasses; (3) compile currently used management practices and examine the feasibility of possible control strategies.

Methods and Materials

Ergot evaluation in fields

A list of grass seed production fields was obtained from a computer data base established by the Oregon Seed Certification Service. One hundred and sixty fields were randomly selected for the survey. Copies of aerial photographs were obtained for each field, to identify sampling locations. In 1991, 400 seed heads were collected from each field just prior to harvest. In 1992, a 454 g sample was collected from local seed companies. From these samples, sub samples were analyzed for incidence and severity of ergot.

Ergot evaluation of grass weeds

In 1991, an assessment of ergot in weed grasses was done in June at peak flowering time of Kentucky bluegrass, and in August after the harvest of bluegrass seed. Sample sites were selected at random across the entire bluegrass growing region in central Oregon. A total of 127 sites were selected. The sample area was two square meters, along roadways or field edges. Ergot was evaluated for each site and notes were taken on the type of weed grass infected and quantity of disease.

Management practices

Grower management practices including irrigation type and timing, fertilizer rate and timing, soil type, post-harvest burning and fungicides were obtained for all the sampled fields, infected and non-infected areas for cause and/or persistence of the disease. Post-harvest burning was broken down into three categories depending on the completeness of the residue removal.

Results

The 1992 data has not been completely analyzed at this point. Preliminary results obtained from 1991 survey include the following: (1) the main distribution of ergot is in the Culver-Metolius area. (2) 14.7 percent of the fields surveyed were infected with ergot. (3) 43 percent of the varieties sampled had ergot. (4) Ergot among weed grasses was found only in the Culver-Metolius area. (5) Of the weed grasses found with ergot, four species were infected brome, rye, tall fescue, and bluegrass.

In 1992, ergot was found in 48 out of 102 samples of Kentucky bluegrass from central Oregon and in 50 out of 113 samples from northeastern Oregon. Levels of ergot are variable ranging from one to greater than 250 sclerotia per 18 g sample.

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ERGOT CONTROL PROGRAM FOR KENTUCKY BLUEGRASS SEED PRODUCTION

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Abstract

Ergot, an important-flower infecting pathogen affecting grass production, is particularly damaging to Kentucky bluegrass. To determine control measures without the use of field burning, the historic method of control, three fungicides in combination with and without a surfactant were evaluated on a Chateau Kentucky bluegrass field near Madras, Oregon. One hundred panicle samples collected at harvest were evaluated for incidence of sclerotia and honeydew, as well as sample weight and weight per 1,000 seed. Due to a light ergot year, incidence of the disease was low and efficacy of the fungicides inconclusive. There were statistical differences between treatments for seed weight per sample, with the surfactant Penaturf appearing to reduce sample weight, while the fungicides had no significant detrimental effect on seed weight.

Introduction

Ergot, caused by the fungus *Claviceps purpurea*, is an important flower-infecting pathogen in grass seed production regions of the Pacific Northwest. The pathogen produces an elongated, black sclerotia that replaces seeds in infected florets and causes a reduction in yield. These sclerotia are the primary means of survival and source of inoculum. In the spring, during flowering, spores from the sclerotia infect the grass flower and produce secondary spores, which causes exudate (honeydew) and makes harvest difficult. These secondary spores can be spread by water, wind, and insects prior to sclerotia formation.

Of the grass species grown for seed in Oregon, Kentucky bluegrass is particularly affected by ergot. Unpublished surveys conducted in central Oregon, where Kentucky bluegrass is the dominant variety being grown, indicate strong regional variation with high levels in the Culver and Metolius areas contrasted to low incidence on the Agency Plains.

Because there are no fungicides registered for ergot, the only method of controlling the disease has been through open field burning. This practice has partially suppressed the disease in the past, as indicated by research conducted by John Hardison, plant pathologist at Oregon State University. Pressure to decrease burning may leave grass seed producers with no effective tools.

Materials and Methods

A Chateau Kentucky bluegrass field in the Trail Crossing area of central Oregon with a history of ergot was chosen for the study. Three fungicides, flusilazole (Punch, Dupont), tebuconazole (Folicur, Mobay) and propiconazole (Tilt, Ciba Geigy), in combination with and without Penaturf surfactant were applied to 10 ft x 20 ft plots replicated four times in a randomized complete block design. Materials were applied with a CO_2 pressurized boom sprayer. Silwet-77 surfactant at 16 oz/100 gallons was applied in combination with all fungicides except the first 7 oz ai/a Punch treatment. The first treatments were applied May 21, 1992 at the initiation of anthesis. On May 25 the 150 ft x 80 ft trial area was covered with 4 mil black plastic to prevent contamination of the plots from an aerial application of Tilt and dimethoate to the field. The second treatment applications were made on June 2.

The plots and the field, as well as all grass growing regions of central Oregon, experienced low levels of ergot during the 1992 season. The warm, dry weather throughout the spring and early summer was likely a contributing factor. Unfortunately, areas of heat damage on the upper portion of panicles resulted from the plastic cover placed over the plots. This occurred despite the fact that the plastic was removed by mid-morning on a cool, overcast day.

One hundred panicle samples were collected from each plot on June 24. The 100 panicle samples were analyzed for the incidence of sclerotia and honeydew. Seed separation was conducted at the seed conditioning lab at the USDA-ARS National Forage Seed Production Research Center in Corvallis. Standard separation procedures were followed and weight was determined per sample (grams) and 1,000 seed count (milligrams).

Results and Discussion

Results are provided in Table 1. When evaluating sclerotia per plot there were no statistically significant differences ($P \leq 0.10$), although the trend was for the untreated plot to have the highest number of sclerotia and the double applications of all three fungicides to have the fewest. Evaluation of the incidence of honeydew provided no statistically significant differences ($P \leq 0.10$) nor any consistent trends.

For seed weight per 100 panicles, there were statistically significant differences ($P \leq 0.05$) between treatments. A single application of 7 oz ai/a of Punch without Silwet-77 provided the greatest weight, and the double application of Penaturf had the lowest weight. Although weights per 1,000 seed count were not statistically different ($P \leq 0.10$), the double application of Penaturf again produced the lightest seed weight, and Penaturf in combination with the three fungicides produced consistently low weights. Fungicide applications alone did not appear to have a significant detrimental effect on seed weight.

With the light incidence of ergot in central Oregon during the 1992 season, and damage to some plots from the plastic cover, it is difficult to draw conclusions from this first year of data. However, some of the trends may provide clues as to what future research may reveal a year with greater ergot incidence.

Table 1. Evaluation of fungicide treatments for ergot control on Kentucky bluegrass in central Oregon, 1992.

Fungicide Treatments	Rate May 21	Rate June 2		Sclerotia per plot	Incidence of honeydew	Weight per sample	1000 seed weight
	---ai/a---			---no. per 100 panicles---		---g---	---mg---
Punch 25EC	7*			1.25	1.75	2.40 a[1]	334
Punch 25EC	14			0.75	1.25	1.62 abc	346
Punch 25EC	7			0.25	1.25	1.30 bc	368
Punch 25EC, Punch 25EC	7	7	0.00	0.25	1.46 bc	354	
Punch 25EC, Penaturf	7	78	1.00	2.25	0.91 bc	334	
Folicur 3.6F	3.6			1.75	2.00	1.57 abc	369
Folicur 3.6F, Folicur 3.6F	1.8	1.8	1.00	0.75	1.33 bc	347	
Folicur 3.6F, Folicur 3.6F	3.6	3.6	0.25	1.00	1.04 bc	369	
Folicur 3.6F, Penaturf	3.6	87	1.00	0.75	1.35 bc	342	
Tilt 3.6E	3.3			1.25	5.25	1.26 bc	350
Tilt 3.6E, Tilt 3.6E	1.7	1.7	1.75	6.50	1.24 bc	357	
Tilt 3.6E, Tilt 3.6E	3.3	3.3	0.25	0.75	1.79 ab	346	
Tilt 3.6E, Penaturf	3.6	87	0.75	0.25	1.43 bc	338	
Penaturf, Penaturf	87	87	0.50	1.75	0.69 c	322	
Untreated				3.25	2.50	1.82 ab	343

[1]Means in columns followed by the same letter are not statistically different by Duncan's Multiple Range test at $P \leq 0.05$

*Fungicide treatment without Silwett-77 surfactant

THE EFFECTS OF PRE-VERNALIZATION N-FORM ON WINTER WHEAT

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Abstract

The form of nitrogen fertilization (N-source) can affect early development and subsequent flowering and yield in spring wheat, although the response is cultivar-dependent. The effects of N-form on growth and development of winter wheat is less understood. Previous work with spring wheat indicated that N-source supplied during early development contributed markedly to effects on growth and yield. The purpose of this study was to determine the effects of pre-vernalization N-form on the growth and development of winter wheats, a club wheat, and a triticale. These field studies complemented growth chamber/greenhouse studies conducted with the same cultivars in Corvallis. Field results for the first year of the study (1991-1992 growing season) suggested that the yield of the club wheat Hyak may have been enhanced by ammonium nitrogen while the remainder of plants were relatively unaffected by N-form. Seed weight and grain protein content were relatively insensitive to pre-vernalization N-nutrition. Because of the variability in these studies, the trials are being conducted a second year at the COARC.

Introduction

Previous studies in corn, barley, and spring wheat have indicated that nitrogen nutrition during early plant development can have marked effects on subsequent growth and yield of the plants. In particular, mixed nitrogen nutrition (use of both nitrate and ammonium) has increased yields in each of these crops. There is less information available regarding the effect of N-source on vernalization-requiring crops. The purpose of this study, and a parallel growth chamber study, was to determine whether pre-vernalization N-source would affect subsequent yield of four wheats or a triticale. Plants received nitrogen fertilizers that contained either nitrate, ammonium, or both forms after emergence, but prior to vernalization. Yield and soil data were taken during the subsequent harvest season.

Materials and Methods

Seeds were planted at a density of 3,000 seeds per 100 ft^2 (5x20 ft) plot on 18 Oct. 1991. Sixteen plots of each variety were planted and the plots were distributed randomly. Field irrigation began within one day after planting. On 21 Nov. 1991, fertilizers were applied by hand to the plots. Four plots of each variety, determined randomly, received either urea, $Ca(NO_3)_2$, $(NH_4)_2SO_4$, or NH_4NO_3. Based upon the results of soil tests take at a 4-8 inch depth and performed by Oregon State University Soils Lab, sufficient fertilizer was added to provide the equivalent of 200 lbs of N per acre for each plot.

Soil samples were collected from each plot on 3 June 1992 for nitrogen and pH determinations, and the plots harvested in July, 1992. Yield per 100 ft^2 plot, weight per 1,000 seeds, and grain protein percentage were determined. Standard wet lab techniques were used for protein determination.

Results and Discussion

By June 1992, soil nitrogen levels were very low and soil pH values ranged from 6.98 - 7.50 (data not shown). Little differences in yield, weight per 1,000 seeds, or grain protein were noted between treatments of the triticale (Celia) or the wheats, with the exception of the club wheat, Hyak (Table 1). Yields in the ammonium sulfate plots appeared to be higher compared to the other nitrogen treatments.

There was considerable variability in the yield data and no conclusion can be based upon a single year's results. These field data are similar to that collected in growth chamber studies, which also indicated little difference in the response of these varieties to pre-vernalization N-form. Field plots have been planted to collect second year information on the effects of N-form on yield of these five varieties.

Table 1. The effect of pre-vernalization N-source on four winter wheats and a triticale, Madras, OR, 1992.

Cultivar	N-Source	Yield	Wt/1000 seeds	Protein
		--kg/ha--	--g--	--%--
Hyak	urea	4814 +/- 117[a]	34.99 +/- 1.17	11.53 +/- 0.99
Hyak	$Ca(NO_3)_2$	4518 +/- 260	35.58 +/- 1.47	11.07 +/- 1.66
Hyak	$(NH_4)_2SO_4$	5475 +/- 42	36.96 +/- 0.49	11.92 +/- 0.28
Hyak	NH_4NO_3	4815 +/- 231	34.18 +/- 0.97	10.77 +/- 1.37
Celia	urea	5937 +/- 188	39.25 +/- 1.58	9.91 +/- 0.41
Celia	$Ca(NO_3)_2$	5945 +/- 146	41.22 +/- 2.82	10.49 +/- 0.19
Celia	$(NH_4)_2SO_4$	6000 +/- 306	37.28 +/- 2.07	9.89 +/- 1.87
Celia	NH_4NO_3	5403 +/- 115	39.05 +/- 0.74	10.15 +/- 0.92
Malcolm	urea	5883 +/- 362	45.97 +/- 0.86	11.32 +/- 1.01
Malcolm	$CaNO_3)_2$	5103 +/- 85	44.54 +/- 5.13	11.40 +/- 0.68
Malcolm	$(NH_4)_2SO_4$	5822 +/- 261	44.25 +/- 1.71	10.04 +/- 1.43
Malcolm	NH_4NO_3	5419 +/- 329	44.21 +/- 1.52	9.91 +/- 1.04
Stephens	urea	5849 +/- 155	50.16 +/- 1.13	11.57 +/- 0.37
Stephens	$Ca(NO_3)_2$	6285 +/- 170	48.17 +/- 1.96	12.30 +/- 1.23
Stephens	$(NH_4)_2SO_4$	6429+/- 77	46.58 +/- 3.77	11.60 +/- 0.53
Stephens	NH_4NO_3	5717 +/- 296	49.23 +/- 1.13	11.08 +/- 1.00
Yamhill	urea	5331 +/- 124	41.65 +/- 2.27	11.07 +/- 0.57
Yamhill	$Ca(NO_3)_2$	4849 +/- 20	42.52 +/- 1.27	11.52 +/- 0.17
Yamhill	$(NH_4)_2SO_4$	4548 +/- 169	40.71 +/- 4.01	11.05 +/- 0.79
Yamhill	NH_4NO_3	5073 +/- 166	41.22 +/- 3.01	11.78 +/- 0.99

[a] Values are presented as means +/- one standard error.

IMPACT OF POLLINATORS ON CORIANDER SEED PRODUCTION

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Abstract

To determine the effect of pollinators on coriander seed production, ten heads were bagged prior to blossom with 1 mm nylon netting in each of two fields near Madras, Oregon. At harvest, plants with bagged umbels were removed from the field, and seed set and percent germination were determined for bagged umbels and paired, non-bagged umbels. There was strong statistical difference ($P \leq 0.01$) in seed set, but no difference in percent germination.

Introduction

Coriander (*Coriandrum sativum* L.) has been grown for seed production in central Oregon since 1984. The foliage is used as a fresh herb (cilantro) and the seed as a spice (coriander). Coriander, a member of the Umbelliferae family, is partially self-fertile and produces umbels with mostly bisexual flowers early in the season followed by male flowers. Pollen release precedes stigma receptivity so pollen from a different flower is required for seed set. Research in Russia during the 1950's indicated that exclusion of pollinators results in a reduction from a 68 percent seed set to 49 percent.

Coriander blossoms are highly attractive to both pollen and nectar-collecting insects, including honey bees. Coriander strongly attracts native pollinators, as well as honey bees, which are brought into central Oregon to service a variety of seed crops including carrot, onion, radish, and dill. As a result, some coriander growers place two hives per acre around the crop to pacify neighboring growers whose bees are attracted away from other seed crops. Coriander yields in central Oregon have been near 2,000 pounds per acre until recent years when yields have dropped to near 1,500 pounds, according to a seed industry representative.

Materials and Methods

This study was conducted during the 1992 season to evaluate the effect of pollinators on seed yield of coriander. To exclude pollinators, ten heads were bagged prior to blossom with 1 mm nylon netting in each of two fields near Madras, Oregon. At harvest, plants with bagged umbels were removed from the field and seed set was determined for the bagged umbels and paired, non-bagged umbels on neighboring stems. Germination tests were conducted to determine percent germination.

Results and Discussion

There was strong statistical difference ($P \leq 0.01$) in seed set between bagged and non-bagged umbels. Seed set was reduced by an average of 76 percent for bagged umbels compared to non-bagged umbels. The percent germination for bagged and non-bagged umbels was non-significant, although the trend was for a slightly lower germination for bagged umbels. This research supports the importance of pollinators for seed set on coriander, but their effect on percent germination appears inconclusive.

Table 1. Comparison of seed set and percent germination for pollinated and non-pollinated heads of coriander, from two locations near, Madras, 1992.

Treatment	Seed Set/Umbel	Germination
Bagged heads	3.4	48
Non-bagged	13.2	55

Differences in seed set are significant at $P \leq 0.01$.
Differences in percent germination are non-significant.

POST IRRIGATION LYGUS CONTROL IN CARROT SEED

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Abstract

Lygus control is a major concern to carrot seed growers in central Oregon. A long-residual material is needed to protect the crop from the time of final irrigation to harvest. Orthene was evaluated in large unreplicated plots against Capture and Lorsban at two locations applied by ground, and against Lorsban at one location applied by air. The results indicate that Orthene's efficacy and residual is superior to the other materials. Lorsban was the least effective insecticide.

Introduction

Carrot seed is an important, high-value crop to many central Oregon growers. Lygus is a major insect pest of carrot seed, and lack of control can reduce yield and germination. After the last irrigation is made and bees are removed from the fields, an insecticide is required to provide control of lygus until harvest. Because lygus resistance to pyrethroid insecticides is a concern in the carrot seed industry, an insecticide of alternate chemistry is necessary for lygus control.

Materials and Methods

The objective of this study was to compare the efficacy of Orthene to other registered materials for lygus control in carrot seed crops in central Oregon. This was done in preparation for request of a 24°C label for Orthene on carrot seed for lygus control after bees are removed.

Orthene, Capture (a synthetic pyrethroid), and Lorsban (currently labelled in Washington state on carrot seed) were applied to large, unreplicated plots at two locations. Application to the 40 ft by 900 ft plots at the Harris location on August 15, 1992, and the 40 ft by 1,200 ft plots at the Zistel locations on August 20, 1992, were made by ground by Dan Springer. At the Jasa location, aerial application of Orthene and Lorsban was made on August 20, 1992, to the 12 and 24 acre plots by Jim Demers. A 2x rate of Orthene was applied at the Harris location to evaluate phytotoxicity to the crop.

Lygus control was evaluated with a pretreatment and four weekly post-application sweepnet samples. Six samples were taken per plot for each sampling date. Each sample consisted of 10, 8 ft x 1 row straightline sweeps. Numbers of both lygus adults and nymphs were recorded.

Results and Discussion

Post treatment lygus numbers indicate that Orthene provides excellent initial and sustained control of lygus. Lorsban appears to be the least effective of the three insecticides.

Table 1. Counts of lygus nymphs, adults and totals from pre- and post-application sweeps in carrot seed at the Harris location, with materials applied, August 15, 1992. [1]

Date of Sample	Day	Orthene 75S 1⅓# Nymph	Adult	Total	Capture 2EC 6.4oz Nymph	Adult	Total	Lorsban 4E 1qt Nymph	Adult	Total
Aug 14	Pre	287	91	378	228	72	300	209	95	304
Aug 17	2	1	2	3	5	0	5	21	18	39
Aug 21	6	1	1	2	16	2	18	22	32	54
Aug 28	13	0	2	2	26	2	28	38	58	96
Sept 4 20	0	4	4	30	44	74	106	34	140	

[1]Total lygus per treatment.

Table 2. Counts of lygus nymphs, adults and totals from pre- and post-application sweeps in carrot seed at the Zistel location, with materials applied, August 15, 1992.[1]

Date of Sample	Day	Orthene 75S 1⅓# Nymph	Adult	Total	Capture 2EC 6.4oz Nymph	Adult	Total	Lorsban 4E 1qt Nymph	Adult	Total
Aug 18	Pre	87	34	121	85	31	116	123	38	161
Aug 21	1	3	1	4	0	0	0	2	0	2
Aug 28	8	0	0	0	2	0	2	2	4	6
Sept 4 15	0	0	0	2	0	2	6	2	8	
Sep 11	22	4	0	4	0	0	0	5	3	8

[1]Total lygus per treatment.

Table 3. Counts of lygus nymphs, adults and totals from pre- and post-application sweeps in carrot seed at the Jasa location, with materials applied, August 20, 1992.[1]

Date of Sample	Day	Orthene 75S 1⅓# Nymph	Adult	Total	Lorsban 4E 1qt Nymph	Adult	Total
Aug 18	Pre	101	29	130	76	21	97
Aug 21	1	8	0	8	5	0	5
Aug 28	8	2	0	2	6	8	14
Sept 4 15	0	1	1	20	10	30	
Sep 11	22	1	2	3	29	20	49

[1]Total lygus per treatment.

WIREWORM ON NEW MINT IN CENTRAL OREGON

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Abstract

Experimental plantings of peppermint were injured by wireworm in 1990. The occurrence of this unusual mint pest was attributed to the previous years of non-irrigation, a condition favorable to the wireworm. Methods of control are suggested.

Introduction

Great Basin wireworm (*Ctenicera pruinina*) can be a problem on new plantings of peppermint in semi-arid regions. Newly irrigated land, or land that has been left fallow for some years, is susceptible. Mint growers in arid regions of the Northwest should be aware of the potential problems if they are considering planting peppermint in land that has been left fallow due to the drought, or (looking ahead) planting in land that has been in the USDA set-aside program.

The wireworm larvae are 1/4 to 1/2 inch long and dark yellow or brown. Adults are slender, tan to nearly black, and from 1/4 to 1/2 inch long. Damage is caused by the larvae that feed in the soil for up to three years before pupating. Wireworms emerge from the soil in early May to June. They feed on the peppermint rhizomes and stems near the soil surface, which can effectively cut off the upper plant from the rhizomes.

Methods

Five acres of peppermint (cvs. 'Murray Mitchum' and 'Black Mitchum') were planted at the Central Oregon Agricultural Research Center's new farm on Dogwood Lane near Madras, OR in March 1990. The farm had previously been in dryland wheat production for several decades. Wireworms were found feeding on the new mint rhizomes in June, 1990, when the plants were 2 to 5 inches tall. The plants showed symptoms of leaf curling, followed by desiccation and chlorosis. The pest damage considerably thinned the plant stand. Although the stand did survive, a full stand was not achieved on the Murray peppermint and the yield was greatly affected. Because the two varieties were planted side-by-side, it was interesting to observe their responses to the pest. The Black Mitchum appeared to be unaffected by the wireworm, although a few injured plants were found under closer observation. Evidently, the higher vigor of the Black Mitchum allowed it to keep ahead of the wireworm's detrimental effects. It achieved full canopy in early August.

Results

Wireworm can be controlled by fumigation prior to planting. Telone II and Telone C-17 (Dow) are registered for preplant mint fumigation, although the cost may not be economical. Lorsban (Dow) is registered for cutworm control on mint, and may be used for control of wireworm in the spring, either as granular powder, spray, or through the irrigation system. Other compounds are registered for wireworm control on other crops, such as potatoes, where wireworms may be a problem. Growers should consult the Pacific Northwest Insect Control Handbook. The Great Basin wireworm will eventually decline in population since the moth does not like the wet soil conditions under irrigation. This is a key to it's control. When bringing land into production after several years of fallow, it may be best to grow other crops before peppermint.

Other crops (potato, bluegrass, etc.) are also susceptible to wireworm damage, thus control measures have become a standard practice at the Central Oregon Agricultural Research Center. Pesticide applied in the spring as a preventative measure to achieve control of wireworm.

LONG TERM WEED CONTROL EFFECTS ON ALFALFA PRODUCTION: THE FIRST YEAR

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ABSTRACT

A long term weed control in alfalfa trial was initiated in central Oregon at Powell Butte and Klamath Falls in the fall and spring of 1990 and 1991. Only the results from Powell Butte are discussed. There were significant differences in the first cutting yield and quality of both the spring and fall-established alfalfa comparing weed control to no weed control. Weed competition from establishment through first cutting significantly reduced the second cutting in the fall-established alfalfa. These are the first year results of a minimum six year study.

Introduction

Over 100,000 acres of alfalfa are grown in central Oregon and the Klamath Basin. Although a few growers consistently produce high yields of weed-free hay, many growers do not. Observations indicate that weed-free hay is often sold first and at premium prices, while weedy hay is the last to be purchased and brings lower prices. In years of excess production, growers may be unable to sell weedy hay at any price. Many alfalfa growers in central Oregon and the Klamath Basin do not use herbicides in the establishment year, and many do not use herbicides in subsequent years.

There is no research or economic data to indicate the effect of long term weed control on alfalfa production in central Oregon and the Klamath Basin. This study will establish a set of field plots at two locations for a minimum six year study to evaluate chemical weed control effects on the long term production of alfalfa. Only the results from Powell Butte will be discussed.

The main objective of this trial will be to determine the economic difference in value of weed control vs. no weed control at different stages in the plant stand life (including chemical weed control on plant stand) over time. The chemical rates used were intended to insure no weeds and to produce clean hay. Over the course of the trial, the difference in the value of clean hay and weedy hay will be used to determine the economics of weed control.

Materials and Methods

Alfalfa variety 'Pioneer 5364' was planted in the late summer of 1990 and the spring of 1991 at the Central Oregon Agricultural Research Center - Powell Butte site (August 28, 1990 and June 11, 1991)and at the Klamath Falls Experiment Station. The experiment was a split plot design consisting of four repititions, with fall and spring plantings as main plots (40 x 100 ft.) and the five weed management schemes (20 x 40 ft.) randomized within the main plots. The five treatments for weed management are:

1. Best herbicide treatment at establishment followed by best herbicide treatment every year thereafter.
2. Best herbicide treatment at establishment followed by no herbicide treatment thereafter.
3. No herbicide treatment at establishment followed by the best herbicide treatment every year thereafter.
4. No herbicide treatment at establishment followed by the best herbicide treatment in year three or year four as salvage treatment.
5. No herbicide treatment at establishment followed by no herbicide treatment thereafter.

For the fall-planting, Buctril (0.2 lb a.i./a), Pursuit (0.094 lb a.i./a), Poast (0.4 lb a.i./a) and crop oil (2 qt/a) were applied on October 3, 1990 for weed control (3-4 trifoliate leaf stage). For the spring planting, the same herbicides and rates were applied on July 18, 1991. Harvest consisted of two cuttings each 52.5 square feet in area for yield from each treatment. Samples were taken for moisture and quality analysis. Samples were oven dried at 149°F until there was no change in weight. The data presented is based on dry matter percentage. Two quadrants, each 2.7 square feet in area, were clipped and the number of alfalfa stems counted. The alfalfa and weeds were separated, weeds into grass and broadleaf components, and weighed separately to determine relative percentage(s). Quality data to be determined includes crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF) and relative feed value (RFV), among others.

In the fall-planting of 1990, shepardspurse was the main weed present followed by nightshades, redstem filaree, lambsquarters, redroot pigweed, groundsel, smart weed, pineappleweed, dogfennel, oats, barley, green foxtail and wild buckwheat.

In the spring-planting of 1991, redroot pigweed was the main weed present followed by lambsquarters, common mallow, redstem filaree, groundsel, field bindweed, wild buckwheat, russian thistle, prostrate knotweed, witchgrass, nightshades, buttercup, quackgrass, smartweed and purslane speedwell.

Winter dormant herbicide treatment consisting of Velpar (1 lb a.i./a) and Paraquat (0.5 lb a.i./a) was applied on January 29, 1992.

Results and Discussion

Only the results from Powell Butte 1991 harvest year are presented. Treatments 1 and 2 have been combined and called herbicide applied (H) while treatments 3, 4, and 5 have been combined and called no herbicides applied (NH) for the first years results. The results for yield, plant percentages, and quality are given in tables 1, 2, and 3.

Alfalfa, weed yield, and quality were affected by chemical weed control compared to no weed control. Weed control produced significantly less weeds (one and one half tons less) in the alfalfa hay. Crude protein was 3.2 percent higher, ADF 2.3 points lower, NDF was 2.4 points lower, and RFV was 11 points higher in the first cutting of fall-established alfalfa. The results were similar for the spring-established alfalfa with crude protein 1.4 percent higher, ADF 6.2 points lower, NDF 5.0 points lower and RFV 35 points higher.

Yield from the second cutting of the fall-established alfalfa was lower in the non-weed control plots because of the weed competition that occurred from establishment to first cutting. Quality was the same for the fall herbicide (FH) and fall no herbicide (FNH) treatments in the fall-planting.

In the third cutting for fall-planting (the second cutting for spring-established), there were no differences in yield or quality. Weed control had a positive effect on the quality of the spring herbicide (SH) treatment compared to the spring no herbicide (SNH) treatment.

Table 1. Fall (F) and spring (S) planted alfalfa yields of first, second and third cuttings for 1991 at Powell Butte.

Treatment	Alfalfa	Broadleaf Weeds	Grass Weeds	Total Weeds	Total Yield
	-------------	------------- lbs/acre	-------------	-------------	-------------
		---------First Cutting---------			
FH	3890	37	96	133	4022
FNH	2393	2620	663	3282	5675
		---------Second cutting---------			
FH	3123	3	2	4	3127
FNH	1967	127	171	298	2265
SH	417	124	1	78	495
SNH	559	1670	72	72	2521
		---------Third Cutting---------			
FH	2968	11	65	71	3044
FNH	2694	148	199	319	3014
SH	434	105	1	106	540
SNH	302	347	68	415	718
		---------Total---------			
FH	9981	51	163	208	10193
FNH	7054	2758	1033	3899	10954
SH	851	229	2	184	1035
SNH	861	2017	140	2156	3239

F = fall, S = spring, H = herbicides applied, NH = no herbicides applied

Table 2. Percentage of plant species by weight and alfalfa stems per square foot for first, second and third cuttings for 1991 at Powell Butte.

Treatment	Alfalfa (%)	Broadleaf Weeds (%)	Grass Weeds (%)	Total Weeds (%)	Alfalfa Stems (ft^2)
		----------First Cutting----------			
FH	96.6	0.9	2.7	3.5	100
FNH	41.5	47.4	11.0	58.5	54
		----------Second Cutting----------			
FH	99.9	0.1	0.1	0.1	87
FNH	84.3	6.5	9.2	15.7	67
SH	78.3	21.6	0.2	21.7	42
SNH	30.2	66.3	3.5	69.8	32
		----------Third Cutting----------			
FH	97.0	0.5	2.6	3.0	111
FNH	86.4	4.3	9.3	13.6	94
SH	76.5	23.5	0.2	23.6	67
SNH	41.3	47.8	11.0	58.8	49

F = fall, S = spring, H = herbicides applied, NH = no herbicides applied

Table 3. Quality of fall (F) and spring (S) planted alfalfa for first, second and third cuttings in 1991 at Powell Butte.

Treatment	% Protein	ADF	NDF	RFV
		----------First Cutting----------		
FH	17.0	33.3	42.3	139
FNH	13.8	35.6	44.7	128
		----------Second Cutting----------		
FH	20.8	33.9	41.4	141
FNH	20.5	33.0	40.5	145
SH	17.4	29.0	34.5	180
SNH	16.0	35.2	39.5	145
		----------Third Cutting----------		
FH	21.6	26.5	36.9	173
FNH	22.2	26.3	37.0	173
SH	21.3	23.7	32.3	204
SNH	19.2	26.3	35.2	183

F = fall, S = spring, H = herbicides applied, NH = no herbicides applied

IRRIGATED ALFALFA VARIETY TRIALS*

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Abstract

Twenty two alfalfa varieties were planted in 1987 at the Central Oregon Agricultural Research Center (COARC) - Powell Butte site. Twelve seed companies and/or originating agencies cooperated with this trial. The cultivars were evaluated for yield potential. The trial was completed in 1992. Twelve varieties yielded above the mean for the five years. 'Vernal' was the lowest yielding variety, 5.25 tons per acre less than Ultra, the top yielder.

Introduction

Alfalfa forage production represents a significant part of the agricultural production in central Oregon. Around 50,000 acres are grown annually. Alfalfa is a major cash crop produced for sale, much of it going to western Oregon dairies. Local use for cattle, sheep, horses and llamas is quite extensive as well.

Alfalfa variety trials have been conducted in central Oregon for years. The Powell Butte Site is the current testing site and will probably remain so in the near future. The elevation at Powell Butte is 3,180 feet and provides good conditions for winter hardiness information and performance of cultivars under a three-cut harvest regime. The growing season is around 80 to 90 days.

Plans are also under way to coordinate the alfalfa variety trials at all of the Oregon State University branch experiment stations in the near future. All trials will be established in the same year so better comparison of the cultivars across locations and climates can be made.

Materials and Methods

Non-coated inoculated seed of 22 alfalfa cultivars were planted in six 8 inch rows on June 29, 1987 at the COARC Powell Butte site. Eighteen pounds of seed were planted with a cone plot planter into plots 5 ft wide x 20 ft long. The trial was replicated four times in a randomized complete block design. In July of 1987, broadleaf weeds were controlled with a tank mix of Buctril and 2,4 DB when the alfalfa had 2 to 3 trifoliate leaves. Velpar (0.75 lb

*These trials were partially supported by initial and annual testing fees collected from ABI/Agri Pro, Andrew Seed Co., Asgrow Seed Co., Cargill Inc., DeKalb-Pfizer Genetics, ICI Seeds, Keller Seed, Northrup King Co., Pioneer Hi-Bred, International, Inc., Seed Tech, and W-L Research, Inc.

controlled with a tank mix of Buctril and 2,4 DB when the alfalfa had 2 to 3 trifoliate leaves. Velpar (0.75 lb a.i./a) and paraquat (0.5 lb a.i./a) were applied in the late winter of 1991.

The cultivar name and source (entering or originating agency) are shown in Table 1. No fertilizer was incorporated into the seedbed before planting. Spring soil test results were as follows: 6.3 pH, 20 ppm P, 179 ppm K, and 10.6 ppm N-NO3. Ninety to 100 lbs of sulfur were applied annually as gypsum over the course of the trial. Two lbs. of boron were applied in 1991 and 1992. One ton of lime was top-dressed in the spring of 1991.

The trial was sprinkler irrigated throughout the year as needed. The area harvested was 3.3 ft wide x 15 ft long in 1988 and 1989, and 3.5 ft x 15 ft in 1990, 1991, and 1992. At harvest a sample (approximately one pound) was taken for moisture determination and dry matter calculation. The samples were oven-dried in all years. From 1990 to 1992 the samples were dried at 149°F until there was no change in weight. The yield data are presented as oven-dry. Harvest dates are listed in the data tables.

Table 1. Variety name and source of alfalfa cultivars tested at Powell Butte from 1987 to 1992.

Variety	Source*
Arrow	ABI/Agri Pro
Apollo II	ABI/Agri Pro
Vernema	Andrew Seed Co.
Wrangler	Andrew Seed Co.
ICI 629	ICI Seeds
ICI 636	ICI Seeds
KS 101	Keller Seed
Commander	Northrup King
Fortress	Northrup King
Meteor	Northrup King
Trumpetor	Northrup King
5432	Pioneer
5331	Pioneer
Ultra	Seed Tech
Max 85	Seed Tech
W 12	WA-USDA
W 45	WA-USDA
Vernal	Andrew Seed Co.
WL 225	W-L Research
WL 320	W-L Research
120	DeKalb-Pfizer

135	DeKalb-Pfizer
Eagle	Asgrow
Endure	Cargill

* Source: entering or originating agency

Results and Discussion

The results from the 1988 crop year are published in the Central Oregon Crop Research 1987-1988 repost, OSU Agricultural Experiment Station Special Report 847, October 1987, "Alfalfa Variety Trials in Central Oregon". The yield data for 1989, 1990, 1991, and 1992 are listed in Tables 2, 3, 4, and 5.

'Vernal', the check variety, was the poorest yielding cultivar in the trial. Vernal's yield was 5.25 ton per acre less than 'Ultra', the top yielder at 33.43 t/a. Twelve varieties yielded between 31.41 (mean total yield for five years) and 33.43 t/a.

To aid in cultivar selection, the annual data have been presented in an annual yield summary (Table 6), cumulative annual yield summary (Table 7), and percent relative yield to check summary (Table 8). If longevity of stand is a concern, compare varieties in the final year of production. There are a lot of good varieties on the market.

Table 2. 1989 yield results of the alfalfa varieties in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Cut 1 & 2	3rd Cut	Total
Arrow	3.41	2.66	6.07	2.20	8.27
Apollo II	3.26	2.81	6.07	1.90	7.96
Vernema	3.36	2.62	5.98	1.92	7.90
Wrangler	2.88	2.54	5.42	2.14	7.56
Eagle	3.34	2.87	6.21	1.83	8.04
Endure	3.20	3.10	6.31	1.98	8.28
DeKalb 120	3.11	2.93	6.04	2.22	7.76
DeKalb 135	3.13	2.86	5.99	1.89	7.89
ICI 629	3.14	2.64	5.78	2.04	7.82
ICI 636	3.05	2.74	5.79	2.13	7.92
KS 101	3.36	2.65	6.01	2.01	8.03
Trumpetor	2.99	2.37	5.36	1.78	7.15
Fortress	3.07	2.82	5.89	2.31	8.20
5432	2.76	2.58	5.34	2.05	7.37
5331	3.18	2.93	6.11	2.06	8.17
Ultra	3.29	2.68	5.97	2.08	8.06
Max 85	3.32	2.67	5.99	2.10	8.09
W 12	3.28	2.92	6.20	2.14	8.35
W 45	3.12	2.55	5.67	2.16	7.83
Vernal*	2.64	2.39	5.03	2.02	7.04
WL 225	3.14	2.84	5.98	2.14	8.12
WL 320	2.81	2.57	5.38	2.05	7.42
Mean	3.12	2.69	5.85	2.05	7.87
Harvest date	6/1	7/20	---	9/12	---
PLSD .05	0.56	0.39	---	0.37	0.81
CV %	12.7	10.1	---	12.7	7.3

* Check variety

Table 3. 1990 yield results of the alfalfa varieties in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Cut 1 & 2	3rd Cut	Total
Arrow	1.83	2.38	4.21	1.69	5.90
Apollo II	1.85	2.56	4.41	1.58	5.99
Vernema	2.11	2.30	4.41	1.18	6.21
Wrangler	1.77	2.82	4.59	1.63	6.22
Eagle	2.08	2.35	4.43	1.39	5.82
Endure	1.77	2.58	4.35	1.77	6.12
DeKalb 120	2.20	2.11	4.31	1.40	5.71
DeKalb 135	1.89	2.32	4.21	1.36	5.57
ICI 629	1.90	2.54	4.44	1.62	6.06
ICI 636	2.08	2.58	5.38	1.71	6.37
KS 101	1.88	2.77	4.65	1.50	6.15
Trumpetor	2.15	2.07	4.22	1.44	5.66
Fortress	1.83	2.65	4.48	1.77	6.25
5432	1.83	2.48	4.31	1.50	5.81
5331	1.88	2.39	4.27	1.62	5.89
Ultra	2.02	2.75	4.77	1.61	6.38
Max 85	1.92	2.17	4.09	1.62	5.71
W 12	1.59	2.50	4.09	1.41	5.50
W 45	2.25	2.10	4.35	1.39	5.74
Vernal	2.11	2.15	4.26	1.30	5.56
WL 225	1.96	2.54	4.50	1.55	6.05
WL 320	1.86	2.07	3.93	1.38	5.31
Mean	1.94	2.41	4.39	1.52	5.91
Harvest date	6/13	7/27	---	9/19	---
PLSD .10	0.31	0.43	---	0.24	NS
PLSD .05	NS	NS	---	0.29	NS
PLSD .01	NS	NS	---	0.39	NS
CV %	13.5	15.2	---	13.6	9.1

Table 4. 1991 alfalfa variety trial yield results in tons per acre at Powell Butte.

	1st cut	2nd cut	Cuts 1 & 2	Cut 3	Cuts 1, 2 & 3
Arrow	2.29	1.54	3.82	1.18	5.00
Apollo II	2.33	1.54	3.87	1.15	5.02
Vernema	2.03	1.42	3.45	0.95	4.39
Wrangler	1.86	1.34	3.20	1.08	4.28
Eagle	1.97	1.40	3.37	1.06	4.42
Endure	2.43	1.62	4.05	1.24	5.28
DeKalb 120	1.89	1.35	3.24	1.03	4.27
DeKalb 135	2.17	1.52	3.69	1.17	4.86
ICI 629	2.30	1.57	3.86	1.03	4.89
ICI 636	2.36	1.73	4.09	1.19	5.28
KS 101	2.12	1.49	3.61	1.10	4.70
Trumpetor	1.96	1.23	3.19	0.81	4.00
Fortress	1.79	1.61	3.39	1.23	4.62
5432	2.16	1.77	3.93	1.03	4.96
5331	2.32	1.48	3.81	1.14	4.94
Ultra	2.23	1.70	3.93	1.07	4.99
Max 85	2.12	1.64	3.76	1.13	4.88
W 12	1.72	1.28	3.00	0.73	3.73
W 45	1.85	1.48	3.33	1.02	4.35
Vernal*	1.75	1.21	2.96	0.72	3.68
WL 225	2.44	1.55	3.99	1.19	5.18
WL 320	1.82	1.38	3.20	1.26	4.46
Mean	2.09	1.49	3.58	1.07	4.64
Harvest Date	6/26	8/5	---	9/27	---
PLSD .10	NS	0.26	NS	0.18	0.73
PLSD .05	NS	0.31	NS	0.22	0.87
PLSD .01	NS	NS	NS	0.29	1.16
CV %	20.7	14.6	16.7	14.4	13.3

* Check variety

Table 5. 1992 alfalfa variety yield results in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Total Cut 1&2	3rd Cut	Total Cuts 1-3	4th Cut	1992 Total
Arrow	1.86	1.74	3.60	1.45	5.05	0.62	5.67
Apollo II	1.86	1.73	3.59	1.49	5.08	0.66	5.74
Vernema	1.87	1.83	3.70	1.47	5.17	0.63	5.80
Wrangler	1.70	1.75	3.44	1.31	4.76	0.59	5.34
Eagle	1.73	1.77	3.50	1.50	5.00	0.68	5.67
Endure	2.10	1.92	4.02	1.45	5.47	0.65	6.12
DeKalb 120	2.19	2.08	4.26	1.54	5.80	0.67	6.47
DeKalb 135	2.03	1.98	4.01	1.52	5.53	0.87	6.40
ICI 629	2.11	2.05	4.17	1.58	5.74	0.73	6.46
ICI 636	2.02	1.93	3.95	1.42	5.37	0.49	5.86
KS 101	1.99	1.85	3.84	1.48	5.32	0.62	5.94
Trumpetor	1.82	1.76	3.57	1.44	5.01	0.61	5.61
Fortress	1.76	1.90	3.66	1.56	5.22	0.72	5.94
5432	1.90	2.02	3.92	1.46	5.38	0.64	6.02
5331	1.87	1.78	3.66	1.45	5.11	0.62	5.73
Ultra	2.07	2.05	4.12	1.44	5.56	0.61	6.16
Max 85	1.99	1.93	3.92	1.56	5.48	0.68	6.16
W 12	1.49	1.66	3.15	1.37	4.52	0.59	5.10
W 45	1.94	1.92	3.86	1.56	5.44	0.74	6.17
Vernal*	1.69	1.79	3.49	1.59	5.07	0.51	5.57
WL 325	2.09	1.88	3.97	1.47	5.44	0.68	6.12
WL 320	1.61	1.59	3.20	1.39	4.58	0.79	5.38
Mean	1.89	1.86	3.75	1.48	5.23	0.65	5.88
Harvest	6/4	7/14	N.A.	8/18	N.A.	10/15	N.A.
PLSD .10	0.32	0.25	0.51	NS	NS	0.16	NS
.05	0.38	NS	0.61	NS	NS	NS	NS
.01	NS	NS	NS	NS	NS	NS	NS
CV%	14.31	11.51	11.57	11.78	10.52	20.32	10.78

* Check variety

Table 6. 1988-1992 alfalfa annual yield summary in tons per acre at Powell Butte.

Variety	1988	1989	1990	1991	1992	Total
Arrow	6.87	8.27	5.90	5.00	5.67	31.71
Apollo II	7.01	7.96	5.99	5.02	5.74	31.72
Vernema	6.95	7.90	6.21	4.39	5.80	31.25
Wrangler	7.31	7.56	6.22	4.28	5.34	30.71
Eagle	7.31	8.04	5.82	4.42	5.67	31.41
Endure	6.92	8.28	6.12	5.28	6.12	32.70
DeKalb 120	6.80	7.76	5.71	4.27	6.47	31.01
DeKalb 135	7.23	7.89	5.57	4.86	6.40	31.95
ICI 629	6.67	7.82	6.06	4.89	6.46	31.90
ICI 636	6.89	7.92	6.37	5.28	5.86	32.32
KS 101	7.05	8.03	6.15	4.70	5.94	31.79
Trumpetor	7.48	7.15	5.66	4.00	5.61	29.90
Fortress	6.91	8.20	6.25	4.62	5.94	31.92
5432	6.94	7.37	5.81	4.96	6.02	31.10
5331	7.50	8.17	5.89	4.94	5.73	32.23
Ultra	7.84	8.06	6.38	4.99	6.16	33.43
Max 85	6.94	8.09	5.71	4.88	6.16	31.78
W 12	7.08	8.35	5.50	3.73	5.10	29.76
W 45	6.71	7.83	5.74	4.35	6.17	30.80
Vernal*	6.33	7.04	5.56	3.68	5.57	28.18
WL 325	7.40	8.12	6.05	5.18	6.12	32.87
WL 320	7.05	7.42	5.31	4.46	5.38	30.34
Mean	7.06	7.87	5.91	4.64	5.88	31.41

* Check variety

Table 7. 1988-1992 cumulative yield summary of alfalfa varieties in tons per acre at Powell Butte.

Variety	1988	1989	1990	1991	1992
Arrow	6.87	15.14	21.04	26.04	31.71
Apollo II	7.01	14.97	20.96	25.98	31.72
Vernema	6.95	14.85	21.06	25.45	30.25
Wrangler	7.31	14.87	21.09	25.37	31.71
Eagle	7.31	15.35	21.17	25.74	31.41
Endure	6.92	15.20	21.32	26.60	32.70
DeKalb 120	6.80	14.56	20.27	24.54	31.01
DeKalb 135	7.23	15.12	20.69	25.55	31.95
ICI 629	6.67	14.49	20.55	25.44	31.90
ICI 636	6.89	14.81	21.18	26.46	32.32
KS 101	7.05	15.08	21.15	25.85	31.79
Trumpetor	7.48	14.63	20.29	24.29	29.90
Fortress	6.91	15.11	21.36	26.98	31.92
5432	6.94	14.31	20.12	25.08	31.10
5331	7.50	15.67	21.56	26.50	32.23
Ultra	7.84	15.90	22.28	27.27	33.43
Max 85	6.94	15.03	20.74	25.62	31.78
W 12	7.08	15.43	20.93	24.66	29.76
W 45	6.71	14.54	20.28	24.63	30.80
Vernal*	6.33	13.37	18.93	22.61	28.18
WL 225	7.40	15.52	21.57	26.75	32.87
L 320	7.05	14.47	19.78	24.96	30.34
Mean	7.06	14.93	20.83	25.52	31.41

*check variety

Table 8. 1988-1992 percent relative yield compared to 'Vernal' at Powell Butte.

Variety	1988	1989	1990	1991	1992	5 Year Total
Arrow	109	117	106	136	102	113
Apollo II	111	113	108	136	103	113
Vernema	110	112	112	119	104	111
Wrangler	115	107	112	116	96	109
Eagle	115	114	105	120	102	111
Endure	109	118	110	143	110	116
DeKalb 120	107	110	103	116	116	110
DeKalb 135	114	112	100	132	115	113
ICI 629	105	111	109	133	116	113
ICI 636	109	113	115	143	105	115
KS 101	111	114	111	128	107	113
Trumpetor	118	102	102	109	101	106
Fortress	109	116	112	126	107	113
5432	110	105	105	135	108	110
5331	118	116	106	134	103	114
Ultra	124	114	115	136	111	119
Max 85	110	115	103	133	111	113
W 12	112	119	99	101	92	106
W 45	106	111	103	118	111	109
Vernal*	100	100	100	100	100	100
WL 325	117	115	109	141	110	117
WL 320	111	105	96	121	97	106
Mean	112	112	106	126	106	111

* Check variety

IRRIGATED SPRING OAT VARIETY TRIALS FOR GRAIN*

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Abstract

Ten spring oat varieties were evaluated under irrigated conditions at Madras and Powell Butte during the crop years 1990 and 1991. In 1990, there was no statistical yield difference for the oat varieties. In 1991, 'Ogle', 'Ajay', 'Dane' and 'Monida' ranked first, second, third and fourth respectively for yield. All the varieties lodged badly both years except for 'Minimax', which did not lodge very much in 1991, but was last in yield both years.

Introduction

Oats are used for animal feed, forage, and for human consumption. Some cultivars are better suited for specific uses. If intended for grain for human consumption, 'Otana' and 'Monida' are the cultivars of choice. If production is intended for the horse market in California, a white hulled cultivar is a must (though hull color does not directly affect feed quality). If producing general feed grain oats is the goal, any high yielding, average or better test weight cultivar will do. Hay can be made from all cultivars, but thin stemmed types are often preferred.

It has been many years since an oat variety trial had been run in central Oregon and there was no recent data for farmers to aid them in cultivar selection. Ten oat cultivars were planted at Madras in 1990 and 1991 to evaluate various agronomic characteristics.

Yield potential: Yield potential varies from cultivar to cultivar, from area to area and from one year to another. Yield potential is a genetic trait that is moderated by other factors such as disease and stress tolerance. It is important to evaluate the yield potential of a cultivar, by reviewing data from test sites with a similar environment using performances over several years. A single year's data is often misleading.

Lodging: Oats as a whole are susceptible to lodging. Lodging reduces both grain yield and grain quality. As soil fertility levels increase, stiffer strawed, more lodging resistant

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*Dr. Steve Broich of Grain Millers, Inc. in Eugene, Oregon provided quality evaluation for percent doubles, percent thins, percent groat yield and percent groat protein.

Lodging is more common under irrigated than dryland conditions.

Disease resistance: Barley yellow dwarf virus (BYDV) is the most widespread disease of oats in Oregon. Several cultivars are tolerant of BYDV. Smut can also lead to yield reductions. However, smut is generally not a problem if seed treatments are used and are applied properly. Crown rust has been observed in some lodged fields, but generally has not been of economic significance.

Maturity: Oats are generally later maturing than other grains; but, differences do exist among cultivars. If late season moisture stress is a problem in your area, choose one of the shorter season cultivars.

Materials and Methods

In 1990, 10 oat cultivars were planted on April 6 at the Madras site and Powell Butte. The varieties were replicated three times in a randomized block design. A single replication was planted at the Powell Butte site. Planting rates were based on 30 seeds per square foot (see data tables for pounds per acre) planted into 5 ft x 20 ft plots using a cone planter with 8 inch row spacing. Planting date was April 6. The plots were fertilized with 80 lbs of nitrogen and 60 lbs of sulfur per acre with a Barber metered feed fertilizer spreader. Weed control was applied in May, 1991. The plots were irrigated as needed with solid set lines. The plots were harvested on September 5 at Madras and on September 6 at Powell Butte with a Hege plot combine.

In 1991, planting date was April 23 and the soil test results at Madras were (based on a 0 to 12 in. sample): 6.8 pH, 50 ppm P, 308 ppm K, 14.0 meq/100 g Ca, 5.2 meq/100g Mg, 0.37 meq/100g Na, 25.3 ppm N-N03, and 1.7 ppm N-NH4. Because of the high residual soil N, only 60 lbs of sulfur per acre was applied to the plots. Weed control was applied in May 1991. Harvesting was done on August 23. All other methods are the same as 1990.

Results and Discussion

Table 1 and 2 gives descriptions and general information of the oat cultivars. In 1990, the spring oat trial in Madras had no significant difference in grain yield. However the test weight for that year showed 'Riel' to have the greatest test weight of 38.0 lb/bu and 'Minimax' having the least with 30.1 lb/bu (Table 3). In the 1991 spring oat trial in Madras 'Riel' again had the highest test weight of 39.3 lb/bu. However 'Riel' did not yield well at 99.7 bu/a compared to the highest yield in the trial, 'Ogle' with a grain yield of 138.2 bu/a (Table 4). The Powell Butte spring oat trial in 1990, had a large variation in yield with the least for 'Dane' of 16.0 bu/a, compared to the greatest 'Monida' with grain yield of 131.2 bu/a. This was a single replication trial, though.

Table 1. Recommended and Other Cultivars

Recommended Cultivars

AJAY: (82Ab1142) is a new release from the University of Idaho/USDA-ARS. It is a short-statured, lodging resistant line with excellent yield potential under irrigated conditions. It has light yellow seed and good test weight.

BORDER: Is a white hulled oat released by Wyoming in 1982. It's parentage is 'Otana'//CokerX848-1-1-2/'Cayuse'. It is mid-to-late season, heading about 4 days later than Cayuse and is slightly taller than Cayuse. Lodging resistance is good.

CAYUSE: Is a yellow hulled oat released by WSU in 1966. It is the most popular cultivar in the Pacific Northwest at this time. It is the progeny of a 'Craig'/'Alamo' cross made at Cornell University in 1952. It is early maturing, is short in stature and has good lodging resistance. It has fair tolerance to BYDV.

MONIDA: Is a white hulled oat released by the University of Idaho/ARS in 1985. It is progeny of an 'Otana'/'Cayuse' cross. It is mid-to-late season, similar in height to Otana and has a test weight intermediate to those of Otana and Cayuse. It has good milling characteristics. Lodging resistance is good.

OGLE: Is a yellow hulled oat released by Illinois in 1983. It has excellent tolerance to BYDV and has been raised on limited acreage in the Pacific Northwest. It is a mid-tall, early maturing cultivar. Test weight and lodging resistance are good. Ogle is the progeny of a 'Brave'/'Tyler'/'Egdolon 23' cross.

OTANA: Is a white hulled oat released by Montana in 1976. It is the progeny of a 'Clinton'/'Overland'/'Zanster' (a Dutch cultivar) cross made in Aberdeen, ID in 1961. It is tall and somewhat susceptible to lodging. Otana consistently has a better test weight than most other Pacific Northwest cultivars and is a preferred milling oat.

Other Cultivars

CALIBRE: Is a yellow hulled oat released by Ag Canada in 1983. It is very tall, but has fair lodging resistance. It is late maturing and has shown good yield potential where soil moisture is not limiting late in the growing season. Test weights are excellent.

KANOTA: Is a red oat *(Avena byzantina)* released in Kansas during the 1920's. It is grown for hay. It is similar in maturity to Cayuse. Kanota is taller than most grain cultivars and has finer stems. Grain yields are generally low. Certified seed stocks are not available as there is no known source of breeder seed.

MONTEZUMA: Is a red hay *(Avena byzantina)* released by California in 1969. It is early in maturity and short statured. Lodging resistance is good.

PARK: Is a white hulled oat released by Idaho in 1953. It is the progeny of a 'Clinton'/2/'Overland' cross. It is similar in height and maturity to Otana, but is lower yielding and has lower test weights. Park is frequently used for oat hay.

PENNUDA: Is a naked (hulless) oat released by Pennsylvania in the mid-1980's. Hulless oats are thought to be beneficial in some feed uses (swine, poultry), but yields to date are low, even if lack of hull is considered.

SWAN: Is a tan hulled oat primarily grown for hay. It was developed in Western Australia and introduced into California in 1970. It is very early in maturity and is similar in height to Cayuse.

Table 2. Agronomic characteristics for various spring oat cultivars.

Cultivar	Year releasing	Releasing state	Species[1]	Hull color[2]	Maturity[3]	Height[4]
Ajay	1991	ID	A. sativa	LY	L	S
Appaloosa	1978	WA	A. sativa	Y	M	M
Border	1982	WY	A. sativa	W	M	M
Calibre	1983	CAN	A. sativa	Y	L	T
Cayuse	1966	WA	A. sativa	Y	E	M
Kanota	1916	KN	A. byzantina	R	E	M
Minimax	1990	Private	A. sativa	T	L	VS
Monida	1985	ID	A. sativa	W	ML	M-T
Montezuma	1969	CA	A. byzantina	R	VE	M
Ogle	1983	IL	A. sativa	Y	M	M
Otana	1976	MT	A. sativa	W	M	T
Park	1953	ID	A. sativa	W	M	M-T
Swan	1970	CA	A. sativa	T	VE	S

1 Genus = Avena
2 Li = light yellow, R = red, T = tan, W = white, Y = yellow
3 VE = very early, E = early, M = mid-season, L = late
4 VS = very short, S = short, M = mid-height, T = tall, VT = very tall

Table 3. Results of 1990 spring oat cultivar trial at Madras, Oregon.

Variety	Yield	Test Weight	Height	Lodging	Seeding Rate
	bu/acre	lbs/bu	inches	%	lbs/acre
Border	120.4	33.3	43	95	101
Cayuse	110.5	33.2	43	83	92
Dane	92.0	35.6	43	63	99
Grizzly	91.9	33.3	47	92	88
Minimax	85.6	30.1	33	70	72
Monida	114.9	30.9	43	80	86
Ogle	114.7	35.6	43	57	86
Otana	106.1	35.2	49	75	71
Riel	114.3	38.0	47	65	96
Ajay	127.8	33.9	43	68	90
Mean	107.8	33.9	43	68	88
PLSD .10	NS	2.1	3.8	NS	---
PLSD .05	NS	2.5	4.6	NS	---
PLSD .01	NS	3.5	6.4	NS	---
CV %	21.1	4.4	6.3	47.1	---

Table 4. Results of 1991 spring oat cultivar trial at Madras, Oregon

Variety	Yield	Test Wt.	Ht.	Lodging	Heading Date	Doubles	Thins	Groat Yield	Protein	Seeding Rate
	bu/acre	lbs/bu	inch	%		%	%	%	%	lbs/ac
Border	114.8	38.3	46	73	7/15	1.2	11.8	69.9	15.8	95
Cayuse	112.7	38.0	46	81	7/11	1.7	8.4	71.0	15.5	89
Dane	124.0	38.5	45	37	7/1	2.5	8.9	70.2	15.4	97
Grizzly	87.9	39.0	50	53	7/16	1.1	9.4	71.0	16.0	102
Minimax	94.8	32.9	35	3	7/19	0.6	27.2	69.7	16.6	95
Monida	120.1	38.6	49	85	7/12	1.2	11.6	66.7	15.3	82
Ogle	138.2	38.7	50	60	7/5	1.0	11.3	68.4	15.8	102
Otana	100.7	39.1	53	77	7/11	0.7	9.3	71.9	16.4	85
Riel	99.7	39.3	49	80	7/10	1.4	13.7	71.9	16.0	101
Ajay	130.2	37.9	38	72	7/13	1.4	15.1	70.2	15.7	94
Mean	112.3	38.0	46	62	7/11	1.3	12.7	70.1	15.9	94
PLSD .10	25.2	2.0	3.4	20.7	one	0.7	3.2	NS	one	---
PLSD .05	30.5	2.4	4.1	25.1	rep	0.8	3.9	NS	rep	---
PLSD .01	NS	3.3	5.6	34.3	only	1.1	5.3	NS	only	---
CV%	15.8	3.7	5.2	23.5	---	36.8	17.8	5.2	---	---

Table 5. Results of 1990 Spring Oat cultivar single rep observations at Powell Butte site, COARC, Oregon.

Variety	Yield	Test Wt.	HT	Lodge	Heading Date	Doubles	Thins	Groat Yield	Protein	Seeding Rate
	bu/ac	lbs/bu	in	%		%	%	%	%	lbs/ac
Border	116.3	41.3	44	0	7/10	1.1	8.9	69.2	13.2	101
Cayuse	102.1	41.1	44	5	7/6	1.6	9.1	69.4	13.0	92
Dane*	16.0	34.2	42	0	6/28	2.2	8.1	62.9	16.1	99
Grizzly	117.6	43.6	52	0	7/9	0.9	2.1	73.8	13.9	88
Minimax	110.7	37.7	36	0	7/10	1.9	9.0	74.5	15.3	72
Monida	131.2	41.6	49	0	7/8	1.0	7.5	72.5	14.3	86
Ogle	80.4	39.0	45	0	6/30	2.8	8.8	69.4	15.7	86
Otana	98.2	40.5	53	0	7/1	1.4	8.1	73.9	15.7	71
Riel	101.8	41.6	51	0	6/31	0.4	6.6	74.8	15.1	96
Ajay	95.7	39.3	90	10	7/9	2.5	8.4	72.7	15.7	90
Mean	97.0	40.0	46	2	7/5	1.6	7.7	71.3	14.8	88

* Yield for Dane is correct

Table 6. Potential seeding rate for 30 seed/ft^2 in pounds per acre from 1991 harvested seed.

Variety	Seeding Rate lbs/acre
Border	86
Cayuse	95
Dane	99
Grizzly	96
Minimax	77
Monida	93
Ogle	85
Otana	97
Riel	82
Mean	89

IRRIGATED SPRING BARLEY VARIETY TRIALS FOR GRAIN*

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Abstract

Ten spring barley cultivars were planted in 1990 and 1991 at Madras and a single replication at Powell Butte in 1990. There were no significant differences in yield in 1990. 'Columbia' was the top yielder in 1991, significantly different than all other varieties. 'Crest' had the top test weight in 1990, followed by 'Crystal', 'Harrington' and 'Micah', which were all over 50 lb/bu. There were no differences in test weight in 1991. Twice as much lodging occurred in 1990 compared to 1991.

Introduction

Barley is grown for several different purposes as animal feed, forage, and for human consumption. Cultivar selection should be based on the market being produced for. In central Oregon it has been several years since a sring barley variety trial was conducted to aid in the producer's decision on cultivar selection. Ten barley varieties were planted in 1990 and 1991 to evaluate agronomic characteristics.

Materials and Methods

In 1990 ten barley cultivars were planted on April 6 at the Madras site and replicated three times in a randomized block design. A single replication was planted at Powell Butte on April 6, 1990. Planting was accomplished with a cone planter (6-8 inch rows) and seeding rates were 30 seeds per square foot. Plots were 5 x 20 ft long. The plots were fertilized with 80 lb N/a and 60 lb S/a with a Barber metered feed fertilizer spreader. Weed control was applied in May. The plots were irrigated as needed with solid set lines. The plots were harvested on September 5 at Madras and on September 6 at Powell Butte with a Hege plot combine.

In 1991, the planting date was April 23 at Madras. Harvest was completed on August 23. The soil test (0-12 in) results for 1991 were 6.8 pH, 50 ppm P, 308 ppm K, 14.0 meq/100g Ca, 5.2 meq/100g Mg, 0.37 meq/100g Na, 25.3 ppm N-NO3, and 1.7 ppm N-NH4. Because of the high residual soil N, only 60 lbs of sulfur was applied to the plots. All other methods were the same as 1990.

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*These trials were partially supported by the Oregon Grains Commission.

Table 1. Some characteristics of some of the barley cultivars tested.

Variety	Growth Habit	Head Type	Awn Type	Maturity	Plant Height	Market Class	State/ Company	Year
Columbia	Spring	6-row	awned	late	V. short	Feed	WPB	1979
Harrington	Spring	6-row	awned	Mid	Medium	Malt	Canada	1986
Micah	Spring	6-row	awned	Late	Medium	Feed	OR	1985
Russell	Spring	6-row	awned	Mid	Medium	Feed	ID	1985
Steptoe	Facultative	6-row	awned	Mid	Tall	Feed	WA	1973

Results and Discussion

The results are listed in tables 2, 3, 4, 5, and 6. Table six contains results from a single rep grown at Powell Butte in 1990. 'Columbia' was the top yielder over the two years as it had an average yield in 1990 and was significantly better yielding than any other variety in 1991. 'Harrington', 'Crest', 'Crystal', and ORSM8408 had test weights above 48 lb/bu both years. 'Gustoe', the shortest cultivar, had the least lodging resistance. 'Crystal' and 'Columbia' were two of the better varieties for lodging resistance over the two years.

Table 2. Combined results of the 1990 and 1991 spring barley variety trials conducted at Madras.

	Yield	Test Wt.	Height	Lodging
	bu/acre	lbs/acre	inches	%
1990	104.2	48.3	35	66
1991	101.3	49.2	36	34
Probability	NS	NS	NS	.063
Bearpaw	104.4	48.5	36	39
Harrington	105.7	50.4	35	40
Crest	94.6	50.9	35	47
ORSM8408	99.8	50.3	37	63
Crystal	91.0	50.8	39	38
Russell	97.2	47.5	38	43
Gustoe	102.0	46.7	30	88
Steptoe	106.5	47.4	40	75
Columbia	118.5	47.2	34	29
Micah	107.9	47.9	35	39

Table 3. 1990 Results of Spring Barley Variety Trial conducted at Madras.

Variety	Yield	Test Wt.	Height	Lodging
	bu/acre	lbs/acre	inches	%
Bearpaw	108.0	50.8	35	65
Harrington	100.8	50.3	37	63
Crest	88.9	49.2	31	68
ORSM8408	110.5	49.7	36	92
Crystal	88.8	49.9	39	38
Russell	104.0	47.4	36	47
Gustoe	107.2	46.0	29	92
Steptoe	114.6	48.0	40	83
Columbia	105.1	46.3	35	42
Micah	114.0	45.7	32	72
PLSD .10	NS	2.0	3.8	NS
PLSD .05	NS	2.5	4.6	NS
PLSD .01	NS	3.4	6.4	NS
CV %	11.7	3.0	7.8	47.1

Table 4. 1991 results of spring barley variety trial conducted at Madras.

Variety	Yield	Test Wt	Heading Date	Height	Lodging	Plumps	Thins
	bu/acre	lbs/bu.	M/D	inches	%	%	%
Bearpaw	100.7	46.2	7/5	36	13	89	4
Harrington	110.7	50.4	7/7	33	17	87	6
Crest	100.3	52.6	7/7	39	25	89	5
ORSM8408	89.0	50.9	7/6	38	33	84	7
Crystal	93.3	51.6	6/28	38	37	83	8
Russell	90.4	47.5	7/5	40	40	75	11
Gustoe	96.7	47.3	7/5	30	85	78	9
Steptoe	98.3	46.9	7/5	40	67	87	5
Columbia	131.8	48.1	7/6	33	16	88	4
Micah	101.8	50.1	6/28	37	7	81	8
PLSD .10	16.5	NS	one	2.9	24.3	5.0	2.0
PLSD .05	20.0	NS	rep	3.6	29.4	6.0	3.0
PLSD .01	27.4	NS	only	4.9	40.4	8.0	4.0
CV %	11.5	6.2		5.7	50.6	4.3	25.3

Table 5. 1990 results of single replication observations for spring barley cultivars at the Powell Butte site, COARC, Oregon.

Variety	Yield	Test Wt	Headin g Date	Height	Lodging	Plumps	Thins
	bu/acre	lbs/bu.	M/D	inches	%	%	%
Bearpaw	66.6	47.4	6/28	36	30	88	4
Harrington	90.3	50.8	6/28	40	0	92	4
Crest	87.7	49.8	6/27	37	10	93	3
ORSM8408	101.7	50.4	6/27	38	10	90	4
Crystal	88.8	50.2	6/27	36	0	95	2
Russell	75.6	49.1	6/22	42	0	91	3
Gustoe	106.7	47.8	6/27	30	0	97	1
Steptoe	76.5	46.5	6/22	35	0	96	2
Columbia	98.8	47.3	6/30	31	0	97	1
Micah	81.3	48.0	6/30	29	0	89	2
Mean	87.4	48.7	6/27	35	5	93	3

Table 6. 1990, 1991 and future seeding rates in pounds per acre based on 30 seeds per square foot.

Variety	1990	1991	Future*
Bearpaw	111	113	130
Harrington	125	136	127
Crest	121	127	106
ORSM8408	121	137	104
Crystal	132	140	122
Russell	113	114	125
Gustoe	120	125	127
Steptoe	131	133	126
Columbia	134	135	128
Micah	106	111	111
Mean	121	127	121

*Seeding rate calculated from 300 seed weights from the 1991 harvested grain.

IRRIGATED WINTER TRITICALE VARIETY TRIAL*

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Abstract

Twenty-eight winter triticale cultivars and experimental lines along with 'Stephens' soft white winter wheat were planted in October, 1991 at the Madras site of the Central Oregon Agricultural Research Center. 'Flora' and new release 'Celia' were the top yielding cultivars. Many of the OSU and WSU experimental lines show excellent potential for grain yield, test weight, and lodging resistance under irrigated conditions.

Introduction

Triticale is a "new" crop to many growers. Triticale is a product of modern crop breeding that is the hybrid progeny of crosses between wheat (genus *Triticum*) and rye (genus *Secale*). The goal in making wheat-rye hybrids is to combine the high yield and high seed protein content of wheat with the broad adaptability and higher lysine content of rye. Such crosses were first successfully made in the 1870's, but the resulting offspring were sterile. Fertile progeny were produced in the late 1930's, and serious research efforts began in the 1950's. Today, triticale is grown on millions of acres around the world, offering new food and animal feed resources.

Triticale has a broad genetic base and varies dramatically in plant characteristics. Some are very wheatlike, but others exhibit more of the rye parent features. Because of their unusual genetic background, triticale varieties will vary significantly in their adaptability and in grain quality.

In the past, growers saw triticale as just another type of rye that was likely to become a weed problem in fields where it was grown. At maturity, triticales will exhibit some shattering, and the resulting volunteer plants can be obvious in the following barley and wheat crops because of their greater height and/or head characteristics. However, barley and wheat also shatter, but their volunteer progeny are often hidden in subsequent crops. Newer triticale has a shatter rate similar to currently grown wheat and barley varieties,

*This trial was partially supported by a grant from the Oregon Grains Commission.

and similar cultural practices can be used to control volunteers. In general, cultural practices for triticale are identical to those for wheat.

Older triticale varieties are tall and are susceptible to lodging. Extensive breeding efforts are producing new semidwarf, lodging-resistant varieties.

Materials and Methods

Twenty-eight triticale cultivars and experimental lines (OSU and WSU) and 'Stephens' soft white wheat (check) were planted on October 17, 1991 at the COARC Madras site. Planting rate was 30 seeds per square foot (Table 3) in a randomized block design in plots 5 ft x 20 ft (six 8 inch rows) and replicated four times. The plots were fertilized with 200 lbs N and 60 lbs S on March 11, 1992. The plots were irrigated as needed.

Yield test weight, crude protein, hardness factor, protein yield, 1,000 kernel weight, flower date (one replication), height, percent lodging, percent chaff, grain N uptake, and potential future seeding rates were determined. All data are reported on a 10 percent moisture basis.

The triticales were harvested July 29, 30, and 31 with a Hege Plot Combine. Protein percentage was predicted with near infrared reflection spectrometry (NIRS) testing by the OSU Crop and Soil Science Department, and bias adjusted after calibration with micro-kjeldahl determined N.

Results and Discussion

All the agronomic data are in the Tables 1, 2, and 3.

Yield: 'Flora' and 'Celia' (new release) of the released cultivars, ranked first and second for yield, but there were eight experimental lines that yielded 7,020 to 8,252 lb/a (top yield). These cultivars and lines all outyielded 'Stephens' soft white winter wheat.

Test Weight: 'Flora' had the lowest test weight at 52.5 lb/bu, while 'Celia', 'Presto' and experimental line FT 90478,P001 had a 59.5 lb/bu test weight, the top test weight for triticale varieties. Stephens test weight was 60.3 lb/bu. Many of the cultivars and lines had excellent test weights in the 58 and 59 lb/bu range.

Crude Protein: 'Breaker' and 'Stan 1' had the highest protein at 14.5 percent and 13.9 percent. Generally, the higher yielding lines had lower percentage protein.

Hardness Factor: This number is a reflection of kernel hardness. 'Stan 1' was by far the hardest kernel of the entries even greater than hard red winter wheat numbers. It was almost 200 percent harder than any other cultivar or line.

Protein Yield: There appears to be tremendous protein production potential with triticale. Many of the cultivars and lines produced in excess of 800 lb grain protein per acre.

1,000 Kernal Weight: Breaker and FT90478, P001 equaled 'Stephens' in 1,000 kernal weight.

Flower Date: The earliest flowering cultivar was 'Newcale', an FT line. Flowering dates ranged from May 18 to June 4. Work is being done to transfer a wheat gene for early flowering into the FT lines.

Height and Lodging: There was a large variation in the plant heights, from 35 inches for WT 06, a WSU line, to 63 inches for 'Breaker'. 'Breaker' is considered to be a stiff strawed variety and generally stands well, but lodged heavily in this trial. 'Flora' and 'Celia', at 39 and 40 inches, were the only cultivars that did not lodge. Many of the experimental lines did not lodge. 'Stephen's' had a 61 percent lodging score.

Percent chaff: This was a measure of the amount of chaff or trash that was in the combine tank with one harvest setting on the Hege combine for all wheat and tricale. The dirty weight minus the clean weight, and divided by the dirty weight times 100, is the percent chaff. Combines would be adjusted for the conditions and the variety grown as needed by this factor. Higher humidity may improve threshability over complete dryness. This field observation has been made by Robert Metzger, retired USDA triticale breeder.

Grain N Uptake: With 200 pounds of nitrogen applied and approximately 60-80 pounds in the top foot of soil at fertilization, WT 06 (the highest yielder) picked up 165 lb N/a in the grain. 'Pika' picked up the least at 73.5 lb N/a.

Seed Rate and Potential Seeding Rates: The range in seeding rates (lb/a) was highly variable based on 30 seeds per square foot. The lowest seeding rate was 'Flora' planted at 73 lb/a, compared to 'Breaker' planted at 185 lb/a, 2.5 times more than 'Flora'. Pay close attention to seeding rates, both by variety and seed source. The average planting rate was 120 lb/a. If the 'Flora' variety used in this trial was seeded at the average rate, 64 percent more seed would have been planted than necessary. 'Breaker', however, would have been underseeded by 54 percent.

The seed harvested in this trial did not have the same range for lb/a. The range of seeding rates necessary to obtain a 30 seeds per square foot would be 87 to 137 lb/a for future planting. The reduction in range is likely the result of having the seed produced in the same environment. The information on the seeding rates of 10 to 25 seeds per square foot are provided to demonstrate the seeding rate in pounds per acre in future situations (Table 3).

Conclusions

Triticale appears to have potential as a viable alternative crop for central Oregon. It is excellent livestock and poultry feed. Triticale is a non-program crop and may be useful as growers consider their farm program options. The key to its success is further development of markets.

'Flora' and 'Celia' would be recommended for central Oregon irrigated conditions. 'Flora' has good winter hardiness while 'Celia' has excellent winter hardiness. 'Whitman' is a widely grown variety, but tends to lodge more, yield less, and is less winter hardy than 'Flora' or 'Celia'. 'Flora' and 'Celia' have excellent lodging resistance. 'Whitman' has good test weight, as does 'Celia'. 'Flora' has poor seed characteristics. 'Whitman' is facultative (low vernalization requirements) and can be planted in the spring. 'Celia' may possibly be facultative too. 'Celia' has been planted in a 1992/1993 statewide spring and winter variety trial to further evaluate this characteristic.

Table 1. Results for yield, test, weight, crude protein, hardness factor and protein yield. All data are at 10% moisture, 1991, Madras, OR.

Variety	Yield	Test Wt.	Crude Protein	Hardness Factor	Protein Yield
	lbs/acre	lbs/bu	%		lbs/acre
Stephens (check)	5406	60.3	11.4	51.7	612
Flora	7760	52.5	11.6	36.0	897
Whitman	5704	56.1	13.1	61.6	749
WT 51	6965	53.6	11.4	48.8	779
WT 06	8252	55.4	11.4	57.1	939
WT 11	5578	58.7	11.4	42.9	632
WT 17	6479	58.6	13.1	42.6	847
Breaker	3890	55.7	14.5	58.1	565
Newcale	5380	58.4	13.2	42.8	712
Pika	3318	55.0	13.1	55.0	429
Lasko	5740	59.2	12.7	50.7	720
Presto	5276	59.5	12.8	53.4	668
Stan 1	6505	59.0	13.9	129.7	900
"239"	4419	56.0	12.6	43.3	555
FT 8046	6505	54.1	11.3	59.5	735
FT 86044, B002	6157	53.8	12.6	51.7	770
FT 86044, B004	7020	53.1	11.2	44.8	780
FT 86044, B0017	6949	53.3	11.8	40.3	808
FT 86053	7874	54.7	10.5	37.3	823
FT 86072, B002	4670	55.2	12.6	48.7	584
FT 89260	6924	58.8	11.2	48.4	772
FT 90234	6535	57.7	12.8	49.3	836
FT 90235	7944	59.2	11.2	51.0	888
FT 90239	7454	57.0	11.3	49.5	838
FT 90478, P007	7529	58.4	11.4	47.0	852
FT 89259	6956	55.5	13.0	51.0	899
Celia (FT 90456)	7378	59.5	11.3	49.5	833
FT 90477, P003	7668	58.0	11.3	66.4	863
FT 90478, P001	7956	59.5	11.4	50.0	906
MEAN	6420	56.8	12.1	52.3	765
PLSD 0.10	901	1.5	1.0	4.8	85.2
PLSD 0.05	1077	1.8	1.2	5.8	101.9
PLSD 0.01	1427	2.3	1.6	7.6	135.0
CV (%)	11.9	2.2	7.1	8.0	9.5

Table 2. Results for 1,000 kernel weight, flower date, height, lodging, chaff, and grain N uptake. All data are at 10% moisture, 1991, Madras, OR.

Variety	1000 Kernel Wt	Flower Date	Height	Lodging	Chaff	Grain N Uptake
	g		inches	%	%	lbs/acre
Stephens (Check)	47.3	5/24	36	61	4.6	107.5
Flora	39.8	5/28	39	0	5.9	157.3
Whitman	44.0	5/22	47	88	7.8	131.5
WT 51	36.2	5/30	37	0	6.6	136.8
WT 06	33.4	5/24	35	0	6.3	165.0
WT 11	30.1	5/30	49	69	11.3	110.8
WT 17	39.7	5/29	56	31	6.6	148.5
Breaker	47.6	5/30	63	98	10.9	99.0
Newcale	41.4	5/18	46	94	7.3	124.8
Pika	37.8	6/2	62	89	9.9	75.3
Lasko	37.2	5/20	52	74	5.4	126.5
Presto	42.2	5/21	53	83	5.1	117.0
Stan 1	37.3	5/24	53	89	5.6	157.8
"239"	44.5	5/22	61	86	7.3	97.3
FT 8046	39.6	6/3	46	51	10.5	128.8
FT 86044, B002	38.0	5/28	47	71	9.1	135.0
FT 86044, B004	32.4	6/4	45	44	9.4	137.0
FT 86044, B0017	31.8	6/3	42	15	8.5	141.8
FT 86053	38.8	5/30	40	0	6.7	144.3
FT 86072, B002	37.9	5/28	47	71	10.9	102.5
FT 89260	41.0	5/30	39	0	9.6	135.5
FT 90234	37.2	5/30	40	0	8.0	146.8
FT 90235	43.2	5/29	38	0	7.1	156.0
FT 90239	38.0	5/22	38	0	7.7	147.0
FT 90478, P007	39.0	5/28	41	0	9.4	149.3
FT 89259	30.4	5/30	37	0	7.5	157.5
Celia (FT 90456)	40.9	5/22	40	0	9.0	146.3
FT 90477, P003	42.4	5/30	40	0	10.7	151.3
FT 90478, P001	46.7	5/24	38	0	7.7	158.8
Mean	39.2	5/27	45	36	8.0	134.2
PLSD .10	2.6	one	2.0	18	2.4	15.0
PLSD .05	3.1	rep	2.4	22	2.9	17.9
PLSD .01	4.1	only	3.1	29	3.9	23.7
CV%	5.7		3.7	43.1	25.9	9.5

Table 3. Seeding rate for the 1991-1992 trial and potential seeding rate for the seed production, Madras, OR.

Variety	Seeding Rate 1991-92 30 seeds/ft²	Potential seeding rate based on 1992 1,000 kernel weights - lbs/acre 30 Seeds/ft²	25 seeds/ft²	20 seeds/ft²	15 seeds/ft²	10 seeds/ft²
	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre
Stephens Check	110	137	114	91	68	46
Flora	73	114	96	77	58	38
Whitman	104	127	106	85	64	43
WT 51	105	104	87	70	52	35
WT 06	87	96	80	65	48	32
WT 11	90	87	72	58	44	29
WT 17	118	114	95	76	57	38
Breaker	185	137	114	92	69	46
Newcale	104	119	99	80	60	40
Pika	108	109	91	73	54	36
Lasko	83	107	89	71	54	36
Presto	107	122	101	81	61	41
Stan 1	119	107	89	72	54	36
"239"	97	128	107	86	64	43
FT 8046	152	114	95	76	57	38
FT 86044, B002	140	110	91	73	55	36
FT 86044, B004	123	93	78	63	47	31
FT 86044, B0017	114	92	76	62	46	30
FT 86053	134	112	93	74	56	37
FT 86072, B002	121	109	91	73	55	36
FT 89260	114	118	98	79	59	39
FT 90234	137	108	89	71	54	36
FT 90235	140	125	104	83	62	42
FT 90239	128	110	91	73	55	36
FT 90478, P007	158	112	94	75	56	37
FT 89259	84	87	73	59	44	29
Celia (FT 90456)	136	118	98	79	59	39
FT 90477, P003	152	122	102	82	61	41
FT 90478, P001	169	134	112	90	67	45
Mean	120	113	94	75	56	37
PLSD .10	N.A.	7.5	6.2	4.9	3.8	2.6
PLSD .05	N.A.	8.9	7.5	5.9	4.5	3.0
PLSD .01	N.A.	11.8	9.9	7.8	6.0	4.1
CV%	N.A.	5.6	5.7	5.5	5.7	5.8

IRRIGATED TALL FESCUE VARIETY TRIAL*

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Abstract

Eight tall fescue cultivars were established in August 1987 at the Powell Butte research site of the Central Oregon Agricultural Research Center. 'Mozark' was the top yielder, while 'Tandem', which equaled 'Mozark' the first two years, was the poorest yielder. 'Fawn', the check variety, was among the lowest yielding cultivars.

Introduction

Grass hay and pasture are important agricultural crops in central Oregon either as pure stands, or in mixtures with alfalfa and clovers. A grass variety trial was conducted from 1968 to 1972 at Redmond, Oregon. Species in that trial included, ranked in the order of most to least productive, orchardgrass, timothy, bromegrass, meadow foxtail, intermediate wheatgrass, tall fescue, and Kentucky bluegrass. This new trial was initiated because many new varieties have been introduced since 1968.

Materials and Methods

Non-coated, non-treated seed of eight tall fescue cultivars was hand broadcast on August 21 and 22, 1987. Tall fescue grass names and sources of each variety planted at Powell Butte, Oregon are as follows:

Variety	Source
Forager	Cenex/Land O'Lakes
Syn W	Cenex/Land O'Lakes
Mozark	International Seeds, Inc.
Martin	International Seeds, Inc.
FA-293-86	Turf Seed, Inc.
Tandem	Turf Seed, Inc.
Johnstone	Willamette Seed & Grain
Fawn	CHECK

The planting rate was 18 lb/a, and the seed was planted into 6 x 20 ft, plots in a randomized complete block design, and replicated four times. The seed was raked in and rolled with a corrugated roller.

*This trial was partially supported by testing fees collected from Cenex/Land O'Lakes, International Seeds, Inc., Turf Seed, Inc. and Willamette Seed and Grain.

Soil test values (samples taken June 1, 1987) were:

pH	P	K	N-NO_3	depth
6.5	13 ppm	281 ppm	6.2 ppm	0-12"

A broadcast fertilizer application of 16-20-0-15 at 410 lb/a was incorporated into the seedbed in August 17, 1987 prior to planting. On April 4, 1988, 500 pounds of 16-20-0-15 was top-dressed.

Table 1. Fertilizer applications in lb/a for nitrogen and sulfur at Powell Butte.

Year	1st Cut N S	2nd Cut N S	3rd Cut N S	4th Cut N S
	--lb/a--	--lb/a--	--lb/a--	--lb/a--
1989	80 - 60	80 - 0	---	---
1990	90 - 60	80 - 0	---	---
1991	100 - 60	90 - 0	90 - 0	---
1992	110 - 60	100 - 0	100 - 0	100 - 0

Plot size harvested in 1989 was 3.3 x 14 ft. In 1990, 1991, and 1992, plot size harvested was 3.5 x 15 ft. Yields were converted to tons per acre after a sample was taken from each plot and oven dried to determine dry matter. In 1990, 1991, and 1992 samples were dried at 149°F. Yield results are reported in oven dry weight.

Results and Discussion

Results for 1988 are published in "Central Oregon Crop Research 1987-1988, OSU Agricultural Experiment Station Special Report 847, October 1989". The yield data for 1989, 1990, 1991, and 1992 are in Tables 2, 3, 4, and 5.

'Mozark' ranked first, second, third, first, and first annually over the five year trial, and ranked first for the five years. 'Johnstone' and 'Syn W' performed above average. 'Tandem's' yield, after being one of the top yielders the first two years, dropped dramatically the third year and was the lowest yielder through the end of the trial. The plant stand was severely reduced at the beginning of the third year. Native grasses and Kentucky bluegrass took over the plot. For the five years, seven tall fescue varieties (excluding 'Tandem') averaged 26.93 tons per acre (trial average was 26.28 t/a), compared to 26.18 tons per acre for the 13 orchardgrass varieties in an adjacent trial.

Tables 6, 7, and 8 summarize the yield data for the duration of the trial: 6) annual yield summary; 7) cumulative annual yield summary, and 8) percent relative yield compared to the check summary.

The potential yield of the tall fescues may not have been approached in this trial based on some unpublished nitrogen rate work on grass hay field trial done in 1992. In those trials yield increases were obtained in applications of up to 150 pounds N per acre per cutting on a two and three cutting harvest regime. The current trials were fertilized from 80 to 110 pounds N per acre per cutting.

Table 2. 1989 Tall fescue variety yield results in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Total
	--t/a--	--t/a--	--t/a--
Forager	1.93	2.37	4.30
Syn W	1.88	2.59	4.47
Mozark	2.03	2.62	4.65
Martin	2.00	2.33	4.33
FA-293	2.01	2.41	4.42
Tandem	2.37	2.48	4.85
Johnstone	2.14	2.38	4.52
Fawn*	2.05	2.48	4.53
Mean	2.05	2.46	4.51
Harvest Date	6/20	8/29	---
PLSD .10	---	---	---
PLSD .05	0.40	0.33	0.54
PLSD .01	---	---	---
CV %	13.2	9.1	8.1

*Check

Table 3. 1990 Tall fescue variety yield in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Total
Forager	1.62	2.23	3.85
Syn W	1.71	2.70	4.40
Mozark	1.61	2.75	4.36
Martin	1.70	2.47	4.17
FA-293	1.43	2.47	3.90
Tandem	0.56	1.04	1.61
Johnstone	2.03	2.39	4.42
Fawn	1.66	2.37	4.03
Mean	1.54	2.30	3.84
Harvest Date	6/27	9/11	---
PLSD .10	0.25	0.34	0.41
PLSD .05	0.30	0.41	0.49
PLSD .01	0.41	0.56	0.67
CV%	13.3	12.2	8.8

*Check

Table 4. 1991 yield results for the tall fescue varieties in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Cuts 1 & 2	3rd Cut	Cuts 1, 2 & 3
Forager	2.11	2.38	4.49	1.67	6.16
Syn W	2.38	2.44	4.82	1.62	6.44
Mozark	2.69	2.38	5.07	1.57	6.64
Martin	2.23	2.09	4.32	1.59	5.91
FA-273	2.09	2.23	4.32	1.65	5.97
Tandem	1.49	1.10	2.59	1.03	3.36
Johnstone	2.23	2.29	4.52	1.59	6.11
Fawn	2.14	2.18	4.32	1.53	5.81
Mean	2.17	2.13	4.31	1.53	5.84
Harvest Date	6/26	8/19	N/A	10/18	N/A
PLSD .10	0.34	0.23	0.71	0.24	0.72
PLSD .05	0.41	0.28	NS	0.29	0.87
PLSD .01	0.55	0.38	NS	0.39	1.19
CV%	12.7	8.9	13.5	12.7	10.2

Table 5. 1992 yield results of the tall fescue varieties in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Cut 1 & 2	3rd Cut	Cuts 1, 2 & 3	4th Cut	Total All Cuts
Forager	2.01	2.20	4.20	1.18	5.38	1.10	6.48
Syn W	2.02	2.14	4.15	1.18	5.33	1.06	6.39
Mozark	2.12	2.32	4.44	1.09	5.53	1.14	6.66
Martin	1.72	1.98	3.70	1.11	4.80	0.99	5.79
FA-273	1.96	2.10	4.06	1.16	5.21	1.18	6.40
Tandem	1.85	1.40	3.24	0.80	4.04	0.98	5.02
Johnstone	1.82	2.43	4.25	1.06	5.30	1.06	6.37
Fawn*	2.08	2.29	4.37	1.17	5.54	1.07	6.61
Mean	1.95	2.11	4.05	1.09	5.14	1.07	6.21
Harvest Date	5/28	7/14	N.A.	8/19	N.A.	10/19	N.A.
PLSD .10	NS	0.43	0.53	0.12	0.54	0.11	0.54
.05	NS	0.52	0.64	0.15	0.66	NS	0.65
.01	NS	NS	NS	0.02	0.89	NS	0.89
CV%	13.8	16.7	10.8	9.3	8.7	8.3	7.2

*Check

Table 6. 1988-1992 Tall fescue variety annual yield summary in tons per acre at Powell Butte.

Variety	1988[2]	1989[2]	1990[2]	1991[3]	1992[4]	Total
Forager	5.26	4.30	3.85	6.16	6.48	26.05
Syn W	6.02	4.47	4.40	6.44	6.39	27.72
Mozark	6.97	4.65	4.36	6.64	6.66	29.28
Martin	5.35	4.33	4.17	5.91	5.79	25.55
FA-273	5.71	4.42	3.90	5.97	6.40	26.40
Tandem	6.75	4.85	1.61	3.62	5.02	21.85
Johnstone	5.64	4.52	4.42	6.18	6.37	27.13
Fawn	5.34	4.53	4.03	5.85	6.61	26.36
Mean	5.88	4.51	3.84	5.84	6.21	26.28
PLSD .10	--	--	0.41	0.72	0.54	--
.05	--	0.54	0.49	0.87	0.65	--
.01	--	--	0.67	1.19	0.89	--
CV%	--	8.1	8.8	10.2	7.2	--

*Check
[2] two cuttings
[3] three cuttings
[4] four cuttings

Table 7. 1988-1992 cumulative yield summary of the tall fescue varieties in tons per acre at Powell Butte.

Variety	1988[2]	1989[2]	1990[2]	1991[3]	1992 & Total[4]
Forager	5.26	9.56	13.41	19.57	26.05
Syn W	6.02	10.49	14.89	21.33	27.72
Mozark	6.97	11.62	15.98	22.62	29.28
Martin	5.35	9.68	13.85	19.76	25.55
FA-273	5.71	10.13	14.03	20.00	26.40
Tandem	6.75	11.60	13.21	16.83	21.85
Johnstone	5.64	10.16	14.58	20.76	26.13
Fawn*	5.34	9.87	13.90	19.75	26.36
Mean	5.88	10.39	14.23	20.07	26.28

[2] two cuttings
[3] three cuttings
[4] four cuttings

Table 8. 1988-1992 percent relative yield to check annual summary of the tall fescue varieties in tons per acre at Powell Butte.

Variety	1988	1989	1990	1991	1992	Five Year Total
Forager	99	95	96	105	98	99
Syn W	113	99	109	110	97	105
Mozark	131	103	108	114	101	111
Martin	100	96	103	101	88	97
FA-273	107	98	97	102	97	100
Tandem	126	107	40	62	76	83
Johnstone	106	100	110	106	96	103
Fawn*	100	100	100	100	100	100
Mean	110	100	95	100	94	100

* Check

IRRIGATED ORCHARDGRASS VARIETY TRIAL*

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Abstract

Thirteen orchardgrass varieties were planted at the Central Oregon Agricultural Research Center's Powell Butte site in August of 1987. The trial was completed in 1992. Many of the orchardgrass varieties outyielded 'Latar', the check variety. The following cultivars were above average in yield: 'Napier', 'Sterling', 'Potomac', 'Comet' and 'Orion' ranked first through fifth, respectively. 'Fawn', the check variety, was among the lowest yielders.

Introduction

Grass hay and pasture are important agricultural crops in central Oregon, either grown as pure stands or in mixtures with alfalfa and clover. A grass variety trial was conducted from 1968 to 1972 at Redmond, Oregon. Species in that trial included, and ranked in order of most productive to least productive, orchardgrass, timothy, bromegrass, meadow foxtail, intermediate wheatgrass, tall fescue and Kentucky bluegrass. This new orchardgrass trial was initiated because many new varieties had been introduced since the last trial.

Materials and Methods

Non-coated, non-treated seed of 13 orchardgrass cultivars (Table 1) was hand broadcast on August 21 and 22, 1987 at the Powell Butte site of the Central Oregon Agricultural Research Center. Eighteen pounds of seed per acre was planted into 6 x 20 ft plots in a randomized complete block design and replicated four times. The seed was raked in and rolled with a corrugated roller.

Soil test values (0-12 in. depth samples were taken June 1, 1987) were 6.5 pH, 13 ppm P, 281 ppm K and 6.2 ppm N-NO3. A 410 lb/a broadcast application of 16-20-0-15 was incorporated into the seedbed on August 17, 1987 prior to planting. On April 4, 1988, 500 lbs of 16-20-0-15 was topdressed. The fertilizer applications for the remainder of the trial years are listed in Table 2.

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*These trials were partially supported by testing fees collected from Cenex/Land O'Lakes, Daehnfeldt, Inc., International Seeds, Inc., Northrup King Co., Turf Seed, Inc., and Willamette Seed and Grain.

Table 1. Orchardgrass cultivar names and sources of each cultivar planted in 1987 at Powell Butte.

Cultivar	Source*
Rancho	Cenex/Land O'Lakes
Phyllox	Daehnfeldt, Inc
Ambassador	International Seeds, Inc.
Comet	Northrup King Co.
Orion	Northrup King Co.
Syn 8SM	Turf Seed, Inc.
Syn 885	Turf Seed, Inc.
Syn 887	Turf Seed, Inc.
Napier	Willamette Seed & Grain
Paiute	USDA
Latar	#
Potomac	#
Sterling	#

* Source or originating agency
# Gooding Seed Co. or Round Butte Seed Growers

Table 2. Nitrogen and sulfur fertilizer applied per cutting in the trial in pounds per acre at Powell Butte.

Year	1st Cut	2nd Cut	3rd Cut	4th Cut
	N S	N S	N S	N S
1989	80 - 60	80 - 0	---	---
1990	90 - 60	80 - 0	---	---
1991	100 - 60	90 - 0	80 - 0	---
1992	110 - 60	100 - 0	100 - 0	100 - 0

Plot size harvested was 3.3 x 14 ft in 1989 and 3.5 x 15 ft in 1990, 1991, and 1992. An approximately one pound forage sample was oven-dried to determine dry matter, and forage yields were converted to tons per acre. The samples were dried at 149°F in 1990, 1991, and 1992. Forage yields are reported in oven dry weight or approximately 0 percent moisture.

Results and Discussion

Results for the 1988 crop year are published in Central Oregon Crop Research 1987-1988, OSU Agricultural Experiment Station Special Report 847, October 1989, "Forage

Grass Variety Trials Preliminary Report". The forage yield data for 1989, 1990, 1991, and 1992 are in Tables 3, 4, 5, and 6.

Over the course of the five year trial, 'Napier', 'Sterling', 'Potomac', 'Comet' and 'Orion' ranked first through fifth, respectively for total yield. 'Orion' was one of the highest yielders the first two years and then yielded slightly less than average the last three years. This variety may have produced more if fertility levels had been higher. Unpublished nitrogen rate trial results from 1992 on grass hay fieldas indicate that grass will respond up to 150 pounds of N per acre. The forage yields would have been higher as well, but only two harvests were taken annually the first three years. These orchardgrass cultivars performed under a medium N fertility regime in this variety trial. The varieties may not have been allowed to express their full potential. 'Napier', 'Sterling', 'Potomac', 'Paiute', 'Comet', 'Ambassador', and 'Rancho' were still producing well in the fifth year. 'Latar' and 'Orion' had average forage yields in the fifth year.

The highest yielding orchardgrass variety yielded less than the highest yielding tall fescue variety in an adjacent trial. The tall fescue cultivars, (especially when excluding 'Tandem' tall fescue from the mean) on average, slightly outyielded the orchardgrass varieties.

To aid in cultivar selection, the 1988-1992 data are presented also as an annual yield summary (Table 7), cumulative annual yield summary, (Table 8) and percent relative yield to check summary (Table 9).

Table 3. 1989 forage yield results of the orchardgrass varieties in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Total
Rancho	2.37	2.50	4.87
Phyllox	2.08	2.74	4.82
Ambassador	2.46	2.64	5.10
Comet	2.38	2.37	4.75
Orion	2.64	2.54	5.18
Syn 8SM	2.04	2.45	4.49
Syn 885	2.19	2.31	4.50
Syn 887	1.98	2.37	4.35
Napier	2.37	2.38	4.75
Paiute	2.17	2.38	4.55
Latar	2.32	2.39	4.70
Potomac	2.52	2.41	4.93
Sterling	2.53	2.69	5.22

Mean	2.32	2.47	4.79
Harvest Date	6/20	8/29	---
PLSD .05	0.35	0.40	0.58
CV %	10.4	11.2	8.5

Table 4. 1990 forage yield results of the orchardgrass varieties in tons per acre Powell Butte.

Variety	1st Cut	2nd Cut	Total
Rancho	1.84	2.05	3.88
Phyllox	1.79	1.91	3.70
Ambassador	2.09	1.81	3.90
Comet	2.11	1.94	4.05
Orion	1.65	2.05	3.70
Syn 8SM	1.61	2.23	3.84
Syn 885	1.53	1.86	3.39
Syn 887	1.75	2.15	3.90
Napier	1.99	2.27	4.26
Paiute	1.76	1.82	3.58
Latar*	1.80	2.10	3.90
Potomac	1.83	1.96	3.79
Sterling	1.96	2.16	4.12
Mean	1.82	2.03	3.84
Harvest Date	6/27	9/11	---
PLSD .10	0.19	NS	NS
PLSD .05	0.23	NS	NS
PLSD .01	0.30	NS	NS
CV %	8.7	15.3	10.3

* Check variety

Table 5. 1991 forage yield results of the orchardgrass varieties in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Cuts 1 & 2	3rd Cut	Total 1, 2 & 3
Rancho	3.16	2.02	5.18	1.03	6.22
Phyllox	2.89	1.95	4.84	0.96	5.80
Ambassador	3.22	2.03	5.25	0.98	6.22
Comet	3.34	2.28	5.63	1.09	6.71
Orion	3.42	2.05	5.47	0.89	6.36
Syn 8SM	3.35	2.12	5.48	0.97	6.45
Syn 885	2.92	1.95	4.87	1.05	5.92
Syn 887	3.44	2.26	5.69	1.05	6.74
Napier	3.55	2.38	5.93	1.11	7.04
Paiute	3.57	1.99	5.56	1.09	6.65
Latar*	3.16	2.29	5.45	1.11	6.56
Potomac	3.56	2.18	5.74	1.15	6.88
Sterling	3.27	2.33	5.60	1.09	6.68
Mean	3.30	2.14	5.44	1.04	6.48
Harvest Date	6/26	8/19	---	10/18	---
PLSD .10	NS	0.20	0.47	NS	0.54
PLSD .05	NS	0.24	0.57	NS	0.65
PLSD .01	NS	0.33	0.76	NS	0.87
CV %	10.8	8.0	7.3	13.2	7.0

* Check variety

Table 6. 1992 forage yield results of the orchardgrass varieties in tons per acre at Powell Butte.

Variety	1st Cut	2nd Cut	Cuts 1 & 2	3rd Cut	Total Cuts 1-3	4th Cut	Total 4 Cuts
Rancho	2.21	1.67	3.88	1.18	5.07	0.86	5.93
Phyllox	1.77	1.25	3.01	1.21	4.22	0.96	5.18
Ambassador	2.17	1.74	3.91	1.14	5.05	0.88	5.93
Comet	2.05	1.85	3.91	1.21	5.12	0.90	6.02
Orion	2.13	1.56	3.69	1.16	4.85	0.79	5.64
Syn 8SM	1.87	1.40	3.27	1.16	4.43	0.86	5.28
Syn 885	1.89	1.35	3.24	1.18	4.42	0.92	5.34
Syn 887	1.81	1.65	3.47	1.21	4.68	0.94	5.62
Napier	2.03	1.97	4.00	1.36	5.35	1.12	6.47
Paiute	1.97	1.88	3.84	1.18	5.03	1.00	6.03
Latar*	1.99	1.57	3.55	1.26	4.81	0.84	5.65
Potomac	2.08	1.64	3.72	1.20	4.92	1.16	6.08
Sterling	2.07	1.85	3.92	1.27	5.19	1.13	6.32
Mean	2.00	1.64	3.65	1.21	4.86	0.95	5.81
Harvest Date	5/28	7/14	NA	8/19	NA	10/19	NA
PLSD .10	NS	0.24	0.39	NS	0.40	0.14	0.43
PLSD .05	NS	0.29	0.47	NS	0.49	0.17	0.51
PLSD .01	NS	0.38	0.63	NS	0.65	0.23	0.69
CV%	13.1	12.2	8.9	8.3	7.0	12.6	6.2

* Check variety

Table 7. 1988-1992 annual forage yield summary of the orchardgrass varieties in tons per acre at Powell Butte.

Variety	1988[1]	1989[1]	1990[1]	1991[2]	1992[3]	Total
Rancho	4.91	4.87	3.83	6.22	5.93	25.76
Phyllox	4.83	4.82	3.88	5.80	5.18	24.51
Ambassador	4.62	5.10	4.23	6.22	5.93	26.10
Comet	4.79	4.75	3.92	6.71	6.02	26.69
Orion	5.50	5.18	3.79	6.36	5.64	26.17
Syn 8SM	5.09	4.49	3.89	6.45	5.28	25.20
Syn 885	4.97	4.50	3.37	5.92	5.34	24.10
Syn 887	4.97	4.35	3.78	6.74	5.62	25.46
Napier	5.45	4.75	3.94	7.04	6.47	27.65
Paiute	4.85	4.55	3.86	6.65	6.03	25.94
Latar*	4.29	4.70	3.85	6.56	5.65	25.05
Potomac	5.31	4.93	3.74	6.88	6.08	26.94
Sterling	5.11	5.22	3.85	6.68	6.32	27.18
Mean	4.98	4.79	3.84	6.48	5.81	26.18
PLSD .10	---	---	NS	0.54	0.43	---
PLSD .05	---	0.58	NS	0.65	0.51	---
PLSD .01	---	---	NS	0.87	0.69	---
CV%	---	8.5	10.3	7.0	6.2	---

[1] Two cuttings
[2] Three cuttings
[3] Four cuttings
* Check variety

Table 8. 1988-1992 cumulative annual forage yield summary of the orchardgrass varieties in tons per acre at Powell Butte.

Variety	1988	1989	1990	1991	1992 & Total
Rancho	4.91	9.78	13.61	19.83	25.76
Phyllox	4.83	9.65	13.53	19.33	24.51
Ambassador	4.62	9.72	13.95	20.17	26.10
Comet	4.79	9.54	13.46	20.17	26.69
Orion	5.50	10.68	14.47	20.83	26.17
Syn 8SM	5.09	9.58	13.47	19.92	25.20
Syn 885	4.97	9.47	12.84	18.76	24.10
Syn 887	4.97	9.32	13.10	19.84	25.46
Napier	5.45	10.20	14.14	21.18	27.65
Paiute	4.85	9.40	13.26	19.91	25.94
Latar*	4.29	8.99	12.84	19.40	25.05
Potomac	5.31	9.61	13.35	20.23	26.94
Sterling	5.11	10.33	14.18	20.86	27.18
Mean	4.98	9.77	13.61	19.42	26.18

* Check variety

Table 9. 1988-1992 percent relative forage yield to check summary for the orchardgrass varieties at Powell Butte.

Variety	1988	1989	1990	1991	1992	Five Year Total
Rancho	114	104	99	95	105	103
Phyllox	113	103	101	88	92	98
Ambassador	108	109	110	95	105	104
Comet	112	101	102	102	107	107
Orion	128	110	98	97	100	105
Syn 8SM	119	96	101	98	93	100
Syn 885	116	96	88	90	95	96
Syn 887	116	93	98	103	99	102
Napier	127	101	102	107	115	110
Paiute	113	97	100	101	107	104
Latar*	100	100	100	100	100	100
Potomac	124	105	97	105	108	108
Sterling	119	111	100	102	112	109
Mean	116	102	100	99	103	105

* Check variety

VARIETAL EVALUATION OF IRRIGATED CEREAL GRAINS IN CENTRAL OREGON

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Abstract

Irrigated cereal trials were conducted in Powell Butte and Madras, Oregon in 1989. Winter wheat selections OR8300801 and OSU-21 for the soft whites were increased for release in 1990 or 1991. Hard red winter wheat selection ORCR8313 is also being increased for release in the near future. None of these have been named at present. Many of the advanced lines for both hard red and soft white winters outperformed the standards. Spring wheat variety OR8501 has out-yielded the other advance lines as well as the standards, however, it's height is taller than most.

Introduction

In 1989, four replicated yield trials were conducted at two sites of the Central Oregon Experiment Station. Cereals were evaluated for yield, test weight, maturity, height, lodging, winter hardiness, and disease resistance. Table 1 gives a summary of location, trials grown, and number of lines investigated in each trial.

Table 1. Cereal grain variety trials planted in Central Oregon in 1988.

Location	Trial	No. Entries
Madras	Hard Red Winter Wheat Elite	36
Madras	Soft White Winter Wheat Elite	52
Powell Butte	Hard Red and Soft White Winter Wheat	16
Powell Butte	Spring Wheat	16

Methods and Materials

Cereal plots (5 x 20 ft) were seeded at a rate of 100 lb/a using an Oyjord plot planter. Fertilizing was accomplished by a Barber metered feed fertilizer spreader. Overhead irrigation was used on 40 x 40 spacing at Powell Butte and 40 x 30 ft spacing at Madras. Harvest was accomplished with a Hege plot combine. Cultural data for the different experiments are summarized in Table 2.

Table 2. Cultural data for 1989 variety trials at Madras and Powell Butte, OR.

Trial	Location	Lbs N/Ac	Date of planting	Date of first irrig.	Date of last irrig.	Date of harvest
SWWWE	Madras	162	10-19-88	4-21-89	7-14-89	8-22-89
HRWWE	Madras	162	10-19-88	4-21-89	7-14-89	8-23-89
WWV	Powell Butte	162	10-19-88	5-5-89	7-26-89	8-23-89
SWV	Powell Butte	175.2	4-5-89	5-5-89	8-4-89	8-28-89

SWWWE Soft White Winter Wheat Elite
HRWWE Hard Red Winter Wheat Elite
WWV Winter Wheat Varieties
SWV Spring Wheat Varieties

Results and Discussion

Above normal grain yield was observed at both Madras and Powell Butte, mainly due to a wet spring and optimum temperatures in the early summer. The 1988-89 winter was a normal winter both in temperature and moisture.

Disease and insect damage were absent throughout the season in 1989, therefore, none will be noted here.

Soft white winter wheat

Soft white winter varieties and advance lines performed well in 1989 with advance lines OR8500933H and OR8500594H doing much better than both 'Malcolm' and 'Stephens' varieties. Table 3 and 4 show the agronomic data for the Madras soft white winter wheat trial, and some of the most common varieties of soft white winter wheat averaged since 1979.

Table 3. Soft white winter wheat varieties grown at Madras, OR 1979-1989.

Variety	Yield	Test wt	Head date	Lodging	Height	Years of data
Hyslop	103.3	56.5	167	16	37	8
Daws	110.4	57.3	167	18	37	9
Dusty	108.6	58.8	165	48	36	4
Hill 81	105.4	57.5	168	13	38	10
Malcolm	122.2	56.6	166	17	36	10
McDermid	95.4	59.2	158	48	36	7
Nugaines	107.4	59.3	167	19	34	9
Stephens	112.9	56.3	164	18	36	10

Table 4. Agronomic data for selected soft white winter wheat lines grown at Madras, Oregon in 1989.

Variety	Yield	Test wt	Hd date	Height	Lodging
	bu/ac	lbs/bu	days	in	%
Stephens	129.7	56.1	161	41	74
Hill	109.2	58.8	164	43	46
Malcolm	136.3	55.9	163	40	31
Oveson	117.4	57.1	162	38	55
Dusty	123.9	58.2	165	39	43
Daws	140.7	57.1	163	42	45
Madsen	130.3	58.0	162	40	46
Whitman	128.2	52.6	157	43	50
OSU-21	116.3	56.8	158	39	56
OR CW8314	149.0	58.0	159	40	5
OR CW8519	130.8	59.4	162	45	40
OR CW8627	124.8	58.7	161	43	30
OR CW8632	134.6	56.7	160	40	46
OR 8300801	131.2	57.4	165	39	33
OR 8302665	123.9	57.8	161	41	88
OR 8302784	125.8	56.2	160	41	48
OR 8303725	124.3	55.2	161	41	70
OR 8303765	138.9	57.5	160	44	60
OR 8400814H	124.1	58.7	159	40	10
OR 8400815H	136.6	58.6	160	42	6
OR 8401073H	126.3	58.5	161	45	28
OR 8401464P	124.4	57.5	162	41	23
OR 8303734	128.6	58.6	164	39	58
OR 8400838H	132.0	56.8	163	42	29
OR 8401389H	131.1	57.3	163	41	26
OR 8401439P	120.3	53.8	166	42	54
OR 8401544P	133.6	56.1	158	37	58
OR 8402961H	139.0	55.4	162	40	65
OR 8502288H	140.8	59.5	159	37	13
OR 8503157H	128.7	56.6	161	41	41
OR 8500583P	137.2	56.8	159	44	50
OR 8500933H	156.0	56.1	159	40	18
OR 8500594H	157.1	57.1	160	40	25
OR 8501048P	137.3	54.7	161	41	48
Mean	131	57	161	41	42

Hard red winter wheat

Advance line ORCW8313 has out-performed the standards as well as the majority of the other lines. ORCW8313 will be released as a variety for the growers in the near future. Hard red winter wheat is still a possible alternative to the soft whites for the farmers. Table 5 shows the performance data for several standards as well as many advance lines.

Table 5. Agronomic data for several hard red winter wheat lines grown at Madras, Oregon in the 1989 Oregon Elite trial

Variety	Yield	Test wt	Hd date	Height	Lodging
	bu/ac	lbs/bu	days	in	%
Wanser	83.6	57.5	158	50	93
OR CR8313	125.3	59.7	158	43	48
Federation	91.7	57.3	156	49	65
Hatton	75.9	60.8	160	49	94
Batum	96.1	56.1	162	44	83
Andrew	130.3	58.7	156	36	90
OR CR8601	127.7	60.6	157	47	23
OR CR8602	131.8	58.4	156	39	38
OR CR8718	131.1	60.5	158	46	13
OR 8300282	147.2	59.9	159	43	20
OR 8400214H	121.5	59.2	156	42	13
OR 8401708P	123.2	58.7	162	44	34
OR 8303372	132.4	57.8	162	43	38
OR 8400159P	120.4	60.6	160	47	59
OR 8401707P	141.8	58.1	161	43	58
OR 8401709P	135.2	56.5	163	41	24
OR 8403309H	127.3	59.4	158	41	65
OR 8500509P	120.2	59.2	158	41	59
OR 8500608H	139.4	57.9	162	44	3
OR 8500694P	143.0	58.0	159	44	20
OR 8500695P	134.8	56.9	160	42	33
OR 8500847P	145.2	59.0	161	40	5
OR 8501018P	131.7	58.9	163	44	8
OR 8504896P	148.0	60.9	158	39	3
OR 8505289P	128.3	58.2	158	40	28
OR 8505424P	126.8	58.9	159	42	38
OR CR8617	132.2	56.7	161	37	39
MEAN	125.6	58.7	159	43	41

Winter wheat (Powell Butte)

A combined hard red and soft white winter wheat trial was established in Powell Butte, Oregon in the 1989 growing season. The yields were extremely high as compared to the past for both hard reds and soft wheats, which shows an optimum year for whet with optimum moisture and temperature. Table 6 shows the agronomic data for the Powell Butte winter wheat trial. Table 7 has the average of 10 years of several varieties of soft white winter wheat grown in Powell Butte.

Table 6. Agronomic data for the soft white and hard red winter wheats grown in Powell Butte, Oregon in 1989

Variety	Yield	Test wt	Hd date	Height	Lodging
	bu/ac	lbs/bu	days	in	%
Stephens*	152.7	59.1	168	34	3
Hill**	140.6	59.4	170	41	13
Malcolm	172.5	59.2	169	35	3
OSU-21	128.9	58.9	165	37	28
OSU-28	145.0	60.1	166	34	0
OR CW8314	175.5	59.7	165	37	3
OR CW8519	153.1	60.6	170	39	0
OR CW8521	158.3	60.9	169	44	0
Wanser*	131.8	60.6	166	46	40
Hatton**	130.0	62.8	168	49	75
Batum**	133.7	56.6	170	38	38
OR CR8313	122.3	62.4	166	36	0
OR CR8601	135.1	62.0	165	39	0
OR CR8602**	119.7	60.8	164	27	0
OR CR8718	148.0	62.2	165	40	0
OR CR8617	158.5	62.9	167	32	0
Mean	144.1	60.5	167	38	13

* Two replicates.
** Three replicates.

Table 7. Soft white winter wheat varieties grown at Powell Butte, 1979-1989.

Variety	Yield	Test wt	Hd date	Height	Lodging	Years of data
	bu/ac	lbs/bu	days	in	%	
Hyslop	107.6	56.2	177	18	35	8
Daws	111.9	57.2	179	9	35	8
Dusty	118.9	58.8	175	8	35	3
Hill 81	114.7	58.1	179	10	37	10
Malcolm	121.8	56.4	177	4	35	10
McDermid	107.8	54.7	176	0	25	8
Nugaines	108.4	58.0	179	15	33	8
Stephens	112.6	55.7	177	6	34	10

Spring wheat

Sixteen lines of spring wheat were planted with eight lines of white and eight lines of hard red spring. Several advance lines look very good with OR484013 as the most popular advance line, which will be released as a variety for the hard whites. Table 8 has the agronomic data for the Powell Butte spring wheat trial.

Table 8. Agronomic data for the spring wheat varieties, Powell Butte, OR, 1989.

Variety	Yield	Test wt	Hd date	Height	Lodging
	bu/ac	lbs/bu	days	in	%
OR 487503	118.4	54.4	180	39	0
OR 487570	114.8	55.8	182	38	0
4870279	112.6	62.5	176	37	0
4870249	110.9	62.7	177	37	0
4870332	116.0	60.3	176	38	0
OR 485010	107.0	63.3	175	37	0
4870355	94.8	62.7	176	38	0
4870456	110.9	62.0	177	35	0
4870475	99.4	59.9	178	30	0
4870400	114.5	63.1	176	38	0
OR 484013	115.7	62.0	176	36	0
OR487316	116.1	60.4	176	32	0
ORS 8501	138.2	59.9	176	40	0
Owens	88.7	60.3	174	26	0
Twin	110.6	60.8	175	39	0
Walladay	97.1	61.7	174	36	0
Mean	110.3	60.7	177	36	0

Conclusion

With the price increase for cereal, wheat has been and will continue to be a major crop in central Oregon. A result of the cooperative effort from Oregon State University and Central Oregon Agricultural Research Center, is the release of many new varieties with Hyak and Madsen in 1988, the soft whites OR830801, and OSU-21 in 1989-1990, and ORCR8313, a hard red, also in 1989. These new releases will continue to add to the quality and production of wheat to help keep prices at an optimum level.

FLOODING FOR THE ERADICATION OF THE ONION AND GARLIC WHITE ROT FUNGUS, *Sclerotium cepivorum,* FROM INFESTED FIELD SOIL

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Abstract

A 20-acre field of "seed" garlic in central Oregon, which was not harvested due to widespread activity of the onion and garlic white rot fungus *(Sclerotium cepivorum),* was flooded continuously beginning in June, 1989, extending into November, 1989. Flooding accomplished several objectives: (1) all white rot disease activity stopped at the onset of flooding, effectively preventing further fungal reproduction, (2) survival of sclerotia, which had formed prior to flooding, was reduced 100, 35, 19, 7, 1, and 1 percent after 0, 2, 6, 9, 11, and 13 weeks of continuous flooding, respectively, in contrast to an expected near-100 percent survival in the absence of flooding, and (3) except for formation of a few aerial bulblets, all garlic cloves decayed during the course of flooding, thus nearly eliminating garlic volunteer plants in future seasons. Soil temperatures at 4 inches were 71, 71, 62, 61 and 59°F after 2, 6, 9, 11, and 13 weeks of continuous flooding, respectively. Decay of dead sclerotia was observed after seven weeks of continuous flooding. Inoculum density in 1990, based on random soil samples, was below the general limit of detectability (1 sclerotium/L soil), in contrast to an expected recovery of 1,000-10,000 sclerotia/g if the field had remained untreated. Nevertheless, in 1990 some surviving sclerotia could be recovered near the centers of abundant early plant loss in 1989. Due to prevention and partial eradication of high potential inoculum buildup, flooding greatly reduced -- but did not totally eliminate -- the risk of movement of sclerotia from this field.

Introduction

We hoped to achieve eradication of the white rot fungus, and of the infested garlic cloves, by flooding an infested 20-acre garlic field in central Oregon during the summer and fall of 1989. In this field, white rot was active in the spring and early summer of 1989. Many garlic plants were decayed, with an abundance of newly-formed sclerotia produced. Disease was evident throughout the field, either in large zones in which plants were 100 percent infected, or in pockets of 1-20 plants separated along beds by 1-20 feet. Because of the presence and severity of white rot, the crop was abandoned for any commercial purpose.

The field was furrow irrigated, with a slope of about 1:100 (rise:run), which was suitable for diking and flooding.

At the time of flooding, we were unaware of any previous attempt to eradicate the white rot fungus with summer flooding. We based our attempt on the information, that poorest survival of sclerotia of the white rot fungus occurs in soils with highest moisture retention (5). In the laboratory, 100 percent of sclerotia of the white rot fungus died within three weeks in saturated soil held at 70°F or higher. Less died during this period of time for lower temperatures, and in non-saturated soils (2). Three weeks of late winter flooding (March-April, 40-65°F) on muck soil in areas of Canada reduced populations of white rot sclerotia by 80 percent in 1986 (1). A related fungus, *Sclerotinia sclerotiorum*, may be eradicated by a 23-45 day flooding period in Florida soils, at temperatures of 75-80°F (4).

Materials and Methods

Prior to flooding, areas of extensive disease loss in the upper end (west), middle and lower end (east) of the field were flagged so these could be located after flooding. The garlic crop was left in the field, without any plant or soil treatments other than flooding. Wide-mesh bags were used to contain diseased plant material and soil in each area, for ease of recovery.

Dikes of non-infested soil were erected by the grower around the entire 20-acre field. The field was flooded by the grower beginning June 26, 1989, and irrigation water intermittently was added through October 15, 1989, to replace evaporation and infiltration. This resulted in continuous flooding through November 1, 1989 (week 18). During this period, the depths of the water on the east and west sides were maintained at 6 to 12, and 28 to 36 inches, respectively. Subsequently, the field was allowed to drain naturally, although soil saturation persisted through December, 1989.

Soil plus garlic plants from the field were sampled on dates shown in Table 1. Each time samples were removed, the temperature of the soil was taken at 4 inches (see Table 2).

Garlic bulbs and cloves were observed from each sample period. Each sample of soil and plant material was sieved through 20- and 60-mesh screens to reduce the soil volume and retain sclerotia on the 60-mesh screen. The residue retained on the 60-mesh screen was then examined under the dissecting microscope. At least 100 intact white rot sclerotia were removed with forceps from two or three of the samples. The sclerotia were then surface sterilized and plated onto either water agar or potato dextrose agar to check for viability by the presence of characteristic fungal growth (3).

In 1990, two soil samples, each composed of twenty 8-inch deep x 1-inch diameter cores collected in an "X" pattern, were taken from quadrants of the field. Also, soil samples were collected from areas flagged in 1989 in which early and extensive pathogen reproduction had occurred. Soil samples were processed as per Crowe, et al. (3), and the inoculum density estimated.

Results

Soil temperature remained at or above 70°F for nearly eight weeks (Table 2). This was followed by four weeks in the 60's°F. During the 12th week of flooding, the temperature dropped just below 60°F. In November, (week 21), the temperature in drained soil was 42°F and 46°F in the remaining flooded area.

The garlic bulbs began to appear translucent about one month after flooding although they still remained firm. By the end of August (week 9), the bulbs all were soft and rotten when gently squeezed.

We were primarily concerned with determining when no more viable sclerotia could be found. We chose to destructively sample from specific areas of the field in which sclerotia were clustered in pockets around the base of rotted plants. Under these conditions, precise and predictable quantitative measures of sclerotia were not possible to derive. By gently squeezing each sclerotium, its physical integrity can be determined (2). As the season progressed, it became more difficult to recover intact sclerotia from the flooded field. Intact sclerotia were recovered in abundance in the first seven weeks, and in moderate amounts through about week 11. In weeks 12 and 13, we had to look carefully to find non-rotted sclerotial bodies.

By growing intact sclerotia on various culture media, it may be determined whether sclerotia are alive and/or heavily parasitized, or dead (2). We were not fully able to distinguish between sclerotia that might be sick and dying, and those fully capable of infection. Conservatively, if a sclerotium was able to show characteristic growth, it was determined to be viable (2). Viability results are listed below (Table 1). Even by July 10, 1989 (two weeks of flooding), viability was only 33-37 percent, which was less than the near 100 percent viability found for intact sclerotia recovered from normal field soil prior to flooding. Viability continued to decline through September 26, 1989 (13 weeks continuous flooding), when only 1 percent of seemingly intact sclerotia proved viable. Although we expected contamination from other organisms, bacteria and other fungi were found growing from only about 2 percent of all intact, surface sterilized sclerotia throughout weeks 2-13.

Inoculum density from quadrants in 1990 was below the level of detectability (1 sclerotium/L soil). However, a few viable sclerotia could be recovered when soil was selectively sampled from "hot spots" of white rot incidence in 1989.

Discussion

Between the drop in numbers of seemingly intact sclerotia recovered (these were not quantitatively collected relative to total field populations), and the loss in viability of seemingly intact sclerotia (Table 1), flooding proved successful in greatly lowering the initial population of sclerotia immediately following the disease incidence in June, 1989.

Continued decay of dead sclerotia, combined with survival of some sclerotia likely resulted in an increase in the proportion of viable sclerotia after week seven. Although it appears as if 99 percent of the sclerotia that were viable at the initiation of flooding were dead after 13 weeks, in fact the proportion was likely much higher (e.g. 99.9 to 99.99 percent). Possibly, if soil temperatures had remained above about 60°F, total eradication may have been achieved.

Subsequent sampling in 1990 revealed that inoculum density across the field was below the level of detectability. Crowe et al. (3) found that soil infestations a year after extensive white rot incidence was between 1,000 and 10,000 sclerotia/L soil when the disease was left unchecked. It appears that flooding to prevent further reproduction, combined with loss of already-formed sclerotia, resulted in 1,000 to 10,000 times fewer sclerotia than might have been present if the field was not treated.

In unpublished experimentation, F. Crowe and D. Hall found that 400 lb/a of commercially-injected and tarped 67/33 percent methyl bromide/chloropicrin killed 99 percent of sclerotia in a California field soil. The one percent remaining averaged over one sclerotia/liter soil, which proved sufficient to incite economically unacceptable losses (approximately 60 percent plant loss) in garlic replanted into the experimental area the next year. For the flooded field, recovery of no sclerotia from normal randomly selected sampling indicates that disease loss would be less than 10 percent of plants if the field were replanted to garlic. On the other hand, recovery of some sclerotia from selected samples where inoculum density would be expected to be highest suggests that at least some plant loss would occur. Perhaps more importantly, these data indicate that future movement of sclerotia away from this field by equipment, etc., would be far less than if left untreated, but that some small risk of such movement of sclerotia remains.

In parts of the world in which summer flooding can be maintained such that soil temperatures remain above about 60°F for longer than 13 weeks, flooding could possibly result in total eradication of the white rot fungus from infested soil.

In subsequent communication with Dr. Eliseo Redondo, governmental pathologist in Mexico, we have discovered that he has similar, but unpublished results from continuous summer flooding of test plots in the state of Guanajuato. At the time of publication of this report, experimentation is in progress in Mexico and Oregon to document the extent of reduction of inoculum density with continuous summer flooding, based on pre-determined inoculum densities.

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Table 1.

Percentage viability of intact (non-decayed) sclerotia (200-300 sclerotia per date) from soil collected in 1989 from a flooded field in central Oregon infested with the onion and garlic white rot pathogen, *Sclerotium cepivorum*. [Note in text that actual survival after week 7 was likely much lower than percentage viability, due to increasing decay of dead sclerotia.]

Date	Weeks Flooded	Field Location East	Middle	West
7/10	2	37		33
7/24	4	*	*	*
8/7	6	28	14	14
8/14	7	*	*	*
8/21	8	24		0
8/28	9	6		8
9/5	10	3.4		7
9/11	11	2		0
9/18	12	1		1
9/26	13	1		1
11/22	21	6		8

* Viability test not reliable.

Table 2.

Temperature (degrees F) from soil collected in 1989 at four inches deep from a flooded field in central Oregon infested with the onion and garlic white rot pathogen, *Sclerotium cepivorum*.

Date	Weeks Flooded	Field Location East	Middle	West
7/10	2	72	72	68
7/24	4	77	76	78
8/7	6	71	71	71
8/14	7	72	71	71
8/21	8	67	69	69
8/28	9	60	62	64
9/5	10	68	68	68
9/11	11	60	62	62
9/18	12	56	56	58
9/26	13	58	58	60
11/22	21	42	42	46

USE OF STIMULANTS OF SCLEROTIAL GERMINATION TO MANAGE INOCULUM DENSITY OF *Sclerotium cepivorum* AND TO CONTROL WHITE ROT OF ONIONS AND GARLIC*

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Abstract

For five field trials throughout western North America, with treatments replicated three or more times in randomized block experimental designs and in diverse soils naturally, and highly infested with sclerotia of *Sclerotium cepivorum*, the numbers of assayed sclerotia were reduced by as much as 98-99 percent in U.S. test plots treated once with 75 percent (plus related and active impurities) diallyl disulfide (DADS), a germination stimulant. All rates of application utilized, 0.56, 5.6, and 56 gal/a, were effective. DADS was less effective at the lower rates in a single Mexican trial. In untreated plots, there was measurable but limited natural reduction in sclerotial recoveries. In two of these trials, other chemically-related germination stimulants gave comparable results to diallyl disulfide, but dimethyl sulfoxide showed only moderate stimulatory effect. Both fall and spring applications of DADS were effective when timed to maximize the stimulus:response period within the temperature range of 48-70°F, based on the daily maximum soil temperature at 4 inches. Following fall application in regions where temperatures dropped below 48°F, the stimulus:response stopped, then resumed after rising above 48°F in the spring, with little or no reduction in net activity. Little or no further germination continued beyond a 2-2.5 month period within this temperature range, presumably due to enhanced loss of volatile stimulants at higher temperatures, and due to elevation of soil temperature out of the stimulus:response range. In all trials, soil moisture was managed to retard loss of volatile stimulants from the soil, to retain a biologically active stimulus:response system, and (in most trials) to initially move stimulants through the soil profile after application. For two trials, in which

* Between 1988-1993, a total of $103,500 was contributed toward this research by the following organizations: The Idaho-Eastern Oregon Onion Research Committee, The Walla Walla Sweet Onion Commission, the American Dehydrated Onion & Garlic Association, The Phillips 66 Company, The Mexican Garlic Export Association, The State of Oregon Center for Applied Agricultural Research (CAAR), and the Washington International Marketing Program for Agricultural Commodities and Trade (IMPACT). In-kind donations were made by Phillips 66 Company. Various growers cooperated in allowing research to be conducted on their farms, and assisted in land preparation, irrigation, etc.

applications of DADS were repeated in a second year, no sclerotia were recovered after the second application, which correlated with a low probability of loss of Allium crop plants based on earlier studies. When these plots later were planted with garlic, 90-100 percent of the plants in untreated plots developed white rot, and 0-10 percent became diseased with white rot in treated plots. In the trial with the best control over possible sources of re-contamination following treatment, no white rot occurred in any twice-treated plots at any rates of application. A sixth trial area not conducive to soil assay was directly planted to onions after comparable single and double applications of germination stimulants, with comparable results to the two trials replanted with garlic.

Introduction

Sclerotia of the white rot fungus *(Sclerotium cepivorum)* remains dormant in the absence of *Allium* plants. For several weeks or months following sclerotial formation, germination is restricted by an unidentified mechanism of constitutive dormancy (1, 2). Following this period, germination of sclerotia may be triggered by a number of specific volatile sulfides and thiols, which are breakdown products of amino acids peculiar to this genus, and which are released into the soil from roots (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 17, 18, 19 -- see 7, 18, and 19 for reference to specific compounds).

Germination in soil is stimulated between about 10-22°C (50-72°F), and may be restricted to the spring and fall months in some regions (8, 13, 23). The fungus itself has a somewhat broader range of temperature tolerance once mycelium is actively growing (13, 23). Germination of white rot sclerotia is optimal at intermediate soil moisture levels (-300 millibars, or about field capacity). Very wet soil (greater than -13 millibars, near saturation) inhibits germination, possibly by preventing volatilization and distribution of stimulants, and prolonged saturation promotes sclerotia decay. Too low moisture (less than -3 bars, quite dry) inhibits both stimulated germination and growth of the pathogen (13), and may promote loss of stimulants from the soil. Although the mechanism of stimulated germination is not well defined, limited germination partly may be a result of rapid volatility of the stimulants and their loss from the soil system before stimulation can be effective (8). Following germination, the fungus dies off without significantly reproducing if the bulbs of a host plant fail to become infected (2, 13, 14, 22). A small number of sclerotia (well below replacement level) form on host roots, and a low frequency of small, secondary sclerotia may form near to sclerotia (22). Neither of these sources are of much importance. In test systems in the lab and greenhouse, in small, highly-controlled field tests, and from observations of field situations, the level of such stimulated germination may be nearly 100 percent (2, 8, 13, 14, 22). Most test systems have utilized sclerotia and stimulants in full or partial confinement. Data from Coley-Smith and Parfitt (8) are the best to use for dosage-response-time in relation to temperature and seasonality in the field.

In the field, mycelium from sclerotia may infect roots up to 1-2 cm away, and successfully decay bulbs from sclerotia located 30 cm below stem plates (12). Abundant bulb infection was shown to result from secondary spread of mycelium among root systems (12, 14).

Initial infection occurred from sclerotia located at various depths, as well as from direct infection of single plants by shallowly-located sclerotia at high inoculum density (12, 14). Further, bulb decay occurred later when secondary infection was dominant, and earlier when direct infection was dominant. Post-season inoculum densities from a wide range of pre-season inoculum densities were similar, which was attributed to the relative amount of host biomass available for reproduction of sclerotia at the time of bulb infection (12, 14).

In addition to natural products, germination stimulants can also be recovered from petroleum. Diallyl disulfide (DADS), a primary flavor ingredient of expressed garlic juice and a primary breakdown product of the amino acid allylcysteine sulfoxide (alliin), which leaks from garlic roots, is one commonly available petroleum-derived stimulatory compound. Relatively pure DADS, applied by injection or irrigation at rates between 0.25 and 12.5 g to 1 m^2 plots in the field in England influenced as many as 90-99 percent of sclerotia to germinate through the soil profile. Activity was sharply reduced in summer months due to rapid loss of DADS from the soil, and was "postponed" during winter months when DADS became non-volatile (8), and during which time sclerotia would have been dormant (13). Very high concentrations of DADS may be inhibitory to germination (22), which further points out that the stimulation mechanism remains poorly defined.

In Australia, in an attempt to develop a commercialized field-scale treatment, artificial onion oil (a proprietary food-grade mixture of diallyl disulfide, di-isopropyl disulfide, allyl isothiocyanate, allyl alcohol, garlic oil, and nut oil) was injected into the soil with a commercial fumigation device at various rates and depths at one month prior to planting of onions. For single applications of several rates, this resulted in 77-91 percent reduction in sclerotia and reduced yield losses due to white rot from 57 percent to 13 percent (16, 20, 21). Actual rates of application were not determined due to the unknown concentrations in the basic product. This approach to control of white rot was not further investigated due to erratic control under annual cropping conditions, lack of availability of a well-defined and inexpensive stimulatory product, and by re-direction of the principle investigator into other endeavors (personal communication, P. Merriman). Data in the western United States (14) indicate that for commercially-acceptable control of white rot, most natural field populations of the pathogen would need to be reduced by 1,000-100,000 times. Reduction by only 90 percent, or less, as in Australia, would be insufficient. Also, based on conversations with P. Merriman, it is likely that timing of application may not have been carefully coordinated with the optimal responsiveness of the pathogen.

We wished to determine whether germination stimulants might be successfully applied to naturally infested commercial fields, such that infested fields might be replanted with onions or garlic without risk of economic crop loss. The basis for evaluation of treatments was the magnitude of drop in viable numbers of sclerotia based on pre- and post-application soil assays, and whether sclerotial numbers could be driven below the approximate economic threshold established for white rot under conducive temperature regimes for several regions of the western United States (14, and see Figure 1). In the field trials described below, we initially wished to determine the response achieved by single applications of a wide range of product amounts and in diverse regions and soil types, in order to better plan future control strategies and costs.

Materials and Methods

Soil sampling/assay. Soil sampling and assay was as per Crowe, et al (14). At each time of sampling two sub-samples, each composed of twenty 12 x 1-inch diameter soil cores, were taken randomly from each field trial plot. For samples taken from recently treated soil, sclerotia frequently were in the process of germination, so samples were processed within two days or air dried at room temperature with the assistance of fans and held in a dry state, in order that the sample reflect the germination status at the time of sampling. For each sub-sample, 500-ml soil were assayed for sclerotia. Soil was washed through 60- and 20-mesh screens to concentrate the size fraction of soil containing sclerotia (approx. 0.5 mm dia). Residue retained on the 60-mesh screen was discarded, and organic matter from the residue from the 20-mesh screen was separated from more dense soil particles by sucrose flotation. The organic residue from each sub-sample was observed under a dissecting microscope. Objects that appeared to be sclerotia of *Sclerotium cepivorum* (smooth, predominantly round, and of the appropriate texture and shade of black) were classified into the following categories: (a) Non-germinated -- rind intact, body firm, no germinating condition, (b) Germinating -- with a plug of characteristic whitish mold emerging from a point on the rind, (c) Sclerotia that probably germinated (or possibly decayed) much earlier -- only the full or partial shell of the rind present, or (d) Sclerotia that probably were decayed or parasitized -- rind not firm to touch with forceps, sometimes with moldy growth of other organisms present. The presence or absence of very small sclerotia were noted to determine the abundance of sclerotia that may have formed secondarily (22). Viability of intact bodies thought to be sclerotia of *S. cepivorum* was determined by plating surface sterilized bodies on water agar following cracking of the rind (14). Inoculum density of plots was estimated by totaling the number of viable sclerotia from 500ml sub-samples. Inoculum density was expressed as the number of intact, viable sclerotia/liter of soil.

Inoculum density was determined from each plot in each trial just prior to treatment with germination stimulants. After application, inoculum density was reassessed monthly until no further response was seen in plots treated with germination stimulants.

Selection of trial areas. Field trials were located in several (not all) regions of western North America in which white rot disease was of high commercial interest, either as a well-established or emerging concern (Table 1). Because of the diversity and expanse of the territory involved, a local cooperator (county extension agent, extension specialist, or similar interested cooperator) was required for certain aspects of management of trial areas. In each area selected, several fields with a well-established history of white rot disease were sampled preliminarily for inoculum density determinations. (The single exception was near Salem, Oregon, on muck soil with nearly 100 percent organic matter, from which sclerotia of *S.*

cepivorum were difficult to assay.) In general, areas within fields were chosen if an area of the field large enough to contain a field trial was generally infested. Inoculum density above 15 sclerotia per liter of soil was preferred, so that inoculum densities before and after treatment would be more reliably evaluated.

Germination stimulants. Most materials tested for their ability to stimulate sclerotia of *S. cepivorum* in the field were obtained from Phillips 66 Company, Bartlesville, OK. Diallyl disulfide (DADS) was used in all trials. DADS 75 percent included 10 percent diallyl sulfide, 10 percent diallyl trisulfide, 1 percent pentane and 6 percent higher order, related sulfur materials (e.g. diallyl pentasulfide and hexasulfide). DADS 90 percent included mostly diallyl trisulfide as the remainder component.

Other Phillips materials used in some trials included 98 percent di-N propyl disulfide (DNPDS), including 2 percent related compounds, and "POLY", which was a mixture of related components produced by removing most of the DADS by distillation. "POLY" included 20-40 percent DADS., 30-69 percent diallyl trisulfide, 10-30 percent diallyl tetrasulfide, 0-2 percent diallyl sulfide, 0-5 percent diallyl pentasulfide, 0-0.2 percent pentane, and 0-2 percent related higher order sulfides. All components for the above products were known or believed to be stimulatory to sclerotia of *S. cepivorum* based on the active C-C-C-S structure common to each compound (7,17, 18, 19).

In some trials, dimethly sulfoxide (DMSO from the Sigma Chemical Co.) also was used. DMSO is related to the above compounds and it is relatively inexpensive. Even though it did not have the common C-C-C-S structure, sulfoxides can convert to disulfides, sometimes rearranging in the process (7, 17, 18). It did not seem to have been specifically tested for stimulated germination of *S. cepivorum* in previous investigations (7, 17, 18, 19). No known germination stimulants were identified as minor components of the DMSO.

Product application. All products were tested at three rates of application: 0.56, 5.6, and 56 gallons per acre. The amount of product per plot area was premixed using an equal amount of non- ionic wetting agent to facilitate mixing, brought to a total volume of either 1 gallon or 5 gallons with water for application to the plot area. In tests not reported here, a range of commercial non-ionic wetting agents had no effect on germination of sclerotia, nor any effect on stimulated germination with DADS. Therefore, no wetting agent was added to untreated check plots. In preliminary tests, surface irrigation following application of DADS to the soil surface moved the detectable odor of DADS to 10-12 inches deep in the soil profile, and sclerotia were stimulated to germinate at that level. In all tests reported here, premixed products were applied to the plot area with watering sprinkler cans, followed by (a) sprinkler irrigation, (b) flood irrigation, (c) rototillage to 10 inches followed by sprinkler irrigation, or (d) rototillage to 10 inches followed by flood irrigation. The time between application and irrigation was minimized to reduce loss of stimulant by volatilization. The time between application and irrigation ranged from 5 to 30 minutes.

Experimental design. All field trials were randomized block designs with four or more replications per treatment, unless otherwise indicated. Plots ranged from 8 x 12 ft to 12 x 12 ft in size. Plots were separated by at least 15 ft in all trials. Data was evaluated by analysis of variance.

Soil temperature and moisture considerations. Products were applied either in the fall or spring, based on soil temperature at 4 inches. Fall applications were made as close as possible to when the daily maximum soil temperature remained below 70°F for several days. Spring application coincided with maximum daily soil temperature rising above 48°F for several days. Soil temperature was monitored weekly during the period of germination activity.

In addition to irrigation immediately following product application, irrigation was further provided (unless there was rainfall) to maintain an active stimulus:response (13). General guidelines were that plots were irrigated with 1-2 inches water whenever soil moisture fell below field capacity during the period when soil temperatures were conducive for stimulated germination. The actual number of irrigations varied among trials.

Weed control. Weeds were eliminated from plots using commercially available herbicides on an as-needed basis. Plots were not tilled or otherwise disturbed during weed control.

Other plot management. In all field trials, traffic of all types was discouraged during the course of the experiments, to prevent movement of untreated soil into plots. In flooded plots, any washing of soil over the surface between plots was prevented by the dikes used to contain the flood irrigation, but in sprinkler irrigated plots, this potential source of contamination was not prevented. For trials that were carried over for second year application or for re-planting, soil in plots was spaded and/or rototilled as needed to encourage product infiltration and normal root development. Care was taken not to move soil among plots during these operations.

Results

Dates of application. Madras: Treated October 15, 1987. Walla Walla: Treated October 10, 1989, and again October 25, 1990. Nampa: Treated April 14, 1990, and again April 10, 1991. Five Points: Treated November 19, 1990. San Miguel de Allende: Treated December 2, 1990. Dates of treatment at Salem were not compiled as of this report.

Qualitative observations of movement through soil of germination stimulants. Initial movement of germination stimulants through soil was evaluated in 1987-88 near Madras, OR. Products were applied as indicated into dammed furrows in plots located in a furrow-irrigated field planted with Kentucky bluegrass. Immediately after application, furrow sections were filled and water was allowed to infiltrate downward and across formed beds, then this was repeated. Soil cores were taken from the tops of beds later in the same or following day. Strong odor of DADS was present at the center of beds in all soil depths to 10-12 inches. It was not determined whether the odor was due totally to bulk movement of

DADS into the lower profile sampled, or to volatile re-distribution of DADS, but based on this and observations of germination of sclerotia at 10-12 inches, we considered there to be few barriers to movement of DADS with irrigation water.

Qualitative observations of recovered sclerotia.. Sclerotia behaved similarly in all trials. In all trials, no sclerotia were found clearly decayed or parasitized at any time of recovery. No sclerotia were found in a germinating state in any untreated plot, and spent rind shells characteristic of recent past germination were rare. After one month, some sclerotia were found intact, others germinating (hyphal plug emanating from single point on rind), and others seemingly well past active germination (only rind shells remaining). For fall-treated plots, there typically was only one month of activity before temperatures dropped below 45°F and all further activity stopped, until soil temperature began to consistently rise above 45-50°F in the spring, at which time sclerotia continued to be found in a germinating state for another 1.5-2 months. For both fall and spring applications, active germination continued until either (a) no intact sclerotia could be recovered, or until (b) about 2.5-3 months of conducive soil temperatures had passed [excluding the time period of winter dormancy], when no more stimulant odor could be detected. For spring treatments, the 2.5-3 month period of activity occurred prior to soil temperatures rising generally above 70°F when the stimulus:response system would become inactive.

Curiously, during the first month following application of all known germination stimulants (but not DMSO), the number of intact sclerotia frequently rose by 50-150 percent in many plots, even though there were abundant germinating sclerotia and spent shells present. This effect was inconsistent among replications. This might be explained if there was a brief period of reproduction of sclerotia during this first month. Even though this was not expected, nor is this supported by any observations in the general literature, such applications would not simulate any natural field condition where stimulants would leak continuously at low rates from host roots. With DADS and "POLY" materials, the numbers of intact sclerotia declined greatly during the second month, whether such a possible reproductive phase occurred or not. With DNPDS, the same apparent rise in intact sclerotia occurred during the first month in two separate tests. In one of the tests (Walla Walla), the second month pattern was similar to that seen with DADS and "POLY" materials -- germination continued and few intact sclerotia were recovered after 2.5 months. However, in the other test in which DNPDS was included, even though germination did continue, decline in number of intact sclerotia were not as great, so that a the difference in final inoculum density in DNPDS treatments was only intermediate between untreated plots and DADS or "POLY" treated plots. In untreated plots, no elevation in intact sclerotia was ever seen in the first month. In DMSO-treated plots, there was a lesser amount of active germination in the first month than in plots treated with DADS, "POLY", or DNPDS, and there was no elevation of intact sclerotia.

In no recoveries from any plots did there seem to be any preponderance of very small sclerotia suggestive of secondary sclerotia (22). Nevertheless, the issue of apparent reproduction described above requires further investigation.

Pre- and post-treatment recoveries -- DADS rate comparisons. Data presented here are for inoculum densities after all activity of germination stimulants had terminated 3 months after treatment. For brevity, data supportive of the qualitative observations described above after one-two months is not presented here.

All data recovery of intact, viable sclerotia at Nampa, Walla Walla, and San Miguel are shown in Table 2. For each plot, each post-treatment recovery was expressed as a percentage of the pre-treatment recovery (Table 3). Percentages for each replication were then averaged to determine the means presented in Table 2. Analysis of variance was evaluated using these percentages.

At Walla Walla, a few days after initial treatment in the fall of 1989, heavy precipitation caused overground movement of water. Surface water passing over certain treated plots was observed to then pass over an adjacent untreated plot over 25 ft away. At the one month post-treatment sampling, some stimulated germination was observed, presumably due to low dosage of stimulant carried in the surface water. This effect did not persist into the following spring. In Walla Walla, additional plots external to the main trial area had been included for other reasons. In these external plots, no loss of sclerotia from stimulated germination occurred, nor did this seem to occur in the untreated plots in the other replications of this trial. For these reasons, the data from the affected replication was substituted with data from one of the external untreated plots.

In all trials, DADS treatments at all rates lowered the recovery of viable, intact sclerotia well below the level of natural attrition in untreated plots. Performance was better in the two U.S. trials than in the Mexican trial. Reasons for this difference in performance are not known, but the great distance between the project leader and the cooperators in Mexico, together with the language difference, did create some difficulties, and possibly some confusion, in plot management.

Pre- and post-treatment recoveries -- comparisons among various germination stimulants. Data are presented here similar to the above section. Data for a separate trial at Walla Walla from the one above, and from the trial at Five Points are also included in Table 2. Data for DADS 75% and DADS 90% were nearly identical, so the means shown on Table 2 are averaged data for the two treatments. Recoveries in DADS treatments were similar to those found for other U.S. trials.

"POLY", containing some DADS but with elevated proportions of less volatile stimulants, performed at least as well as the more purified DADS products.

Recovery of intact sclerotia from plots treated with DNPDS was slightly higher in the Walla Walla trial than recoveries from plots treated with DADS products, but a simple LSD test did not separate the means of DNPDS treatments from DADS and "POLY" treatments. Future analysis using Duncan's Multiple Range test might possibly find the performance of DNPDS significantly different at Walla Walla. In the trial at Five Points, however, recoveries of intact sclerotia from DNPDS treatments was quite high in comparison to DADS treatments. The number of intact sclerotia recovered from the low rate was not statistically different from the untreated check, and the number recovered from the high rate was substantially higher than that found with other known stimulants. Note in the qualitative discussion above, however, that there occurred substantial stimulated germination in all DNPDS plots, and that one-month activity was quite high, whereas there was no germination in the untreated check plots. Again, this data may be explained if substantial early reproduction occurred, followed by an inconsistent level of continued stimulated germination in the second month of biological activity.

Planting of selected field trials, and disease evaluation. Based on failure to recover sclerotia at field trials at Walla Walla and Nampa in 1991, the plots were prepared for planting in the fall of 1991. Soil was hand spaded and tilled. Virus-free garlic cloves that had been sized were hand planted 3 inches deep in rows spaced. At Walla Walla, clove size was 2.9 g $\pm$ 0.1 g, and 115 cloves per five 11 ft rows spaced 1 ft apart were planted on September 25, 1991. At Nampa, clove size was 3.07g $\pm$ 0.1 g, and 117 cloves per nine 12 ft rows spaced 1 ft apart were planted on September 23, 1991. The total number of cloves planted per plot was 575 and 1,056 at Walla Walla and Nampa, respectively. Again, care was taken to not move infested soil into plots during plot preparation or planting. Plots were irrigated as before, once in the fall of 1991, and from spring through early June of 1992. Plots were fertilized with 200 lb/a N as ammonium nitrate in the spring of 1992. Stand counts were taken beginning at emergence until the stand stabilized. Disease evaluations were conducted periodically during the spring and summer of 1992 based on top symptoms of white rot, and were confirmed by gently removing some soil from around the base of some plants. As bulbs matured, irrigation was discontinued, and bulbs were allowed to mature during June, 1992, at both trials. Harvest was on June 30 and July 1, 1992, at Nampa and Walla Walla, respectively. All non-diseased bulbs were recovered, counted, and weighed.

Some fall emergence occurred in all plots, but no plants were determined to be lost to factors other than white rot disease. No symptoms of white rot were observed in the late fall/early winter of 1991. Final stand counts included plants that died early in the season. Mean final stand counts at Nampa were 919, 938, 931, and 939 at Nampa, and 437.0, 454.7, 477.0, and 486.3 plants per plot for treatments of 0 (untreated), 0.56, 5.6, and 56 GPA DADS, respectively. At Walla Walla, plants in untreated plots showed early symptoms of white rot even during emergence. Analysis of variance indicated no significant differences in final stand at either Nampa or Walla Walla ($p \leq 0.05$), despite the trend of less stand where germination stimulants were not treated. Appearance of first white rot symptoms in 1992 at Nampa were in late April, and there was no suggestion of pre-emergence stand loss in stand count data. Excluding any pre-emergence losses, Table 4 shows the expected percentage disease loss based on pre-plant inoculum densities in the fall of 1991, the actual percentage disease loss recorded at harvest in 1992, and the weight of the harvested bulbs from each plot. Statistical differences among plots is not shown, but differences between treated and untreated plots were highly significant ($p \leq 0.001$) with respect to percentage disease and harvested weight. There were no differences among rates of application of DADS with respect to either parameter, except that the small (1%) percentage of white rot in the low rate of application at Nampa was difference from the absence of white rot (0%) at medium and high rates of application ($p \leq 0.05$)

Trials in a muck soil near Salem, Oregon. In this area, muck soil could not be assayed for sclerotia. Trials areas were established in 1990, 1992, using DADS 75 percent, and in 1992 using treatments with DADS 75 percent, DNPDS and "POLY" . Onions were planted in the spring of 1990 following both fall and spring treatments. Data is not well summarized at this time, but results from DADS treatments in 1990, from the same rates of application as in other trials, were similar to the trials above, which were planted with garlic. Onions will be planted in the spring of 1993 in order to determine the effect of the 1992 treatments.

Discussion

In general, we greatly reduced the inoculum density in all field plots in which DADS was used, although reduction was not as much in the Mexican trial as in the U.S. trials. In field trials with germination stimulants, we were careful to eliminate or avoid all sources of interference with product efficacy:

a. We avoided fields in which white rot recently occurred, by at least 1/2 year, to avoid constitutive dormancy of sclerotia.

b. We timed applications at the earliest fall temperature (when temperatures were falling) at which the fungus became responsive, or similarly timed the spring application (when temperatures were increasing).

c. We irrigated over treated soil to help delay loss from soil by volatilization, and to assist retention of volatile germination stimulants in the soil.

d. We avoided re-planting a susceptible crop too soon after application of germination stimulants. Based on soil recoveries, it is likely that this time would need to be at least three months of active stimulatory period. For fall application, this three-month minimum would need to be extended by the period in which soils remained below 10°C during the winter.

f. Where possible, we monitored populations prior to re-planting of onions or garlic, in order not to plant until populations have dropped below the assumed economic thresholds (14).

In our field trials, we obtained excellent results with surface applications of DADS between 0.5-5.0 mL/m^2 product. Less product likely would be less effective (8). It remains uncertain why the results from the single application in Mexico was less effective than in the U.S. trials. Results from small plot trials in England were comparable to our U.S. data (8). More field trials in other parts of the world in which white rot occurs would be desirable.

At Walla Walla and Nampa, we applied twice over a two-year period. Initial populations ranged as high as 100 sclerotia/mL soil in some plots. Based on 98-99 percent drop in population after one treatment, and failure to recover sclerotia at all in repeated soil assays after two treatments, we may have lowered populations by 10,000 times after two treatments. We did lower inoculum below our ability to detect sclerotia with our soil assay.

Our decision to treat twice was based on the expected losses from the remaining one percent after one treatment, assuming that 1 percent was randomly distributed. Randomly distributed, this one percent would be expected to incite higher than acceptable plant loss, based on Figure 1 (14). More recent data from Coley-Smith (personal communication) and from our test results at Salem, Oregon, in which some plots only received one application of stimulant, suggested that this decision could have been conservative. Coley-Smith found as we did that about 1 percent of the population remained after one treatment conducted optimally. However, he further determined that all surviving sclerotia were at or near 30 cm depth (12 inches). Other data (12) indicates that sclerotia at this depth only contribute slightly to the total disease loss. At both Nampa and Walla Walla, no sclerotia could be recovered from repeated soil sampling following the second application, for samples collected to 30 cm.

Little white rot occurred in 1992 in Nampa at the lowest rate of application, and none occurred at medium and high rates of application of DADS. At Walla Walla, no white rot occurred during the first half or more of the spring, although as many as 15 percent of the plants became infected with white rot by harvest. Crowe and Hall (12) found that such late season loss is suggestive of infections that occurred very deep in the soil profile, perhaps 10-12 inches deep. The delay was a combination of the extra time for roots to penetrate to those depths, combined with the time for mycelium to grow upward on the root system to stem plates. No symptoms arise until stem plates become infected. It seems likely that neither of the two applications at Walla Walla were sufficient to stimulate all sclerotia to germinate at that depth. This argument fits with data from Coley-Smith in England (personal communication) who failed to stimulate all sclerotia at 10-12 inches using surface-applied DADS. Most likely, more efficient means of application would surmount this deficiency. White rot at Nampa seemed to appear later in 1992 than it did at Walla Walla. Conceivably, with a longer season, more disease may have appeared at Nampa if deeply-placed intact sclerotia remained there also. In a short disease season, root infections by these sclerotia may not have had time to appear.

The apparent reproduction that occurred during the first month after application with any products containing either DADS or DNPDS was not expected. This phenomenon is not reported elsewhere and begs confirmation. In general, *S. cepivorum* has been found incapable of reproduction on soil organic matter (1, 2, 14, 23) and only limited reproduction has been observed in onion or garlic roots (1, 2, 14, 22). The rates of application used for DADS and DNPDS would not be expected to provide enough nutrient base for reproduction, nor did the size of a significant fraction of intact sclerotia apparently drop during this period (although this was not specifically measured), which would have suggested formation of secondary sclerotia. If secondary sclerotia formed, they were not of the very small sclerotial diameters indicated in other reports (22), although such reports generally have observed secondary sclerotial formation in the absence of any exogenous nutrient supply.

DNPDS seemed to perform almost as well as DADS in the Walla Walla trial, but clearly under-performed in the Five Points trial. On the other hand, first month activity of DNPDS was very similar to that of DADS. This suggests that the apparent failure of DNPDS was more likely due to behavior of the product and pathogen later during the three month period of activity, rather than failure to stimulate sclerotia. Details of the stimulus:response, and of apparent reproduction, seems necessary to determine in future investigations.

The reduction in intact sclerotia in plots treated with DMSO also was unexpected, even though activity was much less than with other products. In the first month following treatment, the level of stimulation directly observed under the microscope was very modest in comparison to products containing DADS or DNPDS. DMSO was only used at the highest rate of application for all products. It seems likely that there would be even less stimulatory activity at lower rates.

Based on manufacturer information, the low and medium rates used for DADS and DNPDS might cost no more than many products used in agriculture. At this time, the product manufacturer and a potential product developer are presenting a chemistry package to the U.S. Environmental Protection Agency for determination of the regulatory procedures required to register these products for pesticidal use against onion and garlic white rot. Future research on the generality of our results, and on improvement in formulations and application procedures, awaits the EPA's response, which will determine the potential developmental costs for the manufacturer and product developer.

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Table 1. Trial areas and soil types in which germination stimulants were tested, 1987-92, for management of inoculum of the onion white rot fungus, <u>Sclerotium cepivorum</u>.

		PRE-TREATMENT INOOCULUM DENSITY*	
TRIAL AREA (nearest town)	SOIL TYPE	Mean	Range
		(viable sclerotia/liter soil)	
Madras, OR (Jefferson Co.)	Madras loam.	22.8	10-81
Milton-Freewater, OR (Umatilla Co.)/Walla Walla, WA (Walla Walla Co.)	Oliphant silt loam	58	15-146
Nampa, ID (Canyon Co.)	Nampa sandy loam	17.6	2-62
Salem, OR (Marion Co.)	100% organic muck	undetermined	
Five Points, CA (Fresno Co.)	Panoche sandy loam	53	6-161
San Miguel de Allende, Gto., Mexico	undetermined	19	35-186

* Average for all plots

Table 2. Percentage recovery of intact, viable (non germinated) sclerotia of Sclerotium cepivorum from plots treated or not treated with germination stimulants, after three months within the temperature range suitable for stimulated germination*.

			percentage recovery of intact, non-germinated sclerotia								
			products and rates (GPA) applied								
			DADS			POLY		DNPDS		MSO	
trial location	when applied	untreated check	0.56	5.6	56	5.6	56	5.6	56	56	LSD.05
Walla Walla	fall, 1989	96.2	3.1	1.2	1.2						17.8
Walla Walla (retreated)	fall, 1990	63.3	0	0	0						8.2
Nampa	spring, 1990	91.8	12.3	0	1.2						34.4
Nampa (retreated)	spring, 1991	80.0	0	0	0						47.4
San Miguel	fall, 1990	90.4	32.9	5.5	3.1						15.5
Walla Walla	fall, 1990	9.8	-	1.8	2.7	0	1.1	6.5	4.4	51.7	16.2
Five Points	fall, 1990	0.7	-	1.1	2.0	2.0	0.5	80.2	30.0	49.6	29.9

* Percentages based on initial pre-treatment inoculum density of viable sclerotia just prior to initiation of field trials.

Table 3. Individual plot inoculum densities of sclerotia of *Sclerotium cepivorum* before and after treatment with diallyl disulfide (DADS). Data are from trials located near Walla Walla, Washington, and Nampa, Idaho. Initial treatment was in October, 1989, and April, 1990, respectively, and plots were retreated in the same months a year later. Final inoculum density was determined in the late spring of 1991 for both trials. This data, or comparable data from other trials, was used to convert to percentage changes in inoculum density as shown in Table 2.

location	Walla Walla				Nampa			
gpa DADS	0	0.6	5.6	56	0	0.6	5.6	56
plot replication number								
1	21/47	0/100	0/70	0/31	8/8	0/25	0/6	0/3
2	25/70	0/38	0/60	0/42	31/59	0/2	0/5	0/3
3	32/113	0/15	0/21	0/146	8/16	0/4	0/5	0/41

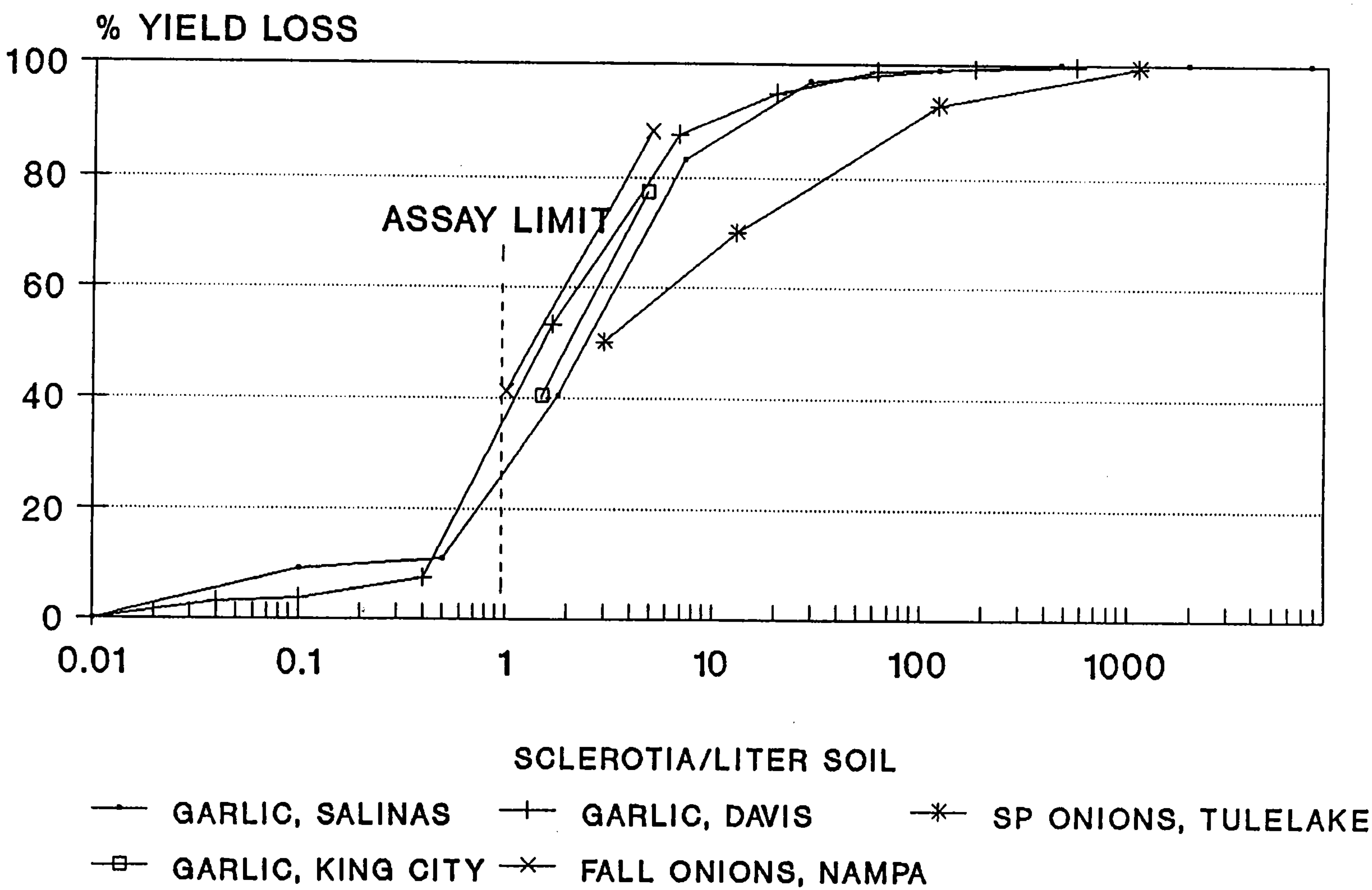
Inoculum density is the number of viable sclerotia recovered per liter of soil per plot. Numerator is the inoculum density after two applications of germination stimulants. Denominator is the inoculum density prior to any treatments.

Table 4. White rot disease (Sclerotium cepivorum) data from field trials near Nampa, Idaho, and Walla Walla, Washington, planted with garlic in September, 1991 and harvested in June, 1992. Expected disease in 1989-90 was based on inoculum density prior to application of germination stimulants, and expected disease in 1992 was based on inoculum density present at the time of planting.

	Walla Walla				Nampa			
gpa DADS	0	0.6	5.6	56	0	0.6	5.6	56
Expected % disease Pre-trt, 1989-90	93	85	87	88	73	63	52	57
Expected % disease Post-trt, 1991-92	72	0-10	0-10	0-10	56	0-10	0-10	0-10
Actual % disease 1991-92 garlic crop	99	16	9	11	65	2	0	0
Harvest wt (Kg/plot) 1991-92 garlic crop	0	7	7	8	20	49	51	53

a. Based on Fig. 1 and Table 2.
b. WW treated 10/89 & 10/90; Nampa treated 4/90 & 4/91.
c. Spring stand counts at Walla Walla were 445-502 plants per 10 m2 plots; at Nampa were 870-1001 plants per 20 m2 plots. Disease data include only bulbs infected with the onion and garlic white rot fungus.

Figure 1. Yield loss Vs. inoculum density relationship for onion and garlic white rot disease (Sclerotium cepivorum) in the Western U.S. Data are from Crowe, et al (14), supplimented with unpublished data. All data are from California, except for data from Nampa, Idaho.



EFFECT OF INOCULUM DENSITY AND CONSECUTIVE YEARS OF PROPANE FLAMING OR TILLAGE ON VERTICILLIUM WILT AND YIELD AND OIL COMPOSITION OF PEPPERMINT*

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Abstract

A field previously cropped to potatoes was fumigated in 1988 with 400 lb/a methyl bromide (54:46). Plots (10 x 160 ft^2) were either non-infested or infested with one of four inoculum densities of the mints strain of *Verticillium dahliae* in fall, 1989. Peppermint (cv 'Todds') was planted in the spring, 1990. Mint stems in half of each plot were either propane flamed in the fall of 1990 and 1991, or tilled in the spring of 1991 and 1992. Experimental design was a 5x-replicated split plot with inoculum density (ID) as the main plot and cultural practices as the subplots. Wilt symptoms increased in tilled plots from 1990 through 1992, but remained similar each year in flamed plots. Averaged for all ID, the number of wilt loci was significantly ($p < .01$) higher (91.4) in tilled plots compared to flamed plots (18.6) in 1992, although there were nearly no wilt symptoms in non- infested plots or in those with the lowest initial ID irrespective of cultural treatment. Winter damage (1991-92) was severe only in the flamed plots with the highest rate of initial infestation, however, stands were generally thinner and weedier in the flamed plots at all ID in 1991 and 1992. Cultural practices had no direct effect on hay or oil yield in 1991 or 1992, but there were significant effects ($p < 0.05$) of ID and there was a significant cultural practice-ID interaction, ($p < 0.05$). In 1992, for example, for initial ID of 0, 0.01, 0.1, 1.0, and 5.0 microsclerotia (MS)/g soil, tilled plots yielded 74.5, 67.9, 67.3, and 58.7 lb/a of peppermint oil, whereas flamed plots yielded 71.7, 65.7, 68.0, 70.1, and 59.9 lb/a of peppermint oil, respectively. Thus, in the second and third year of mint production (two rounds of cultural treatments), mint performed better with tillage for initial ID's lower than 0.1 MS/g soil, but above this initial ID peppermint performed better with flaming. Of 23 oil components analyzed in 1992, two decreased and three increased significantly ($P < 0.05$) with increasing ID. Similarly, two were reduced in tilled vs. flamed plots. These shifts in oil composition with increasing ID were characteristic of oil produced under increasing plant stress. Differences in oil composition between flamed vs. tilled treatments were characteristic of differences due to plant maturity, since plant growth was delayed by spring tillage. Changes in ID are being monitored within the trial area, and evaluations of ID in non-uniformly infested commercial fields are in progress.

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Introduction

Verticillium wilt of peppermint, incited by specialized mint strains of *Verticillium dahliae*, now exists in most fields in most mint-producing regions of the United States. Because of limitations on suitable climate and soils, the mint industry no longer has the option of easily relocating to "wilt-free" areas to maintain reliable production. Similarly, in some regions limitations on agronomically suitable acreage for mint production has forced growers to increasingly replant peppermint into soils that (based on experience) are badly "wilted-out", i.e. soils presumably in which high populations of the mint strain persist from previous disease episodes. With increasing frequency, growers are disappointed to find fields of peppermint developing severe wilt within the first, second, or third harvest year. This situation has occurred in the past in previous mint producing regions. Gradual intensification of wilt forced such a pattern of mint decline until mint production was discontinued in New England near the turn of the century. After relocation of the industry to the mid-West early in the 1900's, many acres were discontinued in Michigan by the late 1940's (18). Since mint introduction in the 1940's and 1950's the current intensification of verticillium in the western states, and continued elimination of acreage in the upper mid-western states, may represent the third cycle of production decline.

In the Willamette Valley of western Oregon, management of *V. dahliae* since the mid-1960's has been by post-harvest flaming of mint, in combination with no fall or spring tillage. Flaming has been shown to kill the pathogen in its main reproduction site in the stems, and no-tillage presumably disallows the return of inoculum missed by flaming into the soil (perhaps 20-40 percent) (10, 16). Yield analyses conducted on plots with various flaming and tillage combinations suggested about half of the improvement in yield could be attributed to flaming, and half to no-tillage. Although changes in soil inoculum density of microsclerotia were not investigated, the success of the flaming and no-tillage combination in preventing increase wilt has been attributed to keeping the inoculum density from increasing. All previous flaming/tillage research was conducted on the highly susceptible cultivar 'Black Mitchum'. Virtual elimination of tillage in the Willamette Valley has led, however, to increased problems with root and stem boring insects, which were largely controlled by tillage (10, 23, and R. Berry, personal communication). The wilt response of the newer and more tolerant peppermint varieties 'Todds' and 'Murray', and similar advanced breeding selections, is less well documented. All are known to succumb to wilt, but less so than 'Black Mitchum'.

In other regions of the western United States, flaming/no-tillage was less tested and is less consistently used. There is the recognized effectiveness in many regions to till for control of insect pests (23), and to lessen the impact of winter damage on shallow rhizomes. In the mid-western United States, annual fall tillage is considered a requirement to avoid winter kill of rhizomes (18), although in the western states winter damage is not as regular an occurrence. Other management practices used in the central Oregon and elsewhere include careful tracking of field histories (and avoiding fields with a known history of excessive wilt); shortening the period of time a mint stand is held; and avoiding crop rotations believed to build inoculum levels (personal observation). More recently, control of nematodes (especially *Pratylenchus*) has been shown likely to lessen the impact of verticillium wilt, as these pathogens seem to interact (20, 21). Other cultural practices generally have proven ineffective in preventing wilt or have not been investigated thoroughly. Acceptably-resistant high quality varieties have been difficult to develop, but likely will develop over time. Other promising developments could include management of wilt via irrigation management as has been demonstrated with potatoes (7, 8)

Many of the perceptions of peppermint wilt progression over time, and of management effects, assume some knowledge of the population dynamics of *V. dahliae* microsclerotia below the soil surface, but no population dynamics have been investigated in mint to confirm these perception. More information exists on similar diseases caused by other strains of *V. dahliae* on other crops such as cotton and tomatoes. In spite of our uncertainty of the changes in population of microsclerotia in our plot soils, we suspect this summary describes the situation with root infection of peppermint.

Although plants in which systemic infections do not develop (immune wilt response) may have the root cortex colonized, these infections do not lead to formation of microsclerotia that survive from year to year (4). Similarly, *V. dahliae* does not successfully colonize plant debris in the soil (4). On the other hand, crop rotation has not proven effective due to the fact that microsclerotia can persist many years (14). Further, *V. dahliae* may systemically infect and successfully reproduce microsclerotia on numerous plants that may not manifest a disease response such as wilt (9, 12, 13).

Huisman and co-workers (9, 12, 13) have described much of the detail of infection of roots by *V. dahliae* and other fungi. The number of root infections that become systemic within the plant is quite small in proportion to the total number of root infections. Several hundred or more root colonies may form per centimeter of root length. Most such root infections only involve a few root surface cells. In general, the number of root infections is proportional to the inoculum density, and this is true of numerous soil fungi including many saprophytes and some pathogens (9, 12, 13). As summarized by Huisman (13) for both his own work and related work of others: "...*V. dahliae* is primarily a colonizer of the rhizoplane and/or root cortex and is adapted to a wide host range. Almost all plants thus far examined (57 out of 63 species), including both dicotyledenous and monocotyledonous plants, were colonized. The colonization rate of roots is surprisingly uniform. ... Whether a plant is susceptible or immune to systemic invasion appears unrelated to the ability of the fungus to colonize the root cortex. The principal difference between wilt susceptible and immune plants would appear to be the ability by the pathogen to systematically invade the vascular system of the former. However, systemic invasion is of profound significance in the buildup of populations in the soil..", as this is where large number of microsclerotia are produced. No differences in initial root colonization were found among cotton cultivars varying widely in resistance to wilt (12, 13).

Although root infections may be proportional to inoculum density, it does not automatically follow that this is true for systemic infections. However, Ashworth and Huisman did report that various cotton (1) and tomato (2) cultivars varying in resistance to wilt showed distinct inoculum density vs. disease relationships in the field. Similarly, the number of systemic, symptomatic infections in the field has been related to the number of propagules of the pathogen in the soil for pistachios and olives (L. Ashworth, personal communication), and potatoes (7).

Various soil factors may affect the relationship between inoculum density and disease. Microsclerotia, normally held dormant by various soil organisms (3, 22) germinate in soil in response to nutrients leaking from plant roots (22). In cotton, Ashworth et al. reported that copper in soil also might influence this fungistasis (3). Cappaert et al. (7) found that early season root infections were those primarily involved in later season potato early dying, and that early season moisture greatly affected the incidence of potato early dying: high early irrigation levels led to higher late season disease, and low early season irrigation resulted in little late season disease. In a follow-up analysis of this effect, Gaudreault (8) found that high soil moisture levels lessened the number of early root infections by *V. dahliae* on potato, but elevated the total number of infections that became systemic, perhaps by orienting these infections near the undifferentiated tissues of root tips in roots that were very slow growing due to the excessive moisture. Gerik and Huisman (9), have shown (along with others cited in their paper) that *V. dahliae* never penetrates matured vascular tissue behind root tips, but must infect the vascular system in the region of early differentiation near to root tips. Others have shown that factors which slow or impede root growth seem to exacerbate wilt infections (2), so a common mechanism may be any condition that slows root grow enough to allow for microsclerotia to germinate and infect prior to rapid root elongation, differentiation and vascular maturity.

It would be desirable to be able to determine the potential losses within a field prior to planting peppermint. High potential losses might be avoided, and stand longevity could better be programmed into an overall planned rotation. This approach requires two sources of information: first, that the population and distribution of the mint strain within a field can be characterized (strain type) and quantified (how much is there); second, that the impact on mint growth and yields of a various numbers of propagules per unit of field soil can be measured under experimental conditions and verified in growers' fields. Such data has been gathered for *V. dahliae* on cotton (1) and tomatoes (2). Commercial services based on soil sampling have been developed for these crops and for pistachios and olives (L. Ashworth, personal communication). Lacy and Horner (16) reported (1-yr microplot data) that peppermint responded adversely to increased inoculum density, however, their ranges of infestation were much higher than typically found in the field. Our first year data of a long term experiment using large field plots confirms this, and may lead to an appreciation of biologically important inoculum levels, in contrast to the very high level utilized by Lacy and Horner.

Knowledge of realistic, field-level inoculum density vs. yield loss relationships might further be utilized to determine the commercially-important number of nematodes or other stress factors that interact with *V. dahliae*. Still other factors might be determined to be of beneficial influence on wilt (7). As an example of how uniformly-infested large field plots might be utilized, and to gain some useful information, in 1989 we initiated two diverse management practices to be conducted on a range of verticillium infestations on large plots. The two practices are: flaming/no-tillage and tillage/no-flaming, and flaming of mint stems and leaves after harvest kills the fungus in the part of the plant in which the fungus reproduces. Combined with the practice of not tilling these infested plant materials back into soil, inoculum does not increase in the soil (11, 17). However, tillage is believed to be necessary in some colder areas, in order to avoid freeze damage to stolons. Also, tillage is one cultural means of control of some insects. Presumably, such tillage necessarily exacerbates the verticillium situation by increasing the amount of fungus in the soil. The relative risk of these opposed practices has not been determined in central Oregon.

Objectives:

a. Determine verticillium wilt incidence arising from various initial soil infestation levels of mint strains of *V. dahliae* in an on-going field trial under relatively controlled, field conditions (initially uniform infestation).

b. Determine relative benefit of tillage/no-flaming vs. flaming/no-tillage in an ongoing field trial with respect to overall peppermint performance, with respect to winter kill, with respect to changes in inoculum of *V. dahliae*, with respect to wilt intensification, and with respect to insect and weed occurrence.

c. Determine an appropriate protocol for field sampling of microsclerotia, considering variability within seasons, among seasons, and among soil types.

Other objectives that may be important to determine include the rate of decay of mint stems in soil, and the time course for release of microsclerotia into soil. In cotton (14) and potatoes (O. Huisman and J. Davis, personal communication) such release may take one to two years, which influences post-disease soil recoveries of microsclerotia. Further, the efficiency of recovery of microsclerotia from different soil types has not been reported. Soil physical, biotic, and even chemical factors (3) could lead to different inoculum recoveries, which may alter the apparent disease loss vs. inoculum density relationships found for these soils, and thus effect the predictability of disease loss based on soil recoveries.

Materials and Methods

On-station uniformly infested trial

Main plot treatments and inoculum preparation: *V. dahliae* inoculum from strains shown to be pathogenic to mint in the laboratory was grown in the laboratory on sterile cellophane agar during 1989. Cellophane heavily colonized by microsclerotia was stripped from petri plates, microsclerotia were dispersed with sand and dried in the laboratory. Three months prior to planting of mint, plots 10 x 80 ft were infested with the sand-inoculum mixture at rates of 0, 0.01, 0.1, 1.0, and 5.0 microsclerotia (MS)/g soil, and to a depth of 6 inches in various plots. Plots were arranged in a randomized strip block experimental design with five replications. Grass borders between plots had been established in 1989, and a rigorous program of equipment sterilization, solid set irrigation and field usage patterns was followed after fumigation, and for the lifetime of the experiment, to limit cross-contamination among test plots.

Trial preparation and management: The trial area on the Powell Butte research field of the Central Oregon Agricultural Research Center had never been planted with mint, but had been in potatoes several times. Using soil assays described below, a low level of "potato" strain of *V. dahliae* was found in the plot area prior to fumigation, but not after. The trial area was commercially fumigated in 1988 with 400 lb/ac MeBr/Pic (54/46), injected under plastic tarp.

'Todd's' peppermint roots were obtained from commercial, field-grown rootstock, which was excluded from certification only because the source field was within 5 miles of fields known to be infested with *V. dahliae*. *V. dahliae* was not cultured from samples taken from this rootstock, and no pathogenic nematodes were found in soil from the rootstock field or from the rootstock. Roots were planted into plots in the trial area in February 1990. Subsequent management was as per local commercial protocol, except where stated otherwise. Rates and timing of application of pesticides was as per recommended practices in the area, and in response to developing field conditions. They are reported under the Results section. In 1990, all plots received 100 lb/a N in early April, and 150 lb/a N in early May. In 1991 and 1992, plots received 80 lb/a N in April, 120 lb/a N in late May, and 75 lb/a N in late June. Mint was irrigated as per typical local farmer practices -- drought stress was not allowed to develop at any time of any year.

Split plot treatments -- tillage vs. flaming: Flaming: Within the trial area above, duplicate sets of plots were created for management under either flame/no-plow or no-flame/plow management systems (11, 17). For 1990, the propane flamer utilized was 6 ft wide, with 10 burners, and with hovers. This design was improved in 1991 to provide more uniform heat distribution, and to allow for a single pass rather than two passes. The burners were extended to twenty along an 11 ft wide frame. The flamer was operated at 30-40 PSI and was pulled through the plots at 1.5-2.0 MPH. The flamer was turned off when traveling across non-flamed plots. In each year, half of the split plots were flamed within one week after harvest, and irrigation was resumed within a few hours of flaming. Tilling: For tilled plots, a rototiller, set to a depth of 6 inches, was used in early spring (last week of February or first week of March), prior to the appearance of top growth of mint. Tilled plots were then rolled to pack down soil and roots following tillage.

Ground cover was determined on first-year mint on August 20, 1990, excluding both bare ground and dead top growth. In 1991 and 1992, ground cover similarly was determined earlier (June) because mint growth was more abundant. Ground cover was again determined in the fall of each year, after harvest. Ground cover is defined here as the square footage within the plot area covered by green mint foliage prior to heavy branching growth of the foliage over bare ground.

In each year, fresh hay was harvested through the center of plots with a 40-inch wide forage swather along the 80-ft plot length (267 sq ft). Fresh hay was weighed and subsamples were taken for dry weight and oil yield determination. Hay from the remainder of the plots was swathed and removed immediately (within one day) following harvest of data strips. Oil was steam distilled at the OSU research stills, either from fresh hay within a few days of harvest, or from bagged, air-dried hay. Mint was harvested on August 27 in 1990, on August 23 in 1991, and on August 1 in 1992, at approximately 10 percent bloom in each season. Differences in maturity associated with tillage or non-tillage were observed in 1991 and 1992, and this is discussed below.

Percentage ground cover, wilt incidence, fresh hay weight, dry hay weight, oil yield, and selected other measurements collected from plots were analyzed by analysis of variance.

Oil composition: Oil collected for yield determination was sent to the A.M Todd Company, Kalamazoo, Michigan, for determination of oil composition by gas chromatography.

Soil sampling and assay for microsclerotia: Soil samples were taken with a 1 inch core sampling tube to 6 inch soil depth. From each sampled plot, 20 sub samples were composited. In some cases repeated samples were taken. Soil was air dried for 4-6 weeks to eliminate spores and mycelium of *V. dahliae*, but not the resistant microsclerotia (1, 6, 19). Following sampling in the field and during air drying, soil was prevented from heating above 75°F, to avoid thermal killing of microsclerotia. Once dry, microsclerotia are more heat tolerant (L. Ashworth, personal communication). After grinding, the soil was assayed for microsclerotia in one of two ways. Wet-sieving: 50 g samples were blended for 30 seconds in 200 ML water containing 2 g Calgon and 2 ML Tergitol to disperse soil particles. Soil was then wet-sieved through 120- and 400-mesh screens and the residue surface sterilized briefly (5 sec) twice between rinses. Residue was allowed to settle and the volume was adjusted to 50 ML with water. The sample was then stirred, and twenty, 1 ML aliquots were spread across twenty petri plates containing a selective growth medium containing sodium pectate and other ingredients (1, 6, 19). Anderson Air Sampler:, 0.1 g aliquots of soil were sucked through an air system, and dispersed through perforated plates and deposited on petri plates containing the above selective medium. With both methods, petri plates were incubated at room temperature for two or more weeks before observing for colonies of *V. dahliae*.

Other investigations, including those from commercial fields

Strain identification: Strain pathogenicity was evaluated by inoculation of the susceptible cultivar 'Black Mitchum'. Plants for inoculation were prepared by planting stolons in a sand/peat mixture in greenhouse trays lined with newspaper. These trays were held at 72°F under growth lights at 16 h exposure. Plants emerged within one week. Two month old freshly cut stems of three to five leaf pairs (approx. 14 cm) were used for inoculation. Collection of strains: Stems from field grown peppermint displaying wilt symptoms were collected and surface sterilized for 5 min in 0.5 percent NaOCl. Stems were cut into 3-5 mm sections and placed with vascular bundles in direct contact with sterile water agar containing streptomycin to facilitate growth of *V. dahliae* into the agar. *V. dahliae* was identified by the formation of microsclerotia and conidial structures. Positive *V. dahliae* colonies were isolated onto new plates. Other *V. dahliae* isolates were collected similarly from potatoes or other sources. All isolates were grown on potato dextrose agar with 2 percent streptomycin sulfate added to inhibit bacterial growth. After three weeks, conidia were removed with sterile water that was adjusted in volume to make a 5 x 10^5 conidial spore suspension. Freshly cut ends from 13-cm stems from 'Black Mitchum' peppermint were held in conidial suspensions for two hours under bright lights. After inoculation, stems were planted into separate 4-inch pots in a three equal parts medium of peat, sand and vermiculite. Pots were kept moist and measured at five weeks for height and symptom development.

Evaluation of soils from commercial fields: From commercial fields, sections ranging from 0.1 to 10 acres of naturally infested fields were sampled similarly to test plots above, usually using a modified "X" or zigzag sampling pattern. Soil sampling and assay was the same as for initially uniformly infested plots above. During July, 1991, soil samples were collected from eight fields in the Willamette Valley and from eight fields in central Oregon, all with a history of verticillium wilt. Five of these 16 fields were in mint production at the time of sampling. For the others, mint had been last grown between two and eight years earlier. As much as possible, fields were partitioned by recollections of wilt severity, or actual wilt symptoms in progress. In numerous cases, growers had strong recollections about sections of fields that had badly wilted out in previous years.

Results

On-station uniformly infested trial

Abiotic crop stresses: Winter stress was extensive in 1990-91, with temperatures reaching -30°F in December 1990, and without snow cover or substantial fall or winter precipitation. Plant stands were affected in some plots (see ground cover below). The winter of 1991-92 was very mild; no significant cold period occurred. Mint in test plots was well irrigated into the fall, and late winter and spring rains precluded winter moisture stress. These mild influences likely were reflected in improved stand, as measured by ground cover below. Summer stress was within normal ranges during 1990 and 1991. The major crop stress during 1992 was from sustained high temperatures in the spring and summer, which also resulted in accelerated plant growth and a very early harvest for all central Oregon. Verticillium wilt results from the interaction of vascular plugging incited by the fungus, combined with transpiration demand. Transpiration demand and wilt are exacerbated during hot weather. Wilt symptoms appeared quite early compared to other years, and appeared on mint regrowth after harvest as the heat persisted into late summer.

Biotic stresses -- Insect and mites: Because some insects are known to be controlled by tillage, plots have been regularly observed for occurrence and differences in insect presence and damage. No serious insect pest problems have yet developed since planting in spring 1990 through the fall of 1992. Two-spotted spider mites were treated once in 1990 with Comite, but a high predatory mite population suppressed two-spotted spider mites in 1991 and 1992 such that no miticide was needed. From 1990 through 1992, no measurable *Pratylenchus* nematodes have been recovered from soil samples taken from all plots. However, in August 1992, an average of over 13,000 *Paratylenchus* (pin) nematodes per qt soil were recovered from all plots. Tilled plots averaged 17,753 pin nematodes/qt soil vs. 10,968 pin nematodes/qt soil in flamed plots, but these differences were not significant ($p \leq 0.05$). Plots initially infested with 0, 0.01, 0.1, 1.0, and 5.0 MS/g soil were found infested with 25,084, 14,220, 13,170, 8,940, and 11,918 pin nematodes/qt soil, but again no significant differences among treatments occurred. It remains unclear whether pin nematodes directly affect mint performance, or whether they may interact with *V. dahliae* or other causes of plant stress.

Biotic stresses -- Weeds: Weed occurrence is affected by tillage and flaming programs, and weeds also may influence mint performance and oil composition. Weed types and numbers have been periodically determined. Sinbar (DuPont) was used in each year at commercial rates for general weed suppression. Over winter annuals: Groundsel was abundant in all untilled plots in the spring of 1992. On May 1, 1991, flamed and tilled plots averaged 35.1 and 1,130.0 groundsel plants per plot, respectively. Data is similar for 1992, but is not shown. Because groundsel was not a problem on the remainder of the farm, it is believed that the groundsel may have been brought in with the mint roots. Tillage in late February or early March of 1991 and 1992 largely eliminated these weeds for several months in each of 1991 and 1992 from the tilled treatments. By summer, these weeds spread back into tilled plots, requiring control efforts in all plots. Buctril was applied after harvest in 1991 and 1992 for groundsel weed control. When necessary, plots were weeded by hand. Grass weeds of several species were abundant in all plots in 1992, having spread into plots from the grass-planted plot borders. Periodic use of the non-registered herbicide Assure (DuPont) provided good control of most grass, and constituted the only non-commercial pesticide applications made in the trial. Weeds were generally absent by the time plots were harvested.

Ground Cover: Figure 1 shows ground cover data for 1990-92, a measure of the plant stand density. Ground cover specifically is a measure of the plot surface area, which is green with late spring/early summer mint growth, prior to branching overgrowth of bare ground by compensative mint growth. A low rating indicates plants are missing for some reason. In 1990 (prior to first tillage in 1991) , and in 1991 and 1992 after tillage, stand density early in the year was quite high (above 95 percent). In plots that were not tilled, stand in 1991 was approximately 80 percent for *V. dahliae* infestations initially below 5 MS/g of soil. The difference between tilled and untilled plot percentage ground cover ratings was statistically significant ($p<0.05$). The greatly reduced stand in untilled plots initially infested with 5.0 MS/g of soil was significantly different ($p<0.05$) from the stand in other untilled plots. In 1992 compared to 1991, percentage ground cover was greater in all plots, both tilled and untilled. Differences in ground cover between tilled and non-tilled plots again were significant ($p<0.05$), as was the difference between flamed plots initially infested at 5.0 MS/g of soil compared to other flamed plots.

Growth and Development: Plant height was measured periodically each season. Plants in all plots in 1990 all sized and matured equally, based on visual observations.

In 1991, it was noticed that tilled plots were slightly delayed in growth and development compared to flamed (untilled) plots. This was reflected in height from emergence/greenup through May, but heights were similar after May. Casual observation revealed no treatment differences with respect to maturity near harvest, at what appears to be roughly 10 percent bloom, the industry standard for ensuring acceptable yields and oil composition. However, careful observation suggested slightly greater bloom development in flamed plots. This difference was not quantified in 1991, and oil samples were collected and handled insufficiently to determine whether oil from tilled plots might be more "immature" than oil from untilled plots. In 1992, a similar delay in spring growth was seen in tilled plots. After about mid-June, canopy height was comparable among all treatments irrespective of treatment.

Two days prior to 1992 harvest, no plots were overmature based on field observations of station staff and commercial oil buyers, and most observers saw relatively little difference among treatments. On that day, plant development was characterized in the following manner: 10 groups of 10 stems were selected randomly throughout each 80 x 10 ft plot on July 28, three days prior to harvest. Floral development on each stem was rated by the following scale:

- 0 = no buds
- 1 = tight first buds only
- 2 = one or more flowers one half mature length
- 3 = one or more flowers full length, no bloom
- 4 = one or more flowers in bloom
- 5 = post-bloom

An average rating was determined for each plot, and analysis of variance performed using the average value per plot. No treatment differences occurred among verticillium infestations, but tilled plots averaged an 0.97 rating, and untilled plots averaged a 1.88 rating, which were significantly different ($p<0.05$). It was determined to be unfeasible in 1991 and 1992 to have split harvest schedules, i.e. to harvest each plot on the basis of a standard of plant development such as 10 percent bloom.

Wilt incidence: Wilt symptoms first appeared in test plots in mid-late June, 1992, at least several weeks earlier than in either 1990 or 1991. Figure 1 shows accumulated wilt strikes or loci at harvest for each of 1990, 1991, and 1992. The number of weeks during which visual wilt symptoms accumulated prior to harvest was approximately four, six, and six for 1990, 1991, and 1992, respectively. For each year, wilt incidence was greater (and statistically significant, $p\leq 0.05$) with increasing initial infestation. For flamed but untilled plots, wilt incidence in 1992 was comparable to 1991. For tilled but unflamed plots, wilt incidence was greatly increased in 1992 compared to 1991. In both 1991 and 1992, significant interaction effects ($p\leq 0.05$ were seen between inoculum density and cultural practices: the amount of wilt observed with increasing inoculum density was greatly different with tillage vs. flaming.

Figure 3 shows graphically an interesting block effect with respect to wilt and inoculum density in 1992, and which was also observed in 1990 and 1992. Although this trend occurred with other rates of initial infestation, only data from the highest initial infestation is shown. Wilt incidence consistently decreased from east to west (replicate 1 is the easternmost) across the trial area. The significance of this relationship is discussed below.

Plot integrity: It would shorten the useful lifetime of this field trial if wilt were to intensify in initially non-infested plots. During 1991 and 1992, a slight amount of wilt symptoms appeared in initially non-infested plots, presumably from cross-contamination. Rodents and deer have browsed in the plots, worms and insects have been found in the soil profile. In spite of strict measures to prevent movement with machinery and personnel, these may have transported some inoculum among plots. To date, there has been nearly no gopher activity in the plots, although these exist elsewhere on our field. Nevertheless, if relatively little disease continues to occur in these plots, we believe that this study can continue for several more years.

Harvest yields: Harvest yield was determined by several different measures. Fresh hay weight was measured from the 40 in x 80 ft harvested strip (267 sq ft) along the plot centers. Percentage moisture was determined from sub-samples of fresh hay, which were then dried. Dry weights were calculated from fresh weights and percentage moisture, and were highly correlated (>95 percent) with the directly measured fresh weights. Dry weight means for each treatment are shown graphically in Figure 2 for all three years. Oil was distilled from sub-samples of fresh hay from each plot (or this sample was dried for later distillation), ranging from 8-11 pounds of fresh hay per plot. Oil yield on a per acre basis was calculated using fresh weights and the proportion of oil recovered from sub-samples. Mean oil yield per acre for each treatment is expressed graphically in Figure 2 for 1990, 1991, and 1992. Both dry weights and oil yields were correlated with oil yields above 92 percent for 1990, but only between 60-70 percent for 1991 and 1992.

In 1990, *V. dahliae* infestation significantly ($p<0.05$) enhanced both dry weight and oil yield at 1.0 MS/g of soil initial infestation over the yield in other infested and the non-infested plots.

In 1991, oil yield in all infested plots was significantly ($p<0.05$) higher than oil yield in the non-infested plots. Such enhancement was seen for intermediate infestation levels in 1991 with respect to dry weight. Any such yield enhancement was not anticipated and is not noted from other literature on *V. dahliae* from other crops. (Some farmers have suggested that they have seen such indications in commercial fields.)

In 1991, excluding the non-infested treatment, oil yield dropped with increasing rate of infestation, and this drop was statistically significant ($p<0.05$). Flamed treatments out yielded tilled treatments in 1991 ($p<0.05$), except for the non-infested treatments, which yielded similarly.

In 1992, the relationship between initial inoculum density and both dry weight and oil yield was consistent: oil yield declined ($p\leq0.5$) with increasing inoculum density -- no increase in yield at some level of infestation occurred. There was no overall differences between flaming and tillage, but there were significant statistical interactions ($p\leq0.05$) between these cultural practices and inoculum density. For example, for initial inoculum density of 0. 0.01. 0.1, 1.0, and 5.0 MS/g soil, tilled plots yielded 74.5, 67.9, 67.3, and 58.7 lb/a of peppermint oil, whereas flamed plots yielded 71.7, 65.7, 68.0, 70.1, and 59.9 lb/a of peppermint oil, respectively. In 1992, mint performed better with tillage for initial inoculum densities below 0.1 MS/g soil, but above this initial inoculum density peppermint performed better where flamed.

Figure 3 shows graphically some significant ($p \leq 0.05$) and interesting block vs. inoculum density interactions with respect to yield parameters in 1992, although the same relationships were seen in 1990 and 1991. In this case fresh weight is shown. Fresh weights for all inoculum densities of 1.0 MS/g soil and lower are averaged for each replication. These means in general decline across the five replications in the field trial. The fresh weight for each replication for initial inoculum density of 5.0 MS/g soil, in contrast, increases across the trial. Possible implications of these observations are discussed below.

Oil Composition: Twenty-four components of mint oil were evaluated by gas chromatography, and means for percent composition of each component are shown in Table 1. If no statistically significant differences ($p \leq 0.05$) were found, only the overall mean is shown. Otherwise, treatment for *V. dahliae*, esters, neomenthol, and menthol significantly increased, and 3-octanol and menthone significantly decreased with increasing initial infestation. This seems to fit with a common concept of mint produced under increasing stress (R. Croteau, Wash. St. Univ., personal communication). For oil from mint in tilled vs. flamed plots, menthofuran and pulegone were lower from tilled plots, and esters and neo were lower from flamed plots. Oil composition from tilled plots is consistent with oil produced from less mature plants than the oil from flamed plots (R. Croteau, Wash. St. Univ., personal communication).

Recovery of MS from infested plots: Investigations into sampling protocol. In 1990, we addressed soil assay methods, confirming that wet sieving and the Anderson Air Sampler were useful tools and procedures for assay of soil. In general, as suspected, wet sieving proved more tedious, but seemed more likely to be useful for low soil populations of microsclerotia, because more soil can be assayed. However, this remains unclear, since small microsclerotia may pass through the screens generally required. We continue to use both methods, or one or the other, at various times.

Initially, we were to sample plots every four to six weeks during the season to determine the seasonal dynamics of population density of microsclerotia. Reported data elsewhere suggests some slight fluctuation during the year, peaking in summer, with fall and spring being slightly lower (15). With reduced technical help, we determined the inoculum density just in the late spring through summer.

Following fumigation, no microsclerotia could be recovered from our test plots by either wet sieving or by the Anderson Air Sampler. This was verified in an independent laboratory. As shown in Table 2, in the spring of 1990, numbers of microsclerotia recovered from plots initially infested with 1.0 and 5.0 MS/g soil gave similar values to initial infestation in the fall of 1989. As roughly 1.0 MS/g soil was considered to be an effective limit to our ability to detect microsclerotia, recovery from plots initially infested at lower levels was not attempted.

In June, 1991, recoveries of microsclerotia were 0.45 and 1.64 MS/g soil for flamed plots, and 1.06 and 1.42 MS/g soil for tilled plots, respectively, from plots initially infested at 1.0 and 5.0 MS/g soil, which also appears on Table 2. In 1992, microsclerotia in the soil of our late spring sample was damaged by heat during drying. Data from a fall soil sampling (September) is shown in Table 2. For initial infestations of 0, 0.01, 0.1, 1.0 and 5.0 MS/g soil, recoveries in 1992 were 1.6, 3.2, 7.6, 32.2, and 9.4 for tilled plots and 0.6, 6.0, 2.0, 3.4, and 5.0 MS/g of soil for flamed plots, respectively. Neither directly, nor with various transformations, are the data significantly different with respect to tillage and flaming for any recovery period. The 1992 data are quite variable, and possibly with repeated sampling some trend may emerge -- there does seem to be more sclerotia recovered from tilled than from flamed plots, but this is by no means clear.

Commercial field evaluations:

Recovery of microsclerotia from naturally infested field soils: During 1991, evaluation of field sampling methods was curtailed by the loss of a pathology research assistant due to university-imposed budget reductions. Some results were obtained and are reported here.

For 16 commercial field samples, the fields were partitioned into from four to eight areas based on recollections of wilt history, based on subsequent cropping regimes, and based on soil type or local geography. Some areas were repeatedly sub-sampled (maximum of 5) to check sampling reliability. Assays on soil samples were conducted with both wet sieving and Anderson Air Sampler methods. Each soil sampled or sub-sample was assayed twice over several weeks, to evaluate assay consistency. Recovered MS/g soil ranged from 0 (i.e. no recovered microsclerotia) to over 30 MS/gm soil. Variability between repeated assays was slight. Variability between repeated sub-samples was substantial. The coefficient of variability is defined as the standard deviation expressed as a percentage of the sample mean. The coefficient of variability for 2, 3, 4, and 5 repeated sub-samplings did not drop much from an initial value of about 80 percent.

In general, with this limited sampling, there was no apparent relationship between total microsclerotial recoveries and field wilt history or crop rotation. However, colonies on assay plates were not recultured and tested for pathogenicity, so other strains of *V. dahliae* may also have been present and contributed to the total assayed count. Perhaps more meaningful was the failure to recover any microsclerotia from sections of some fields in which there was strong farmer recollection that wilt was very chronic and abundant through the years. In some cases, these fields had been planted several times with repeated high wilt incidence.

Strain evaluation: During 1991, evaluation of methods for distinguishing among strains was curtailed by the loss of a pathology research assistant due to university-imposed budget reductions. Some results were obtained and are reported here.

After potting, mint stems were about 5-6 cm above the soil level. Symptoms appeared after about 2-3 wks. At that time, growth of peppermint cuttings inoculated with *V. dahliae* averaged 9 cm (7-10 cm range) for those inoculated with isolates of mint taken originally from wilted mint. All plants arising from cuttings dipped into *V. dahliae* isolated from diseased potatoes, and non-inoculated plants in the water control, averaged 16 cm (13-20 cm range). The potato strain inoculated peppermint plants appeared to have superior growth to even that of the water control. Some of the peppermint plants inoculated with *V. dahliae* originally isolated from peppermint died while others commonly had chlorosis and/or bilateral leaf curling.

Discussion

Mint performance in relation to inoculum density and cultural practices:
Winter damage x verticillium interaction x cultural practices? Record cold temperatures and dry soil conditions occurred in the winter of 1990-91. This likely caused the 20 percent reduction in percentage ground cover in the spring of 1991 in plots initially infested at or below 1.0 MS/g soil, even for non-infested plots. Such stand reductions were common throughout central Oregon in the spring of 1991. Because tilled plots were treated in the spring of 1991, rather than tilled in the fall of 1990 as is also common, winter and *V. dahliae* effects were present prior to tillage. Tillage redistributed the surviving roots, rhizomes, stolons, and stems resulting in a full stand in all tilled plots. Fall tillage was not evaluated in this trial, but there is much local discussion as to whether spring or fall tillage is superior with respect to avoiding effects of dry, open, and cold winters. Clearly, even in the most severe conditions to occur for many years, spring tillage was sufficient to re-establish excellent plant stands.

The most startling result, however, was the 70 percent reduction in ground cover in plots most highly infested with *V. dahliae*. A similar large decline was observed in the winter of 1990-91 by G. Santo in micro-plots heavily infested with *Pratylenchus* nematodes (20, 22). These results suggest a common mechanism, perhaps reduced root carbohydrate reserves resulting from the activity of either pathogen during post-harvest growth in the fall. Although this great reduction did not result in much yield loss, due to abundant foliage compensative growth into bare patches in the plots, it is likely that the greatly reduced stand puts these plots precariously close to large yield losses if the stand is further reduced. The large amount of bare patches certainly result in enhanced weed growth.

Weediness x cultural practices: Spring tillage provided substantial weed control for winter annual weeds, compared to no tillage. This has been reported before (23) and is well known to farmers. It would be interesting to compare fall and spring tillage in this respect.

Insect and nematode influences: To date, no insect, mite or nematode has emerged as a problem in our field trial. The trial was begun with relatively clean rootstock on previously fumigated land around which the nearest recent mint plantings are several hundred yards away. This has prevented rapid influx of insect problems. Many of the problem insect pests are not strong flyers. Further, even though our plots are large by experimental standards, there are still large edge effects. The grass borders may harbor insect predators, which suppress increase of problem insects. We do find high populations of predatory mites, which must be suppressing population increases of the two-spotted spider mite. That *Pratylenchus* (lesion) nematodes have not yet generally established in our plots suggests that the initial clean rootstock and routine cleaning of any mechanical equipment entering the plots have obviated this pest. With respect to lesion nematodes, their absence is enabling us to get a clearer idea of what *V. dahliae* can do to mint by itself, since much of the early work on effects of *V. dahliae* was accomplished without knowledge of the interactive effect of lesion nematodes (16, 18), confusing interpretation of the earlier studies.

Can *V. dahliae* be beneficial at times? Mint performance data for 1990 and 1991 suggests that some *V. dahliae,* even the pathogenic mint strain, accounted for improved mint performance. This was not an expected result, and it did not carry over into 1992. Nevertheless, many growers have observed improved mint performance in fields showing just a little bit of wilt, in contrast to "virgin" soil or fields showing abundant wilt symptoms. Further, the effect of potato strains shown above suggests a similar beneficial effect. These may be observations to be further investigated, but they are difficult to evaluate or draw conclusions from. Only one other instance of beneficial effect has been reported for *V. dahliae*, for tomato, (5) but, most scientists have not looked for beneficial effects at low inoculum dosage. Based on the 1992 data, any such beneficial effect is likely to be transitory and undependable.

In-season wilt and its relationship to peppermint performance: In 1992, and to some extent for 1991, increasing amounts of *V. dahliae* in the soil resulted in more in-season wilt incidence. This supports the idea that various means of adjusting the inoculum density downward could prove worthwhile. However, it also appears that a substantial amount of wilt can be present before much yield reduction occurs. From a yield perspective, even our most highly infested plots have not truly "wilted out" yet -- in their third harvest season they are still yielding about 80 percent of what non-infested plots are yielding. Some of this resilience is undoubtedly due to our use of the moderately tolerant variety 'Todds'. If we had selected 'Black Mitchum', it likely would have performed much worse, and at lower initial inoculum densities. It will be important to observe the performance of 'Todds' over the next several years, to see how it (a) withstands the stand reduction impact of the winter of 1990-91 combined with stable in-season wilt pressure in flamed plots, and (b) withstands rapidly intensifying in-season wilt in tilled plots.

Our yield data also clearly shows that, when the mint strain of *V. dahliae*, is present in the soil, the Horner flaming/no-tillage program (11, 16) applies to central Oregon, even in the presence of enhanced winter damage. However, in the absence of *V. dahliae*, tillage was directly beneficial for mint performance, even in the absence of insect pests. Tillage also helped control weeds, and improved root distribution when thinned by winter damage. Tillage may help overcome the effects of soil compaction, which were visible in our plots since tractor tires travel the same line each pass. However, when number of wilt loci per plot is adjusted to wilt loci per unit of ground actually covered, then the differences between the flamed and tilled plots at the highest rate of initial infestation is reduced considerably. In other words, in heavily infested tilled plots the loss of a plant to in-season wilt had less impact than did the loss of a plant in a heavily infested flamed plot, since there were relatively fewer plants in the flamed plots. This discussion is less applicable to plots initially infested at 1.0 MS/g soil or less, since stand differences are far less.

With respect to oil composition, effects associated with increasing inoculum density in 1992 were described by oil companies to be similar to those they associate with increasing stress on plants -- stress from various sources. This fits conceptually with how we believe verticillium affects plants, by interfering with water conduction.

Effect of tillage on growth: Presumably, tilled plants needed to re-establish a root system whereas untilled plants were not delayed, and/or perhaps rhizomes were more shallow in flamed plots than in tilled plots, which encouraged earlier emergence of foliage. Such growth and developmental differences might account for yield and quality differences at harvest. Yield effects due to a few days difference in plant maturity near flowering are likely to be small, based on other studies (24). However, in 1993, we intend to harvest small sections of our plots at various times to confirm this.

With respect to oil composition, however, a few days difference in flower part development can greatly affect composition (24). Oil company representatives attributed most oil composition differences between tilled and flamed plots as those expected from plants of differing maturity -- with the tilled plots manifesting the least mature oil. Thus, a field in which spring tillage is practiced might require a slightly later harvest time to yield the same oil composition as a non-tilled field.

Block effects: Mint height and yield were greatest on the east end of the field where soil was deepest (12-18 in), but diminished toward the west, where soil was shallower (8-12 in) and where soil stayed wetter after irrigation or precipitation. Wilt incidence was highest on the east, and diminished toward the west. These generalizations were true for both non-infested plots and for all infested plots up through the initial 1.0 MS/g soil infestation rate. However, in the highly infested plots (initially 5.0 MS/g of soil) these relationships were reversed. Plots on the east end were watered sufficiently to avoid drought stresses, such that plots toward the west were at times over-watered. Possibly these observations relate to relative root extension and growth rate, and responses to *V. dahliae* as reported by Ashworth and Huisman on impeded tomato root growth (verticillium wilt was worse where soil impeded root growth) (2), or to observations by Geudreault (8) on potato root infections in wet soils (systemic infections were favored by wet soils), but the relationship is not clear without further study. Further study may reveal clues to optimum management for both mint performance and wilt control.

Soil assays and changes in inoculum density: Our 1990 recovery of microsclerotia suggested that we could recover numbers similar to what was originally infested -- presumably there would be little change between early winter 1989 and late spring 1990. During the 1990 through 1992 seasons, these initial levels would be expected to change somewhat.

Based on studies on other plants, the number of microsclerotia formed in superficial root infections (i.e. the ones that do not become systemic) may not much affect inoculum densities (9, 12, 13). On the other hand, large upward shifts in microsclerotial populations arise from the large numbers of MS that form in above ground stems, and which **eventually** find their way into the soil (1, 9, 12, 13, 22). This is the reasoning behind the benefit of flaming of stems after harvest, since flaming kills most of the fungus in stems. "Eventually", however, is not a well-defined period -- it could take a year or two or more for sclerotia bound in stems to become free in soil as stems decay, and soil is tilled or mixed by animals in the soil. Huisman and Ashworth (14) working with cotton, and Davis and Huisman (Univ. Idaho and Univ. Calif., respectively, personal communication) working with *V. dahliae* on potatoes, found that increases in soil populations usually lagged disease incidence by a year or two, until stems broke down and released MS and the soil was tilled. Further, J. Davis (Univ. Idaho, personal communication) has observed an increase in potato early dying prior to his ability to recover increasing MS from soil during the stem decay processes -- an observation similar to ours above for mint. In 1991, sample cores could have missed these clumps of MS forming from stems infected in 1990. On this basis, our low microsclerotial recovery in 1991 might primarily represent residual inoculum free in the soil.

How, then, do we account for the recoveries listed in Table 2 for 1992? The most anomalous results are for flamed/non-tilled treatments and for non-infested treatments where either very low maintenance reproduction, or no reproduction, was expected. Further, even for intermediate to high initial inoculum densities we expected a large difference between flamed/non-tilled (low expectation) and tilled/non-flamed (high expectation) -- but this large difference is not apparent. Greater sampling efforts will be expended in 1993 to verify these 1992 figures.

It may not be the case that microsclerotial populations develop equally in all situations. And, although plots initially were uniformly infested, plots would be expected to become less uniformly infested over time. Conceivably, even incompletely decayed stems or aggregated clumps still containing abundant verticillium as MS might serve as potent infection points (J. Davis, personal observations).

Grower field data: Little relationship seemed to exist between estimated inoculum levels from growers fields, wilt histories, or other factors. Conceivably, recovery efficiency may be poor for some soils, perhaps including the soil from our trial. MS recoveries can vary seasonally, with mid-summer recoveries two to four times early spring and late fall levels (16). We have taken some care to measure our populations at mid-season when they are thought to be highest. The actual number of MS in soil may not be so highly variable: measured seasonal variability might have much to do with the ability of MS to germinate on selective media at different times of the year, perhaps due to the seasonal dynamics of other soil biological factors. Data on comparisons of recovery for different soil is not currently available, and may be a future objective.

Strains: The data suggests that the strain or type of isolate of *V. dahliae* will influence the quality of symptoms and associated severity of wilt. Potato strains of *V. dahliae* may not produce symptoms in peppermint or may even positively influence plant health by the root:fungus association. This also points out the need for strain typing in conjunction with soil assays for reasonable interpretation of assays.

Conclusion

a. Verticillium can interact with cold temperatures to lower winter hardiness of peppermint.

b. Mint (at least the 'Todds' variety used in our field trial) can greatly compensate for poor stands due to verticillium, either in-season wilt or enhanced winter kill. This likely is true for reduced stands from other causes.

c. Weeds are encouraged and weed control is exacerbated with poor stands. Thus, verticillium wilt (or other causes of stand thinning) exacerbate weed problems.

d. The number of plants that die following development of wilt symptoms in the field during the growing season increases with increasing numbers of MS present in the soil prior to planting. (This relationship is less clear for populations that develop following the planting, and clarifying these post-planting population dynamics remains an objective of this study.)

e. The "Horner" model for control of wilt by propane flaming of stems after harvest seems to apply in central Oregon, even for a moderately tolerant variety to *V. dahliae*: Tillage without flaming increases the amount of wilt each year. Flaming without tillage results in no increase in wilt incidence over that resulting from initial levels at planting.

f. The relatively straightforward relationship of applied inoculum density in the test plots seems somewhat confounded by the soil recoveries from both test plots and growers fields. Probably, the process of microsclerotial formation in stems, release from stems into soil, and survival and re-infection is not a simple nor straightforward process. The story is further confounded by the uncertainties of soil sampling and assay. It is disturbing that no sclerotia could be recovered from parts of some commercial fields with known severe history of wilt, and that relatively high recoveries were found in test plots from which few or no microsclerotia were expected. Resolving these uncertainties will be an objective of future research.

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Table 1. Composition of peppermint oil in 1992 from a central Oregon field trial initially infested in 1989 with a range of microsclerotia (MS) of Verticillium dahliae (main treatment). Plots were split and spring tilled or propane flamed after harvest. Overall means are shown for each component, and treatment means are shown if statistical significance ($p \leq 0.05$) among treatments*.

	percentage composition of oil							
		cultural practice		MS/g soil of V. dahliae				
Component	Overall Mean	tilled	flamed	0	0.01	0.1	1.0	5.0
Alpha Pinene	0.80							
Beta Pinene	1.56							
Myrcene	0.24							
Alpha Terpinene	0.12							
Limonene	1.36							
Cineole	5.05							
Gamma Terpinene	0.25							
Para Cymene	0.16							
Terpinol	0.18							
3-Octanol	0.21			0.22	0.22	0.22	0.22	0.18
Sabinene Hydrate	3.07							
Menthone	30.71			31.76	31.53	31.15	30.35	28.45
Menthofuran	1.64	1.43	1.63					
D-Isomethone	3.07							
Beta-Bourbonene	0.55							
Ester = Menthyl Acetate	2.85	3.17	2.81	2.36	2.55	2.64	2.80	3.72
Neomenthol	2.68	2.77	2.69	2.58	2.60	2.63	2.68	2.97
Beta Caryophyllene	2.50							
L Menthol	33.82			33.09	33.53	33.46	34.26	34.99
Pulegone	0.31	0.21	0.31					
Germacrene-D	3.25							
Piperitone	0.53							
Total Heads**	9.86							

* Statistical significance at 5%: Menthol (vert), Menthofuran (cultural practices), Neomenthol (cultural practices). At 1%: 3-Octanol (vert). At 0.1%: Menthone (vert), Ester (vert, cultural practices), Neomenthol (vert), Pulegone (cultural practices). Statistically significant interactions between V. dahliae and cultural practices (5%): B-Bourbonene, Ester. Block effect for Ester (5%).

** All low boiling compounds up to and including terpinolene

Table 2. Infested and recovered microsclerotia (MS) of Verticillium dahliae per gram of soil from a field trial in central Oregon, 1990-1992.

MS/g of soil					
uniform infestation (Calculated)	means (S.D.) of recovered amounts				
		1991		1992	
1989	1990	flame	till	flame	till
0	*	*	*	0.6(0.5)	1.6(3.0)
0.01	*	*	*	6.0(5,7)	3.2(1.8)
0.1	0 (0)	0 (0)	0 (0)	2.0(2.9)	7.6(7.8)
1.0	0.6(0.6)	0.45(0.32)	1.06(0.43)	3.4(3.5)	32.2(50.3)
5.0	7.1(3.4)	1.64(0.32)	1.42(1.06)	5.0(3.2)	9.4(9.3)

* not attempted.

Fig. 1. Percentage of test plot area covered with spring mint growth, and cumulative verticillium wilt incidence in plots at harvest, 1990-1992, in a central Oregon field trial initially infested in 1989 with a range of microsclerotai (MS) of Verticillium dahliae. Data points are means of five replications from a randomized split block experimental design. See text for statistical analyses.

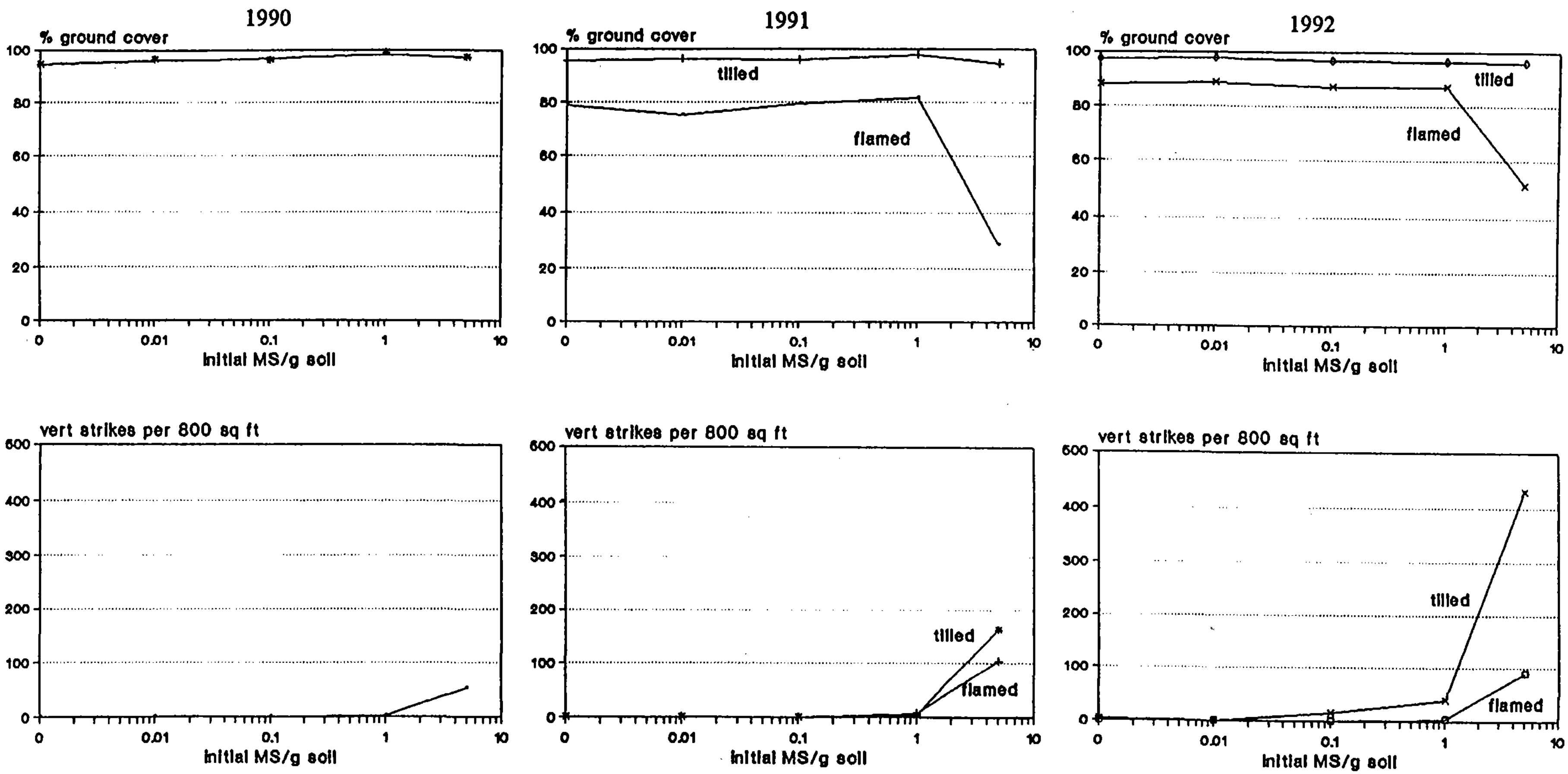


Fig. 2. Dry peppermint hay weights and oil yields at harvest, 1990-1992, in a central Oregon field trial initially infested in 1989 with a range of microsclerotia (MS) of Verticillium dahliae. Data points are means of five replications from a randomized split block experimental design. See text for statistical analysis.

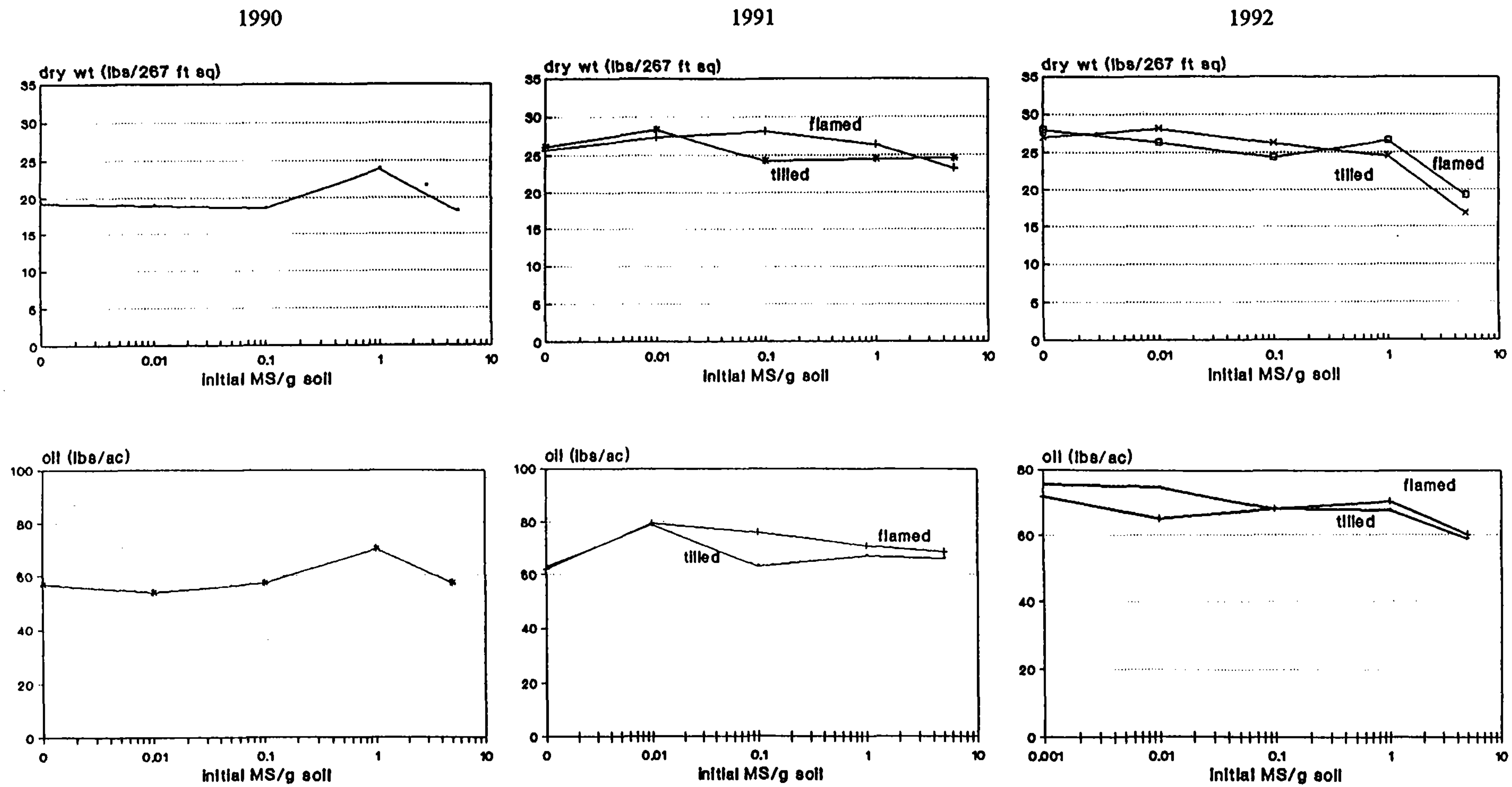
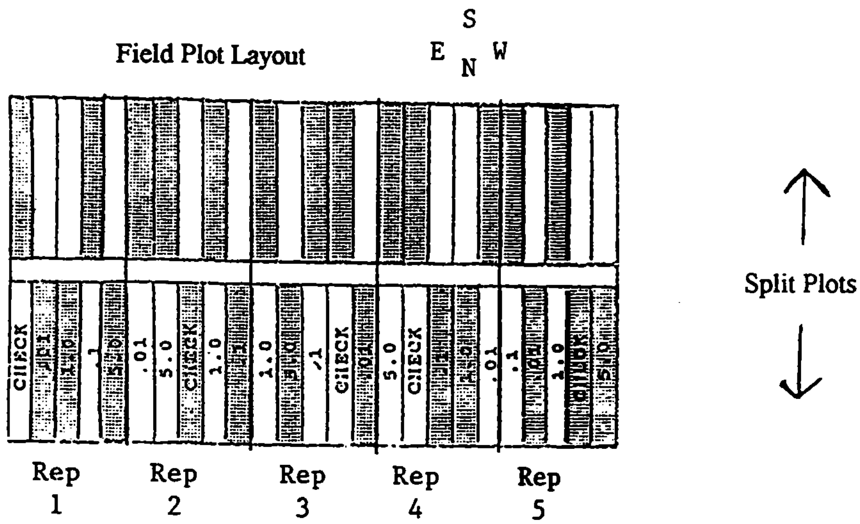


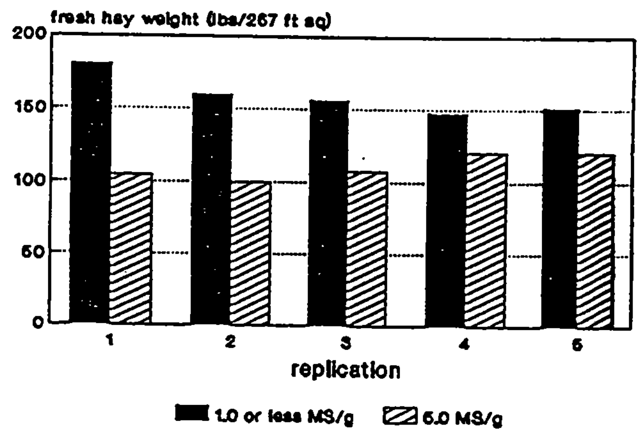
Fig. 3. 3a: Field plot layout at COARC Powell Butte research farm showing five replications of treatments. Main plots were various numbers of microsclerotia (MS) per gram of soil of Verticillium dahliae. For split plots, peppermint was either spring tilled or flamed just after harvest. 3b: Means of fresh hay weight from 1991 showing a significant ($p \leq 0.05$) block X infestation rate effect. Means for fresh hay weight among all infestations or 1.0 MS/g soil or less were similar. Note decreasing yields from east to west at lower infestations, but increasing yields from east to west at highest infestation. Similar responses were seen in 1990 and 1992. 3c: Verticillium incidence in 1992 with significant block effect ($p \leq 0.05$). Note decreasing incidence of wilt from east to west. Similar responses were seen in 1990 and 1991.

3a.

shaded = flammed
open = tilled



3b.



3c.